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HYDROLOGICAL SIMULATION PROGRAM - FORTRAN
USER'S MANUAL FOR RELEASE 11

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FOREWORD

As environmental controls become more costly to implement and the penalties of judgment errors become more severe, environmental quality management requires more efficient analytical tools based on greater knowledge of the environmental phenomena to be managed. As part of this Laboratory's research on the occurrence, movement, transformation, impact, and control of environmental contaminants, the Assessment Branch develops management or engineering tools to help pollution control officials achieve water quality goals through watershed management.

The development and application of mathematical models to simulate the movement of pollutants through a watershed and thus to anticipate environmental problems has been the subject of intensive EPA research for a number of years. An important tool in this modeling approach is the Hydrological Simulation Program - FORTRAN (HSPF), which uses computers to simulate hydrology and water quality in natural and man-made water systems. HSPF is designed for easy application to most watersheds using existing meteorologic and hydrologic data. Although data requirements are extensive and running costs are significant, HSPF is thought to be the most accurate and appropriate management tool presently available for the continuous simulation of hydrology and water quality in watersheds.

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ABSTRACT

The Hydrological Simulation Program - FORTRAN (HSPF) is a set of computer codes that can simulate the hydrologic, and associated water quality, processes on pervious and impervious land surfaces and in streams and well-mixed impoundments. The manual discusses the structure of the system, and presents a detailed discussion of the algorithms used to simulate various water quantity and quality processes. It also contains all of the information necessary to develop input files for applying the program, including descriptions of program options, parameter definitions, and detailed input formatting data.

The original version of this report was submitted in fulfillment of Grant No. R804971-01 by Hydrocomp, Inc., under the sponsorship of the U.S. Environmental Protection Agency. That work was completed in January 1980.

Extensive revisions, modifications, and corrections to the original report and the HSPF code were performed by Anderson-Nichols and Co. under Contract No. 68-03-2895, also sponsored by the U.S. EPA. That work was completed in January 1981. Versions 7 and 8 of HSPF and the corresponding documents were prepared by Linsley, Kraeger Associates, Ltd. and Anderson-Nichols under Contract No. 68-01-6207, the HSPF maintenance and user support activities directed by the U.S. EPA laboratory in Athens, GA.

The HSPF User's Manual for Versions 10 and 11 were prepared by AQUA TERRA Consultants of Mountain View, CA, incorporating code modifications, corrections, and documentation of algorithm enhancements sponsored by the U.S. Geological Survey, the U.S. EPA Chesapeake Bay Program, the U.S. Army Corps of Engineers, and the U.S. EPA Athens Environmental Research Laboratory. The Version 11 manual and code were prepared under sponsorship of the U.S. Geological Survey under Contract No. 14-08-0001-23472. The manual is available in WordPerfect format.

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PART A

INTRODUCTION

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1.0 PURPOSE AND SCOPE OF THE HSPF SOFTWARE

The use of models which simulate continuously the quantity/quality processes occurring in the hydrological cycle is increasing rapidly. Recently there has been a proliferation in the variety of models and in the range of processes they simulate. This has been a mixed blessing to a user. To get the benefits of simulation, a user must select a model from a bewildering array and then spend much effort amassing and manipulating the huge quantities of data which the model requires. If the modeler wishes to couple two or more subprocess models to simulate a complete process, he often encounters further difficulties. The underlying assumptions and/or structures of the subprocess models may make them somewhat incompatible. More frequently, the data structures are so different that coupling requires extensive data conversion work.

One reason for these problems is that the boom in modeling work has not included enough work on the development of good model structures. That is, very few software packages for water resource modeling are built on a systematic framework in which a variety of process modules can fit.

With HSPF we have attempted to overcome these problems as far as possible. HSPF consists of a set of modules arranged in a hierarchical structure, which permit the continuous simulation of a comprehensive range of hydrologic and water quality processes. Our experience with sophisticated models indicates that much of the human effort is associated with data management. This fact, often overlooked by model builders, means that a successful comprehensive model must include a sound data management component. Otherwise, the user may become so entangled in data manipulation that his progress on the simulation work itself is drastically retarded. Consequently, the HSPF software is planned around a time series management system operating on direct access principles. The simulation modules draw input from time series storage files and are capable of writing output to them. Because these transfers require very few instructions from the user, the problems referred to above are minimized.

The system is designed so that the various simulation and utility modules can be invoked conveniently, either individually or in tandem. A top down approach emphasizing structured design has been followed. First, the overall framework and the Time Series Management System were designed. Then, work progressed down the structure from the highest, most general level to the lowest, most detailed one. Every level was planned before the code was written. Uniform data structures, logic figures, and programming conventions were used throughout. Modules were separated according to function so that, as much as possible, they contained only those activities which are unique to them. Structured design has made the system relatively easy to extend, so that users can add their own modules with relatively little disruption of the existing code.

Now, a note on the initial contents of the system. Presently, it includes modules which can handle almost all the functions which are available in the following existing models:

- (1) HSP (LIBRARY, UTILITY, LANDS, CHANNEL, QUALITY)
- (2) ARM
- (3) NPS
- (4) SERATRA

The HSPF software is not merely a translation of the above models, but a new system with a framework designed to accommodate a variety of simulation modules; the modules described above are the initial contents. Many extensions have been made to the above models in the course of restructuring them into the HSPF system.

It is hoped that HSPF will become a valuable tool for water resource planners. Because it is more comprehensive than most existing systems, it should permit more effective planning. More specifically, the package can benefit the user in the following ways:

1. The time-series-oriented direct access data system and its associated modules can serve as a convenient means of inputting, organizing, and updating the large files needed for continuous simulation.
2. The unified user-oriented structure of the model makes it relatively simple to operate. The user can select those modules and options that are needed in one run, and the system will ensure that the correct sets of code are invoked and that internal and external transfers of data are handled. This is achieved with a minimum of manual intervention. Input of control information is simplified because a consistent system is used for this data for all the modules.
3. Because the system has been carefully planned using top-down programming techniques, it is relatively easy to modify and extend. The use of uniform programming standards and conventions has assisted in this respect.
4. Since the code is written almost entirely in ANSI standard Fortran, implementation on a wide variety of computers is possible.

2.0 REQUIREMENTS FOR HSPF

In awarding the grant for development of HSPF, the EPA set the following requirements:

1. It must manage and perform deterministic simulation of a variety of aquatic processes which occur on and under land surfaces and in channels and reservoirs.
2. It must readily accommodate alternate or additional simulation modules.
3. It must permit easy operation of several modules in series, and thus be capable of feeding output from any operation to subsequent operations.
4. It must be in ANSI Fortran with minor specified extensions.

With the concurrence of the EPA, we expanded on these requirements:

1. It must have a totally new design. Existing modules should not merely be translated, but should be fitted into a new framework.
2. It must be designed from the top down, using some of the new improved programming techniques, such as Structured Design and Structured Programming.
3. Duplication of blocks of code which perform similar or identical functions should be avoided.
4. The user's control input must have a logically consistent structure throughout the package.
5. Uniform standards and practices must be followed throughout the design, development and documentation of the system.
6. It must have a conveniently operated disk-based time series storage file built on the principle of direct access.
7. The design must be geared to implementation on larger models of the current generation of minicomputers. It must be compatible with Operating Systems which share memory using either the virtual memory approach or a conventional overlay technique.

3.0 PURPOSE AND ORGANIZATION OF THIS DOCUMENT

This report contains all the documentation of the HSPF system. It is designed to:

1. introduce new users to the principles and concepts on which the system is founded
2. describe the technical foundations of the algorithms in the various application (simulation) modules
3. describe the input which the user supplies to run the system

To meet these needs and, at the same time, to produce a document which is reasonably easy to use, we have divided this report into several distinct parts, each with its own organization and table of contents.

Part A (this one) contains introductory material.

Part B outlines the general principles on which the HSPF system is based. This includes a discussion of the "world view" which our simulation modules embody. A firm grasp of this material is necessary before the detailed material can be properly understood.

Part C Standards and Conventions (not included)

Part D Visual Table of Contents (not included)

Part E documents the function of each part of the software. The organization of this part follows the layout of the software itself. The relationship between, and the functions of, the various modules are described, starting at the highest most general level and proceeding down to the lowest most detailed level. The algorithms used to simulate the quantity and quality processes which occur in the real world are described in this part.

Part F describes the User's Control Input; that is, the information which the user must provide in order to run HSPF.

Material which might obscure the structure of this document if it were included in the body of the report appears in Appendices. These include a glossary of terms and descriptions of sample runs.

4.0 DEFINITION OF TERMS

In this document, terms which have a special meaning in HSPF, are enclosed in quotes the first time they occur. Usually an explanation follows immediately. A glossary of terms can be found in Appendix I.

5.0 NOTICE OF USER RESPONSIBILITY

This product has been carefully developed. Although the work included testing of the software, the ultimate responsibility for its use and for ensuring correctness of the results obtained, rests with the user.

The EPA and the developers of this software make no warranty of any kind with regard to this software and associated documentation, including, but not limited to, the implied warranties of merchantability and fitness for a particular purpose. They shall not be liable for errors or for incidental or consequential damages in connection with the furnishing, performance or use of this material.

While we intend to correct any errors which users report, we are not obliged to do so. We reserve the right to make a reasonable charge for work which is performed for a specific user at his request.

6.0 ACKNOWLEDGMENTS

The original development of HSPF was sponsored by the Environmental Research Laboratory in Athens, Georgia. David Duttweiler was the laboratory director and Robert Swank the head of the Technology Development and Applications Branch, which supervised the project during the code development period. Mr. Jim Falco was the Project Officer initially on the HSPF development work; he was succeeded by Mr. Tom Barnwell who continues to oversee HSPF support activities for EPA.

Recent development of HSPF has been sponsored by the U.S. Geological Survey Water Resources Division in Reston, Virginia. Dr. Alan Lumb is the Contract Officer and directs that effort for the USGS.

The initial HSPF and user manual development work was performed by Hydrocomp, Inc.; members of the entire project team are acknowledged in the original (Release 5.0) version of the user manual (EPA Publication No. EPA-600/9-80-015) published in April 1980. Subsequent revisions and extensions to the HSPF code and user manual were performed by Anderson-Nichols & Co., Inc. and AQUA TERRA Consultants. The primary participants in the work noted above, and their contributions, are discussed below.

Robert Johanson was Project Manager for Hydrocomp on the initial development work, and provided consulting assistance to Anderson-Nichols & Co., Inc. and Linsley, Kraeger Associates on subsequent development and maintenance work.

John Imhoff had primary responsibility for the RCHRES water quality sections, both during the initial development work for Hydrocomp and subsequent modifications and development for Anderson-Nichols and AQUA TERRA.

Introduction

Harley Davis designed, coded and documented much of the PERLND and IMPLND modules for Hydrocomp during the initial development effort.

Delbert Franz participated in the overall design of the system and supervised the work on the time series management system at Hydrocomp.

Jack Kittle performed or directed most HSPF software development activities since 1979. His focus has been on the software structure, time series improvements, and addition of new components. He designed the MUTSIN (Multiple Timeseries Sequential Input) module, water categories in the RCHRES module, conditional Special Actions, major structural improvements to the software, and was responsible for production of Releases 7, 8 and 9. He continues to be a principal advisor in HSPF development and maintenance.

Tony Donigian participated in the design of the PERLND algorithms in the initial project at Hydrocomp. Since 1980, he has been the Principal Investigator/Project Manager, providing overall guidance and supervision, on all projects related to HSPF algorithm development, with particular focus on the improvements to the AGCHEM sections of the program.

Brian Bicknell has been involved in HSPF maintenance and software development since 1981. He has developed or directed all recent algorithm enhancements and software corrections. He added the WDM file interaction, the MASS-LINK and SCHEMATIC blocks, and the FILES block. He directed the development and documentation of Versions 10 and 11, including major enhancements for simulating forest nitrogen, atmospheric deposition, the DSS file interface, and sediment-nutrient interactions and bed temperature interactions in RCHRES.

Tom Jobes has been the primary software engineer with day-to-day responsibility for HSPF development and maintenance since 1992. He implemented most of the enhancements and software corrections in Version 11, with particular responsibility for the DSS file interface, atmospheric deposition, forest nitrogen and plant uptake enhancements in AGCHEM, multiple WDM files, code structure improvements, conditional Special Actions, and water categories.

PART B

GENERAL PRINCIPLES

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1.0 VIEW OF THE REAL WORLD

1.1 General Concepts

To design a comprehensive simulation system, one must have a consistent means of representing the prototype; in our case, the real world. We view it as a set of constituents which move through a fixed environment and interact with each other. Water is one constituent; others are sediment, chemicals, etc. The motions and interactions are called processes.

1.2 Nodes, Zones, and Elements

The prototype is a continuum of constituents and processes. Simulation of such a system on a digital computer requires representation in a discrete fashion. In general, we do this by subdividing the prototype into "elements" which consist of "nodes" and "zones."

A node corresponds to a point in space. Therefore, a particular value of a spatially variable function can be associated with it, for example, channel flow rate and/or flow cross sectional area. A zone corresponds to a finite portion of the real world. It is usually associated with the integral of a spatially variable quantity, for example, storage in a channel reach. The zone the smallest unit into which we subdivide the world. The relationship between zonal and nodal values is similar to that between the definite integral of a function and its values at the limits of integration.

An element is a collection of nodes and/or zones. Figure 1-1 illustrates these concepts. We simulate the response of the land phase of the hydrological cycle using elements called "segments." A segment is a portion of the land assumed to have areally uniform properties. A segment of land with a pervious surface is called a "Pervious Land-segment" (PLS). Constituents in a PLS are represented as resident in a set of zones (Fig. 1-1a). A PLS has no nodes. As a further example, consider our formulation of channel routing. We model a channel reach as a one dimensional element consisting of a single zone situated between two nodes (Fig. 1-1b). We simulate the flow rate and depth at the nodes; the zone is associated with storage.

The conventions of the finite element technique also fall within the scope of these concepts. Figure 1-1c shows a two dimensional finite element used in the simulation of an estuary. Three nodes define the boundaries of the triangular element. A fourth node, situated inside, may be viewed as subdividing the element into three zones. This last type of element is not presently used in any HSPF module, but is included in this discussion to show the generality provided by HSPF. The system can accommodate a wide variety of simulation modules.

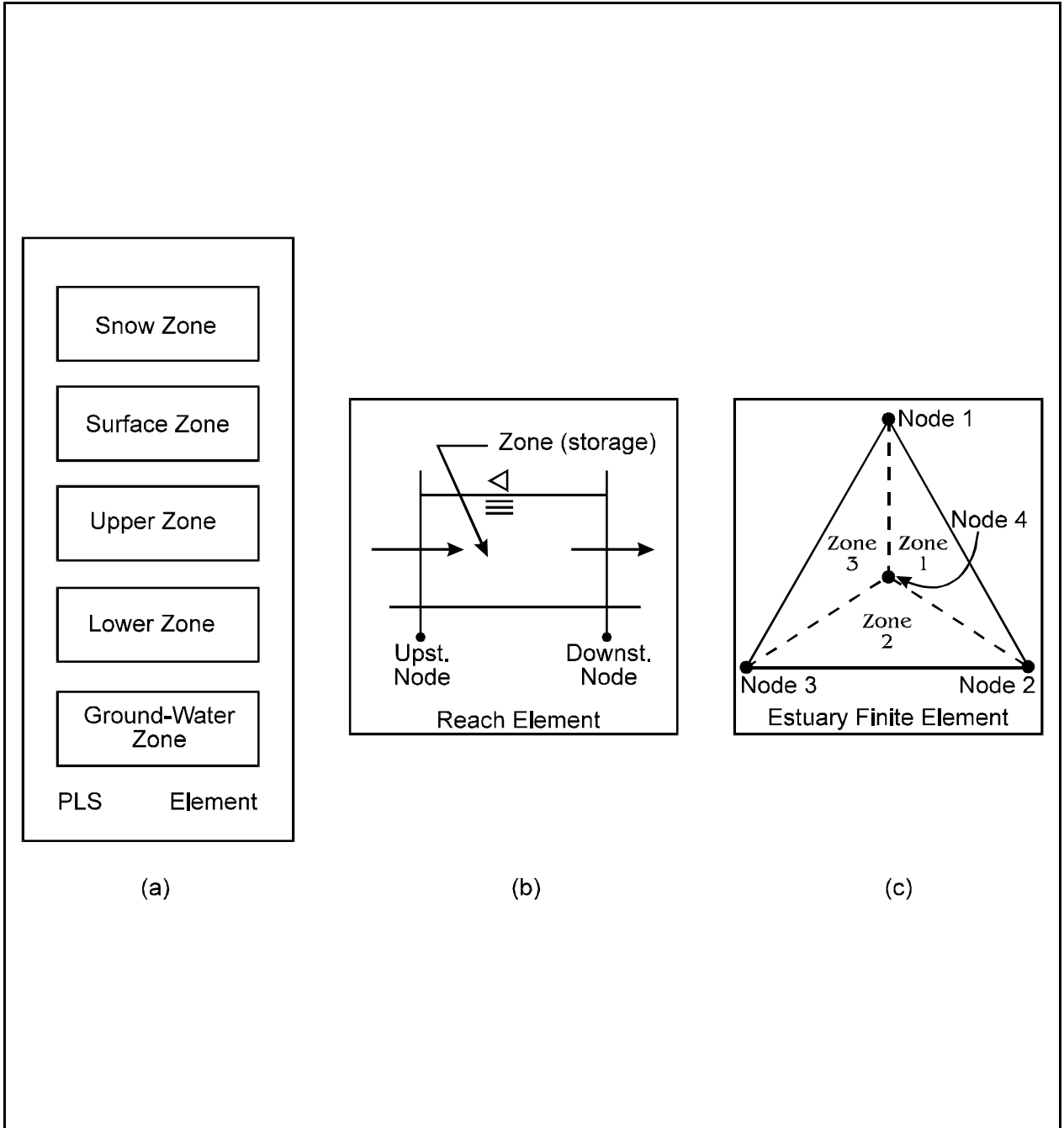


Figure 1-1 Nodes, zones, and elements

There are no fixed rules governing the grouping of zones and nodes to form elements. The model builder must decide what grouping is reasonable and meaningful, based on his view of the real world processes being simulated. In the foregoing material we presented some elements used in HSP and other systems. In general, it is convenient to define elements so that a large portion of the real world can be represented by a collection of conceptually identical elements. In this way, a single parameter structure can be defined which applies to every element in the group. Thus, each element is a variation on the basic theme. It is then meaningful to speak of an "element type." For example, elements of type "PLS" all embody the same arrangement of nodes and are represented by sets of parameters with identical structure. Variations between segments are represented only by variations in the values of parameters. The same applies to any other element, such as a Reach, layered lake or a triangular finite element.

As illustrated in the above discussion, nodes are often used to define the boundaries of zones and elements. A zone, characterized by storage, receives inflows and disperses outflows; these are called "fluxes." Note that if the nodal values of a field variable are known, it is often possible to compute the zonal values (storages). The reverse process does not work.

1.3 Processing Units and Networks

To simulate a prototype we must handle the processes occurring within the elements and the transfer of information and constituents between them. The simulation of large prototypes is made convenient by designing a single "application module" for a given type of element or element group, and applying it repetitively to all similar members in the system. For example, we may use the RCHRES module to simulate all the reaches in a watershed using storage routing. This approach is most efficient computationally if one element or group of elements, called a "processing unit" (PU), is simulated for an extended period of time before switching to the next one. To permit this, we must be able to define a processing sequence such that all information required by any PU comes from sources external to the system or from PU's already simulated. This can only happen if the PU's and their connecting fluxes form one or more networks which are "directed graphs." In a directed graph there are no bi-directional paths and no cycles. Figure 1-2 shows some directed and non-directed graphs.

The requirement that PU's form directed graphs provides the rule for grouping elements into PU's. Any elements interacting with each other via loops or bi-directional fluxes must be grouped into a single PU because none of them can be simulated apart from the others.

Thus, we can have both single element and multi-element PU's. A PLS is an example of the former and a channel network simulated using the full equations of flow exemplifies the latter (Fig. 1-3). A multi-element PU is also known as a "feedback region." The collection of PU's which are simulated in a given run is called a "network."

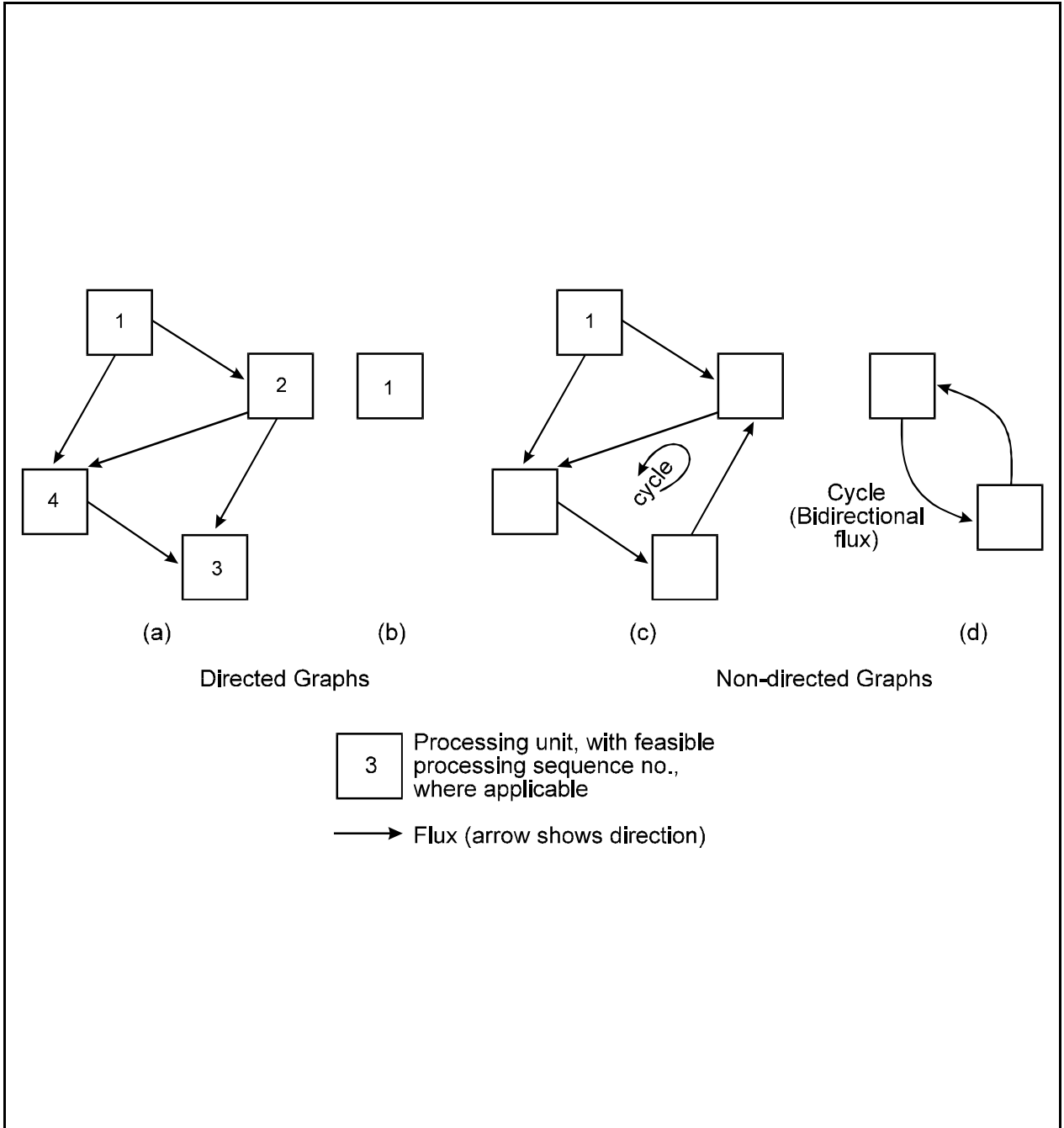


Figure 1-2 Directed and Non-directed graphs

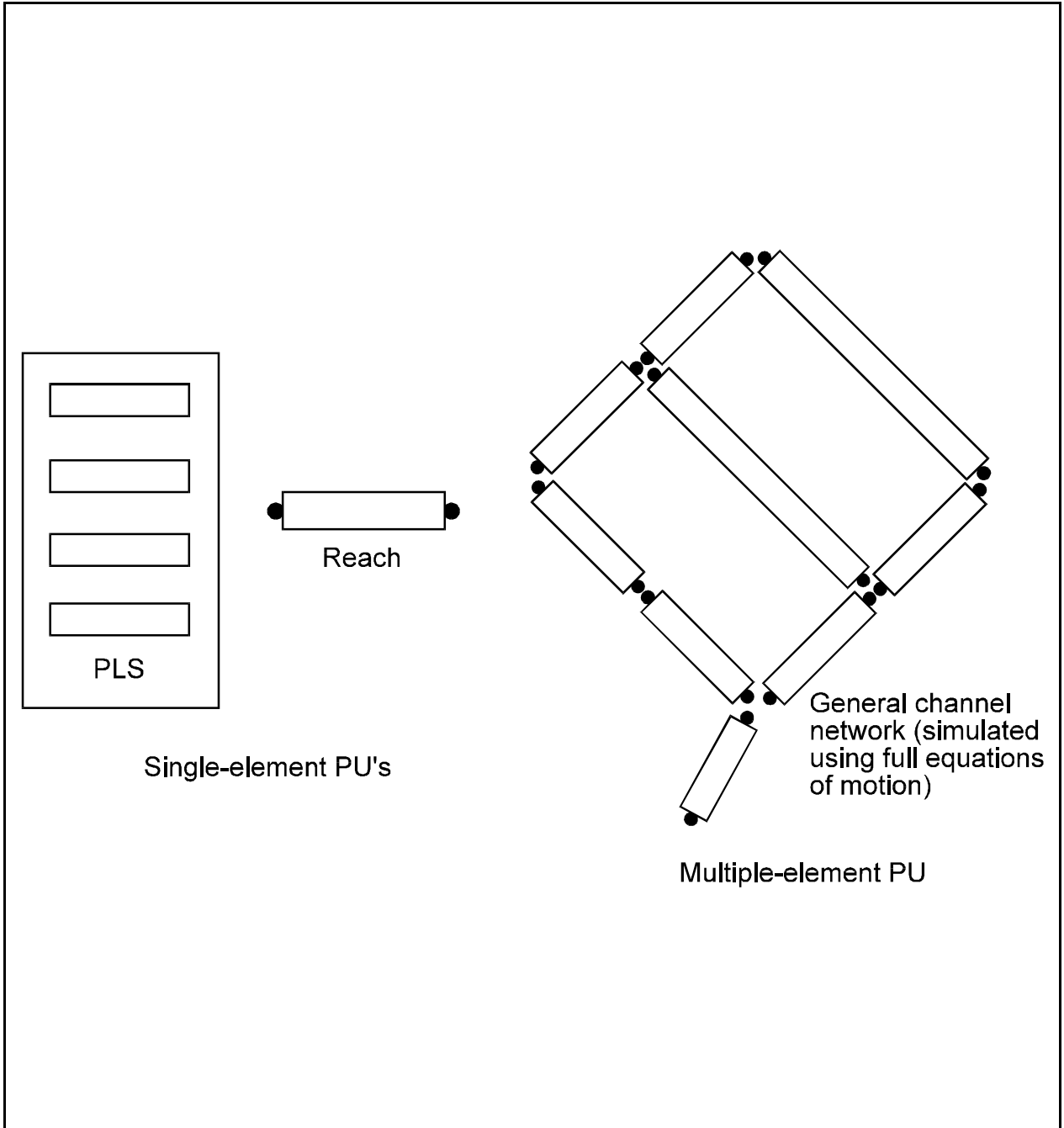


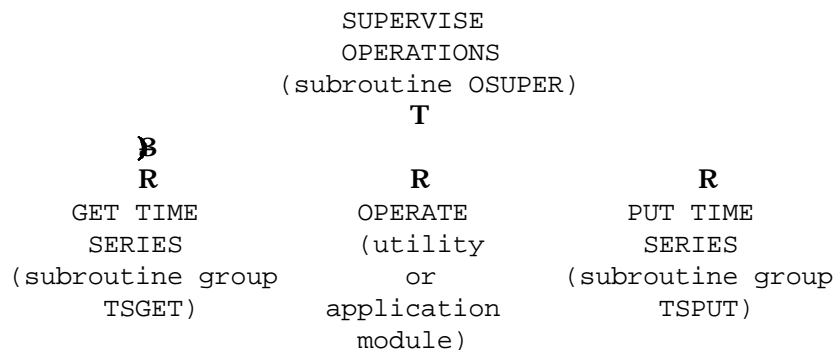
Figure 1-3 Single- and multi-element processing units

The processes which occur within a PU are represented mathematically in an "application model." The corresponding computer code is called an "application module" or "simulation module."

2.0 SOFTWARE STRUCTURE

2.1 Concept of an Operation

A great variety of activities are performed by HSPF; for example, input a time series to the WDM file, find the cross correlation coefficient for two time series, or simulate the processes in a land segment. They all incorporate two or more of the following functions: get a set of time series, operate on the set of input time series to produce other time series, and output the resulting time series. This applies both to application modules (already discussed) and to utility modules, which perform operations ancillary or incidental to simulation. Thus, a simulation run may be viewed as a set of operations performed in sequence. All operations have the following structure:



The OPERATE function is the central activity in the operation. This work is done by an "operating module" (OM) and its subordinate subprograms. They operate for a specified time on a given set of input time series and produce a specified set of output time series, under control of the "operations supervisor" (OSUPER). All of the pieces of time series involved in this internal operation have the same interval and duration. They are therefore viewed as written on an "internal scratch pad" (INPAD), resident in the memory of the computer (Fig. 2-1). The operating module receives the scratch pad with some rows filled with input and, after its work is done, returns control to the supervisor with another set of rows filled with output. The operating module may overwrite an input row with its own output. The computing module being executed, together with the options being invoked, will determine the number of rows required in the INPAD. For example, simulation of the hydraulic behavior of a stream requires relatively few time series (eg. inflow, depth and outflow) but the inclusion of water quality simulation adds many more time series to the list. Now, the total quantity of memory space available for storage of time series is also fixed (specified in a COMMON block) by the options in effect; this is the size (area) of the INPAD. Since both the size (N*M) and number of rows (M) in the INPAD are known, the "width" (no. of intervals,N) can be found. The corresponding physical time is called the "internal scratch pad span (INSPAN)."

Row Number	Time Interval Numbers								
	1	2	3	4	5	6	-	-	N
1									
2									
3									
4									
5									
-									
-									
M									

NOTE: there is one time series per row.

Figure 2-1 Logical structure of the internal scratch pad

The "get time series" function prepares the input time series. This work is done by a subroutine group called TSGET. It obtains the correct piece of a time series from the appropriate file, aggregates or disaggregates it to the correct time interval, multiplies the values by a user specified constant (if required), and places the data in the required row of the internal scratch pad. Subroutine group TSPUT performs the reverse set of operations. TSGET and TSPUT are sometimes bypassed if a required time series is already in the INPAD when the operation is started, or if the output is being passed to the next operation via the internal scratch pad.

2.2 Time Series Storage

The time series used and produced by an operation can reside in four types of storage.

1. The Watershed Data Management (WDM) File

The WDM file has replaced the TSS as the principal library for storage of time series. As far as the computer's operating system is concerned, it consists of a single large direct access file. This space is subdivided into many data sets containing individual time series. Each is logically self-contained but may be physically scattered through the file. A directory keeps track of data sets and their attributes. Before time series are written to the WDM file, the file and its directory must be created using the interactive program ANNIE, which is documented separately.

2. The Hydrologic Engineering Center Data Storage System (DSS)

The DSS is the primary hydrologic data storage system of the U.S. Army Engineers Hydrologic Engineering Center (HEC). It is similar in design and function to the WDM file. A DSS file consists of a single, large, direct-access file containing many individual data sets that are identified by unique identifiers called "pathnames". A pathname is a string of characters from 5 to 80 characters long, and similar in construction to a file pathname on computer disk. Creation and maintenance of DSS files is typically performed by a utility program such as DSSUTL, which is documented separately.

3. Sequential Files

These are ASCII, formatted disk files with a constant logical record length. Time series received from agencies such as the National Weather Service are typically stored in sequential files.

4. Internal Scratch Pad (INPAD)

If two or more operations performed in sequence use the same internal time step, time series may be passed between them via the INPAD. Successive operations may simply pick up the data written by the previous ones, without any external (disk) transfer taking place. This is typically done when time series representing the flow of water (and constituents) are routed from one stream reach to the one next downstream.

2.3 Time Series Management For An Operation

Any operation involves a subset of the activities shown in Fig. 2-2. The operating module expects a certain set of time series in the INPAD. The operations supervisor, acting under user control, ensures that the appropriate input time series are loaded from whichever source has been selected, and informs the computing module of the rows in the INPAD where it will find its input. Similar arrangements hold for output of time series.

2.4 HSPF Software Hierarchy

The hierarchy of functions in HSPF is shown in Fig. 2-3. Some explanatory notes follow.

The "Run Interpreter" is the group of subprograms which reads and interprets the "Users Control Input." It sets up internal information instructing the system regarding the sequence of operations to be performed. It stores the initial conditions and the parameters for each operation in the appropriate file on disk and creates an instruction file which will ensure that time series are correctly passed between operations, where necessary.

The "Operations Supervisor" is a subroutine which acts on information provided by the Run Interpreter, invoking the appropriate "application" or "utility" modules. It provides them with the correct values for parameters and state variables by reading the files created by the Run Interpreter.

Operating modules are either "application modules" or "utility modules." They perform the operations which make up a run. Each time one of those modules is called, an operation is performed for a period corresponding to the span of the internal scratch pad (INSPAN). The Operations Supervisor ensures that the correct module is invoked.

"Service subprograms" perform tasks such as reading from and writing to time series storage areas, adding T minutes to a given date and time, to get a new date and time, etc.

The "Time Series Management System" (TSMS) consists of all the modules which are only concerned with manipulation of time series or the files used to store time series. It includes the WDM management functions, and TSGET and TSPUT.

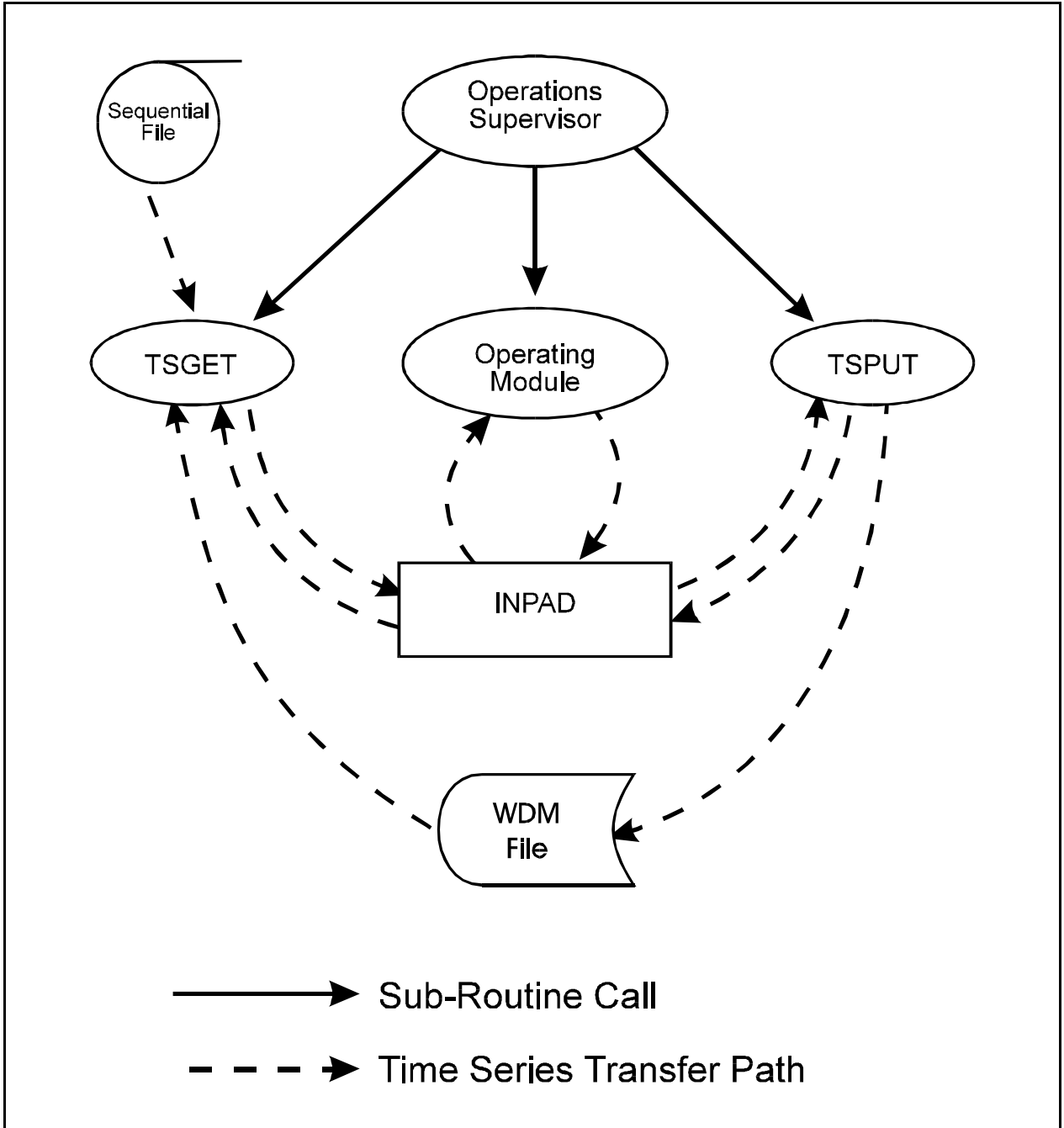


Figure 2-2 Activities involved in an operation

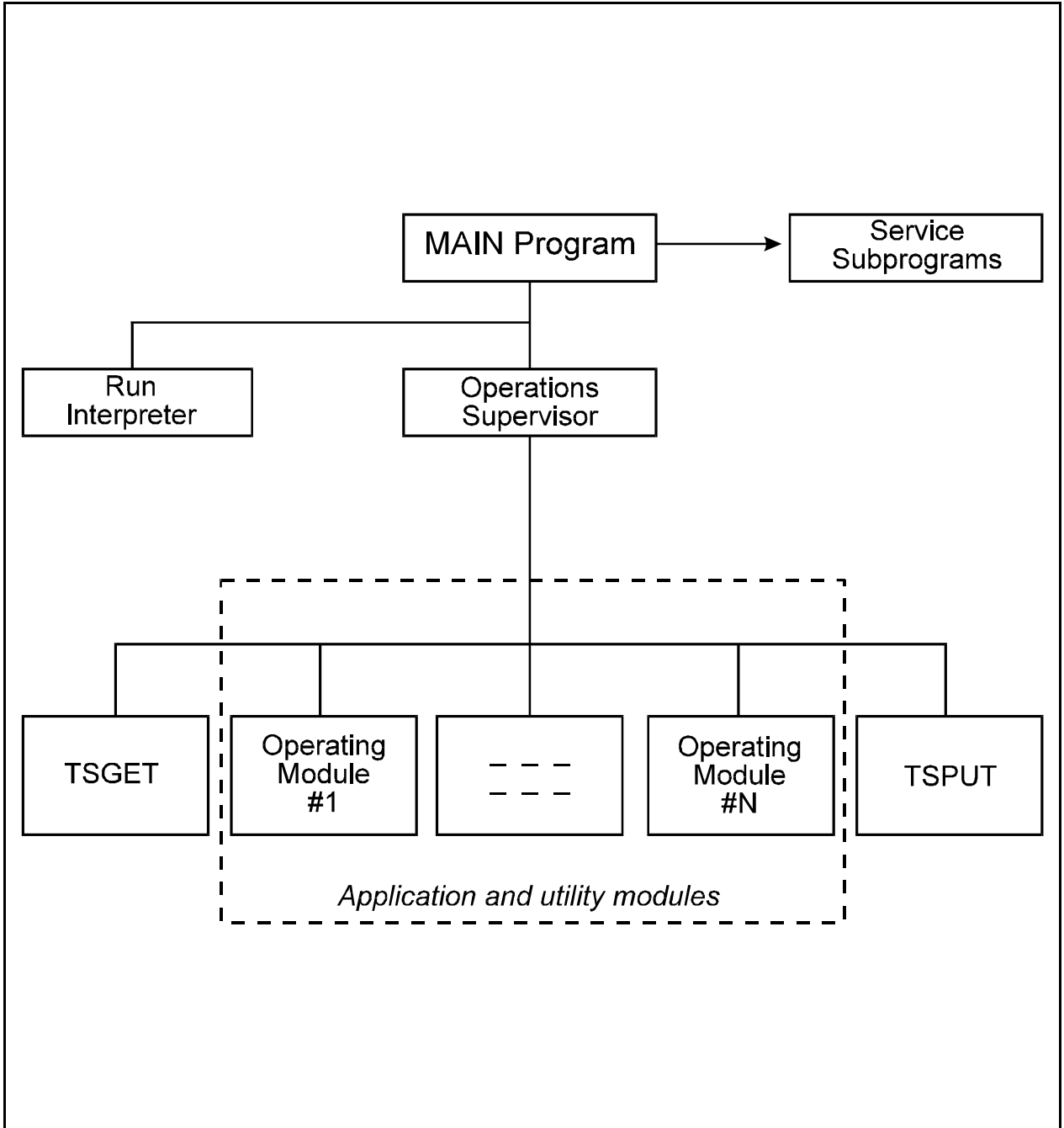


Figure 2-3 Overview of HSPF software

3.0 STRUCTURE OF A JOB

3.1 Elements of a Job

A "JOB" is the work performed by HSPF in response to a complete set of Users Control Input. It consists of one or more "RUNs". A RUN is a set of operations which can be performed serially, and which all cover the same period of time (span). The operations are performed in a sequence specified in the Users Control Input. To avoid having to store large quantities of intermediate data on disk, operations may be collected in a group in which they share a common INPAD (INGRP).

3.2 Groups Of Operations

In most runs, time series have to be passed between operations. As described in Section 2.2, each operation can communicate with four different time series storage areas: the WDM file, DSS file, the INPAD, and sequential files. This is illustrated in Fig. 3-1.

Potentially, any time series required by or output by any operation can be stored in the WDM file, DSS, or a sequential file. The user simply specifies the exact origin or destination for the time series, and the HSPF system moves the data between that device and the appropriate row of the INPAD. This system can also be used to transfer data between operations. However, it does require that all transferred data be written to the WDM file, DSS, or a sequential file. This may be very cumbersome and/or inefficient and it is better to transfer data via the INPAD, where possible.

To transfer data via the INPAD, operations must share the same pad. This means that all time series placed in the pad have the same time interval and span. This requirement provides a logical basis for grouping operations; those sharing a common INPAD are called an INGRP (Fig. 3-1). The user specifies the presence of groups in his "Users Control Input (UCI)." A typical sequence of input is shown in Fig. 3-2.

The user also indicates (directly or indirectly) in the control input the source and disposition of all time series required by or output by an operation. If the user indicates that a time series must be passed to another operation then the system assumes that the transfer will be made via the scratch pad. If they are not in the same INGRP there is an error. Without a common INPAD, the data must go via the WDM file or DSS. The structure of the Users Control Input is documented in Part F.

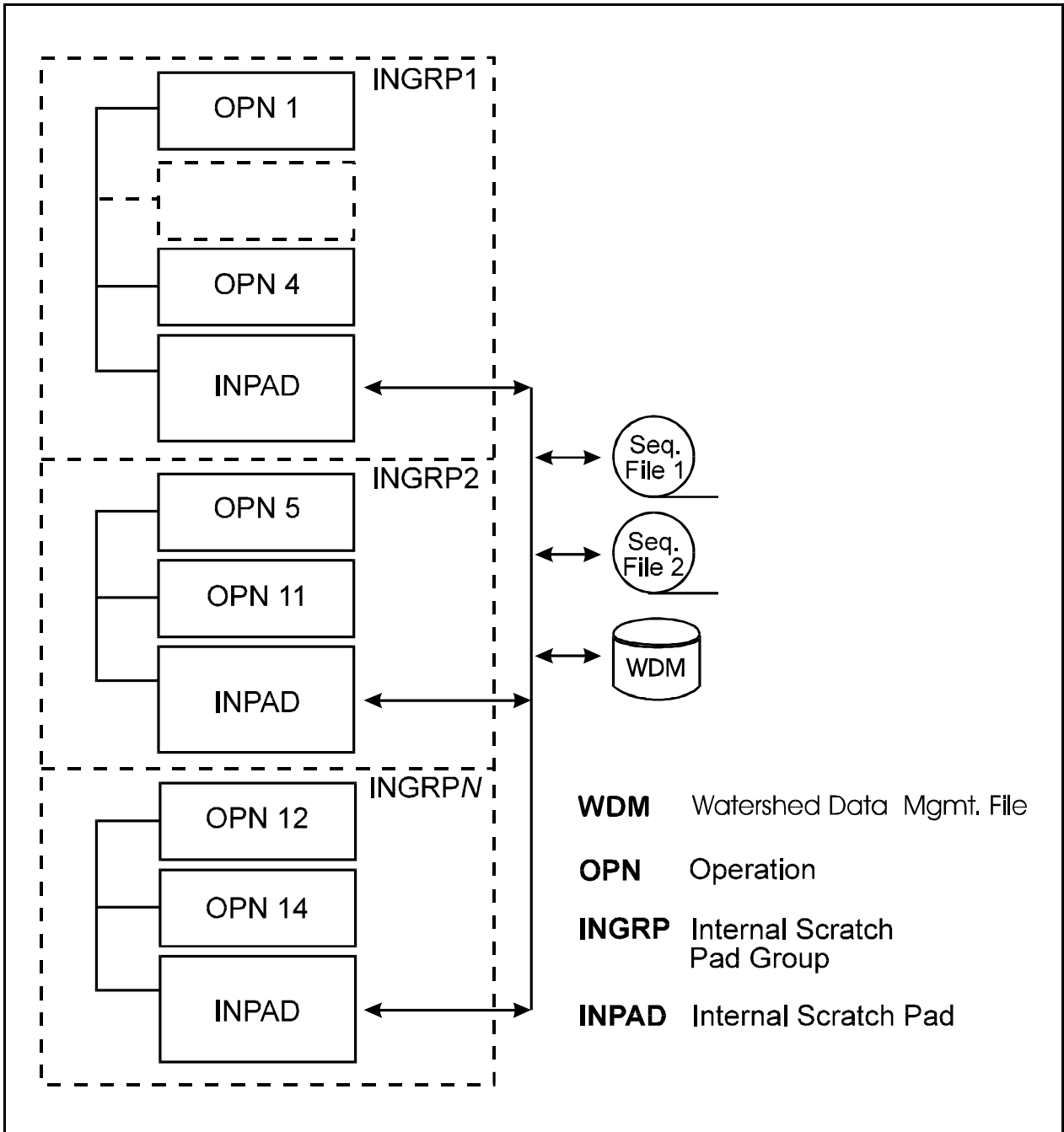


Figure 3-1 Schematic of data flow and storage for a single run

General Principles

The sequence of events in a run is as follows (refer to Fig.3-1).

- a. Operation 1 is performed until its output rows in the INPAD are filled.
- b. Data are transferred from those rows to other time series storage areas, as required. If any of these data are not required by other operations in INGRP1, their INPAD rows are available for reuse by other operations in INGRP1.
- c. Steps (a) and (b) are repeated for each operation in INGRP1.
- d. Steps (a), (b), and (c) are repeated, if necessary, until the run span is complete.
- e. The INPAD is reconfigured and work on operations 5 through 11 proceeds as in steps (a-d) above. The step repeats until all INGRP's have been handled. The run is now complete.

Note that reconfiguration of a scratch pad implies that its contents will be overwritten.

```
OPN SEQUENCE
  INGRP                                INDELT = 00:30
    COPY      1
    PERLND    1
  END INGRP
    PERLND    2                                INDELT = 00:30
    PERLND    3                                INDELT = 00:20
  INGRP                                INDELT = 00:30
    COPY      2
    RCHRES    1
    RCHRES    3
    RCHRES    5
    RCHRES   20
    RCHRES   22
    RCHRES   23
    RCHRES    7
    RCHRES    8
    RCHRES   50
    RCHRES  100
    RCHRES  200
  END INGRP
  INGRP                                INDELT = 00:10
    DURANL    1
    PLTGEN    1
  END INGRP
END OPN SEQUENCE
```

Fig. 3-2 Extract from typical Users Control Input,
showing how grouping of operations is specified

4.0 CONVENTIONS USED IN FUNCTIONAL DESCRIPTION

The primary purpose of the Functional Description (Part E) is:

1. to describe the functions performed by the various subprograms
2. to explain the technical algorithms and equations which the code implements.

Subprograms are described in numerical order in the text. This system provides a logical progression for the descriptions. General comments regarding a group of subprograms can be made when the "top" subprogram is described, while details specific to an individual subordinate subprogram can be deferred until that part is described. For example, a general description of the PERLND module (Section 4.2(1)) is followed by more detailed descriptions of its twelve sections, ATEMP (Section 4.2(1).1) through TRACER (Section 4.2(1).12).

5.0 METHOD OF DOCUMENTING DATA STRUCTURES

5.1 Structure of Data in Memory

The way in which we arrange the variables used in our programs is important. We structure them, as far as possible, using techniques like those used in Structured Program Design. We try to group data items that logically belong together.

Most of the variables in an Operating Module are contained in the Operation Status Vector (OSV). The OSVs for the application modules are shown in the Programmer's Supplement (Johanson, et al. 1979). The format used to document a data structure is similar to that used to declare a "structure" in PL/1. We do this because the technique is logical and convenient, not because of language considerations.

5.2 Structure of Data on Disk Files

The HSPF system makes use of two different types of disk-based data files:

1. Watershed Data Management (WDM) file and HEC Data Storage System (DSS) files contain time series data input and output.
2. The message/information file (HSPFMSG.WDM), is a read-only, binary file that contains information used by the program, such as keyword names, input formats, parameter defaults and limits, and error/warning messages.

6.0 METHOD OF HANDLING DIAGNOSTIC MESSAGES

HSPF makes use of two kinds of diagnostic message; error messages and warnings, which are printed to the Run Interpreter Output file during both the Run Interpretation and simulation phases of a run. These messages are all stored on the "message/information" file: HSPFMSG.WDM. This system for storing the messages has at least two advantages:

1. Because the messages are not embedded in the Fortran, they do not normally occupy any memory. This reduces the length of the executable code.
2. The files are easier to maintain than if the messages were embedded in the code. A user can obtain a listing of the contents by "exporting" data sets from the message file using the ANNIE program's Archive function.

Each message has been given a "maximum count". If the count for a message reaches this value, HSPF informs the user of the fact. Then:

1. If it is an error message, HSPF quits.
2. If it is a warning, HSPF continues but suppresses any future printing of this message.

In addition to the above features, the Run Interpreter has been designed to:

1. Stop if 20 errors of any kind have been detected. This gives the user a fair number of messages to work on, but avoids producing huge quantities of error messages, many of which may be spurious (say, if the code could not recover from early error conditions).
2. Stop at the end of its work if any errors have been detected by it. Thus, HSPF will not enter any costly time loop if the Run Interpreter has found any errors in the User's Control Input.

PART C

STANDARDS AND CONVENTIONS

This section has been omitted.

PART D

VISUAL TABLE OF CONTENTS

This section has been omitted.

PART E

FUNCTIONAL DESCRIPTION

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Functional Description

GENERAL COMMENTS

For a discussion on how this part of the documentation is organized, refer to Section 4 in Part B "General Principles".

1.0 MAIN Program

The MAIN program calls, directly or indirectly, all the other modules in the system. The functions performed are:

1. Preprocess the Users Control Input (UCI). Subroutine USRRDR transfers the UCI to memory, sets up a pointer system to non-comment lines, and recognizes input set headings and delimiters: RUN, END RUN.
2. If a RUN input set has been found, call subroutine INTERP to interpret it and then call OSUPER to supervise execution of it.

2.0 Manage the Time Series Store (Omitted)

3.0 Interpret a RUN Data Set in the User's Control Input (Module INTERP)

General Description of Module INTERP

This module, known as the Run Interpreter, translates a RUN data set in the User's Control Input (documented in Section 4 of Part F) into many elementary instructions, for later use by other parts of the system, when the time series are operated on. To do this, the Run Interpreter performs such tasks as:

1. Check and augment the data supplied by the user.
2. Decide which time series will be required and produced by each operation, based on the user's data and built-in tables which contain information on the various operations.
3. Allocate INPAD rows to the various time series.
4. Read the control data, parameters, and initial conditions supplied for each operation, convert them to internal units, and supply default values where required.

The output of the Run Interpreter is stored in memory arrays containing instructions to be read by the Operations Supervisor, TSGET and TSPUT (Figure 3.0-1). The instruction arrays contain the following information:

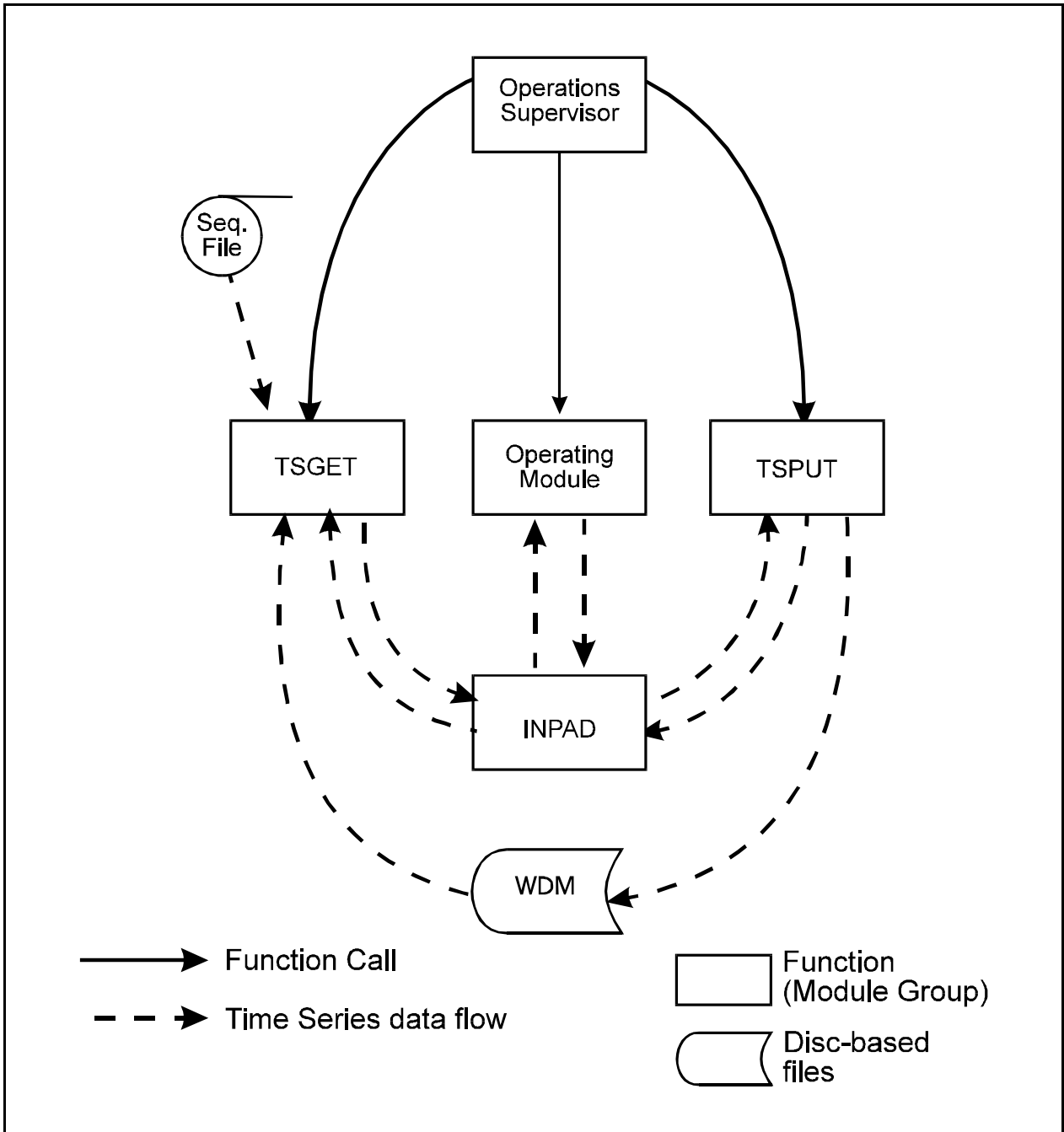


Figure 3.0-1 Functions and data transfers involved in the operations portion of HSPF

1. The Operations Supervisor Instructions Array. This array contains instructions which the Operations Supervisor reads to manage the operations in a run. This includes information on:
 - a) the configuration of the scratch pads (time intervals and widths)
 - b) the configuration of the INGROUPEs, such as the number of INGROUPEs, operations in each INGROUPE, etc.
2. The Operation Status Vector Array. The operations in a run are interrupted every time an INPAD span is completed (Part B, Section 3.2). To save computer memory, the system is designed so that the various operations all use the same area of memory. This requires that upon interruption of an operation, all information necessary to restart an operation be stored in a disk file or another memory area. The data, called the "Operation Status Vector" (OSV), reside in a string of contiguous locations in memory and have a structure specified in the Programmer's Supplement (Johanson, et al., 1979). The array OSV MEM contains an exact copy of the OSV for each operation. It is used to restore the OSV in the common memory area when the operation is resumed after interruption.
3. The Input Time Series Instruction Array (TSGETM) and the Output Time Series Instruction Array (TSPUTM). These arrays contain instructions which govern the transfer of pieces of time series into and out of the INPAD, respectively. Each instruction enables module TSGET to retrieve a specified piece of time series from one of the source volumes (Figure 3.0-1), transform it to the interval and form required for the INPAD, and insert it in the desired row of the INPAD. In the case of TSPUTM, the sequence is the reverse of that just described.

Each operation has its own set of instructions in TSGETM and TSPUTM which are read whenever modules TSGET and TSPUT are called upon to service that operation (every INSPAN).
4. The Special Action Instruction Array (SPACM). Each record of this array contains a single special action instruction, which specifies the action required to be taken in a given operation at a specific time, e.g., report operation state, modify a state variable.

4.0 Supervise and Perform Operations (module OSUPER)

Function of Operations Group

The Operations group of modules handles all the manipulations of time series and thus, performs most of the work in a run. Subroutine OSUPER controls the group. It performs some of the tasks itself, but it invokes subordinate modules to do other tasks.

General Description of Subroutine OSUPER

The primary tasks of subroutine OSUPER are to ensure that the various operations in the run are called in the correct sequence and that the associated time series and OSVs are input and/or output at the required junctures (see Part B, Section 3.2). OSUPER uses a nest of DO-loops to control the sequencing. The instruction array OSUPM specifies the ranges of the loops and supplies information ("keys") which enable OSUPER, TSGET and TSPUT to correctly access the other instruction arrays. OSUPER reads an instruction each time an operation starts a new INSPAN. Using this information, it then:

1. calls TSGET, to supply the required input time series
2. reads the OSV from disk or memory storage
3. calls the operating module

When the INSPAN is over, OSUPER:

1. writes the OSV to disk or memory storage
2. calls TSPUT, to output time series

4.03 Perform Special Actions (Subroutine SPECL)

HSPF permits the user to perform certain "Special Actions" during the course of a run. A special action instruction specifies the following:

1. The operation on which the action is to be performed (e.g., PERLND 10)
2. The date/time at which the action is to be taken.
3. The variable name and element (if the variable is an array) or the type and location within COMMON block SCRTCH of the data item to be updated.
4. The action to be performed. Two choices are available:
 - a) Reset the variable to a specified value
 - b) Increment the variable by a specified value

The special action facility is used to accommodate things such as:

1. Human intervention in a watershed. Events such as plowing, cultivation, fertilizer and pesticide application, and harvesting are simulated in this way.

2. Changes to parameters. For example, a user may wish to alter the value of a parameter for which 12 monthly values cannot be supplied. This can be done by specifying a special action for that variable. The parameter could be reset to its original value by specifying another special action, to be taken at a later time.

Special Actions can be performed on variables in the PERLND, IMPLND, RCHRES, COPY, PLTGEN, and GENER modules. The input is documented in Section 4.10 of Part F.

4.1 Get Required Input Time Series (module TSGET)

The task of this module is to insert in the INPAD all input time series required by an operation. OSUPER calls it each time an operation is to commence an INSPAN, passing to it the keys of the first and last records in the TSGET instruction array which must be read and acted upon. Each instruction causes a row of the INPAD to be filled. TSGET can draw its input time series from any of the following source "volumes": WDM file, DSS file, sequential file and INPAD (Figure 3.0-1).

TSGET will, if necessary, automatically transform the time interval and "kind" (Appendix V) of the time series, as it is transferred from the source location to the INPAD (target). TSGET can also perform a linear transformation on the values in a time series; for example, if the source contains temperatures in degrees C and the INPAD needs them in degrees F.

4.2 Perform an Operation

Function of an Operating Module

An operating module is at the center of every operation (Part B, Section 2.1). When the Operations Supervisor calls an operating module the time series which it requires are already in the INPAD. The task of the operating module is to operate on these input time series. The results of this work are:

1. updated state variables. The operating module constantly updates any state variables. These are located in the OSV. Thus, when the operating module returns control to the Operations Supervisor, which copies the OSV to disk or memory storage area, the latest values of all state variables are automatically preserved.
2. printed output. The operating module accumulates values, formats them and routes these data to the line printer.
3. output time series. The operating module places these in the INPAD, but is not concerned with their ultimate disposition; this is handled by module TSPUT.

Note that all time series simultaneously present in an INPAD have the same constant time interval. This implies that, internally, all time series involved in an operation have the same time interval. Externally, the time series may have differing time intervals. Part of the function of modules TSGET and TSPUT is to convert time series from external to internal time intervals and vice versa.

Sub-divisions in an Operating Module

An operating module may be divided into several distinct sections, each of which may be selectively activated in a given run, under the user's control, e.g., the Pervious Land-segment module (PERLND) contains twelve sections, the first being air temperature correction, and the last is tracer (conservative substance) simulation. The operating procedure is as follows: in each time interval of the INSPAN, the operating module calls each of its active sections in the order in which they are built into the code (the sequence can not be altered by the user). When the INSPAN has been covered, the operating module returns control to OSUPER which determines the next action to be taken. This procedure implies that an operating module must be arranged so that a section is called after any others from which it requires information. For example, in the Pervious Land-segment module, the sediment calculation section may use data computed by the snow and water balance sections, but not by sections listed after sediment. This kind of information flow is called an inter-section data transfer (ISDT).

Partitioning of an Operation

A user may activate one group of module sections in an initial run and other groups in subsequent runs. Thus, it is possible to "partition" an operation. For example, it is possible to calibrate the hydraulic response of a set of river reaches before moving on to simulate the behavior of constituents contained in the water. If this type of work involves ISDT's between the sections handled in different runs, it follows that:

1. The time series involved in the ISDT's must be stored between runs, probably in the WDM file.
2. In the second run the system will expect the user to specify external sources for all of these time series.

Some users will be confused by the rules for partitioning operations, but our experience indicates this will be outweighed by the flexibility which it brings.

Numbering of Operating Modules

In principle, there is no limit to the number of operating modules which the system can accommodate. Ultimately, we expect a large number of modules ranging from very simple utility modules (e.g., COPY) to very complex simulation algorithms (e.g., PERLND). Although the size and complexity of the modules vary greatly, they all are, logically, of equal rank (Figure 2-3, Part B). The adopted numbering system reflects this. Every operating module is identified by the number 4.2 and is distinguished from the others only by a subscript. For example, the Pervious Land-segment Module is 4.2(1) and the Reach/Mixed Reservoir Module 4.2(3).

Inserting Additional Operating Modules

A programmer may insert additional modules. This requires the following tasks:

1. Write or adapt the operating module. This includes restructuring the data into an OSV which conforms with the requirements of the HSPF system.
2. Add a section of code to the Run Interpreter to interpret the UCI for the new module.
3. Add data to the message/information file (HSPFMSG.WDM).
4. Make minor changes to subroutines OPNBLK and OSUPER.

Types of Operating Modules

There are two types of operating modules; utility modules and application modules. Utility modules perform any operations involving time series which are essentially auxiliary to application operations, e.g., input time series data from ASCII formatted files to the WDM file using COPY, multiply two time series together to obtain a third one, plot several time series on the same graph. Application (simulation) modules represent processes, or groups of processes, which occur in the real world.

4.2(1) Simulate a Pervious Land Segment (Module PERLND)

A land segment is a subdivision of the simulated watershed. The boundaries are established according to the user's needs, but generally, a segment is defined as an area with similar hydrologic characteristics. For modeling purposes, water, sediment, and water quality constituents leaving the watershed move laterally to a downslope segment or to a reach/reservoir. A segment of land which has the capacity to allow enough infiltration to influence the water budget is considered pervious. In HSPF, PERLND is the module that simulates the water quality and quantity processes which occur on a pervious land segment.

The primary module sections in PERLND simulate snow accumulation and melt (Section SNOW), the water budget (section PWATER), sediment produced by land surface erosion (section SEDMNT), and water quality constituents by various methods (section PQUAL and the agri-chemical sections). Other sections perform the auxiliary functions of correcting air temperature (section ATEMP) for use in snowmelt and soil temperature calculations, producing soil temperatures (section PSTEMP) for estimating the outflow temperatures and influencing reaction rates in the agri-chemical sections, and determining outflow temperatures which influence the solubility of oxygen and carbon dioxide. The structure chart for the PERLND module (Figure 4.2(1)-1) shows these sections and their relationships to each other and to PPTOT, PBAROT, and PPRINT. These last three sections manipulate the data produced. Section PPTOT places state variables (point values) and PBAROT places flux variables which are actually averages over the interval (mean values) into the INPAD. PPRINT produces the printable results in the quantity and frequency that the user specifies. The sections in the structure chart are executed from left to right.

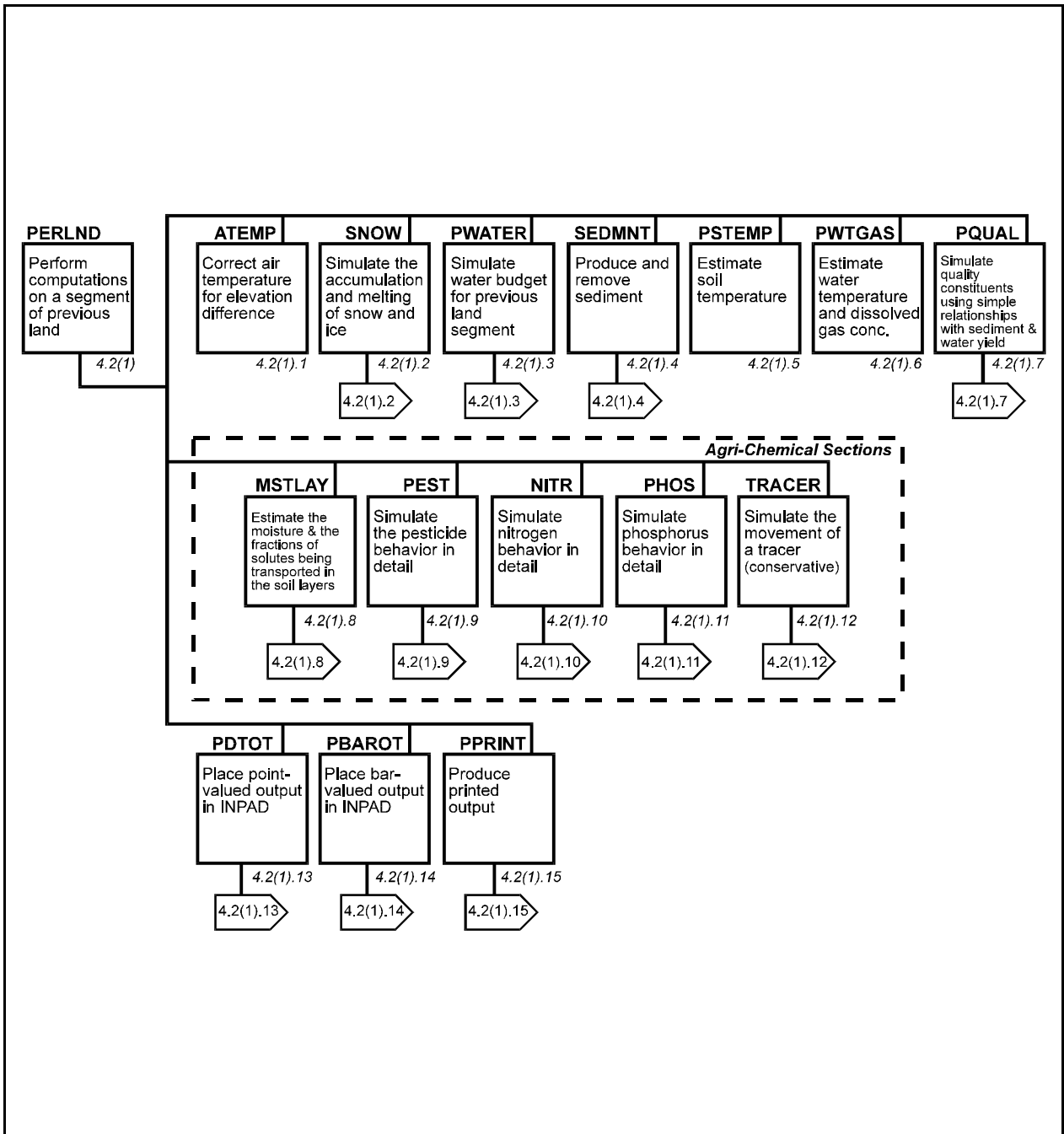


Figure 4.2(1)-1 Structure chart for PERLND Module

4.2(1).1 Correct Air Temperature for Elevation Difference (Section ATEMP of Modules PERLND and IMPLND)

Purpose

The purpose of ATEMP is to modify the input air temperature to represent the mean air temperature over the land segment. This module section is used by both PERLND and IMPLND. Air temperature correction is needed when the elevation of the land segment is significantly different than the elevation at the temperature gage. If no correction for elevation is needed, this module section can be skipped.

Method

The lapse rate for air temperature is dependent upon precipitation during the time interval. If precipitation occurs, a wet lapse rate of 0.0035 degrees F per foot difference in elevation is assumed. Otherwise, a dry lapse rate, that varies with the time of day, is used. A table of 24 hourly dry lapse rates varying between 0.0035 to 0.005 is built into the system. A different, user-defined lapse rate may be implemented by modifying the HSPF message/information file (HSPFMSG.WDM). The corrected air temperature is:

$$\text{AIRTMP} = \text{GATMP} - \text{LAPS} * \text{ELDAT} \quad (1)$$

where:

AIRTMP = corrected air temperature (degrees F)
GATMP = air temperature at gage (degrees F)
LAPS = lapse rate (degrees F/ft)
ELDAT = elevation difference between the land segment and the
gage (ft)

4.2(1).2 Simulate Accumulation and Melting of Snow and Ice (section SNOW of modules PERLND and IMPLND)

Purpose

SNOW deals with the runoff derived from the fall, accumulation, and melt of snow. This is a necessary part of any complete hydrologic package since much of the runoff, especially in the northern half of the United States, is derived from snow conditions.

Approach

Figure 4.2(1).2-1 illustrates the processes involved in snow accumulation and melt on a land segment. The algorithms used are based on the work by the Corps of Engineers (1956), Anderson and Crawford (1964), and Anderson (1968). Empirical relationships are employed when physical ones are not well known. The snow algorithms use meteorologic data to determine whether precipitation is rain or snow, to simulate an energy balance for the snowpack, and to determine the effect of the heat fluxes on the snowpack.

Five meteorologic time series are required by SNOW for each land segment simulated. They are:

- precipitation
- air temperature
- solar radiation
- dewpoint
- wind velocity

A value from each of these time series is input to SNOW at the start of each simulation interval. However, some of the meteorological time series are only used intermittently for calculating rates, such as in the calculation of the potential rate of evaporation from the snowpack.

Air temperature is used to determine when snow is falling. Once snow begins to accumulate on the ground, the snowpack accumulation and melt calculations take place. Five sources of heat which influence the melting of the snowpack are simulated:

1. net radiation heat (RADHT), both longwave and shortwave
2. convection of sensible heat from the air (CONVHT)
3. latent heat transfer by condensation of moist air on the snowpack (CONDHT)
4. heat from rain, sensible heat from rain falling (RNSHT) and latent heat from rain freezing on the snowpack
5. conduction of heat from the underlying ground to the snowpack (GMELTR)

Other heat exchange processes such as latent heat from evaporation are considered less significant and are not simulated.

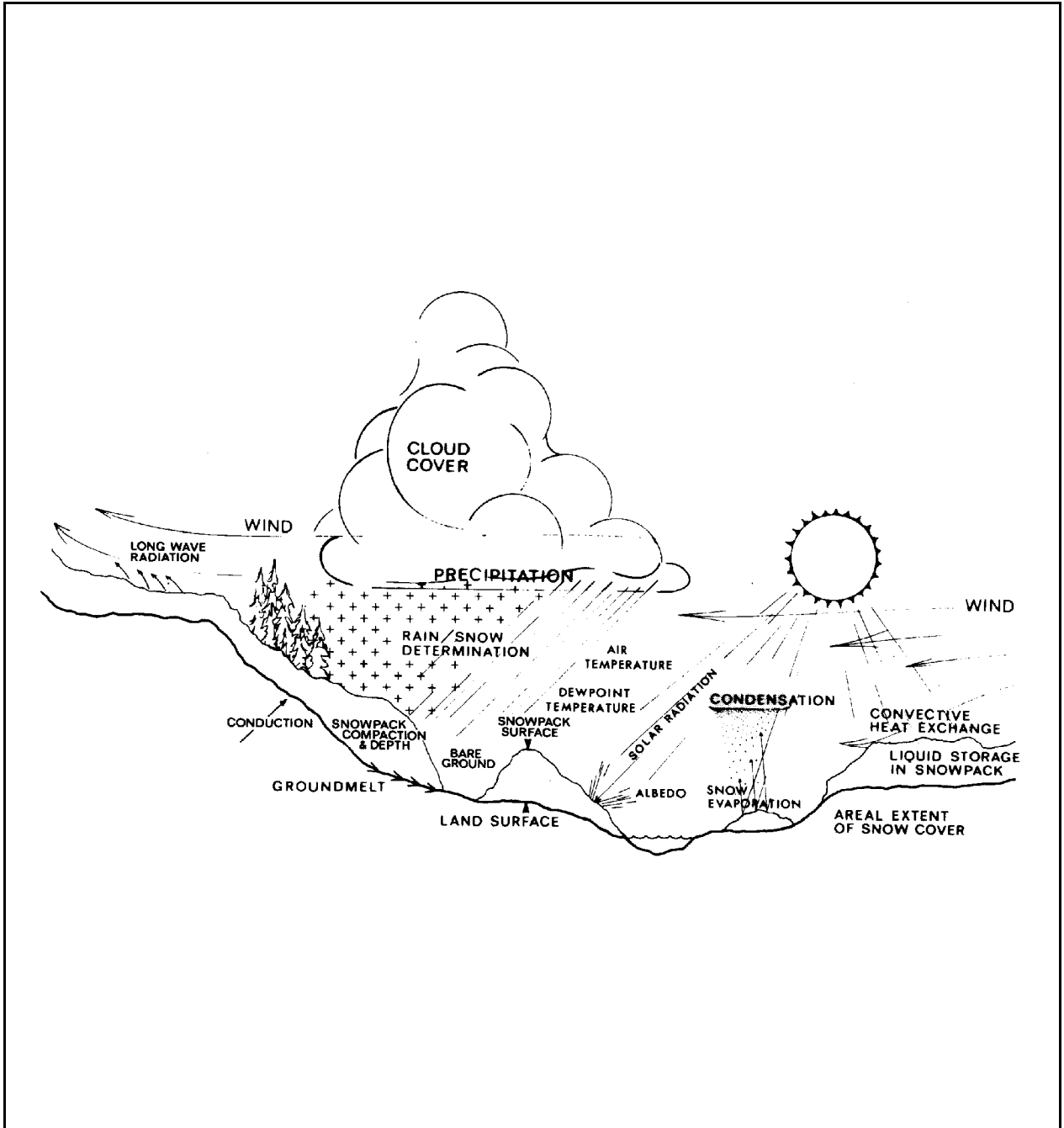


Figure 4.2(1).2-1 Snow accumulation and melt processes

The energy calculations for RADHT, CONVHT, and CONDHT are performed by subroutine HEXCHR while GMELTR is calculated in subroutine GMELT. Latent heat from rain freezing is considered in subroutine WARMUP. RNSHT is computed in the parent subroutine SNOW. For uniformity and accounting, energy values are calculated in terms of the water equivalent which they could melt. It takes 202.4 calories per square cm on the surface to melt one inch water equivalent of snow at 32 degrees F. All the sources of heat including RNSHT are considered to be positive (incoming to the pack) or zero, except RADHT which can also be negative (leaving the pack).

Net incoming heat from the atmosphere (the sum of RADHT, CONVHT, CONDHT, and RNSHT) is used to warm the snowpack. The snowpack can be further warmed by the latent heat released upon rain freezing. Any excess heat above that required to warm the snowpack to 32 degrees F is used to melt the pack. Likewise, net loss of heat is used to cool the snowpack producing a negative heat storage. Furthermore, incoming heat from the ground melts the snowpack from the bottom independent of the atmospheric heat sources except that the rate depends on the temperature of the snowpack.

Figure 4.2(1).2.2 gives a schematic view of the moisture related processes modeled in section SNOW. Precipitation may fall as rain or snow on the snowpack or the ground. Evaporation only occurs from the frozen portion of the pack (PACKF). The frozen portion of the pack is composed of snow and ice. The ice portion of PACKF is considered to be in the lower part of the snowpack, so it is the first to melt when heat is conducted from the ground. Similarly, the snow portion of PACKF is the first to melt when atmospheric heat increases. Melted PACKF and rain falling on the snowpack produce the water portion of the total snowpack which may overflow the capacity of the pack. The water yield and rain on the bare ground becomes input to module section PWATER or IWATER. These moisture related processes as well as the heat exchange processes are discussed later in more detail.

Heat transfer from incoming rain (RNSHT) to the snowpack is calculated in the parent subroutine SNOW (Section 4.2(1).2). The following physically based equation is used:

$$\text{RNSHT} = (\text{AIRTMP} - 32.0) * \text{RAINF} / 144.0 \quad (2)$$

where:

AIRTMP = temperature of the air (degrees F)
 RAINF = rainfall (inches)
 144.0 = factor to convert to equivalent depth of melt
 32.0 = freezing point (degrees F)

Other characteristics of the snowpack are also determined in the main subroutine SNOW. The fraction of the land segment covered by the snowpack is estimated by merely dividing the depth of the snowpack by a cover index (COVINX) which is a function of the parameter COVIND and the history of the pack as explained in subroutine EFFPRC. The temperature of the snowpack is estimated by:

$$\text{PAKTMP} = 32.0 - \text{NEGHTS} / (0.00695 * \text{PACKF}) \quad (3)$$

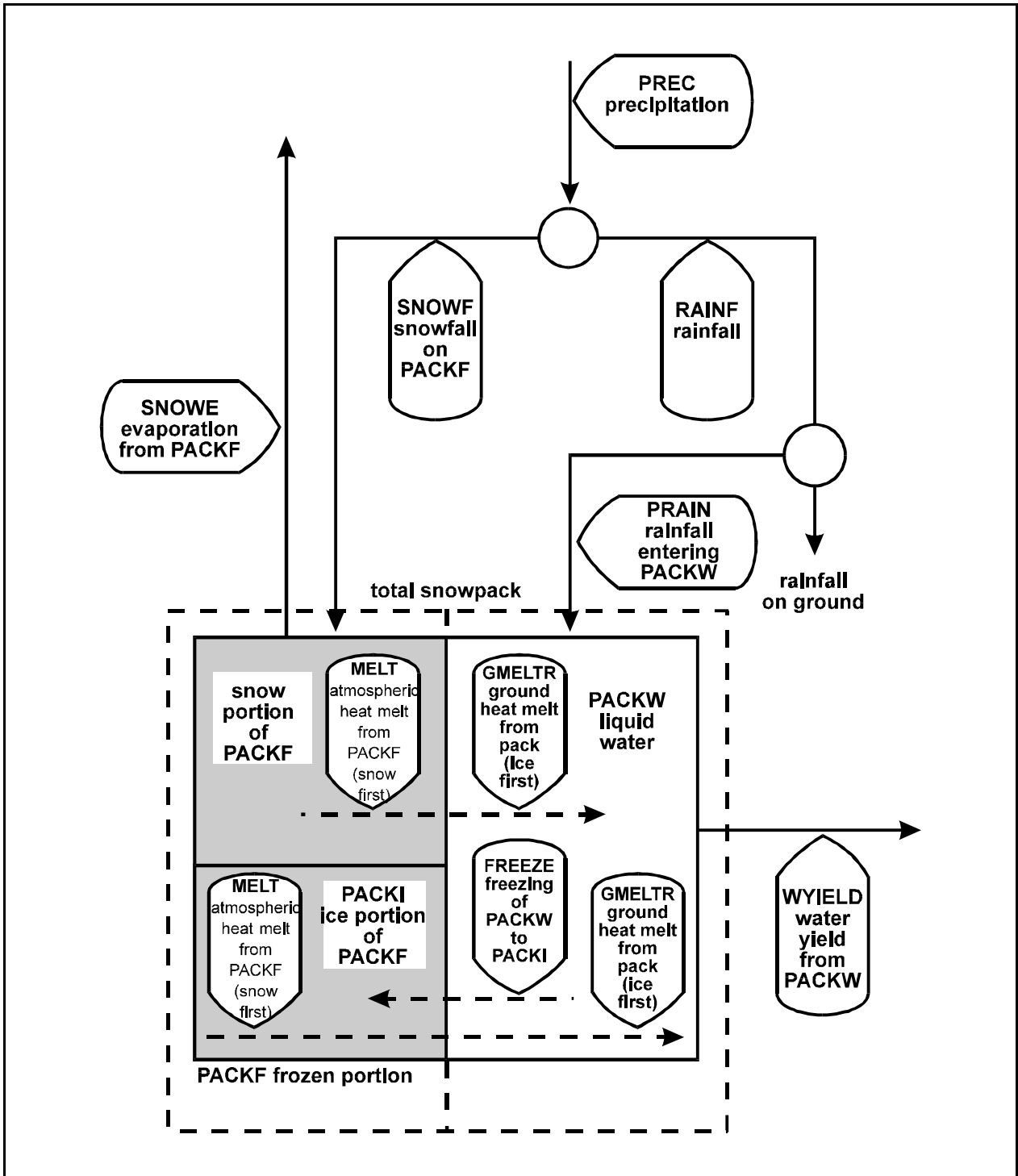


Figure 4.2(1).2-2 Flow diagram of water movement, storages, and phase changes modeled in the SNOW section of the PERLND and IMPLND Application Modules

where:

PAKTMP = mean temperature of the snowpack (degrees F)
 NEGHTS = negative heat storage (inches of water equivalent)
 PACKF = frozen contents of the snowpack (inches of water equivalent)
 0.00695 = physically based conversion factor

4.2(1).2.1 Estimate Meteorological Conditions (subroutine METEOR)

Purpose

Subroutine METEOR estimates the effects of certain meteorological conditions on specific snow-related processes by the use of empirical equations. It determines whether precipitation is falling as snow or rain. The form of precipitation is critical to the reliable simulation of runoff and snowmelt. When snow is falling, the density is calculated in order to estimate the depth of the new snowpack. The fraction of the sky which is clear is also estimated for use in the radiation algorithms, and the gage dewpoint temperature is corrected if it is warmer than air temperature.

Method

The following expression is used to calculate hourly the effective air temperature below which snowfall occurs:

$$\text{SNOTMP} = \text{TSNOW} + (\text{AIRTMP} - \text{DEWTMP}) * (0.12 + 0.008 * \text{AIRTMP}) \quad (4)$$

where:

SNOTMP = air temperature below which snowfall occurs (degrees F)
 TSNOW = parameter (degrees F)
 AIRTMP = air temperature (degrees F)
 DEWTMP = dewpoint (degrees F)

SNOTMP is allowed to vary in this calculation by a maximum of one degree F from TSNOW. When AIRTMP is equal to or greater than SNOTMP, precipitation is assumed to be rain.

When snowfall occurs, its density is estimated as a function of air temperature according to:

$$\text{RDNSN} = \text{RDNSN} + (\text{AIRTMP}/100.0)**2 \quad (5)$$

where:

RDNSN = density of new snowfall (at zero degrees F or greater)
 relative to liquid water
 RDNSN = parameter designating density of new snow at an air temperature
 of zero degrees F and lower, relative to liquid water

RDNSN is used in subroutine EFFPRC to calculate the new depth of the snowpack resulting from the addition of the snow. This and all other snow density terms are in water equivalent (inches) per depth of the snowpack (inches).

The fraction of the sky which is clear (SKYCLR) is needed for the calculation of the longwave back radiation to the snowpack from the clouds (done in subroutine HEXCHR). SKYCLR is set to the minimum value of 0.15 when precipitation occurs. Otherwise, it is increased each simulation time interval as follows:

$$\text{SKYCLR} = \text{SKYCLR} + (0.0004 * \text{DELT}) \quad (6)$$

where:

DELT = simulation time interval (min)

SKYCLR increases until either it reaches unity or precipitation causes it to be reset.

A gage dewpoint higher than air temperature is not physically possible and will give erroneous results in the calculation of snowpack evaporation. Therefore, dewpoint is set equal to the air temperature when this situation occurs. Otherwise, the gage dewpoint is used.

4.2(1).2.2 Determine the Effect of Precipitation on the Pack (subroutine EFFPRC)

Purpose

The purpose of this subroutine is to add the falling snow to the pack, determine the amount of rain falling on the snowpack, and adjust the snowpack dullness to take into account new snow.

Method

The amount of precipitation falling as snow or rain is determined in subroutine METEOR. Subroutine EFFPRC accounts for the influence that snowfall and rain have on the land segment. The subroutine begins by increasing the snowpack depth by the amount of snow falling on the pack divided by its density.

The fraction of the land segment which is covered by the snowpack (SNOCOV) is determined by re-evaluating the index to areal coverage (COVINX). When the frozen contents of the pack (PACKF) exceeds the value of the parameter describing the maximum PACKF required to insure complete areal coverage by snow cover (COVIND), then COVINX is set equal to COVIND. Otherwise, COVINX is equal to the largest previous value of PACKF. SNOCOV is PACKF/COVINX if PACKF < COVINX. The amount of rain falling on the snowpack is that fraction of the precipitation which falls as rain multiplied by the SNOCOV. Rain falling on the snowpack will either freeze, adding to the frozen portion of the pack and produce heat used to warm the pack (see subroutine WARMUP), or it will increase the liquid water content of the pack (see subroutine LIQUID). Any rain not falling on the pack is assumed to land on bare ground.

When snowfall occurs, the index to the dullness of the snowpack (DULL) is decreased by one thousand times the snowfall for that interval. However, if one thousand times the snowfall is greater than the previous value for DULL, then DULL is set to zero to account for a new layer of perfectly reflectable snow. Otherwise, when snowfall does not occur, DULL is increased by one index unit per hour up to a maximum of 800. Since DULL is an empirical term used as an index, it has no physical units. DULL is used to determine the albedo of the snowpack, which in turn is used in the shortwave energy calculations in subroutine HEXCHR.

4.2(1).2.3 Compact the Pack (subroutine COMPAC)

Purpose

The addition of new snow will reduce the density as well as increase the depth of the snowpack as in subroutine EFFPRC. The pack will tend to compact with age until a maximum density is reached. The purpose of subroutine COMPAC is to determine the rate of compaction and calculate the actual change in the depth due to compaction.

Method

When the relative density is less than 55 percent, compaction is assumed to occur. The rate of compaction is computed according to the empirical expression:

$$\text{COMPCT} = 1.0 - (0.00002 * \text{DELT60} * \text{PDEPTH} * (0.55 - \text{RDENPF})) \quad (7)$$

where:

COMPCT = unit rate of compaction of the snowpack per interval
 DELT60 = number of hours in an interval
 PDEPTH = depth of the snowpack in inches of total snowpack
 RDENPF = density of the pack relative to liquid water

The new value for PDEPTH is COMPCT times PDEPTH. PDEPTH is used to calculate the relative density of the snowpack which affects the liquid water holding capacity as determined in subroutine LIQUID.

4.2(1).2.4 Simulate Evaporation from the Pack (subroutine SNOWEV)

Purpose

The SNOWEV subroutine estimates evaporation from the snowpack (sublimation).

Method

Evaporation from the snowpack will occur only when the vapor pressure of the air is less than that of the snow surface, that is, only when the air vapor pressure is less than 6.108 mbar, which is the maximum vapor pressure that the thin surface film of air over the snowpack can attain. When this condition is met the evaporation is computed by the empirical relationship:

$$\text{SNOWEP} = \text{SNOEVP} * 0.0002 * \text{WINMOV} * (\text{SATVAP} - \text{VAP}) * \text{SNOCOV} \quad (8)$$

where:

SNOWEP = potential rate of evaporation from the frozen part of the snowpack (inches of water equivalent/interval)
 SNOEVP = parameter used to adjust the calculation to field conditions
 WINMOV = wind movement (miles/interval)
 SATVAP = saturated vapor pressure of the air at the current air temperature (mbar)
 VAP = vapor pressure of the air at the current air temp (mbar)
 SNOCOV = fraction of the land segment covered by the snowpack

The potential (SNOWEP) will be fulfilled if there is sufficient snowpack. Otherwise, only the remaining pack will evaporate. For either case, evaporation occurs only from the frozen content of the snowpack (PACKF).

4.2(1).2.5 Estimate Heat Exchange Rates (except ground melt and rain heat) (subroutine HEXCHR)

Purpose

The purpose of this subroutine is to estimate the heat exchange from the atmosphere due to condensation, convection, and radiation. All heat exchanges are calculated in terms of equivalent depth of melted or frozen water.

Method of Determining Heat Supplied by Condensation

Transfer of latent heat of condensation can be important when warm moist air masses travel over the snowpack. Condensation occurs when the air is moist enough to condense on the snowpack. That is, when the vapor pressure of the air is greater than 6.108 mbar. This physical process is the opposite of snow evaporation; the heat produced by it is calculated by another empirical relationship:

$$\text{CONDHT} = 8.59 * (\text{VAP} - 6.108) * \text{CCFACT} * 0.00026 * \text{WINMOV} \quad (9)$$

where:

CONDHT = condensation heat flux to the snowpack (inches of water equivalent/interval)
 VAP = vapor pressure of the air at the current air temp (mbar)
 CCFACT = parameter used to correct melt values to field conditions
 WINMOV = wind movement (miles/interval)

CONDHT can only be positive or zero, that is, incoming to the pack.

Method of Determining Heat Supplied by Convection

Heat supplied by turbulent exchange with the atmosphere can occur only when air temperatures are greater than freezing. This convection of heat is calculated by the empirical expression:

$$\text{CONVHT} = (\text{AIRTMP} - 32.0) * (1.0 - 0.3 * \text{MELEV} / 10000.0) * \text{CCFACT} * 0.00026 * \text{WINMOV} \quad (10)$$

where:

CONVHT = convective heat flux to the snowpack (inches of water equivalent/interval)
 AIRTMP = air temperature (degrees F)
 MELEV = mean elevation of the land segment above sea level (ft)

In the simulation, CONVHT also can only be positive or zero, that is, only incoming.

Method of Determining Heat Supplied by Radiation

Heat supplied by radiation is determined by:

$$\text{RADHT} = (\text{SHORT} + \text{LONG}) / 203.2 \quad (11)$$

where:

RADHT = radiation heat flux to the snowpack (inches of water equivalent/interval)
 SHORT = net solar or shortwave radiation (langleys/interval)
 LONG = net terrestrial or longwave radiation (langleys/interval)

The constant 203.2 is the number of langleys required to produce one inch of melt from snow at 32 degrees F. RADHT can be either positive or negative, that is, incoming or outgoing.

SHORT and LONG are calculated as follows. Solar radiation, a required time series, is modified by the albedo and the effect of shading. The albedo or reflectivity of the snowpack is a function of the dullness of the pack (see subroutine EFFPRC for a discussion of DULL) and the season. The equation for calculating albedo (ALBEDO) for the 6 summer months is:

$$\text{ALBEDO} = 0.80 - 0.10 * (\text{DULL} / 24.0) ** 0.5 \quad (12)$$

The corresponding equation for the winter months is:

$$\text{ALBEDO} = 0.85 - 0.07 * (\text{DULL} / 24.0) ** 0.5 \quad (13)$$

ALBEDO is allowed a minimum value of 0.45 for summer and 0.60 for winter. The hemispheric location of the land segment is taken into account for determining summer and winter in using the above equation. This is done through the use of the latitude parameter which is positive for the northern hemisphere.

Once the albedo of the pack is found then solar radiation (SHORT) is modified according to the equation:

$$\text{SHORT} = \text{SOLRAD} * (1.0 - \text{ALBEDO}) * (1.0 - \text{SHADE}) \quad (14)$$

where:

SOLRAD = solar radiation (langleys/interval)
 SHADE = parameter indicating the fraction of the land segment which is shaded

Unlike shortwave radiation which is more commonly measured, longwave radiation (LONG) is estimated from theoretical consideration of the emitting properties of the snowpack and its environment. The following equations are based on Stefan's law of black body radiation and are linear approximations of curves in Plate 5-3, Figure 6 in Snow Hydrology (Corps of Engineers, 1956). They vary only by the constants which depend on air temperature. For air temperatures above freezing:

$$\text{LONG} = \text{SHADE} * 0.26 * \text{RELTMP} + (1.0 - \text{SHADE}) * (0.2 * \text{RELTMP} - 6.6) \quad (15)$$

And for air temperatures at freezing and below:

$$\text{LONG} = \text{SHADE} * 0.20 * \text{RELTMP} + (1.0 - \text{SHADE}) * (0.17 * \text{RELTMP} - 6.6) \quad (16)$$

where:

RELTMP = air temperature minus 32 (degrees F)
 6.6 = average back radiation lost from the snowpack in open areas (langleys/hr)

Since the constants in these equations were originally based on hourly time steps, both calculated values are multiplied by DELT60, the number of hours per interval, so that they correspond to the simulation interval. In addition, LONG is multiplied by the fraction of clear sky (SKYCLR) when it is negative, to account for back radiation from clouds.

4.2(1).2.6 Simulate Loss of Heat from Pack (subroutine COOLER)

Purpose

The purpose of this code is to cool the snowpack whenever it is warmer than the ambient air and thus loses heat. This is accomplished by accumulating negative heat storage which increases the capacity of the pack to later absorb heat without melting as simulated in subroutine WARMUP.

Method

In every interval where there is heat loss to the atmosphere and the temperature of the snowpack is greater than the air temperature, the negative heat storage will increase; that is, the pack will cool. However, there is a maximum negative heat storage. The maximum negative heat storage that can exist at any time is found by assuming a linear temperature distribution from the air temperature which is considered to be above the pack to 32 degrees at the bottom of the snowpack. This maximum negative heat storage is calculated hourly as follows:

$$\text{MNEGHS} = 0.00695 * (\text{PACKF} / 2.0) * (-\text{RELTMP}) \quad (17)$$

where:

MNEGHS = maximum negative heat storage (inches of water equivalent)
 PACKF = water equivalent of the frozen contents of the snowpack (inches)
 RELTMP = air temperature above freezing (degrees F)

The accumulation of the negative heat storage is calculated hourly from the following empirical relationship:

$$\text{NEGHT} = 0.0007 * (\text{PAKTMP} - \text{AIRTMP}) * \text{DELT60} \quad (18)$$

where:

NEGHT = potential rate of cooling of the snowpack (inches of water equivalent per interval)
 PAKTMP = mean temperature of the snowpack (degrees F)
 AIRTMP = air temperature (degrees F)
 DELT60 = number of hours per interval

NEGHT is added to the negative heat storage (NEGHTS) every interval except when limited by MNEGHS. NEGHTS is used in the parent subroutine SNOW to calculate the temperature of the snowpack and in subroutine WARMUP to determine the extent that the pack must be warmed to reach 32 degrees F.

4.2(1).2.7 Warm the Snowpack if Possible (subroutine WARMUP)

Purpose

This subroutine warms the snowpack to as much as 32 degrees F when possible.

Method

When there is negative heat storage in the pack (see subroutine COOLER for a discussion of NEGHTS), and there is net incoming energy as calculated in previous subroutines, then NEGHTS will decrease resulting in a warmer snowpack and possible melt.

The calculations in this subroutine are merely accounting. They decrease NEGHTS to a minimum of zero by subtracting the net incoming heat. If any negative heat storage remains, then the latent heat released by the freezing of any incoming rain is added to the pack. Since NEGHTS and all other heat variables are in units of inches of melt, the inches of rain falling on the pack and freezing is subtracted from NEGHTS without any conversion.

4.2(1).2.8 Melt the Pack Using Any Remaining Heat (subroutine MELTER)

Purpose

MELTER simulates the actual melting of the pack with whatever incoming heat remains. Any heat which was not used to heat the snowpack in subroutine WARMUP can now be used to melt the snowpack.

Method

This subroutine is also merely an accounting subroutine. The net incoming heat has already been calculated in terms of water equivalents of melt. Hence, any remaining incoming heat is used directly to melt the snowpack either partially or entirely depending on the size of the snowpack.

4.2(1).2.9 Handle Liquid Water in the Pack (subroutine LIQUID)

Purpose

Subroutine LIQUID first determines the liquid storage capacity of the snowpack. It then determines how much liquid water is available to fill the storage capacity. Any liquid water above the capacity will leave the snowpack unless it freezes (see subroutine ICING).

Method

The liquid water holding capacity of the snowpack can be at the maximum as specified by the parameter MWATER, at zero, or somewhere in between depending on the density of the pack: the less dense the snowpack the greater the holding capacity. The following relationships define the capacity:

for $RDENPF > 0.91$,

$$PACKWC = 0.0 \quad (19)$$

for $0.6 < RDENPF < 0.91$,

$$PACKWC = MWATER * (3.0 - 3.33 * RDENPF) \quad (20)$$

for $RDENPF < 0.61$,

$$PACKWC = MWATER \quad (21)$$

where:

PACKWC = liquid water holding capacity of the snowpack (in/in)

MWATER = parameter specifying the maximum liquid water content of the snowpack (in/in)

RDENPF = density of the snowpack relative to liquid water

MWATER is a function of the mass of ice layers, the size, the shape, and spacing of snow crystals and the degree of channelization and honeycombing of the snowpack.

Once PACKWC is calculated, it is compared to the available liquid water in the pack PWSUPY. PWSUPY is calculated by summing any storage remaining at the start of the interval, any melt, and any rain that fell on the pack which did not freeze. If PWSUPY is more than PACKWC, then water is yielded to the land surface from the snowpack.

4.2(1).2.10 Simulate Occurrence of Ice in the Pack (subroutine ICING)

Purpose

The purpose of subroutine ICING is to simulate the possible freezing of water which would otherwise leave the snowpack. This freezing in turn produces ice or frozen ground at the bottom of the snowpack. In this subroutine, the ice can be considered to be at the bottom of the pack or frozen in the ground below the snow portion of the pack thus extending the total pack into the soil. This subroutine may only be applicable in certain areas; therefore, it is optional.

Method

The freezing of the water yield of the snowpack depends on the capacity of the environment to freeze it. Every day at approximately 6 a.m. the capacity is reassessed. A new value is estimated in terms of inches of melt by multiplying the Fahrenheit degrees of the air temperature below 32.0 by 0.01. This estimate is compared with the freezing capacity if any which remains from the previous 24-hr period. If it is greater, then the new estimated capacity replaces the old, else the old value remains as the potential. Any water yield that occurs freezes and is added to the ice portion of the snowpack until the capacity is met. Any subsequent water yield is released from the snowpack.

4.2(1).2.11 Melt the Pack Using Heat from the Ground
(subroutine GMELT)

Purpose

The purpose of the GMELT subroutine is to simulate the melt caused by heat conducted from the surface underlying the snowpack. This ground heat melts the pack only from below. Therefore, melt from this process is considered independent of other previously calculated heat influences except for an indirect effect via the temperature of the snowpack. Unlike the other melt processes, ground heat melts the ice portion of the snowpack first since ice is considered to be located at the lower depths of the pack.

Method

The potential rate of ground melt is calculated hourly as a function of snowpack temperature (PAKTMP) and a lumped parameter (MGMELT). MGMELT is the maximum rate of melt in water equivalent caused by heat from the ground at a PAKTMP of 32 degrees F. MGMELT would depend upon the thermal conductivity of the soil and the normal depth of soil freezing. The potential ground melt is reduced below MGMELT by 3 percent for each degree that PAKTMP is below 32 degrees F to a minimum of 19 percent of MGMELT at 5 degrees F or lower. As long as a snowpack is present, ground melt occurs at this potential rate.

4.2(1).2.12 Reset State Variables When Snowpack Disappears
(subroutine NOPACK)

Purpose

This code resets the state variables (for example, SNOCOV) when the snowpack completely disappears.

Method

The frozen contents of the snowpack required for complete areal cover of snow (COVINX) is set to a tenth of the maximum value (COVIND). All other variables are either set to zero or the "undefined" value of -1.0E30.

4.2(1).3 Simulate Water Budget for a Pervious Land Segment
(Section PWATER of Module PERLND)

Purpose

PWATER is used to calculate the components of the water budget, primarily to predict the total runoff from a pervious area. PWATER is the key component of module PERLND; subsequent major sections of PERLND (eg. SEDMNT) depend on the outputs of this section.

Background

The hydrologic processes that are modeled by PWATER are illustrated in Figure 4.2(1).3-1. The algorithms used to simulate these land related processes are the product of over 15 years of research and testing. They are based on the original research for the LANDS subprogram of the Stanford Watershed Model IV (Crawford and Linsley, 1966). LANDS has been incorporated into many models and used to successfully simulate the hydrologic responses of widely varying watersheds. The equations used in module section PWATER are nearly identical to the ones in the current version of LANDS in the PTR Model (Crawford and Donigian, 1973), HSP (Hydrocomp, 1976), and the ARM and NPS Models (Donigian and Crawford, 1976 a,b). However, some changes have been made to LANDS to make the algorithms internally more amenable to a range of calculation time steps. Also, many of the parameter names have been changed to make them more descriptive, and some can be input on a monthly basis to allow for seasonal variation.

Data Requirements and Manipulation

The number of time series required by module section PWATER depends on whether snow accumulation and melt are considered. When such conditions are not considered, only potential evapotranspiration and precipitation are required. However, when snow conditions are considered, air temperature, rainfall, snow cover, water yield, and ice content of the snowpack are also required. Also, the evaporation data are adjusted when snow is considered. The input evaporation values are reduced to account for the fraction of the land segment covered by the snowpack (determined from the generated time series for snow cover), with an allowance for the fraction of area covered by coniferous forest which, it is assumed, can transpire through any snow cover. Furthermore, PET is reduced to zero when air temperature is below the parameter PETMIN. If air temperature is below PETMAX but above PETMIN, PET will be reduced to 50% of the input value, unless the first adjustment already reduced it to less than this amount.

The estimated potential evapotranspiration (PET) is used to calculate actual ET in subroutine group EVAPT.

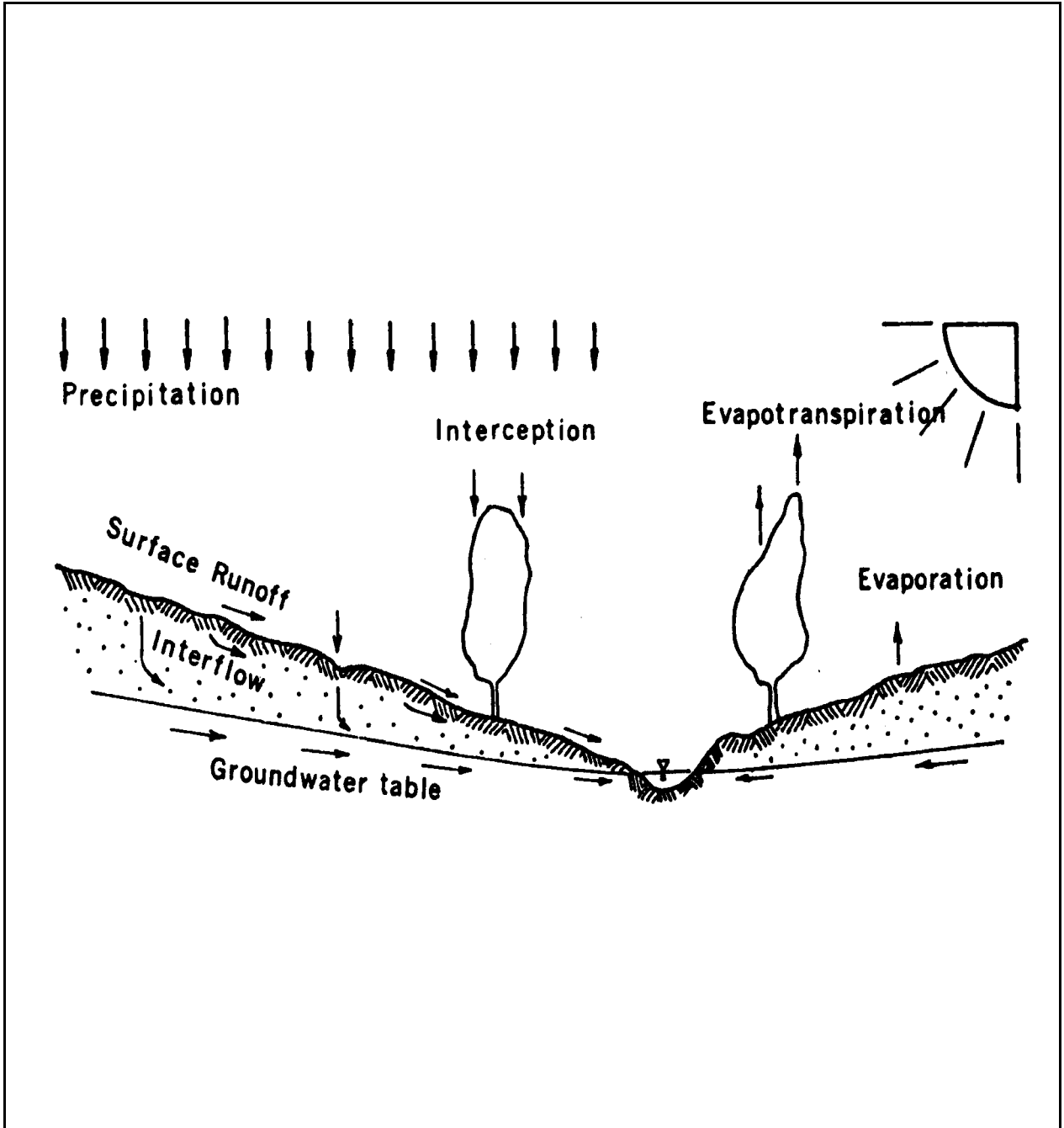


Figure 4.2(1).3-1 Hydrologic cycle

Approach

Figure 4.2(1).3-2 represents the fluxes and storages simulated in module section PWATER. The time series SUPY representing moisture supplied to the land segment includes rain, and when snow conditions are considered, rain plus water from the snowpack. SUPY is then available for interception. Interception storage is water retained by any storage above the overland flow plane. For pervious areas, interception storage is mostly on vegetation. Any overflow from interception storage is added to the optionally supplied time series of surface external lateral inflow to produce the total inflow into the surface detention storage.

Inflow to the surface detention storage is added to existing storage to make up the water available for infiltration and runoff. Moisture which directly infiltrates moves to the lower zone and groundwater storages. Other water may go to the upper zone storage, may be routed as runoff from surface detention or interflow storage, or may stay on the overland flow plane, from which it runs off or infiltrates at a later time.

The processes of infiltration and overland flow interact and occur simultaneously in nature. Surface conditions such as heavy turf on mild slopes restrict the velocity of overland flow and reduce the total quantity of runoff by allowing more time for infiltration. Increased soil moisture due to prolonged infiltration will in time reduce the infiltration rate producing more overland flow. Surface detention will modify flow. For example, high intensity rainfall is attenuated by storage and the maximum outflow rate is reduced. The water in the surface detention may also later infiltrate reoccurring as interflow, or it can be contained in upper zone storage.

Water infiltrating through the surface and percolating from the upper zone storage to the lower zone storage may flow to active groundwater storage or may be lost by deep percolation. Active groundwater eventually reappears as baseflow, but deep percolation is considered lost from the simulated system.

Lateral external inflows to interflow and active groundwater storages are also possible in section PWATER. One may wish to use this option if an upslope land segment is significantly different to merit separating it from a downslope land segment and no channel exists between them.

Not only are flows important in the simulation of the water budget, but so are storages. As stated, soil storage affects infiltration. The water holding capacity of the two soil storages, upper zone and lower zone, in module section PERLND is defined in terms of nominal capacities. Nominal, rather than absolute capacities, serve the purpose of smoothing any abrupt change that would occur if an absolute capacity is reached. Such capacities permit a smooth transition in hydrologic performance as the water content fluctuates.

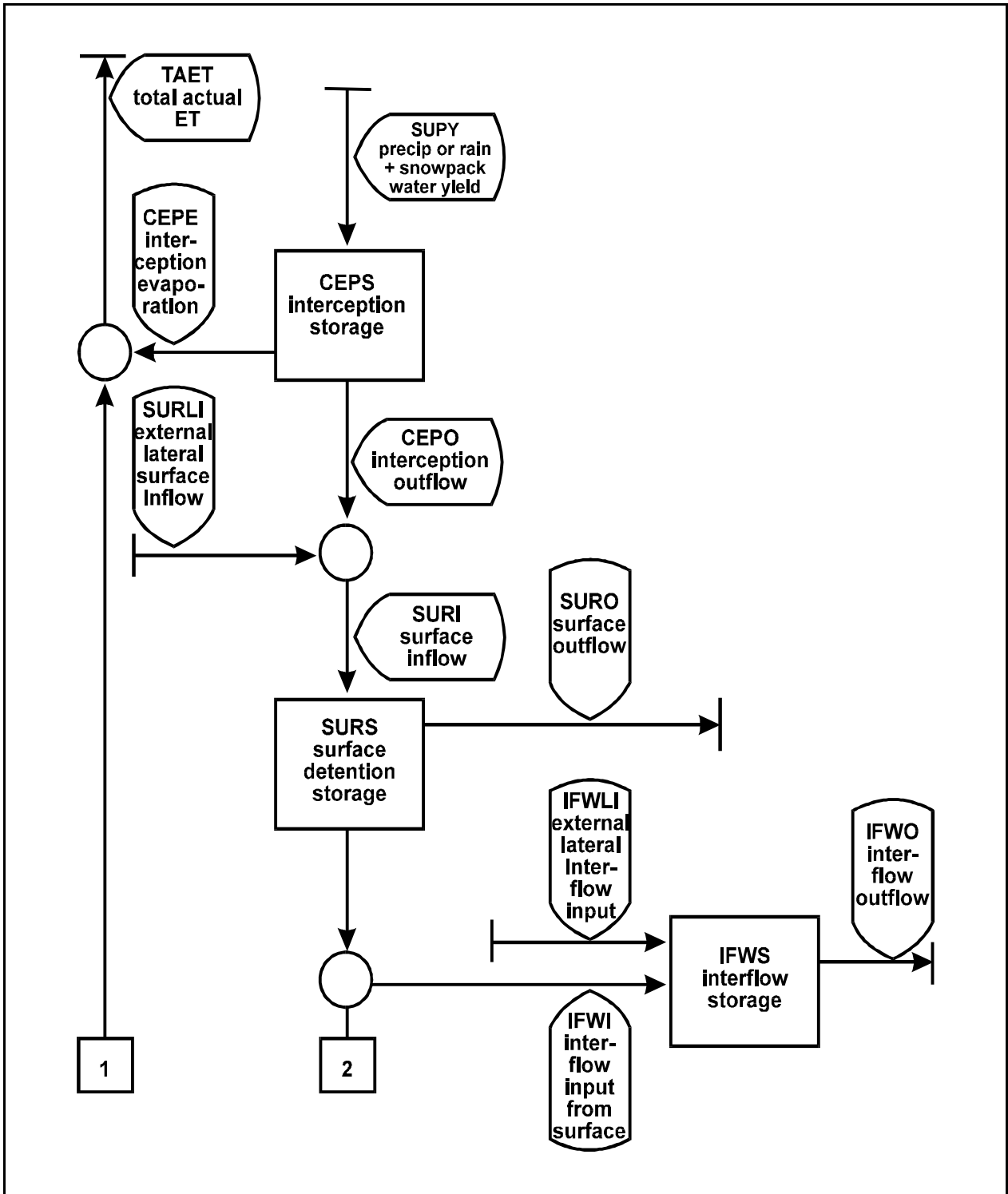


Figure 4.2(1).3-2 Flow diagram of water movement and storages modeled in the PWATER section of the PERLND Application Module

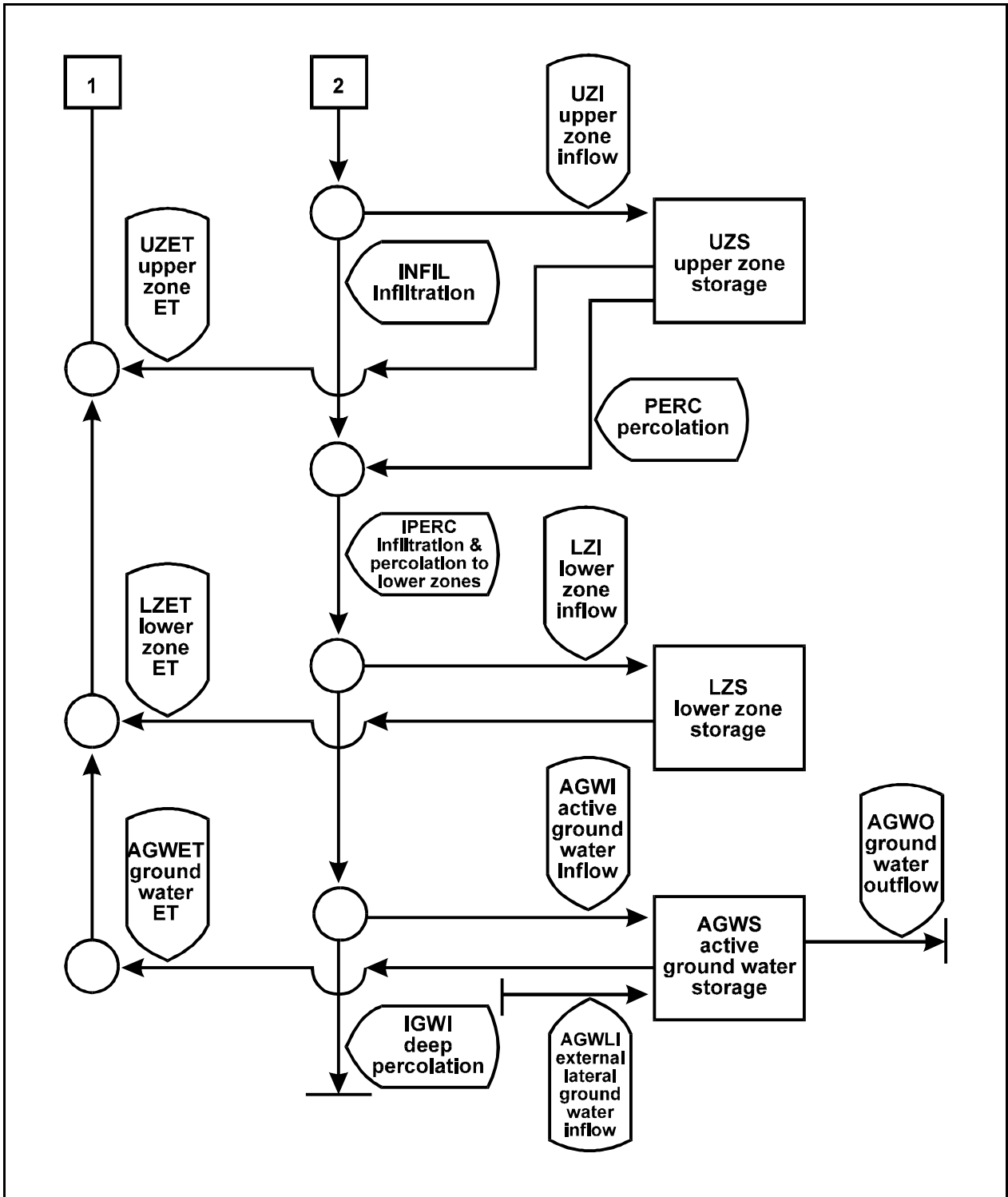


Figure 4.2(1).3-2 Flow diagram of water movement and storages modeled in the PWATER section of the PERLND Application Module (continued)

Storages also affect evapotranspiration loss. Evapotranspiration can be simulated from interception storage, upper and lower zone storages, active groundwater storage, and directly from baseflow.

Storages and flows can also be instrumental in the transformation and movement of chemicals simulated in the agri-chemical module sections. Soil moisture levels affect the adsorption and transformations of pesticides and nutrients. Soil moisture contents may vary greatly over a land segment. Therefore, a more detailed representation of the moisture contents and fluxes may be needed to simulate the transport and reaction of agricultural chemicals.

The following subroutine descriptions explain the algorithms of the PWATER module section in more detail. Further detail can be found in the reports cited above.

4.2(1).3.1 Simulate Interception (subroutine ICEPT)

Purpose

The purpose of this code is to simulate the interception of moisture by vegetal or other ground cover. Moisture is supplied by precipitation, or under snow conditions, it is supplied by the rain not falling on the snowpack plus the water yielded by the snowpack.

Method

The user may supply the interception capacity on a monthly basis to account for seasonal variations, or may supply one value designating a fixed capacity. The interception capacity parameter can be used to designate any retention of moisture which does not infiltrate or reach the overland flow plane. Typically for pervious areas this capacity represents storage on grass blades, leaves, branches, trunks, and stems of vegetation.

Moisture exceeding the interception capacity overflows the storage and is ready for either infiltration or runoff as determined by subroutine group SURFAC. Water held in interception storage is removed by evaporation; the amount is determined in subroutine EVICEP.

4.2(1).3.2 Distribute the Water Available for Infiltration and Runoff (subroutine SURFAC)

Purpose

Subroutine SURFAC determines what happens to the moisture on the surface of the land. It may infiltrate, go to the upper zone storage or interflow storage, remain in surface detention storage, or run off.

Method

The algorithms which simulate infiltration represent both the continuous variation of infiltration rate with time as a function of soil moisture and the areal variation of infiltration over the land segment. The equations representing the dependence of infiltration on soil moisture are based on the work of Philip (1957) and are derived in detail in the previously cited reports.

The infiltration capacity, the maximum rate at which soil will accept infiltration, is a function of both the fixed and variable characteristics of the watershed. Fixed characteristics include primarily soil permeability and land slopes, while variables are soil surface conditions and soil moisture content. Fixed and variable characteristics vary spatially over the land segment. A linear probability density function is used to account for areal variation. Figure 4.2(1).3-3 represents the infiltration/interflow/surface runoff distribution function of section PWATER. Careful attention to this figure and Figure 4.2(1).3-2 will facilitate understanding of subroutine SURFAC and the subordinate subroutines DISPOS, DIVISN, UZINF, and PROUTE.

The infiltration distribution represented by Figure 4.2(1).3-3 is focused around the two lines which separate the moisture available to the land surface (MSUPY) into what infiltrates and what goes to interflow. A number of the variables that are used to determine the location of lines I and II are calculated in subroutine SURFAC. They are calculated by the following relationships:

$$IBAR = (INFILT/(LZS/LZSN)**INFEXP)*INFFAC \quad (1)$$

$$IMAX = INFILD*IBAR \quad (2)$$

$$IMIN = IBAR - (IMAX - IBAR) \quad (3)$$

$$RATIO = INTFW*(2.0**(LZS/LZSN)) \quad (4)$$

where:

IBAR = mean infiltration capacity over the land segment (in/interval)

INFILT = infiltration parameter (in/interval)

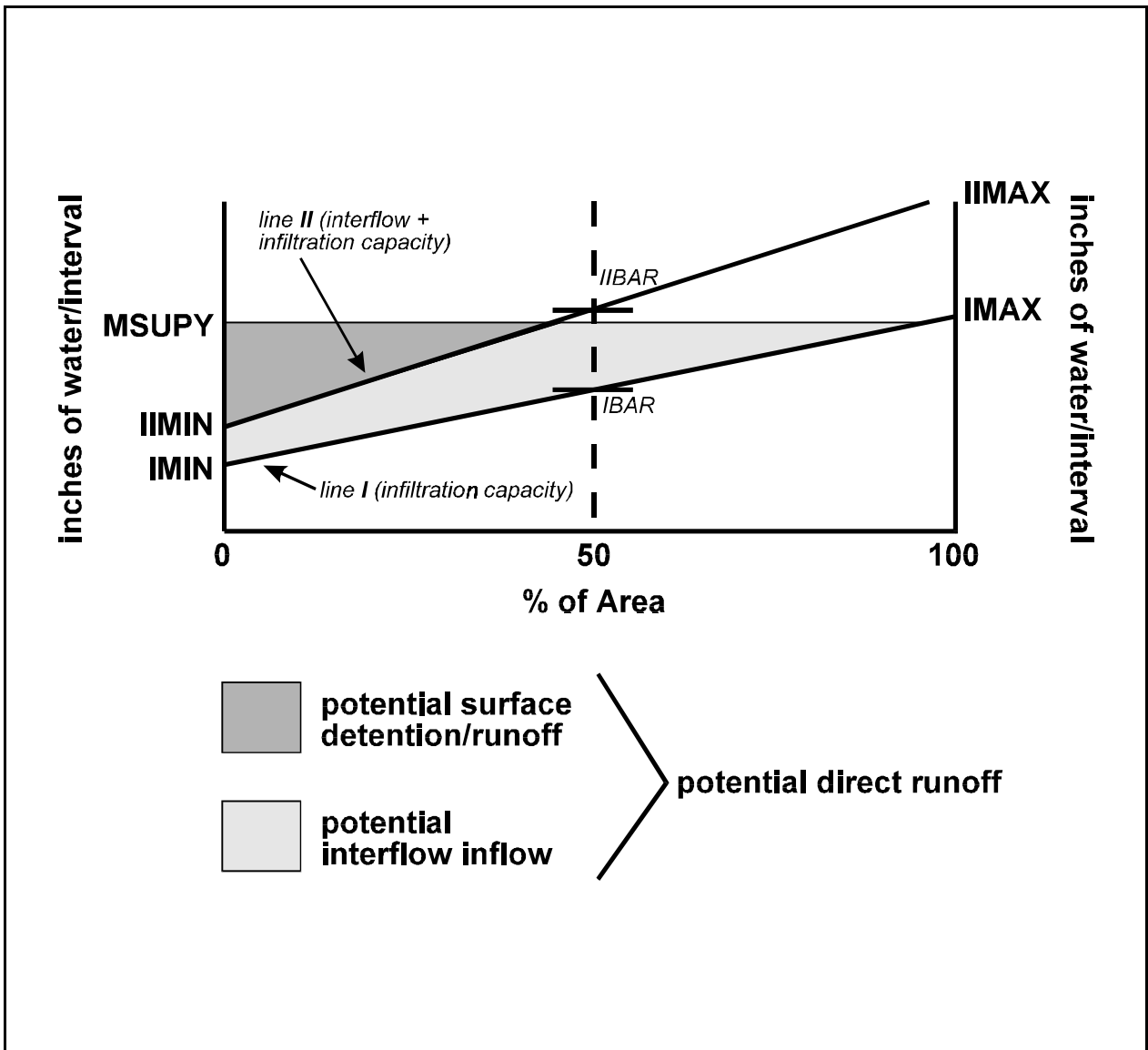


Figure 4.2(1).3-3 Determination of infiltration and interflow inflow

LZS = lower zone storage (inches)
 LZSN = parameter for lower zone nominal storage (inches)
 INFEXP = exponent parameter greater than one
 INFFAC = factor to account for frozen ground effects, if applicable
 IMAX = maximum infiltration capacity (in/interval)
 INFILD = parameter giving the ratio of maximum to mean infiltration capacity over the land segment
 IMIN = minimum infiltration capacity (in/interval)
 RATIO = ratio of the ordinates of line II to line I
 INTFW = interflow inflow parameter

The parameter INTFW can be input on a monthly basis to allow for variation throughout the year.

The factor that reduces infiltration (and also upper zone percolation) to account for the freezing of the ground surface (INFFAC) is calculated in one of two ways. In the first method, it is derived from the water equivalent of ice in the snowpack according to the equation:

$$\text{INFFAC} = 1.0 - \text{FZG} * \text{PACKI}$$

where:

FZG = parameter indicating how much icing reduces infiltration (/inches)
 PACKI = water equivalent of ice in snowpack (inches)

In this method, INFFAC is subject to a minimum, supplied as the dimensionless parameter FZGL.

The second method determines INFFAC according to the soil temperature in the lower layer. If this temperature is less than 0 degrees C, then INFFAC is set to the parameter FZGL; otherwise it is set to 1.0. This method can only be used if section PSTEMP is active.

4.2(1)3.2.1 Dispose of Moisture Supply (subroutine DISPOS)

Purpose

Subroutine DISPOS determines what happens to the moisture supply (MSUPY) on the land segment.

Method

This subroutine calls subordinate routines DIVISN, UZINF, and PROUTE. DIVISN is called to determine how much of MSUPY falls above and below line I in Figure 4.2(1).3-3. The quantity under this line is considered to be infiltrated. The amount over the line but under the MSUPY line (the entire shaded portion) is the potential direct runoff (PDRO), which is the combined increment to interflow, and upper zone storage plus the quantities which will stay on the surface and run off. PDRO is subdivided by line II. The ordinates of line II are found by multiplying the ordinates of line I by RATIO (see subroutine SURFAC for definition). The

quantity underneath both line II and the MSUPY line but above line I is called potential interflow inflow. This consists of actual interflow plus an increment to upper zone storage. Any amount above line II but below the MSUPY (potential surface detention/runoff) is that portion of the moisture supply which stays on the surface and is available for overland flow routing, plus a further increment to upper zone storage. The fractions of the potential interflow inflow and potential surface detention/runoff which are combined to compose the upper zone inflow are determined in subroutine UZINF.

4.2(1).3.2.1.2 Compute Inflow to Upper Zone (subroutines UZINF1 and UZINF2)

Purpose

The purpose of this code is to compute the inflow to the upper zone when there is some potential direct runoff (PDRO). PDRO, which is determined in subroutine DISPOS, will either enter the upper zone storage or be available for either interflow or overland flow. This subroutine determines what amount, if any, will go to the upper zone storage.

Method

The fraction of the potential direct runoff which becomes inflow to the upper zone storage is a function of the ratio (UZRAT) of the storage to the nominal capacity. Figure 4.2(1).3-4 diagrams this relationship. The equations used to define this curve follow:

$$\text{FRAC} = 1 - (\text{UZRAT}/2) * (1/(4 - \text{UZRAT})) ** (3 - \text{UZRAT}) \quad (7)$$

for UZRAT less than or equal to two. For UZRAT greater than two,

$$\text{FRAC} = (0.5/(\text{UZRAT}-1)) ** (2*\text{UZRAT}-3) \quad (8)$$

where:

FRAC = fraction of PDRO retained by the upper zone storage
UZRAT = UZS/UZSN

Since UZS and FRAC are dynamically affected by the inflow process it becomes desirable when using particularly large time steps to integrate over the interval to find the inflow to the upper zone. This is done in subroutine UZINF1. The solution is simplified by assuming that inflow to and outflow from the upper zone are handled separately. Considering inflow, the following differential equation results:

$$d(\text{UZS})/dt = (d(\text{UZRAT})/dt) * \text{UZSN} = \text{PDRO} * \text{FRAC} \quad (9)$$

Thus

$$d(\text{UZRAT})/\text{FRAC} = (\text{PDRO}/\text{UZSN}) * dt \quad (10)$$

Now taking the definite integral of both sides of the equation:

$$\text{INTGRL} = \int_{\text{UZRAT}_{t_1}}^{\text{UZRAT}_{t_2}} \frac{d(\text{UZRAT})}{\text{FRAC}} = (\text{PDRO}/\text{UZSN})(t_2-t_1) \quad (11)$$

where:

t1 = time at start of interval

t2 = time at end of interval

The integral on the left side must be evaluated numerically. Subroutine UZINF1 uses tabulated corresponding values of INTGRL and UZRAT to evaluate it. This relationship, plus Equations 9 and 11, enable one to find the change in UZRAT over the interval, and hence, the quantity of inflow.

Subroutine UZINF2, which is an alternative to UZINF1, uses the algorithm used in the predecessor models HSP, ARM and NPS. That is, Equations 7 and 8 are used directly to estimate the fraction of PDRO retained by the upper zone. Only the value of UZRAT at the start of the simulation interval is used; thus, no account is taken of the possible steady reduction in inflow to the upper zone within a single time step, due to its being filled (Figure 4.2(1).3-4).

4.2(1).3.2.1.3 Determine Surface Runoff (subroutine PROUTE)

Purpose

The purpose of subroutine PROUTE is to determine how much potential surface detention runs off in one simulation interval.

Method of Routing

Overland flow is treated as a turbulent flow process. It is simulated using the Chezy-Manning equation and an empirical expression which relates outflow depth to detention storage. A more detailed explanation and derivation can be found in the reports cited in the initial background discussion. The rate of overland flow discharge is determined by the equations:

for SURSM < SURSE

$$\text{SURO} = \text{DELT60} * \text{SRC} * (\text{SURSM} * (1.0 + 0.6(\text{SURSM}/\text{SURSE})^{**3})^{**1.67} \quad (12)$$

for SURSM >= SURSE

$$\text{SURO} = \text{DELT60} * \text{SRC} * (\text{SURSM} * 1.6)^{**1.67}$$

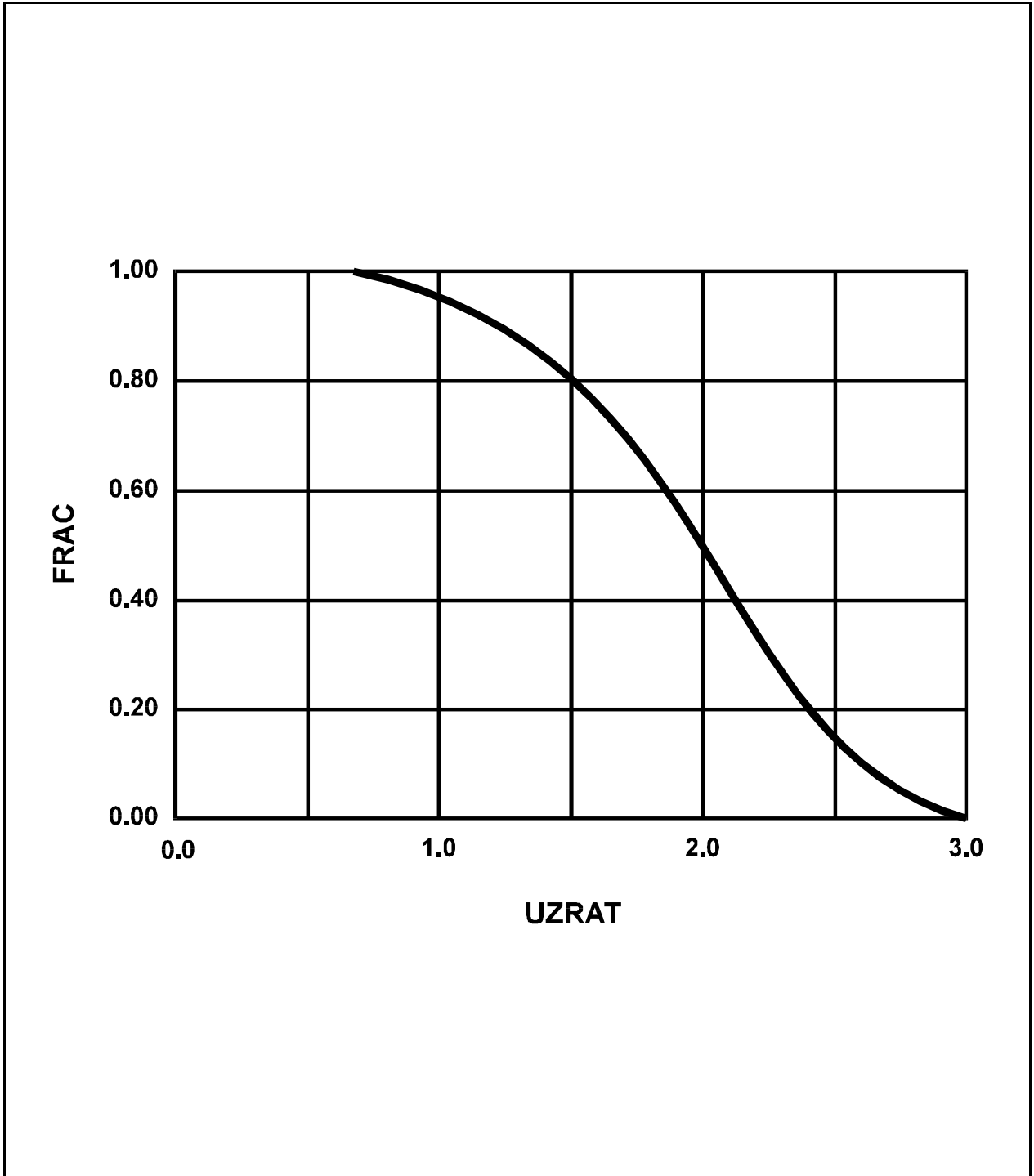


Figure 4.2(1).3-4 Fraction of the potential direct runoff retained by the upper zone (FRAC) as a function of the upper zone soil moisture ratio (UZRAT)

where:

SURO = surface outflow (in/interval)
 DELT60 = DELT/60.0 (hr/interval)
 SRC = routing variable, described below
 SURSM = mean surface detention storage over the time interval (in)
 SURSE = equilibrium surface detention storage (inches) for current supply rate

DELT60 makes the equations applicable to a range of time steps (DELT). The first equation represents the case where the overland flow rate is increasing, and the second case where the surface is at equilibrium or receding. Equilibrium surface detention storage is calculated by:

$$\text{SURSE} = \text{DEC} * \text{SSUPR} ** 0.6 \quad (13)$$

where:

DEC = calculated routing variable, described below
 SSUPR = rate of moisture supply to the overland flow surface

There are two optional ways of determining SSUPR and SURSM. One option - the same method used in the predecessor models - HSP, ARM, and NPS - estimates SSUPR by subtracting the surface storage at the start of the interval (SURS) from the potential surface detention (PSUR) which was determined in subroutine DISPOS. The units of SSUPR are inches per interval. SURSM is estimated as the mean of SURS and PSUR. The other option estimates SSUPR by the same method except that the result is divided by DELT60 to obtain a value with units of inches per hour. SURSM is set equal to SURS. This option is dimensionally consistent for any time step.

The variables DEC and SRC are calculated daily in subroutine SURFAC, but their equations will be given here since they pertain to routing. They are:

$$\text{DEC} = 0.00982 * (\text{NSUR} * \text{LSUR} / \text{SQRT}(\text{SLSUR})) ** 0.6 \quad (14)$$

$$\text{SRC} = 1020.0 * (\text{SQRT}(\text{SLSUR}) / (\text{NSUR} * \text{LSUR})) \quad (15)$$

where:

NSUR = Manning's n for the overland flow plane
 LSUR = length of the overland flow plane (ft)
 SLSUR = slope of the overland flow plane (ft/ft)

NSUR can be input on a monthly basis to allow for variations in roughness of the overland flow plane throughout the year.

4.2(1).3.3 Simulate Interflow (subroutine INTFLW)

Purpose

Interflow can have an important influence on storm hydrographs particularly when vertical percolation is retarded by a shallow, less permeable soil layer. Additions to the interflow component are retained in storage or routed as outflow from the land segment. Inflows to the interflow component may occur from the surface or from upslope external lateral flows. The purpose of this subroutine is to determine the amount of interflow and to update the storage.

Method of Determining Interflow

The calculation of interflow outflow assumes a linear relationship to storage. Thus outflow is a function of a recession parameter, inflow, and storage. Moisture that remains will occupy interflow storage. Interflow discharge is calculated by:

$$\text{IFWO} = (\text{IFWK1} * \text{INFLO}) + (\text{IFWK2} * \text{IFWS}) \quad (16)$$

where:

IFWO = interflow outflow (in/interval)
 INFLO = inflow into interflow storage (in/interval)
 IFWS = interflow storage at the start of the interval (inches)

IFWK1 and IFWK2 are variables determined by:

$$\text{IFWK1} = 1.0 - (\text{IFWK2} / \text{KIFW}) \quad (17)$$

$$\text{IFWK2} = 1.0 - \text{EXP}(-\text{KIFW}) \quad (18)$$

and

$$\text{KIFW} = -\text{ALOG}(\text{IRC}) * \text{DELT60} / 24.0 \quad (19)$$

where:

IRC = interflow recession parameter (per day)
 DELT60 = number of hr per interval
 24.0 = number of hours per day
 EXP = exponential function
 ALOG = natural logarithm function

IRC is the ratio of the present rate of interflow outflow to the value 24 hours earlier, if there was no inflow. IRC can be input on a monthly basis to allow for variation in soil properties throughout the year.

4.2(1).3.4 Simulate Upper Zone Behavior (subroutine UZONE)

Purpose

This subroutine and the subsidiary subroutine UZONES are used to calculate the water percolating from the upper zone. Water not percolated remains in upper zone storage available for evapotranspiration in subroutine ETUZON.

Method of Determining Percolation

The upper zone inflow calculated in DISPOS is first added to the upper zone storage at the start of the interval to obtain the total water available for percolation from the upper zone.

Percolation only occurs when UZRAT minus LZRAT is greater than 0.01. When this happens, percolation from the upper zone storage is calculated by the empirical expression:

$$\text{PERC} = 0.1 * \text{INFILT} * \text{INFFAC} * \text{UZSN} * (\text{UZRAT} - \text{LZRAT}) ** 3 \quad (20)$$

where:

PERC = percolation from the upper zone (in/interval)
 INFILT = infiltration parameter (in/interval)
 INFFAC = factor to account for frozen ground, if any
 UZSN = parameter for upper zone nominal storage (inches)
 UZRAT = ratio of upper zone storage to UZSN
 LZRAT = ratio of lower zone storage to lower zone nominal storage (LZSN)

The upper zone nominal capacity can be input on a monthly basis to allow for variations throughout the year. The monthly values are interpolated to obtain daily values.

4.2(1).3.5 Simulate Lower Zone Behavior (subroutine LZONE)

Purpose

This subroutine determines the quantity of infiltrated and percolated water which enters the lower zone. The infiltrated moisture supply is determined in subroutine DISPOS. The percolated moisture from the upper zone is found in subroutine UZONE.

Method

The fraction of the direct infiltration plus percolation that enters the lower zone storage (LZS) is based on the lower zone storage ratio of LZS/LZSN where LZSN is the lower zone nominal capacity. The inflowing fraction is determined empirically by:

$$\text{LZFRAC} = 1.0 - \text{LZRAT} * (1.0 / (1.0 + \text{INDX})) ** \text{INDX} \quad (21)$$

when LZRAT is less than 1.0, and by

$$\text{LZFRAC} = (1.0 / (1.0 + \text{INDX})) ** \text{INDX} \quad (22)$$

when LZRAT is greater than 1.0. INDX is defined by:

$$\text{INDX} = 1.5 * \text{ABS}(\text{LZRAT} - 1.0) + 1.0 \quad (23)$$

where:

LZFRAC = fraction of infiltration plus percolation entering LZS

LZRAT = LZS/LZSN

ABS = function for determining absolute value

These relationships are plotted in Figure 4.2(1).3-5. The fraction of the moisture supply remaining after the surface, upper zone, and lower zone components are subtracted is added to the groundwater storages.

4.2(1).3.6 Simulate Groundwater Behavior (subroutine GWATER)

Purpose

The purpose of this subroutine is to determine the amount of the inflow to groundwater that is lost to deep or inactive groundwater and to determine the amount of active groundwater outflow. These two fluxes will in turn affect the active groundwater storage.

Method of Determining Groundwater Fluxes

The quantity of direct infiltration plus percolation from the upper zone which does not go to the lower zone (determined in subroutine LZONE) will be inflow to either inactive or active groundwater. The distribution to active and inactive groundwater is user designated by parameter DEEPFR. DEEPFR is that fraction of the groundwater inflow which goes to inactive groundwater. The remaining portion of the percolating water and all external lateral inflow if any make up the total inflow to the active groundwater storage.

The outflow from active groundwater storage is based on a simplified model. It assumes that the discharge of an aquifer is proportional to the product of the cross-sectional area and the energy gradient of the flow. Further, a representative cross-sectional area of flow is assumed to be related to the groundwater storage level at the start of the interval. The energy gradient is estimated as a basic gradient plus a variable gradient that depends on past active groundwater accretion.

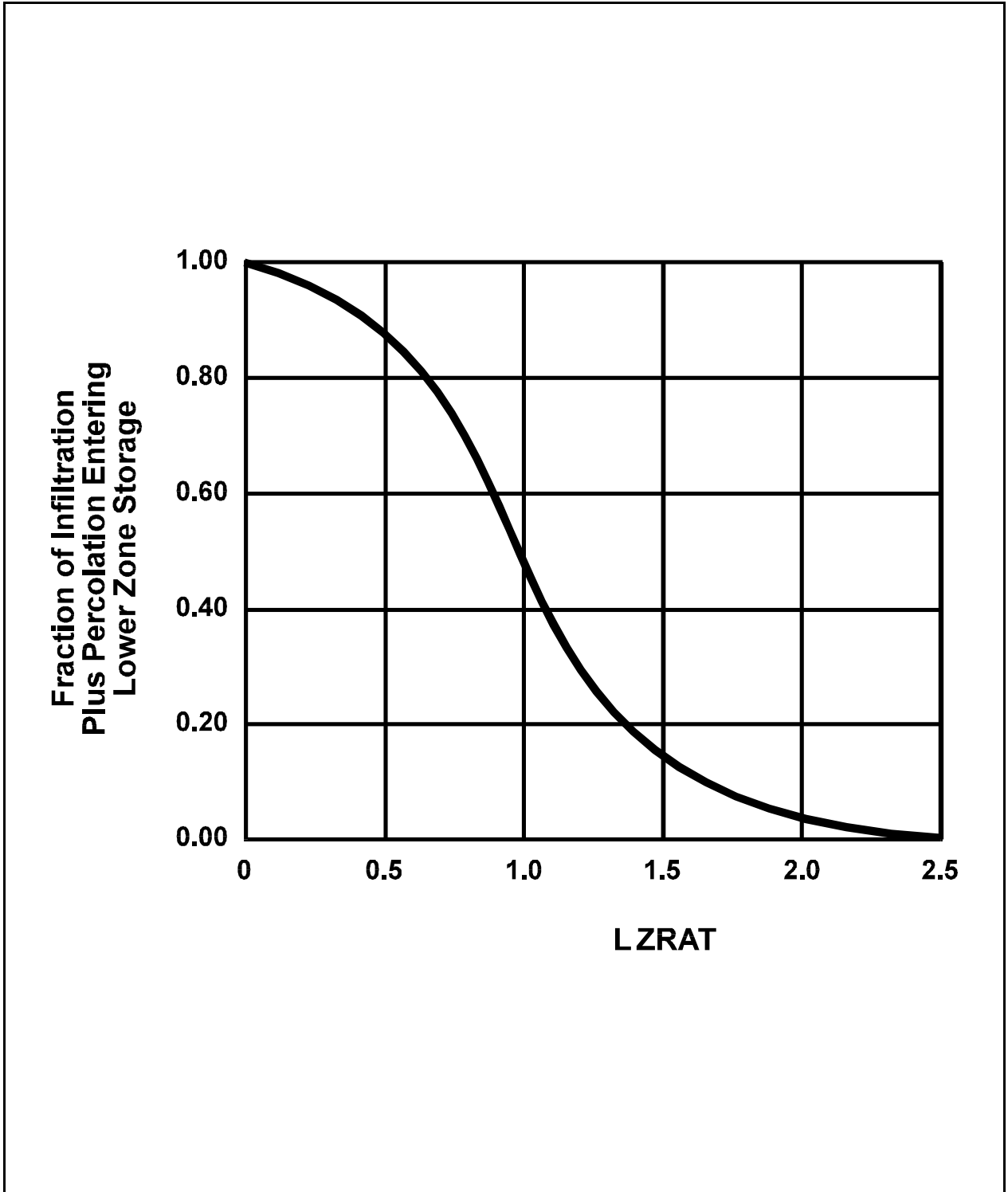


Figure 4.2(1).3-5 Fraction of infiltration plus percolation entering lower zone storage

Thus, the groundwater outflow is estimated by:

$$AGWO = KGW*(1.0 + KVARY*GWVS)*AGWS \quad (24)$$

where:

AGWO = active groundwater outflow (in/interval)
 KGW = groundwater outflow recession parameter (/interval)
 KVARY = parameter which can make active groundwater storage to outflow relation nonlinear (/inches)
 GWVS = index to groundwater slope (inches)
 AGWS = active groundwater storage at the start of the interval (inches)

GWVS is increased each interval by the inflow to active groundwater but is also decreased by 3 percent once a day. It is a measure of antecedent active groundwater inflow. KVARY is introduced to allow variable groundwater recession rates. When KVARY is nonzero, a semilog plot of discharge versus time is nonlinear. This parameter adds flexibility in groundwater outflow simulation which is useful in simulating many watersheds.

The parameter KGW is calculated by the Run Interpreter using the relationship:

$$KGW = 1.0 - (AGWRC)**(DELT60/24.0) \quad (25)$$

where:

AGWRC = daily recession constant of groundwater flow if KVARY or GWVS = 0.0
 That is, the ratio of current groundwater discharge
 to groundwater discharge 24-hr earlier
 DELT60 = hr/interval

4.2(1).3.7 Simulate Evapotranspiration (subroutine EVAPT)

Purpose

The purpose of EVAPT and its subordinate subroutines is to simulate evaporation and evapotranspiration fluxes from all zones of the pervious land segment. Since in most hydrologic regimes the volume of water that leaves a watershed as evapotranspiration exceeds the total volume of streamflow, this is an important aspect of the water budget.

Method of Determining Actual Evapotranspiration

There are two separate issues involved in estimating evapotranspiration (ET). First, potential ET must be estimated. ET potential or demand is supplied as an input times series, typically using U.S. Weather Bureau Class A pan records plus an adjustment factor. The data are further adjusted for cover in the parent subroutine PWATER. Second, actual ET must be calculated, usually as a function of moisture storages and the potential. The actual ET is estimated by trying to meet the demand from five sources in the order described below. The sum of the ET from these five sources is the total actual evapotranspiration from the land segment.

Subroutine ETBASE

The first source from which ET can be taken is the active groundwater outflow or baseflow. This simulates effects such as ET from riparian vegetation in which groundwater is withdrawn as it enters the stream. The user may specify by the parameter BASETP the fraction, if any, of the potential ET that can be sought from the baseflow. That portion can only be fulfilled if outflow exists. Any remaining potential not met by actual baseflow evaporation will try next to be satisfied in subroutine EVICEP.

Subroutine EVICEP

Remaining potential ET exerts its demand on the water in interception storage. Unlike baseflow, there is no parameter regulating the rate of ET from interception storage. The demand will draw upon all of the interception storage unless the demand is less than the storage. When the demand is greater than the storage, the remaining demand will try to be satisfied in subroutine ETUZON.

Subroutine ETUZON

There are no special ET parameters for the upper zone, but rather ET is based on the moisture in storage in relation to its nominal capacity. Actual evapotranspiration will occur from the upper zone storage at the remaining potential demand if the ratio of UZS/UZSN, upper zone storage to nominal capacity, is greater than 2.0. Otherwise the remaining potential ET demand on the upper zone storage is reduced; the adjusted value depends on UZS/UZSN. Subroutine ETAGW will attempt to satisfy any remaining demand.

Subroutine ETAGW

Like ET from baseflow, actual evapotranspiration from active groundwater is regulated by a parameter. The parameter AGWETP is the fraction of the remaining potential ET that can be sought from the active groundwater storage. That portion of the ET demand can be met only if there is enough active groundwater storage to satisfy it. Any remaining potential will try to be met in subroutine ETLZON.

Subroutine ETLZON

The lower zone is the last storage from which ET is drawn. Evapotranspiration from the lower zone is more involved than that from the other storages. ET from the lower zone depends upon vegetation transpiration. Evapotranspiration opportunity will vary with the vegetation type, the depth of rooting, density of the vegetation cover, and the stage of plant growth along with the moisture characteristics of the soil zone. These influences on the ET opportunity are lumped into the LZETP parameter. Unlike the other ET parameters LZETP can be input on a monthly basis to account for temporal changes in the above characteristics.

If the LZETP parameter is at its maximum value of one, representing near complete areal coverage of deep rooted vegetation, then the potential ET for the lower zone is equal to the demand that remains. However, this is normally not the case. Usually vegetation type and/or rooting depths will vary over the land segment. To simulate this, a linear probability density function for ET opportunity is assumed (Figure 4.2(1).3-6). This approach is similar to that used to handle areal variations in infiltration/percolation capacity.

The variable RPARM, the index to maximum ET opportunity, is estimated by:

$$RPARM = (0.25/(1.0 - LZETP))*(LZS/LZSN)*DEL60/24.0 \quad (26)$$

where:

RPARM = maximum ET opportunity (in/interval)
 LZETP = lower zone ET parameter
 LZS = current lower zone storage (inches)
 LZSN = lower zone nominal storage parameter (inches)
 DEL60 = hr/interval

The quantity of water lost by ET from the lower zone storage, when remaining potential ET (REMPET) is less than RPARM, is given by the cross-hatched area of Figure 4.2(1).3-6. When REMPET is more than RPARM the lower zone ET is equal to the entire area under the triangle, RPARM/2.

ET from the lower zone storage is further reduced when LZETP is less than 0.5 by multiplying by LZETP*2.0. This is designed to account for the fraction of the land segment devoid of any vegetation that can draw from the lower zone.

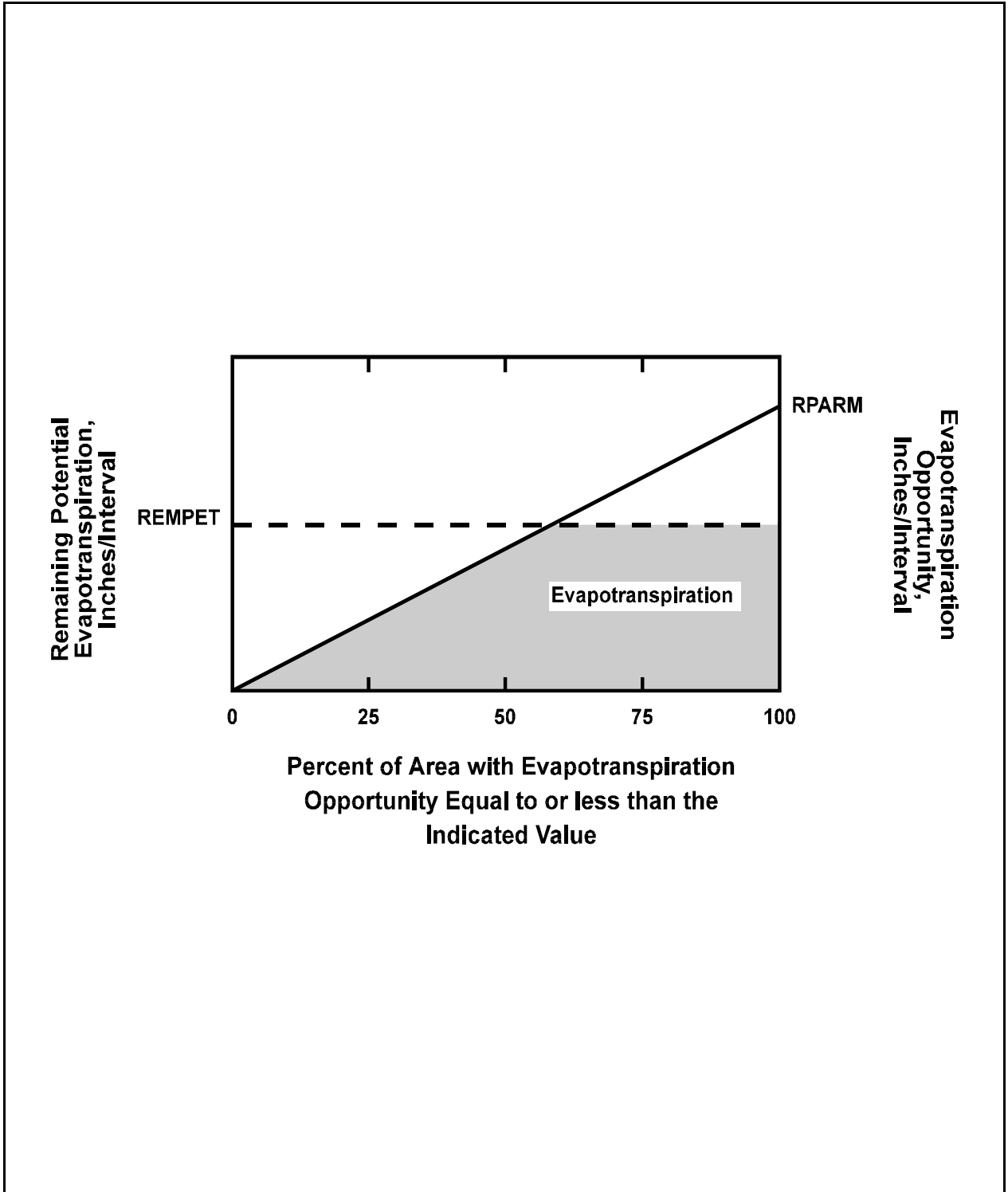


Figure 4.2(1).3-6 Potential and actual evapotranspiration from the lower zone

4.2(1).4 Simulate Production and Removal of Sediment (Section SEDMNT of Module PERLND)

Purpose

Module section SEDMNT simulates the production and removal of sediment from a pervious land segment. Sediment can be considered to be inorganic, organic, or both; the definition is up to the user.

Sediment from the land surface is one of the most common pollutants of waters from urban, agricultural, and forested lands. It muddies waters, covers fish eggs, and limits the capacity of reservoirs. Nutrients and toxic chemicals are carried by it.

Approach

The equations used to produce and remove sediment are based on the predecessor models ARM and NPS (Donigian and Crawford, 1976 a,b). The algorithms representing land surface erosion in these models were derived from a sediment model developed by Moshe Negev (1967) and influenced by Meyer and Wischmeier (1969) and Onstad and Foster (1975). The supporting management practice factor which has been added to the soil detachment by rainfall equation was based on the "P" factor in the Universal Soil Loss Equation (Wischmeier and Smith, 1965). It was introduced in order to better evaluate agricultural conservation practices. The equation that represents scouring of the matrix soil (which was not included in ARM or NPS) was derived from Negev's method for simulating gully erosion.

Figure 4.2(1).4-1 shows the detachment, attachment, and removal involved in the erosion processes on the pervious land surface, while Figure 4.2(1).4-2 schematically represents the fluxes and storages used to simulate these processes. Two of the sediment fluxes, SLSED and NSVI, are added directly to the detached sediment storage variable DETS in the parent routine SEDMNT while the other fluxes are computed in subordinate routines. SLSED represents external lateral input from an upslope land segment. It is a time series which the user may optionally specify. NSVI is a parameter that represents any net external additions or removals of sediment caused by human activities or wind.

Removal of sediment by water is simulated as washoff of detached sediment in storage (WSSD) and scour of matrix soil (SCRSD). The washoff process involves two parts: the detachment/attachment of sediment from/to the soil matrix and the transport of this sediment. Detachment (DET) occurs by rainfall. Attachment occurs only on days without rainfall; the rate of attachment is specified by parameter AFFIX. Transport of detached sediment is by overland flow. The scouring of the matrix soil includes both pick-up and transport by overland flow combined into one process.

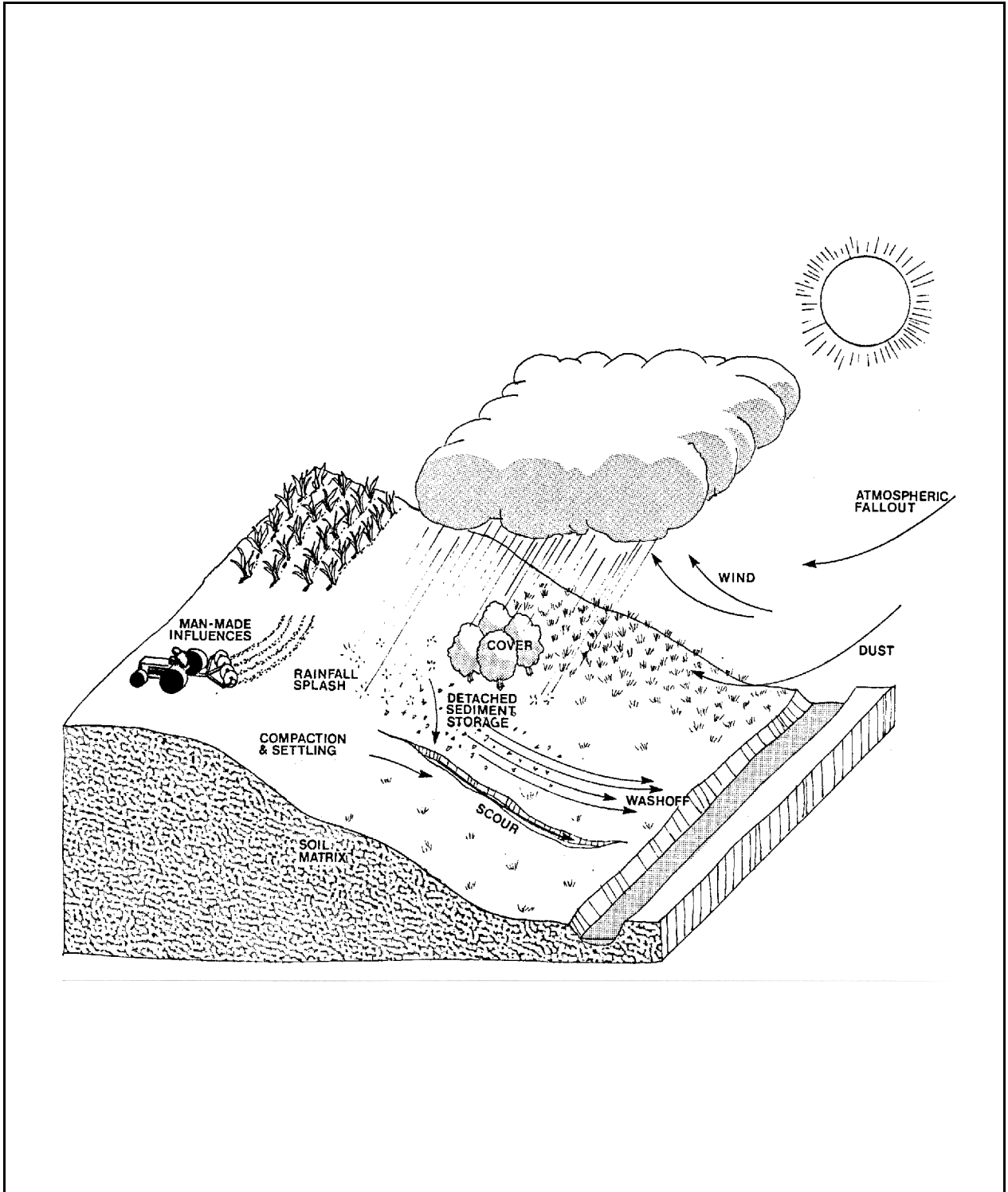


Figure 4.2(1).4-1 Erosion processes

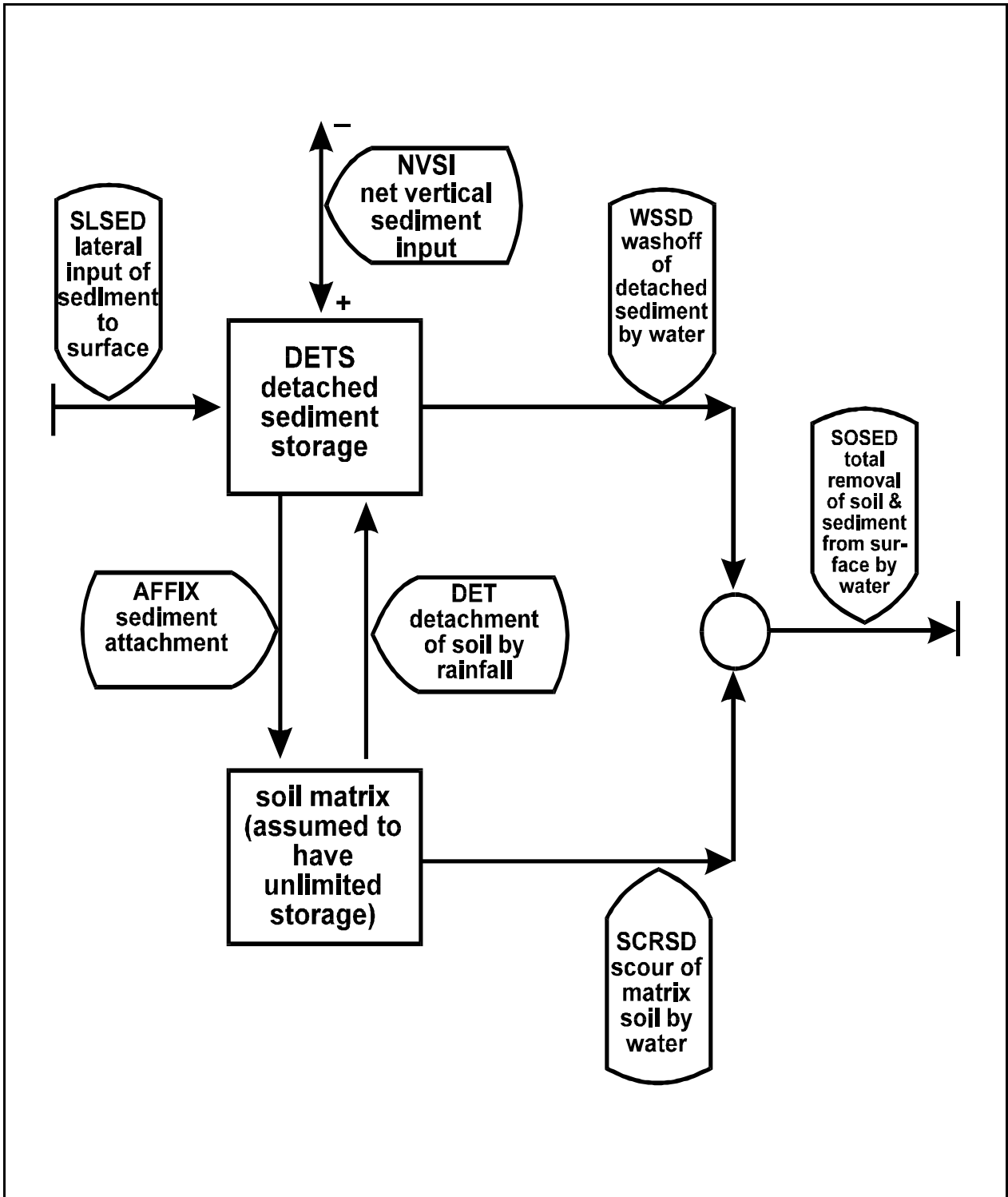


Figure 4.2(1).4-2 Flow diagram for SEDMNT section of PERLND Application Module

Module section SEDMNT has two options for simulating washoff of detached sediment and scour of soil. One uses subroutine SOSED1 which is identical to the method used in the ARM and the NPS Models. However, some equations used in this method are dimensionally nonhomogeneous, and were designed for 15- and 5-min intervals. The results obtained are probably highly dependent on the simulation time step. The other option uses subroutine SOSED2, which is dimensionally homogeneous and is, generally less dependent on the time step.

4.2(1).4.1 Detach Soil By Rainfall
(subroutine DETACH)

Purpose

The purpose of DETACH is to simulate the splash detachment of the soil matrix caused by impact of rain.

Method of Detaching Soil by Rainfall

Kinetic energy from rain falling on the soil detaches particles which are then available to be transported by overland flow. The equation that simulates detachment is:

$$DET = DELT60 * (1.0 - CR) * SMPF * KRER * (RAIN / DELT60) ** JRER \quad (1)$$

where:

- DET = sediment detached from the soil matrix by rainfall
(tons/ac/interval)
- DELT60 = number of hours/interval
- CR = fraction of the land covered by snow and other cover
- SMPF = supporting management practice factor
- KRER = detachment coefficient dependent on soil properties
- RAIN = rainfall (in/interval)
- JRER = detachment exponent dependent on soil properties

The variable CR is the sum of the fraction of the area covered by the snowpack (SNOCOV), if any, and the fraction that is covered by anything else but snow (COVER). SNOCOV is computed by section SNOW. COVER is a parameter which for pervious areas will typically be the fraction of the area covered by vegetation and mulch. It can be input on a monthly basis.

4.2(1).4.2 Remove by Surface Flow Using Method 1
(subroutine SOSED1)

Purpose

Subroutines SOSED1 and SOSED2 perform the same task but by different methods. They simulate the washoff of the detached sediment and the scouring of the soil matrix.

Method

When simulating the washoff of detached sediment, the transport capacity of the overland flow is estimated and compared to the amount of detached sediment available. The transport capacity is calculated by the equation:

$$\text{STCAP} = \text{DELT60} * \text{KSER} * ((\text{SURS} + \text{SURO}) / \text{DELT60}) ** \text{JSER} \quad (2)$$

where:

STCAP = capacity for removing detached sediment (tons/ac/interval)
 DELT60 = hr/interval
 KSER = coefficient for transport of detached sediment
 SURS = surface water storage (inches)
 SURO = surface outflow of water (in/interval)
 JSER = exponent for transport of detached sediment

When STCAP is greater than the amount of detached sediment in storage, washoff is calculated by:

$$\text{WSSD} = \text{DETS} * \text{SURO} / (\text{SURS} + \text{SURO}) \quad (3)$$

If the storage is sufficient to fulfill the transport capacity, then the following relationship is used:

$$\text{WSSD} = \text{STCAP} * \text{SURO} / (\text{SURS} + \text{SURO}) \quad (4)$$

where:

WSSD = washoff of detached sediment (tons/ac/interval)
 DETS = detached sediment storage (tons/ac)

WSSD is then subtracted from DETS.

Transport and detachment of soil particles from the soil matrix is simulated with the following equation:

$$\text{SCRSD} = \text{SURO} / (\text{SURS} + \text{SURO}) * \text{DELT60} * \text{KGER} * ((\text{SURS} + \text{SURO}) / \text{DELT60}) ** \text{JGER} \quad (5)$$

where:

SCRSD = scour of matrix soil (tons/ac/interval)
 KGER = coefficient for scour of the matrix soil
 JGER = exponent for scour of the matrix soil

The sum of the two fluxes, WSSD and SCRSD, represents the total sediment outflow from the land segment.

Subroutine SOSED1 differs from SOSED2 in that it uses the dimensionally nonhomogeneous term $(\text{SURS} + \text{SURO}) / \text{DELT60}$ in the above equations, while SOSED2 uses the homogeneous term $\text{SURO} / \text{DELT60}$.

4.2(1).4.3 Remove by Surface Flow Using Method 2 (subroutine SOSED2)

Purpose

The purpose of this subroutine is the same as SOSED1. It only differs in method.

Method of Determining Removal

This method of determining sediment removal makes use of the dimensionally homogeneous term $SURO/DELT60$ instead of $(SURO+SURS)/DELT60$.

The capacity of the overland flow to transport detached sediment is determined in this subroutine by:

$$STCAP = DELT60 * KSER * (SURO/DELT60) ** JSER \quad (6)$$

When STCAP is more than the amount of detached sediment in storage, the flow washes off all of the detached sediment storage (DETS). However, when STCAP is less than the amount of detached sediment in storage, the situation is transport limiting, so WSSD is equal to STCAP.

Direct detachment and transport of the soil matrix by scouring (e.g., gullyng) is simulated with the equation:

$$SCRSD = DELT60 * KGER * (SURO/DELT60) ** JGER \quad (7)$$

Definitions of the above terms can be found in subroutine SOSED2. The coefficients and exponents will have different values than in subroutine SOSED1 because they modify different variables.

4.2(1).4.4 Simulate Re-attachment of Detached Sediment (subroutine ATTACH)

Purpose

Subroutine ATTACH simulates the re-attachment of detached sediment (DETS) on the surface (soil compaction).

Method

Attachment to the soil matrix is simulated by merely reducing DETS. Since the soil matrix is considered to be unlimited, no addition to the soil matrix is necessary when this occurs. DETS is diminished at the start of each day that follows a day with no precipitation by multiplying it by $(1.0 - AFFIX)$, where AFFIX is a parameter. This represents a first-order rate of reduction of the detached soil storage.

4.2(1).5 Estimate Soil Temperatures (Section PSTEMP of Module PERLND)

Purpose

PSTEMP simulates soil temperatures for the surface, upper, and lower/groundwater layers of a land segment for use in module section PWTGAS and the agri-chemical sections. Good estimates of soil temperatures are particularly important for simulating first-order transformations in the agri-chemical sections.

Method

The two methods used for estimating soil temperatures are based on the regression equation approach in the ARM Model (Donigian, et al., 1977) and the smoothing factor approach used in HSP QUALITY (Hydrocomp, 1977) to simulate the temperatures of subsurface flows.

Simulation of soil temperatures is done by layers which correspond to those specified in the agri-chemical sections. The surface layer is the portion of the land segment that affects overland flow water quality characteristics. The subsurface layers are upper, lower, and groundwater. The upper layer affects interflow quality characteristics while the lower layer is a transition zone to groundwater. The temperature of the groundwater layer affects groundwater quality transformations and outflow characteristics. Lower layer and groundwater temperatures are considered approximately equal; a single value is estimated for both layers.

Surface layer soil temperatures are estimated by the following regression equation:

$$SLTMP = ASLT + BSLT \cdot AIRTC \quad (1)$$

where:

SLTMP = surface layer temperature (degrees C)

ASLT = Y-intercept

BSLT = slope

AIRTC = air temperature (degrees C)

Temperatures of the other layers are simulated by one of two methods. If TSOPFG is set equal to 1 in the User's Control Input, the upper layer soil temperature is estimated by a regression equation as a function of air temperature (similar to equation above), and the lower layer/groundwater layer temperature is specified by a parameter which can vary monthly. This method is similar to that used in the ARM Model except that ARM relates the upper layer temperature to the computed soil surface temperature instead of directly to air temperature.

If TSOPFG is set equal to zero, both the upper layer and the lower layer/groundwater layer temperatures are computed by using a mean departure from air temperature plus a smoothing factor. The same basic equation is used with separate state variables and parameters for each layer:

$$TMP = TMPS + SMO \cdot (AIRTC + TDIF - TMPS) \quad (2)$$

where:

TMP = layer temperature at the end of the current interval (degrees C)
SMO = smoothing factor (parameter)
AIRTCS = air temperature at the start of the current interval (degrees C)
TDIF = parameter which specifies the difference between the mean air
temperature and the mean temperature of the soil layer (degrees C)
TMPS = layer temperature at the start of the current interval (degrees C)

If TSOPFG is set to 2, then the method is identical to the above, except that the lower layer/groundwater layer temperature is estimated from the upper layer temperature (ULTMP), instead of directly from the air temperature.

The values of the parameters for any of the layer computations can be linearly interpolated from monthly input values to obtain daily variations throughout the year. If this variation is not desired, the user may supply yearly (constant) values.

4.2(1).6 Estimate Water Temperature and Dissolved Gas Concentrations
(Section PWTGAS of Module PERLND)

Purpose

PWTGAS estimates water temperature and concentrations of dissolved oxygen and carbon dioxide in surface, interflow, and groundwater outflows from a land segment.

Method

The temperature of each outflow is considered to be the same as the soil temperature of the layer from which the flow originates, except that water temperature can not be less than freezing. Soil temperatures must either be computed in module section PSTEMP or supplied directly as an input time series. The temperature of the surface outflow is equal to the surface layer soil temperature, the temperature of interflow to the upper layer soil temperature, and the temperature of the active groundwater outflow equals the lower layer and groundwater layer soil temperature.

The dissolved oxygen and carbon dioxide concentrations of the overland flow are assumed to be at saturation and are calculated as direct functions of water temperature. PWTGAS uses the following empirical nonlinear equation to relate dissolved oxygen at saturation to water temperature (Committee on Sanitary Engineering Research, 1960):

$$\text{SODOX} = (14.652 + \text{SOTMP} * (-0.41022 + \text{SOTMP} * (0.007991 - 0.000077774 * \text{SOTMP}))) * \text{ELEVGC} \quad (1)$$

where:

SODOX = concentration of dissolved oxygen in surface outflow (mg/l)
 SOTMP = surface outflow temperature (degrees C)
 ELEVGC = correction factor for elevation above sea level
 (ELEVGC is calculated by the Run Interpreter dependent upon mean elevation of the segment)

The empirical equation for dissolved carbon dioxide concentration of the overland flow (Harnard and Davis, 1943) is:

$$\text{SOCO2} = (10^{**}(2385.73/\text{ABSTMP} - 14.0184 + 0.0152642 * \text{ABSTMP})) * 0.000316 * \text{ELEVGC} * 12000.0 \quad (2)$$

where:

SOCO2 = concentration of dissolved carbon dioxide in surface outflow (mg C/l)
 ABSTMP = temperature of surface outflow (degrees K)

The concentrations of dissolved oxygen and carbon dioxide in the interflow and the active groundwater flow cannot be assumed to be at saturation. Values for these concentrations are provided by the user. They may be specified as constant values or 12 monthly values. If monthly values are provided, daily variation in values will automatically be obtained by linear interpolation between the monthly values.

4.2(1).7 Simulate Quality Constituents Using Simple Relationships with Sediment and Water Yield (Section PQUAL of Module PERLND)

Purpose

The PQUAL module section simulates water quality constituents or pollutants in the outflows from a pervious land segment using simple relationships with water and/or sediment yield. Any constituent can be simulated by this module section. The user supplies the name, units and parameter values appropriate to each of the constituents that are needed in the simulation. However, more detailed methods of simulating sediment, heat, dissolved oxygen, dissolved carbon dioxide, nitrogen, phosphorus, soluble tracers, and pesticide removal from a pervious land segment are available, in other module sections.

Approach

The basic algorithms used to simulate quality constituents are a synthesis of those used in the NPS Model (Donigian and Crawford, 1976b) and HSP QUALITY (Hydrocomp, 1977). However, some options and combinations are unique to HSPF.

Figure 4.2(1).7-1 shows schematically the fluxes and storages represented in module section PQUAL. The occurrence of a water quality constituent in both surface and subsurface outflow can be simulated. The behavior of a constituent in surface outflow is considered more complex and dynamic than the behavior in subsurface flow. A constituent on the surface can be affected greatly by adhesion to the soil and by temperature, light, wind, atmospheric deposition, and direct human influences. Section PQUAL is able to represent these processes in a general fashion. It allows quantities in the surface outflow to be simulated by two methods. One approach is to simulate the constituent by association with sediment removal. The other approach is to simulate it using atmospheric deposition and/or basic accumulation and depletion rates together with depletion by washoff; that is, constituent outflow from the surface is a function of the water flow and the constituent in storage. A combination of the two methods may be used in which the individual outfluxes are added to obtain the total surface outflow. These approaches will be discussed further in the descriptions of the corresponding subroutines. Concentrations of quality constituents in the subsurface flows of interflow and active groundwater are specified by the user. The concentration may be linearly interpolated to obtain daily values from input monthly values.

The user has the option of simulating the constituents by any combination of these surface and subsurface outflow pathways. The outflux from the combination of the pathways simulated will be the total outflow from the land segment. In addition, the user is able to select the units to be associated with the fluxes. These options provide considerable flexibility. For example, a user may wish to simulate coliforms in units of organisms/ac by association with sediment in the surface runoff and use a concentration in the groundwater which varies seasonally. Or a user may want to simulate total dissolved salts in pounds per acre by direct association with overland flow and a constant concentration in interflow and groundwater flow.

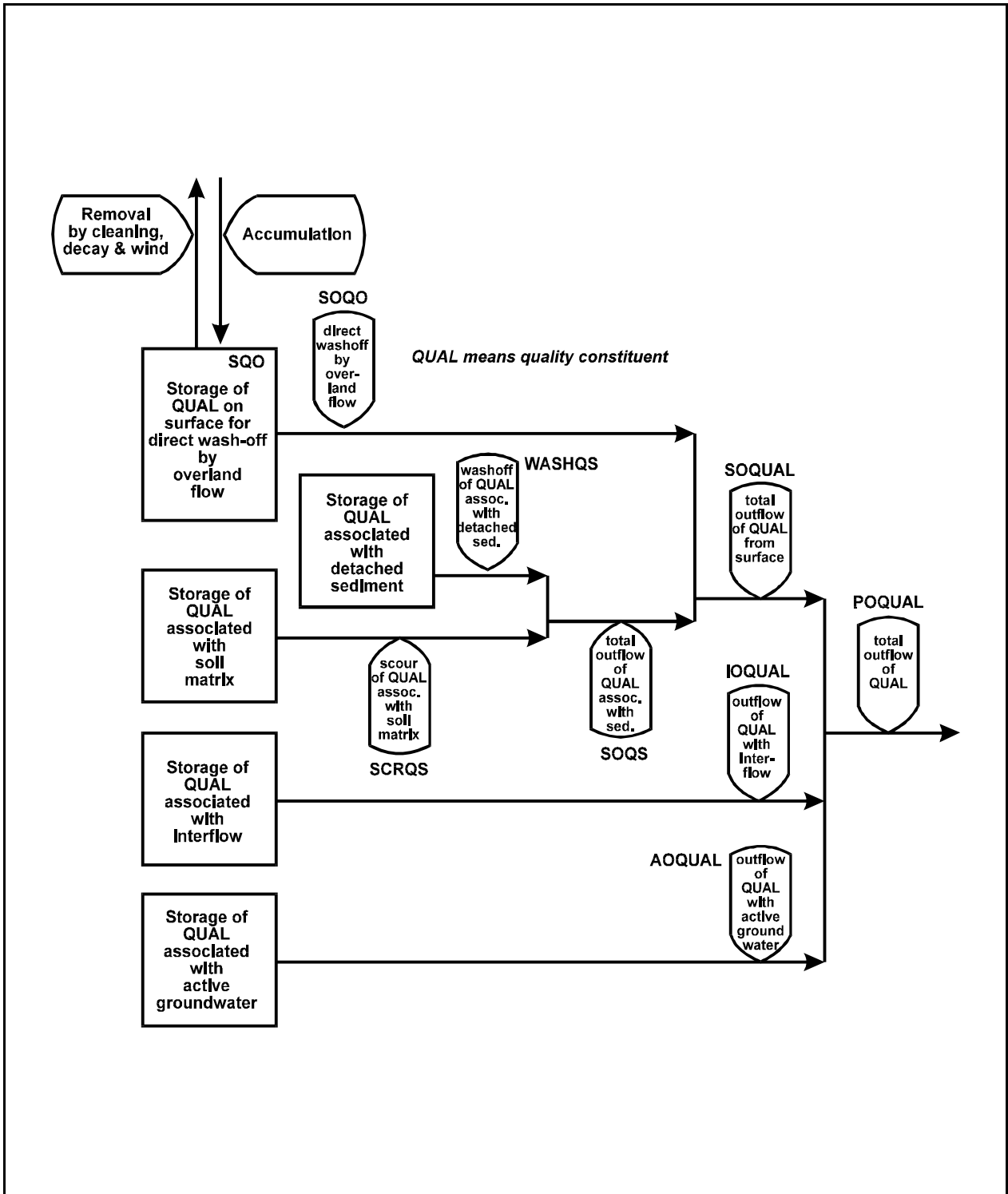


Figure 4.2(1).7-1 Flow diagram for PQUAL section of the PERLND Application Module

PQUAL allows the user to simulate up to 10 quality constituents at a time. Each of the 10 constituents may be defined as one or a combination of the following types: QUALSD, QUALOF, QUALIF, and/or QUALGW. If a constituent is considered to be associated with sediment, it is called a QUALSD. The corresponding terms for constituents associated with overland flow, interflow, and groundwater flow are QUALOF, QUALIF, and QUALGW, respectively. Note that only a QUALOF may receive atmospheric deposition, since it is the only type to maintain a storage. However, no more than seven of any one of the constituent types (QUALSD, QUALOF, QUALIF, or QUALGW) may be simulated in one operation. The program uses a set of flag pointers to keep track of these associations. For example, QSDFP(3) = 0 means that the third constituent is not associated with sediment, whereas QSDFP(6) = 4 means that the sixth constituent is the fourth sediment associated constituent (QUALSD). Similar flag pointer arrays are used to indicate whether or not a quality constituent is a QUALOF, QUALIF, or QUALGW.

4.2(1).7.1 Remove by Association with Sediment
(subroutine QUALSD)

Purpose

QUALSD simulates the removal of a quality constituent from a pervious land surface by association with the sediment removal determined in module section SEDMNT.

Method

This approach assumes that the particular quality constituent removed from the land surface is in proportion to the sediment removal. The relation is specified with user-input "potency factors." Potency factors indicate the constituent strength relative to the sediment removed from the surface. Various quality constituents such as iron, lead, and strongly adsorbed toxicants are actually attached to the sediment being removed from the land surface. Some other pollutants such as ammonia, organics, pathogens, and BOD may not be extensively adsorbed, but can be considered highly correlated to sediment yield.

For each quality constituent associated with sediment, the user supplies separate potency factors for association with washed off and scoured sediment (WSSD and SCRSD). Typically, the washoff potency factor would be larger than the scour potency factor because washed off sediment is usually finer than the scoured material and thus has a higher adsorption capacity. Organic nitrogen would be a common example of such a constituent. The user is also able to supply monthly potency factors for constituents that vary somewhat consistently during the year. For instance, constituents that are associated with spring and fall fertilization may require such monthly input values.

Removal of the sediment associated constituent by detached sediment washoff is simulated by:

$$\text{WASHQS} = \text{WSSD} * \text{POTFW} \quad (1)$$

where:

WASHQS = flux of quality constituent associated with
detached sediment washoff (quantity/ac per interval)
WSSD = washoff of detached sediment (tons/ac per interval)
POTFW = washoff potency factor (quantity/ton)

Removal of constituents by scouring of the soil matrix is similar:

$$\text{SCRQS} = \text{SCRSD} * \text{POTFS} \quad (2)$$

where:

SCRQS = flux of quality constituent associated with scouring
of the matrix soil (quantity/ac per interval)
SCRSD = scour of matrix soil (tons/ac per interval)
POTFS = scour potency factor (quantity/ton)

WASHQS and SCRQS are combined to give the total sediment associated flux of the constituent from the land segment, SOQS.

The unit "quantity" refers to mass units (pounds or tons in the English system) or some other quantity, such as number of organisms for coliforms. The unit is user-specified.

4.2(1).7.2 Accumulate and Remove by a Constant Unit Rate and by Overland Flow (subroutine QUALOF)

Purpose

QUALOF simulates the accumulation of a quality constituent on the pervious land surface and its removal by a constant unit rate and by overland flow.

Method

This subroutine differs from the others in module section PQUAL in that the storage of the quality constituent on the land surface is simulated. The constituent can be accumulated and removed by processes which are independent of storm events such as cleaning, decay, and wind erosion and deposition, or it can be washed off by overland flow. The accumulation and removal rates can have monthly values to account for seasonal fluctuations. A pollution indicator such as fecal coliform from range land is an example of a constituent with accumulation and removal rates which may need to vary throughout the year. The concentration of the coliform in the surface runoff may fluctuate with the seasonal grazing density, and the weather.

The constituent may, alternatively or additionally, receive atmospheric deposition. Atmospheric deposition inputs can be specified in two possible ways depending on the form of the available data. If the deposition is in the form of a flux (mass per area per time), then it is considered "dry deposition". If the deposition is in the form of a concentration in rainfall, then it is considered "wet deposition", and the program automatically combines it with the input rainfall time series to compute the resulting flux. Either type of deposition data can be input as a time

series, which covers the entire simulation period, or as a set of monthly values that is used for each year of the simulation. The specific atmospheric deposition time series are documented in the EXTNL table of the Time Series Catalog for PERLND, and are specified in the EXT SOURCES block of the UCI. The monthly values are input in the MONTH-DATA block in the UCI.

If atmospheric deposition data are input to the model, the storage of qual is updated as follows:

$$SQO = SQO + ADFX + PREC*ADCN \quad (3)$$

where:

SQO = storage of available quality constituent on the surface (mass/area)
 ADFX = dry or total atmospheric deposition flux (mass/area per interval)
 PREC = precipitation depth
 ADCN = concentration for wet atmospheric deposition (mass/volume)

When there is surface outflow and some quality constituent is in storage, washoff is simulated using the commonly used relationship:

$$SQOQ = SQO*(1.0 - EXP(-SURO*WSFAC)) \quad (4)$$

where:

SQOQ = washoff of the quality constituent from the land
 surface (quantity/ac per interval)
 SQO = storage of available quality constituent on the surface (quantity/ac)
 SURO = surface outflow of water (in/interval)
 WSFAC = susceptibility of the quality constituent to washoff (/in)
 EXP = exponential function

The storage is updated once a day to account for accumulation and removal which occurs independent of runoff by the equation:

$$SQO = ACQOP + SQOS*(1.0 - REMQOP) \quad (5)$$

where:

ACQOP = accumulation rate of the constituent (quantity/ac per day)
 SQOS = SQO at the start of the interval
 REMQOP = unit removal rate of the stored constituent (per day)

The Run Interpreter computes REMQOP and WSFAC for this subroutine according to:

$$REMQOP = ACQOP/SQOLIM \quad (6)$$

where:

SQOLIM = asymptotic limit for SQO as time approaches infinity
 (quantity/ac), if no washoff occurs

and

$$WSFAC = 2.30/WSQOP \quad (7)$$

where:

WSQOP = rate of surface runoff that results in 90 percent washoff in
one hour (in/hr)

Since the unit removal rate of the stored constituent (REMQOP) is computed from two other parameters, it does not have to be supplied by the user.

4.2(1).7.3 Simulate by Association with Interflow Outflow (subroutine QUALIF)

Purpose

QUALIF is designed to permit the user to simulate the occurrence of a constituent in interflow.

Method

The user specifies a concentration for each constituent which is a QUALIF. Optionally, one can specify 12 monthly values, to account for seasonal variation. In this case, the system interpolates a new value each day.

4.2(1).7.4 Simulate by Association with Active Groundwater Outflow (subroutine QUALGW)

Purpose

QUALGW is designed to permit the user to simulate the occurrence of a constituent in groundwater outflow.

Method

The method is identical to that for QUALIF.

Introduction to the Agri-Chemical Sections

Introduction to the Agri-chemical Sections

The introduction of agricultural chemicals into streams, lakes, and groundwater from agricultural land may be detrimental. For example, persistent fat soluble pesticides, such as DDT, have been known to concentrate in the fatty tissue of animals causing toxic effects. Nitrogen and phosphorus are essential plant nutrients which when introduced into certain surface waters will increase productivity. This may or may not be desirable depending upon management objectives. Significant productivity results in algal blooms, but some increase in productivity will increase fish production. Drinking water containing high nitrate concentrations may cause methemoglobinemia in small children.

Pesticide, nitrogen, and phosphorus compounds are important to agricultural production, but prediction of their removal from the field is necessary for wise management of both land and water resources. HSPF can be used to predict such outflows. The agri-chemical sections of the PERLND module of HSPF simulate in detail nutrient and pesticide processes, both biological and chemical, and the movement of any nonreactive tracer in a land segment. These chemicals can also be simulated in module section PQUAL, but in a simplified manner. The dynamic and continuous processes that affect the storages and outflow of pesticides and of nutrients from fertilized fields should be simulated in detail to fully analyze agricultural runoff. If the situation does not require full representation of these processes, or if data are not available, the PQUAL subroutines could be used.

Atmospheric deposition inputs can be specified in two possible ways depending on the form of the available data. If the deposition is in the form of a flux (mass per area per time), then it is considered "dry deposition". If the deposition is in the form of a concentration in rainfall, then it is considered "wet deposition", and the program automatically combines it with the input rainfall time series to compute the resulting flux. Either type of deposition data can be input as a time series, which covers the entire simulation period, or as a set of monthly values that is used for each year of the simulation. The specific atmospheric deposition time series are documented in the EXTNL table of the Time Series Catalog for module PERLND, and are specified in the EXT SOURCES block of the UCI. The monthly values are input in the MONTH-DATA block in the UCI.

An additional use of the atmospheric deposition time series is specifying inputs of agricultural chemicals and fertilizers instead of changing soil storages in the SPEC-ACTIONS block. For this purpose, deposition to the upper soil layer in addition to the surface soil layer has been provided for in sections NITR, PHOS, and TRACER. (Section PEST has time series only for the surface layer, since pesticides are not normally incorporated into the soil as are fertilizers.) Depending on the complexity of the agricultural practices being modeled, the user should decide whether the SPEC-ACTIONS block or the time series is simpler to construct.

The basic algorithms in the agri-chemical sections of HSPF were originally developed for use on agricultural lands, but can be used on other pervious areas where pesticides and plant nutrients occur, for example, orchards, nursery land, parks, golf courses, and forests. All pervious land contains nitrogen and phosphorus in the soil; it is possible to use this module to simulate the behavior of agricultural chemicals in any such area.

Introduction to the Agri-Chemical Sections

Comparison of HSPF and ARM

The methods used to simulate pesticide processes in the agri-chemical sections were developed originally for the Pesticide Transport and Runoff (PTR) Model (Crawford and Donigian, 1973), then expanded to include nutrients in the Agricultural Runoff Management (ARM) Model (Donigian and Crawford, 1976) and tested and modified in ARM Version II (Donigian, et al., 1977). In HSPF the ARM Version II algorithms were recreated with some additional options. (For more detail on the basic methods, refer to the above reports.)

The differences between HSPF and ARM Model Version II should, however, be discussed. The biggest difference is the availability of new options to simulate soil nutrient and pesticide adsorption and desorption. Ammonium and phosphate adsorption/desorption in HSPF can be accomplished by using Freundlich isotherms as well as by first-order kinetics. Pesticides can be adsorbed and desorbed by the two Freundlich methods used in the ARM Model or by first-order kinetics. In addition, the pesticide parameter values are now input for each separate soil layer instead of inputting one parameter set for all the layers. HSPF also allows the user to simulate more than one pesticide in a run. (The ARM Model only simulates one per run). In addition to the percolation factors which can still be used to retard any solute leaching from the upper layer and lower layer, a multiplication factor has been introduced that can reduce leaching from the surface layer. Also, in HSPF, nitrogen and phosphorus chemical and biochemical transformations can each be simulated at different time steps to save computer time. Plant uptake of ammonium is also available in HSPF.

Units

The fluxes and storages of chemicals modeled in these module sections are in mass per area units. The user must supply the input in appropriate units; kg/ha for the Metric system, and lb/ac for the English system. Internally, most of the code does not differentiate between the unit systems. Fluxes are determined by either proportionality constants, fractions of chemicals in storage, or unitless concentrations. First-order kinetics makes use of proportionality constants for determining reaction fluxes. Chemicals are transported based on the fractions of that compound in storage. Freundlich adsorption/desorption is based on ppm concentrations.

Module Sections

There are five agri-chemical module sections. They are shown in the structure chart of PERLND (Figure 4.2(1)-1). Module section MSTLAY manipulates water storages and fluxes calculated in module section PWATER. This section must be run before the following sections can be run, since it supplies them with data for simulating the storage and movement of solutes. Module section PEST simulates pesticide behavior while NITR and PHOS simulate the plant nutrients of nitrogen and phosphorus. Simulation of a nonreactive solute is accomplished in module section TRACER.

4.2(1).8 Estimate Moisture Content of Soil Layers and Fractional Fluxes (Section MSTLAY of Module PERLND)

Purpose

This module section estimates the storages of moisture in the four soil layers with which the agricultural chemical sections deal (Figure 4.2(1).8-1); and the fluxes of moisture between the storages. MSTLAY is required because the moisture storages and fluxes computed by module section PWATER can not be directly used to simulate solute transport through the soil. For example, in PWATER, some moisture which infiltrates can reach the groundwater in a single time step (Figure 4.2(1).3-2). While this phenomenon does not have any serious effect in simulating the hydrologic response of a land segment, it does seriously affect the simulation of solute transport.

Thus, MSTLAY takes the fluxes and storages computed in PWATER and adapts them to fit the storage/flow path picture in Figure 4.2(1).8-1. The revised storages, in inches of water, are also expressed in mass/area units (that is, lb/ac or kg/ha) for use in the adsorption/desorption calculations.

Method

Figure 4.2(1).8-1 schematically diagrams the moisture storages and fluxes used in subroutine MSTLAY. Note that the fluxes are represented in terms of both quantity (e.g., IFWI, in inches/interval) and as a fraction of the contributing storage (e.g., FII, as a fraction of UMST/interval). The reader should also refer to Figure 4.2(1).3-2 in module section PWATER when studying this diagram and the following discussion.

For the agri-chemical sections the moisture storages (the variables in Figure 4.2(1).8-1 ending in MST) are calculated by the general equation:

$$\text{MST} = \text{WSTOR} + \text{WFLUX} \quad (1)$$

The variable WSTOR is the related storage calculated in module section PWATER (Figure 4.2(1).3-2). For example, in the calculation of the lower layer moisture storage (LMST), WSTOR is the lower zone storage (LZS). The variable WFLUX generally corresponds to the flux of moisture through the soil layer. For the computation of LMST, WFLUX is the sum of water percolating from the lower zone to the inactive (IGWI) and active groundwater (AGWI) as determined in section PWATER. Note that these equations are dimensionally non-homogeneous, because storages (inches) and fluxes (inches/interval) are added together. Thus, the results given are likely to be highly dependent on the simulation time step. The ARM Model, from which the equations come, uses a time step of 5 minutes. Caution should be exercised if the agricultural chemical sections (including MSTLAY) are run with any other time step.

The upper layer has been subdivided into two storages, principal and transitory. The transitory (interflow) storage is used to transport chemicals from the upper layer to interflow outflow. The chemicals in it do not undergo any reactions. However, reactions do occur in the principal storage.

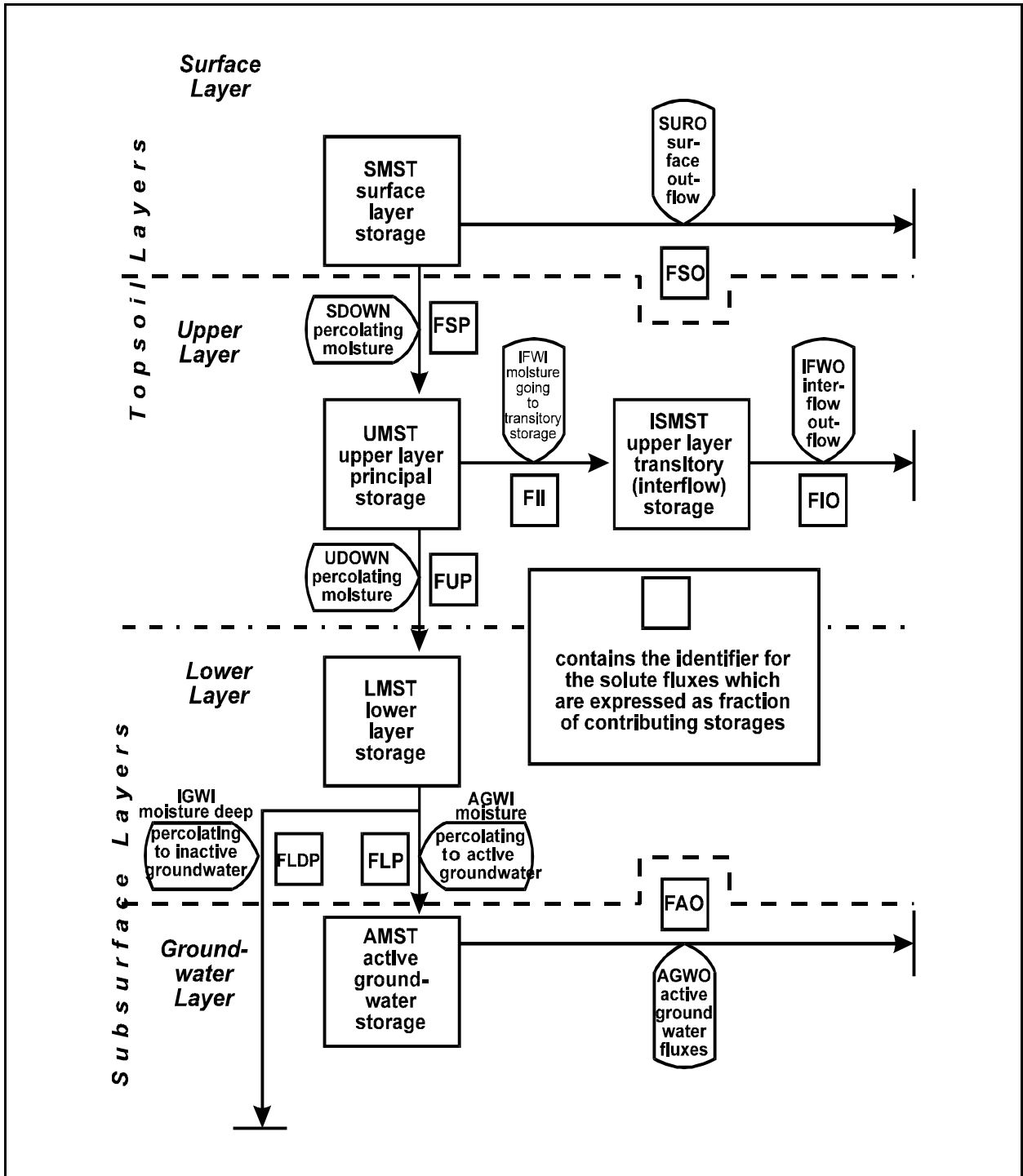


Figure 4.2(1).8-1 Flow diagram showing transport of moisture and solutes as estimated in the MSTLAY section of the PERLND Application Module

The fluxes shown in Figure 4.2(1).8-1 are the same as those in Figure 4.2(1).3-2 with the exceptions of SDOWN and UDOWN. SDOWN encompasses all the water that moves downward from the surface layer storage. It is the combination of the water infiltrating from the surface detention storage directly to the lower zone (INFIL), the inflow to the upper zone (UZI), and the water flowing into interflow storage (IFWI). UDOWN is all the water percolating through the upper layer. It is INFIL plus the percolation from the upper zone storage to the lower zone storage (PERC).

Each fractional solute flux is the appropriate moisture flux divided by the contributing storage. For example, the fraction of chemical in solution that is transported overland from the surface layer storage (FSO) is the surface moisture outflow (SURO) divided by the surface layer moisture storage (SMST).

The above estimates are based on the assumption that the concentration of the solute being transported is the same as that in storage. They also assume uniform flow through the layers and continuous mixing of the solutes. However, these assumptions may need to be revised or implemented differently for some of the transport. Past testing has shown that the above method leads to excessive leaching of solutes (Donigian, et al., 1977). Factors that retard solute leaching were added in the ARM Model Version II to remedy this problem. For the surface layer, the percolation factor (SLMPF) affects the solute fraction percolating (FSP) by the relationship:

$$FSP = SLMPF * SDOWN / SMST \quad (2)$$

The variables SDOWN and SMST are defined in Figure 4.2(1).8-1. FSP will typically be between 0 and 1.

For the upper or lower layer percolating fraction (FUP, FLDP, or FLP), the retardation factor only has an influence when the ratio of the respective zone storage to the nominal storage times the factor ($ZS / (ZSN * LPF)$) is less than one. The relationship under this condition is:

$$F = (ZS / (ZSN * LPF)) * (PFLUX / MST) \quad (3)$$

where:

- F = layer solute percolating fraction
- ZS = zone moisture storage, either UZS or LZS
- ZSN = zone nominal moisture storage, either UZSN or LZSN
- LPF = factor which retards solute leaching for the layer, either ULPF or LLPF
- PFLUX = percolation flux, either UDOWN, IGWI, or AGWI
- MST = layer moisture storage, either UMST or LMST

4.2(1).9 Simulate Pesticide Behavior in Detail (Section PEST of Module PERLND)

Purpose

Because of the complexity of pesticide behavior on the land, simulation of the processes frequently requires considerable detail. Pesticide applications vary in amount and time during the year. Various pesticides adsorb and degrade differently. Some, like paraquat, attach themselves strongly to the soil, thereby appearing in low concentrations in water but in high concentrations on soil particles. Others, like atrazine, undergo complex interactions with the soil and are found in higher concentrations in the runoff water than on the eroded sediment.

Section PEST models pesticide behavior by simulating the processes of degradation and adsorption as well as transport. The pesticides are simulated in the soil and runoff in three forms: dissolved, adsorbed, and crystallized. These phases in the soil affect the forms and amounts in the runoff.

Method

Pesticides are simulated by using the time series generated by other PERLND module sections to transport and influence the adsorption and degradation processes. Pesticides move with water flow or by association with the sediment. They also may be adsorbed to the soil in varying degree as a function of the chemical characteristics of the toxicant and the exchange capacity of the soil layer. Pesticide degradation occurs to varying degrees depending upon the susceptibility of the compound to volatilization and breakdown by light, heat, microorganisms and chemical processes. The subroutines in module section PEST consider these transport and reaction processes.

All the subroutines described in this module section except NONSV and DEGRAS are accessed by other agri-chemical module sections because many of the basic transport and reaction processes are similar. The subroutines are described here because they are physically located in this subroutine group. Subroutine AGRGET is first to be called. This subroutine has no computing function; it obtains any required time series (that is not already available) from the INPAD.

Inputs of pesticide to the surface soil layer may be simulated using either or both of two methods: 1) as changes to storage variables in the SPEC-ACTIONS block or 2) as atmospheric deposition. However, atmospheric deposition affects only the surface layer, so if a pesticide is incorporated into the upper soil layer, special actions must be used.

Atmospheric deposition inputs of pesticide can be specified in two possible ways depending on the form of the available data. If the deposition is in the form of a flux (mass per area per time), then it is considered "dry deposition". If the deposition is in the form of a concentration in rainfall, then it is considered "wet deposition", and the program automatically combines it with the input rainfall time series to compute the resulting flux. Either type of deposition data can be input as a time series, which covers the entire simulation period, or as a set of

monthly values that is used for each year of the simulation. The specific pesticide atmospheric deposition time series are documented in the EXTNL table of the Time Series Catalog for PERLND, and are specified in the EXT SOURCES block of the UCI. The monthly values are input in the MONTH-DATA block in the UCI.

If atmospheric deposition data are input to the model, the surface storage is updated for each of the three forms of each pesticide using the formula:

$$\text{SPS} = \text{SPS} + \text{ADFX} + \text{PREC} * \text{ADCN} \quad (1)$$

where:

SPS = storage of pesticide form on the surface (mass/area)
 ADFX = dry or total atmospheric deposition flux (mass/area per interval)
 PREC = precipitation depth
 ADCN = concentration for wet atmospheric deposition (mass/volume)

Subroutine SDFRAC determines the fraction of the surface layer soil that has eroded. The amount eroded is the total sediment removed by scour and washoff as determined in module section SEDMNT. The mass of soil in the surface layer is a parameter value which does not vary even when material is removed. The chemical which is associated with the sediment is assumed to be removed from the surface layer storage in the same proportion that the layer has eroded. Chemical removal is simulated in subroutine SEDMOV. A sediment associated chemical is one that may be attached to the eroding soil or one which may move with the soil. With pesticides the adsorbed form will be attached to the soil particle, while the crystalline form will move with the soil particle being eroded but will not be attached to it. Both forms are taken from their respective surface layer storages in proportion to the fraction of the surface soil layer removed by overland flow.

Subroutines TOPMOV and SUBMOV perform a function similar to SEDMOV except they move the solutes. Chemicals in solution move to and from the storages according to the fractions calculated in section MSTLAY. Figure 4.2(1).9-1 schematically illustrates the fluxes and storages used in these subroutines. The fractions (variables beginning with the letter "F") of the storages are used to compute the solute fluxes. The equations used to compute the solute transport fluxes from the fractions and storages are given in the figure. Subroutine TOPMOV performs the calculations of the fluxes and the resulting changes in storage for the topsoil layers (surface and upper), while SUBMOV performs them for the subsurface layers (lower and active groundwater).

Biological and chemical reactions are performed on the pesticides (and other chemicals) in each layer storage. Chemicals in the upper layer principal storage undergo reactions while those in the transitory (interflow) storage do not. The upper layer transitory storage is a temporary storage of chemicals on their way to interflow outflow. Subroutine PSTRXN is called to perform reactions on the pesticide in each layer.

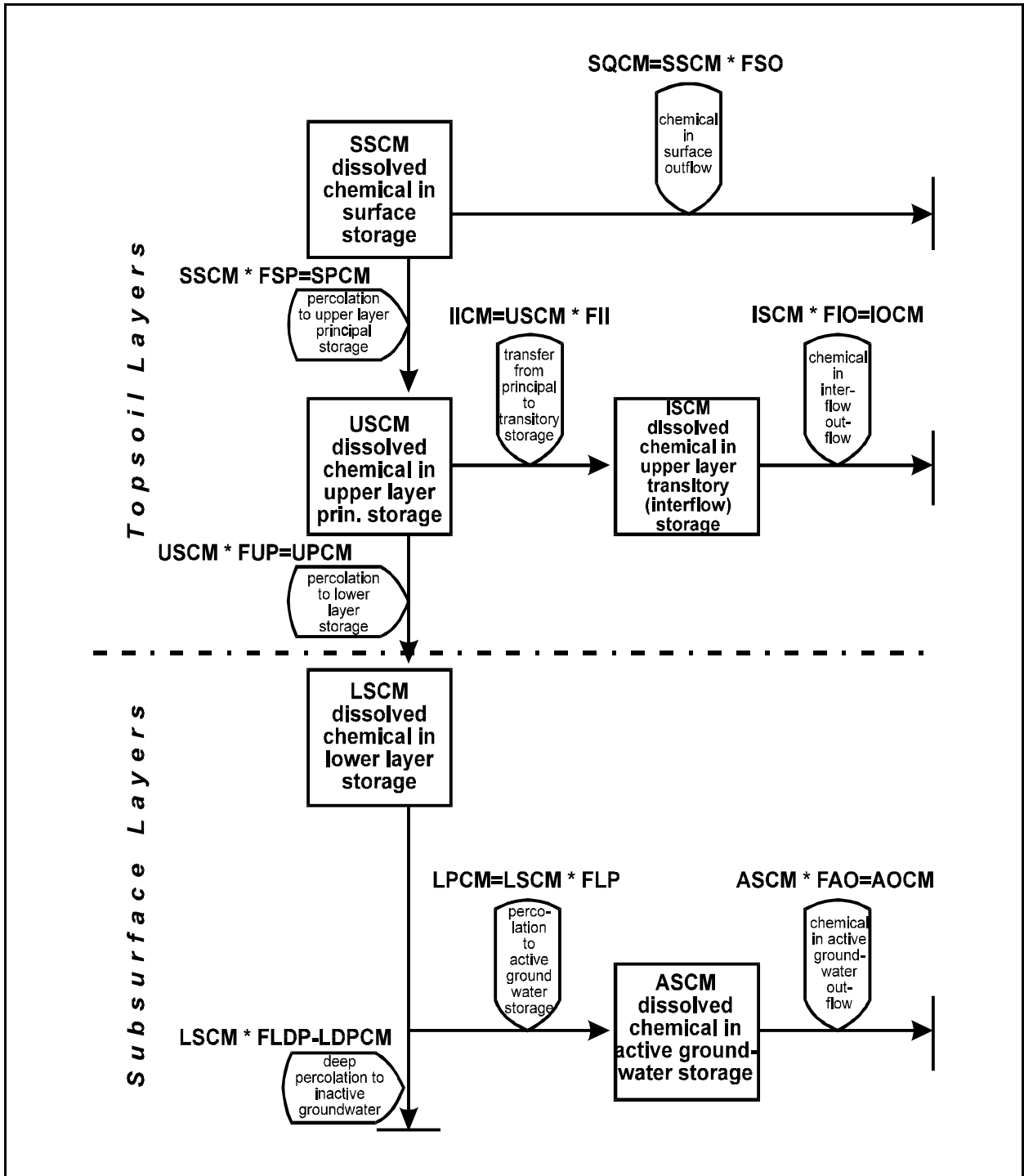


Figure 4.2(1).9-1 Flow diagram showing modeled movement of chemicals in solution

4.2(1).9.5 Perform Reactions on Pesticides
(subroutine PSTRXN)

Purpose

This code simulates the degradation and adsorption/desorption of pesticides. This subroutine is called for each of the four soil layers and each pesticide.

Method of Reacting Pesticides

The user has the option of adsorbing/desorbing the pesticide by one of three methods. The first method is by first-order kinetics. This method assumes that the pesticide adsorbs and desorbs at a rate based on the amount in soil solution and on the amount on the soil particle. It makes use of a proportionality constant and is independent of the concentration. The second method is by use of the single value Freundlich isotherm. This method makes use of a single adsorption/desorption curve for determining the concentration on the soil and in solution. The third method is by use of multiple curves based on a varying Freundlich K value. Further details of these methods can be found in the discussion of the individual subroutines that follows and in documentation of the ARM Model (Donigian and Crawford, 1976; Donigian, et al., 1977).

Degradation is performed once a day in each of the four layers that contain pesticide. The amount degraded is determined simply by multiplying a decay rate parameter specified for each soil layer by each of the three forms (adsorbed, solution, and crystalline) of pesticide in storage. The degraded amounts are then subtracted from their respective storages. This method of simulating degradation lumps complex processes in a simple parameter.

4.2(1).9.5.1 Adsorb/Desorb Using First-Order Kinetics (subroutine FIRORD)

Purpose

The purpose of this subroutine is to calculate the adsorption and desorption reaction fluxes of chemicals using temperature dependent first-order kinetics. These fluxes are calculated every simulation interval when the subroutine is called by section PEST, but they are determined only at the designated chemical reaction frequency when called by sections NITR and PHOS.

Method

The calculation of adsorption and desorption reaction fluxes by first-order kinetics for soil layer temperatures less than 35 degrees C takes the form:

$$DES = CMAD * KDS * THKDS ** (TMP - 35.0) \quad (1)$$

$$ADS = CMSU * KAD * THKAD ** (TMP - 35.0) \quad (2)$$

where:

DES = current desorption flux of chemical (mass/area per interval)
 CMAD = storage of adsorbed chemical (mass/area)
 KDS = first-order desorption rate parameter (per interval)
 THKDS = temperature correction parameter for desorption
 TMP = soil layer temperature (degrees C)
 ADS = current adsorption flux of chemical (mass/area per interval)
 CMSU = storage of chemical in solution (mass/area)
 KAD = first-order adsorption rate parameter (per interval)
 THKAD = temperature correction parameter for adsorption
 THKDS and THKAD are typically about 1.06

All of the variables except the temperature coefficients may vary with the layer of the soil being simulated. The soil temperatures are time series which may be input (e.g., using field data) or simulated in module section PSTEMP. The temperature correction of the reaction rate parameter is based on the Arrhenius equation. At temperatures of 35 degrees C or above, no correction is made. When the temperature is at 0 degrees C or below or the soil layer is dry, no adsorption and desorption occurs.

The storage of the solution chemical is updated every simulation interval in the calling subroutine, that is, in PSTRXN, NITRXN, or PHORXN, by adding DES minus ADS. Likewise, the storage of the adsorbed chemical is updated there also by adding ADS minus DES. An adjustment is made in the calling subroutine if any of the fluxes would cause a storage to go negative. When this happens a warning message is produced and fluxes are adjusted so that no storage goes negative. This usually occurs when large time steps are used in conjunction with large KAD and KDS values.

4.2(1).9.5.2 Adsorb/Desorb Using the Single Value Freundlich Method (subroutine SV)

Purpose

Subroutine SV calculates the adsorption and desorption and the resulting new storages of a chemical using the single value Freundlich method.

Method

The Freundlich isotherm methods, unlike first-order kinetics, assume instantaneous equilibrium. That is, no matter how much chemical is added to a particular phase, equilibrium is assumed to be established between the solution and adsorbed phase of the chemical. These methods also assume that for any given amount of chemical in the soil, the equilibrium distribution of the chemical between the soil solution and on the soil particle can be found from an isotherm. Figure 4.2(1).9-2 illustrates such an isotherm.

Three phases of the chemical are actually possible; crystalline, adsorbed, and solution. The crystalline form is assumed to occur only when the soil layer is dry, or when there is more chemical in the layer than the combined capacity to adsorb and hold in solution. When the soil is dry, all the chemical is considered to be crystalline salt. When there is more total chemical in the soil layer than the soil adsorption sites can contain and more than that saturated in solution, then the chemical content which exceeds these capacities is considered to be crystalline salt. Module section PEST considers crystalline phase storage, but module sections NITR and PHOS do not. Instead, any crystalline phosphate or ammonium predicted by an isotherm is added to the adsorbed phase storage.

The adsorbed and solution phases of the chemical are determined in this subroutine by the standard Freundlich equation as plotted by curve 1 in Figure 4.2(1).9-2. When the amount of chemical is less than the capacity of the soil particle lattice to permanently bind the chemical (XFIX), then all the material is considered fixed. All the fixed chemical is contained in the adsorbed phase of the layer storage. Otherwise, the Freundlich equation for curve 1 is used to determine the partitioning of the chemical into the adsorbed and solution phases:

$$X = KF1 * C^{1/N1} + XFIX \quad (3)$$

where:

- X = chemical adsorbed on soil (ppm of soil)
- KF1 = single value Freundlich K coefficient
- C = equilibrium chemical concentration in solution (ppm of solution)
- N1 = single value Freundlich exponent
- XFIX = chemical which is permanently fixed (ppm of soil)

The above equation is solved in subroutine ITER by an iteration technique. The parameters used in the computation can differ for each layer of the soil.

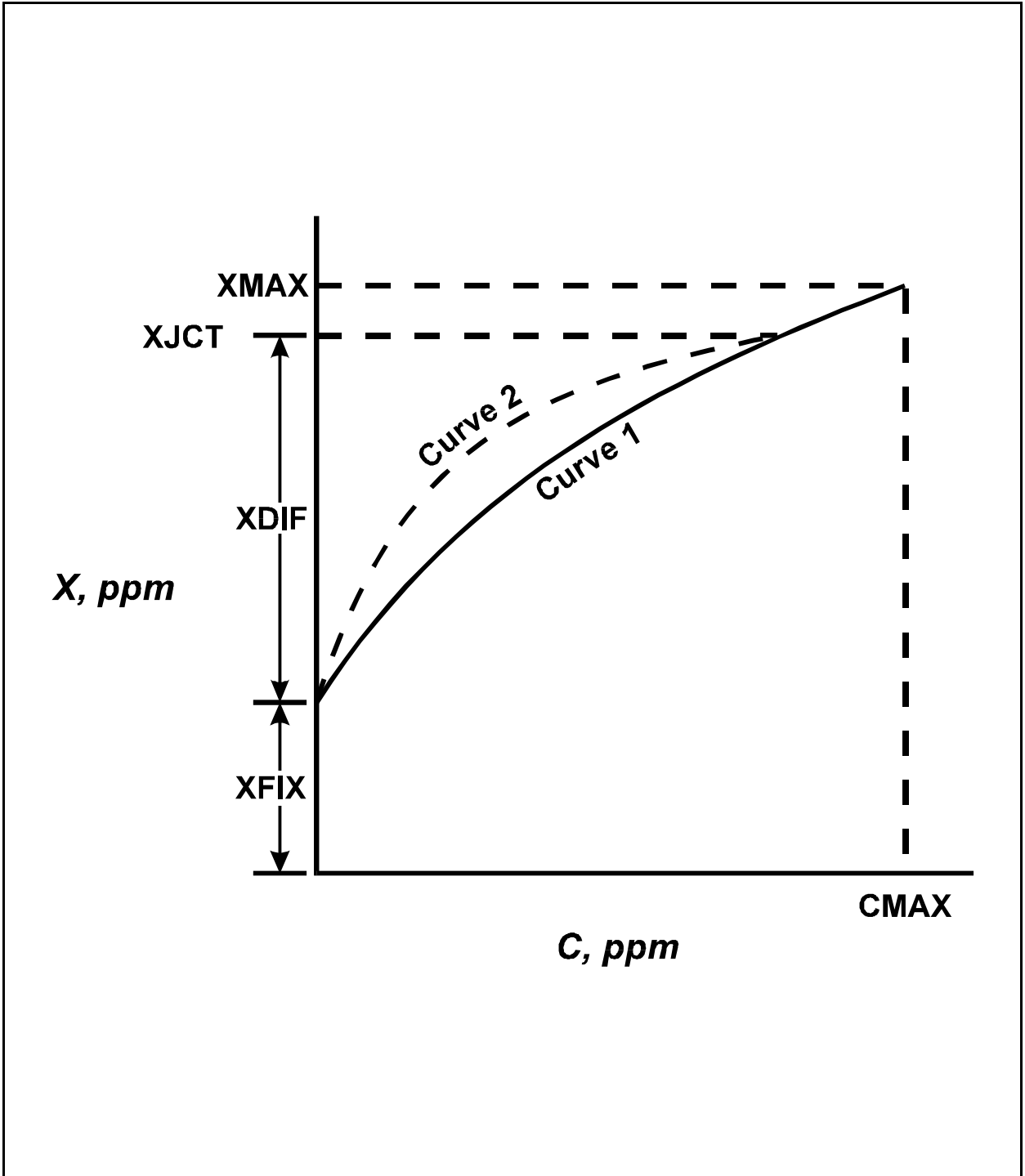


Figure 4.2(1).9-2 Freundlich isotherm calculations

4.2(1).9.5.3 Adsorb/Desorb Using the Non-single Value Freundlich Method
(subroutine NONSV)

Purpose

The purpose of this subroutine is to calculate the adsorption/desorption of a chemical by the nonsingle value Freundlich method. The single value Freundlich method was found to inadequately represent the division of some pesticides between the soil particle and solution phases, so this method was developed as an option in the ARM Model (Donigian and Crawford, 1976). This routine is only available for use by the PEST module section.

Method

The approach in this code uses the same algorithms and solution technique as subroutine SV for determining curve 1 in Figure 4.2(1).9-2. However, curve 1 is used solely for adsorption. That is, only when the concentration of the adsorbed chemical is increasing. When desorption occurs a new curve (curve 2) is used:

$$X = KF2 * C^{(1/N2)} + XFIX \quad (4)$$

$$KF2 = (KF1/XDIF)^{(N1/N2)} * XDIF \quad (5)$$

where:

KF2 = nonsingle value Freundlich coefficient

N2 = nonsingle value Freundlich exponent parameter

XDIF = XJCT - XFIX

XJCT = the adsorbed concentration where curve 1 joins curve 2
(i.e., where desorption started)
as shown in Figure 4.2(1).9-2 (ppm of soil)

The other variables are as defined for subroutine SV.

Once curve 2 is used, both desorption and adsorption follow it until the adsorbed concentration is less than or equal to XFIX or until it reaches XJCT. Then, adsorption will again take place following curve 1 until desorption reoccurs, following a newly calculated curve 2. The solution of the Freundlich equations for curves 1 and 2 utilizes the same iteration technique introduced in subroutine SV (subroutine ITER).

4.2(1).10 Simulate Nitrogen Behavior in Detail (section NITR of module PERLND)

Purpose

NITR, like section PEST, simulates the behavior of chemicals in the soil profile of a land segment. Section NITR handles the nitrogen species of nitrate, ammonia, and organic nitrogen. This involves simulating nitrogen transport and soil reactions. Nitrogen, like phosphorus, may be a limiting nutrient in the eutrophication process in lakes and streams. Nitrates in high concentrations may also pose a health hazard to infants.

Method

Nitrogen species are transported by the same methods used for the pesticide forms. The subroutines that are called to transport nitrogen are located in and described with the PEST module section. Adsorbed ammonium and two forms of particulate organic nitrogen (labile and refractory) are removed from the surface layer storage by association with sediment. These processes are handled by subroutines SDFRAC and SEDMOV. Nitrate, ammonium, and two forms of dissolved organic nitrogen (labile and refractory) in the soil water are transported using the subroutines TOPMOV and SUBMOV. Nitrogen reactions are simulated separately for each of the soil layers. The methods are described below, in the discussion of subroutine NITRXN, and are shown schematically in Figure 4.2(1).10-1.

Inputs of nitrogen to the soil

Natural and agricultural inputs of nitrogen to the surface and upper soil layers can be simulated using either or both of two methods: 1) as changes to storage variables in the SPEC-ACTIONS block, or 2) as atmospheric deposition inputs. Atmospheric deposition inputs are implemented for three species: nitrate, ammonium, and particulate labile organic nitrogen.

Atmospheric deposition inputs can be specified in two possible ways depending on the form of the available data. If the deposition is in the form of a flux (mass per area per time), then it is considered "dry deposition". If the deposition is in the form of a concentration in rainfall, then it is considered "wet deposition", and the program automatically combines it with the input rainfall time series to compute the resulting flux. Either type of deposition data can be input as a time series, which covers the entire simulation period, or as a set of monthly values that is used for each year of the simulation. The specific atmospheric deposition time series are documented in the EXTNL table of the Time Series Catalog for PERLND, and are specified in the EXT SOURCES block of the UCI. The monthly values are input in the MONTH-DATA block in the UCI.

If atmospheric deposition data are input to the model, the soil storage is updated for each of the three species of nitrogen in each soil layer (surface and upper) using the general formula:

$$\text{NSTOR} = \text{NSTOR} + \text{ADFX} + \text{PREC} * \text{ADCN} \quad (1)$$

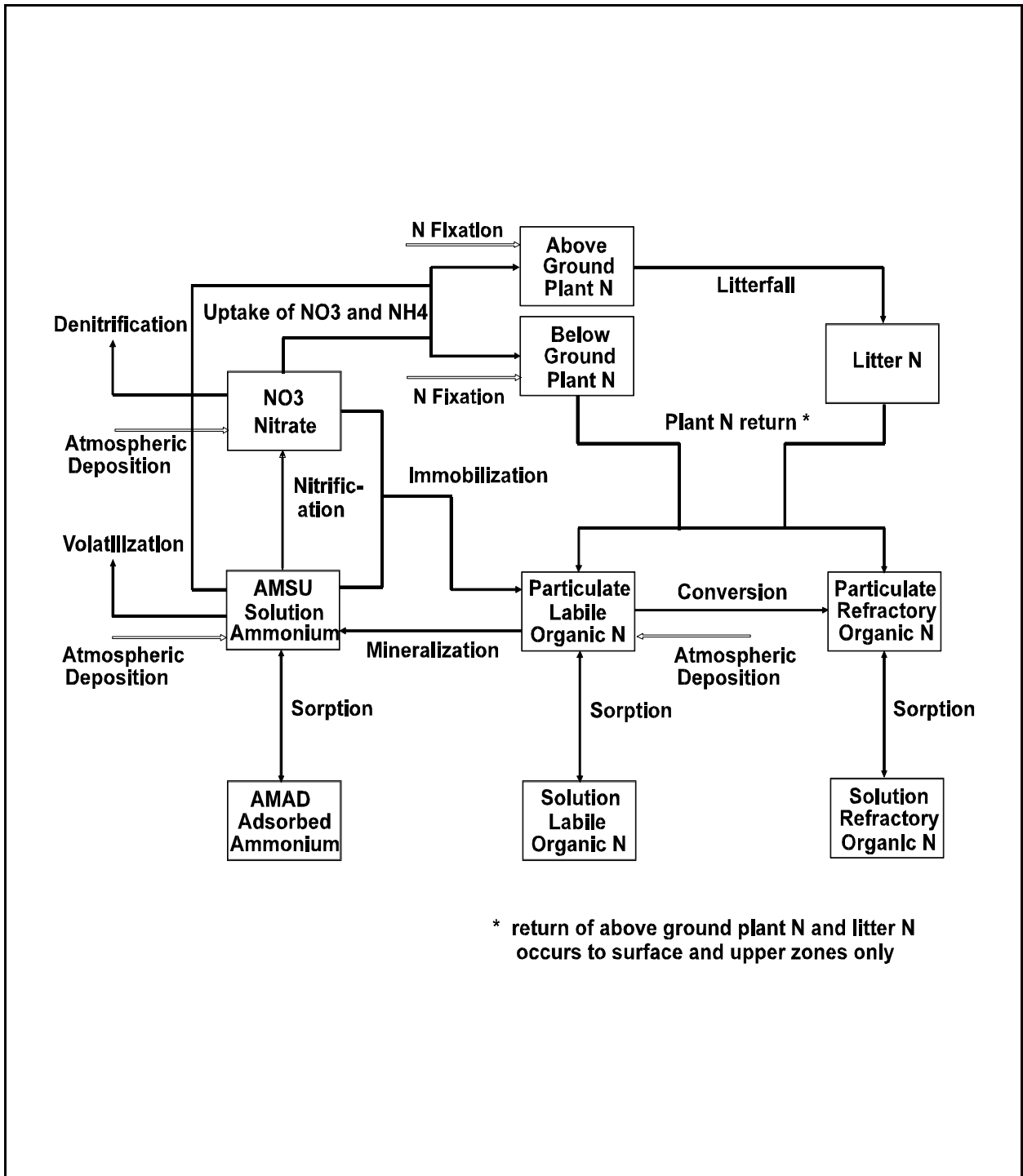


Figure 4.2(1).10-1 Flow diagram for nitrogen reactions

where:

NSTOR = storage of nitrogen species in the soil layer (mass/area)
 ADFX = dry or total atmospheric deposition flux (mass/area per interval)
 PREC = precipitation (depth per interval)
 ADCN = concentration of nitrogen species in rainfall (mass/volume)4.2(1).10.1

Perform Reactions on Nitrogen Forms
(subroutine NITRXN)

Purpose

The purpose of NITRXN is to simulate soil nitrogen transformations. This includes plant uptake of nitrate and ammonium, return of plant nitrogen to organic nitrogen, denitrification or reduction of nitrate-nitrite, immobilization of nitrate-nitrite and ammonium, mineralization of organic nitrogen, fixation of atmospheric nitrogen, volatilization of ammonium, adsorption/desorption of ammonium, and partitioning of two types of organic nitrogen between solution and particulate forms.

Method of Nitrogen Transformations

Adsorption/desorption of ammonium

Nitrogen reactions can be divided between those that are chemical in nature and those that are a combination of chemical and biological reactions. The adsorption and desorption of ammonium is a chemical process. The user has the option of simulating ammonium adsorption and desorption by first-order kinetics with subroutine FIRORD or by the Freundlich isotherm method with subroutine SV. These subroutines are described in the PEST module section.

The user has the option of specifying how often the adsorption and desorption rates are calculated. When adsorption/desorption is simulated by the Freundlich method, the solution and adsorbed storages of ammonium are determined instantaneously at the specified frequency of reaction. However, when the first-order method is used, the temperature-corrected reaction fluxes (Figure 4.2(1).10-1) are recomputed intermittently, but the storages are updated every simulation interval.

Organic Nitrogen Partitioning

Organic nitrogen is assumed to exist in the following four forms in each soil layer.

Particulate labile
 Solution labile
 Particulate refractory
 Solution refractory

The particulate labile species is the default form of organic N in the model; if default values of organic N-related sorption parameters and reaction rates are used, only this form will exist. This species is formed by immobilization of nitrate and ammonia, and is converted back to ammonia by mineralization in the

soil. It also is transported on the surface by association with sediment. However, if the user inputs non-zero values of the parameters, it can undergo conversion by first-order rate to the particulate refractory form, and it can also desorb to the solution labile form. The particulate refractory species can also desorb to the solution refractory form. The two solution species are available for transport with surface runoff and within the soil profile, and the particulate refractory form can be transported on the surface with sediment.

The organic nitrogen partitioning reactions (sorption-desorption) are described by equilibrium isotherms as shown in the following equations:

$$\begin{aligned} \text{KLON} &= \text{PLON}/\text{SLON} \\ \text{KRON} &= \text{PRON}/\text{SRON} \end{aligned} \quad (2)$$

where:

KLON and KRON = partition coefficients for the labile and refractory organic nitrogen, respectively (-)
 PLON = particulate labile organic N (lb N/ac or kg N/ha)
 SLON = solution labile organic N (lb N/ac or kg N/ha)
 PRON = particulate refractory organic N (lb N/ac or kg N/ha)
 SRON = solution refractory organic N (lb N/ac or kg N/ha)

The four organic nitrogen forms and their assorted reactions are illustrated in Figure 4.2(1).10-1. Note that the storages and transformations in this figure are generally repeated in each soil layer except for the aboveground plant N and the litter compartments.

Note that the three new organic nitrogen state variables described above are always present in the NITR module, i.e., they are not optional. However, in order to make the program compatible with previous versions, the default inputs result in the three new forms maintaining zero concentrations; therefore, there should be no impact on the simulation results of existing applications when using the current version of HSPF.

Other Nitrogen Transformations

The other reactions are a combination of biological and chemical transformations. All of these reactions can be modeled using first-order kinetics; optional algorithms can be used for plant uptake of N and immobilization of organic N. The optimum first-order kinetic rate parameter is corrected for soil temperatures below 35 degrees C by the generalized equation:

$$\text{KK} = \text{K} * \text{TH}^{**}(\text{TMP} - 35.0) \quad (3)$$

where:

KK = temperature-corrected first-order reaction rate (/interval)
 K = optimum first-order reaction rate at 35 degrees C (/interval)
 TH = temperature correction coefficient for reaction (typically about 1.06)
 TMP = soil layer temperature (degrees C)

When temperatures are greater than 35 degrees C, the rate is considered optimum, that is, KK is set equal to K . When the temperature of the soil layer is below 4 degrees C or the layer is dry, no biochemical transformations occur.

The corrected reaction rate parameters are determined every biochemical reaction interval and multiplied by the respective storages as shown in Figure 4.2(1).10-1 to obtain the reaction fluxes. Plant uptake can vary monthly and can be distributed between nitrate and ammonium by the parameters $NO3UTF$ and $NH4UTF$. These parameters are intended to designate the fraction of plant uptake from each species of N; the sum of $NO3UTF$ and $NH4UTF$ should be 1.0.

The biochemical reaction rate fluxes that are shown in Figure 4.2(1).10-1 are coupled, that is, added to and subtracted from the storages simultaneously. The coupling of the fluxes is efficient in use of computer time, but has a tendency to produce unrealistic negative storages when large reaction intervals and large reaction rates are used jointly. A method is used which modifies the reaction fluxes so that they do not produce negative storages. A warning message is issued when this modification occurs.

Immobilization of nitrate and ammonia (conversion to particulate labile organic N) can be simulated using either first-order kinetics as described above, or a saturation kinetics (Michaelis-Menten) method. The saturation kinetics option is intended primarily for forests, and is activated when $NUPTFG = 2$ or -2 . Details of this option are presented below, under plant uptake optional methods.

Ammonia Volatilization

Ammonia volatilization is included as an optional ($AMVOFG = 1$) first-order reaction in order to allow large concentrations of ammonia in the soil, resulting from animal waste and fertilizer applications, to be attenuated by losses to the atmosphere. The original formulation by Reddy et al., (1979) included adjustment for variable soil cation exchange capacity (CEC) and wind speed, and it could be "turned off" after seven days. In HSPF, it is assumed that: (1) the CEC factor can be incorporated into the first-order rate constant by the user, and (2) the wind (air flow) is always high enough to result in maximum loss; Reddy's original method reduced the volatilization rate only when wind speed was less than 1.4 km/day. Downward adjustment of the rate, after an initial period of high losses, requires use of the Special Actions capability.

The temperature correction for volatilization of ammonia is slightly different than the standard method used for the other reactions. The reference temperature is user-specified, instead of 35 degrees C, since rates in the literature are often given at a temperature of 20 degrees C. Also, instead of attaining a maximum value at the reference temperature, the volatilization rate is adjusted upwards when the soil temperature exceeds the reference temperature.

Plant nitrogen

The user can select between two optional scenarios for simulating plant nitrogen. If $ALPNFG = 0$, plant N is simulated in each of the four standard soil layers (i.e., surface, upper, lower, and active groundwater). If $ALPNFG = 1$, plant N is also simulated in above-ground and litter compartments, in addition to the standard

below-ground layers. Plant N simulation involves uptake of ammonium and nitrate by the plant, and "return" of plant N to organic N in the soil. Above-ground plant N returns to the litter compartment, and litter plant N returns to the particulate organic N compartments in the surface and upper soil layers. These return "reactions" from above-ground plant N to litter and from litter to surface/upper organic N are simulated using first-order kinetics. No other reactions affect these nitrogen storages except for plant uptake to the above-ground compartment.

Return of plant N to particulate organic N is divided into labile and refractory fractions. By using default values of the return parameters, all plant return becomes labile organic N.

Optional Methods for Modeling Plant Uptake of Nitrogen

There are three optional methods for simulating plant uptake, including the default, first-order method described above. These options are selected using the input flag NUPTFG.

The second method for simulating plant uptake is to use a yield-based algorithm (NUPTFG = 1). This approach is a modification of the algorithm used in the Nitrate Leaching and Economic Analysis Package (NLEAP model) (Shaffer et al, 1991). It is designed to be less sensitive to soil nutrient levels and nutrient application rates than the first-order rate approach (NUPTFG = 0); thus, it allows crop needs to be satisfied, subject to nutrient and moisture availability, without being calculated as a direct function of the soil nutrient level. This approach allows a better representation of nutrient management practices, since uptake levels will not change dramatically with changes in application rates.

In this method, a total annual target, NUPTGT, is specified by the user, and is then divided into monthly targets during the crop growing season; the target is further divided into the four soil layers. The monthly target for each soil layer is calculated as:

$$\text{MONTGT} = \text{NUPTGT} * \text{NUPTFM}(\text{MON}) * \text{NUPTM}(\text{MON}) * \text{CRPFRC}(\text{MON}, \text{ICROP}) \quad (4)$$

where:

MONTGT= monthly plant uptake target for current crop (lb N/ac or kg N/ha)
 NUPTGT= total annual uptake target (lb N/ac or kg N/ha)
 NUPTFM= monthly fraction of total annual uptake target (-)
 NUPTM = soil layer fraction of monthly uptake target (-)
 CRPFRC= fraction of monthly uptake target for current crop (-)

This is 1.0 unless the month contains parts of two or more crop seasons, in which case the monthly uptake target is divided among the crops according to the number of days of the month belonging to each season.

MON = current month
 ICROP = index for current crop

Planting and harvesting dates can be specified for up to three separate crops during the year. Plant uptake is assumed to occur only during a growing season, defined as the time period between planting and harvest. When portions of two

growing seasons are contained within one month, the total monthly target is divided between the two crops in proportion to the number of days in each season in that month. The daily target is calculated by starting at zero at the beginning of a crop season and using a trapezoidal rule to solve for monthly boundaries; linear interpolation is used to solve for daily values between the monthly boundaries, and between a monthly boundary and a planting or harvest date.

Yield-based plant uptake only occurs when the soil moisture is above the wilting point, which is specified by the user for each soil layer. No temperature rate adjustment is performed, but all uptake is stopped when soil temperature is below 4 degrees C. If the uptake target is not met during a given interval, whether from nutrient, temperature, or moisture stress, then an uptake deficit is accumulated, and applied to the next interval's target. When uptake later becomes possible, the program will attempt to make up the deficit by taking up nitrogen at a rate higher than the normal daily target, up to a user-specified maximum defined as a multiple of the target rate. The deficit is tracked for each soil layer, and is reset to zero at harvest, i.e. it does not carry over from one crop season to the next.

When using the yield-based plant uptake option, it is also possible to represent leguminous plants (e.g. soybeans) that will fix nitrogen from the atmosphere. The algorithm is designed to allow N fixation only to make up any shortfall in soil nitrogen, i.e., fixation is only allowed if the available soil nitrogen (nitrate and solution ammonium) is insufficient to satisfy the target uptake. The maximum daily nitrogen fixation rate is subject to the same limits as the uptake under deficit conditions noted above.

The third option for simulating plant uptake is to use a Michaelis-Menten or saturation kinetics method. This algorithm is included in HSPF primarily for simulating forested areas, and whenever it is selected, the same method is also used to simulate immobilization of ammonium and nitrate. Saturation kinetics is activated for both uptake and immobilization by setting NUPTFG to 2 or -2.

The user specifies a maximum rate and a half-saturation constant for each of the four processes (uptake of nitrate and ammonia, and immobilization of nitrate and ammonia). The input maximum rates can vary monthly. The corresponding reaction fluxes are computed using the general equation:

$$\text{FLUX} = \text{KK} * \text{CONC} / (\text{CS} + \text{CONC}) \quad (5)$$

where:

FLUX = amount of flux (mg/l/interval)
 KK = temperature corrected maximum rate (mg/l/interval)
 CONC = concentration of nitrogen species in soil layer (mg/l)
 CS = half-saturation constant (mg/l)

The flux is then converted to units of mass per interval.

Regardless of the option used to simulate plant uptake, if the above-ground and litter compartments are being simulated, then the user can specify the fraction of uptake from each layer that goes to the above-ground plant N storage. The remainder is assumed to become plant N within that soil layer.

4.2(1).11 Simulate Phosphorous Behavior in Detail (Section PHOS of Module PERLND)

Purpose

Module section PHOS simulates the behavior of phosphorus in a pervious land segment. This involves modeling the transport, plant uptake, adsorption/desorption, immobilization, and mineralization of the various forms of phosphorus. Because phosphorus is readily tied to soil and sediment, it is usually scarce in streams and lakes. In fact, in many cases it is the limiting nutrient in the eutrophication process. Because of its scarcity, accurate simulation is particularly important.

Method

The method used to transport and react phosphorus is the same as that used for nitrogen in module section NITR. The subroutines used to transport phosphorus are described in module section PEST. Organic phosphorus and adsorbed phosphate are removed with sediment by calling subroutine SEDMOV. Phosphate in solution is transported in the moving water using subroutines TOPMOV and SUBMOV. Phosphorus reactions are simulated in the soil by subroutine PHORXN.

Inputs of the two species of phosphorus to the surface and upper soil layers, natural or agricultural, can be simulated using either or both of two methods: 1) as changes to storage variables in the SPEC-ACTIONS block, or 2) as atmospheric deposition.

Atmospheric deposition inputs can be specified in two possible ways depending on the form of the available data. If the deposition is in the form of a flux (mass per area per time), then it is considered "dry deposition". If the deposition is in the form of a concentration in rainfall, then it is considered "wet deposition", and the program automatically combines it with the input rainfall time series to compute the resulting flux. Either type of deposition data can be input as a time series, which covers the entire simulation period, or as a set of monthly values that is used for each year of the simulation. The specific atmospheric deposition time series are documented in the EXTNL table of the Time Series Catalog for PERLND, and are specified in the EXT SOURCES block of the UCI. The monthly values are input in the MONTH-DATA block in the UCI.

If atmospheric deposition data are input to the model, the soil storage is updated for each of the two species of phosphorus for both affected soil layers using the formula:

$$P = P + ADFX + PREC*ADCN \quad (1)$$

where:

P = storage of phosphorus species in the soil layer (mass/area)
 ADFX = dry or total atmospheric deposition flux (mass/area per interval)
 PREC = precipitation depth
 ADCN = concentration for wet atmospheric deposition (mass/volume)

In subroutine PHORXN, phosphate is adsorbed and desorbed by either first-order kinetics or by the Freundlich method. The mechanics of these methods are described in module section PEST. As with the simulation of ammonium adsorption/desorption, the frequency of this chemical reaction for phosphate can also be specified. Unlike ammonium, typically phosphate includes a large portion which is not attached to the soil particle but is combined with cations. This is because phosphate is much less soluble with the ions found in soils than ammonium.

Other reactions performed by subroutine PHORXN include mineralization, immobilization, and plant uptake. These are accomplished using temperature dependent, first-order kinetics; the same method used for the nitrogen reactions. As for nitrogen, a yield-based plant uptake option is available for phosphorus and is activated with PUPTFG = 1. The saturation-kinetics option for uptake and immobilization, however, is not available for phosphorus. The only other difference between nitrogen and phosphorus plant uptake is that only solution phosphate can be taken up by the plant and no fixation process is modeled. The general description of these processes is in module section NITR. Figure 4.2(1).11-1 shows the parameters and equations used to calculate the reaction fluxes for phosphorus. Reactions are simulated for each of the four soil layers using separate parameter sets for each layer. As with nitrogen, the biochemical phosphate reaction fluxes of mineralization, immobilization, and plant uptake can be determined at an interval less frequent than the basic simulation interval.

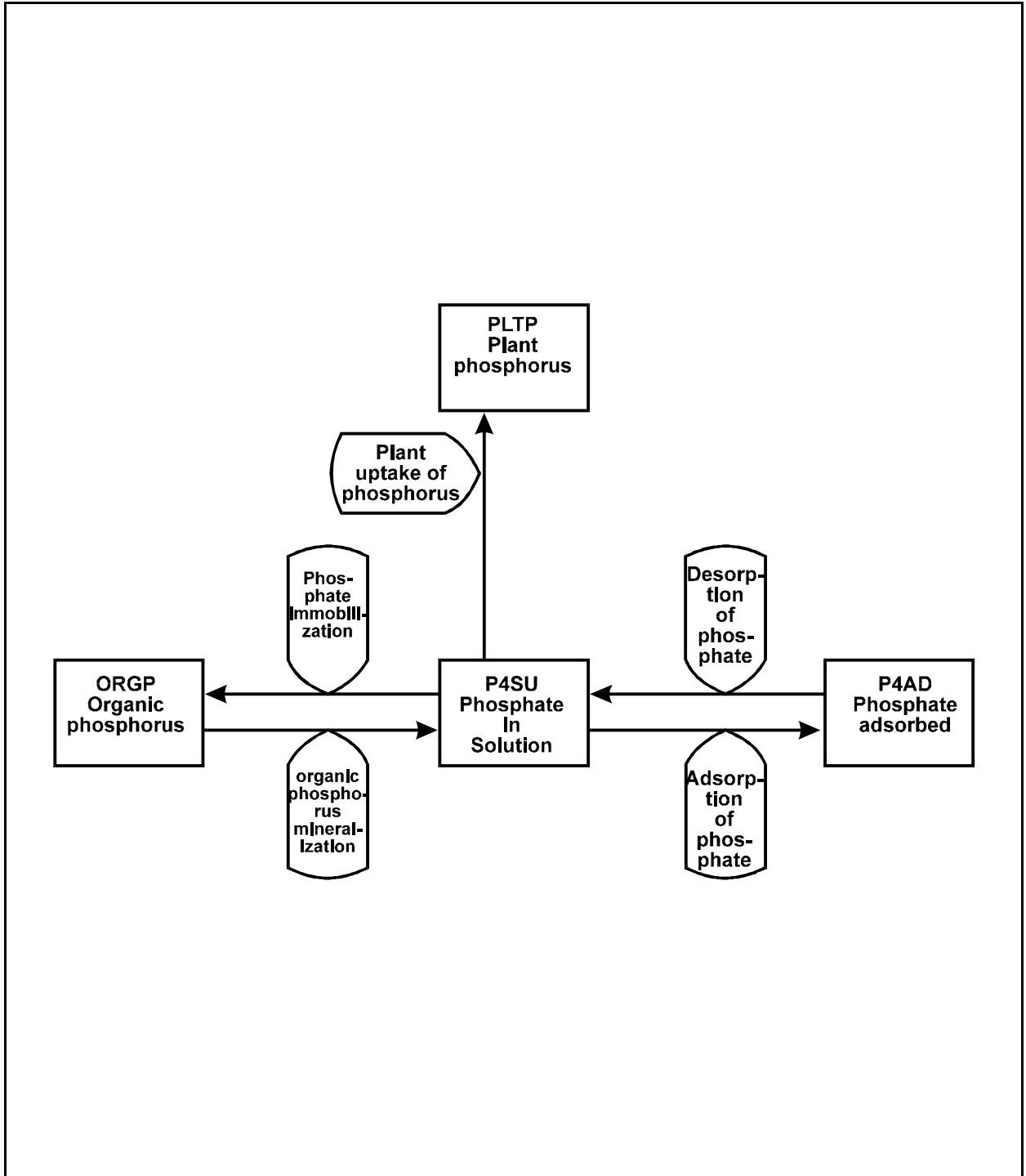


Figure 4.2(1).11-1 Flow diagram for phosphorus reactions

4.2(1).12 Simulate Movement of a Tracer (Section TRACER of Module PERLND)

Purpose

The purpose of this code is to simulate the movement of any nonreactive tracer (conservative) in a pervious land segment. Chloride, bromide, and dyes are commonly used tracers which can be simulated by section TRACER. Also, total dissolved salts could possibly be modeled by this section. Typically, this code is applied to chloride to calibrate solute movement through the soil profile. This involves adjustment of the percolation retardation factors (see section MSTLAY) until good agreement with observed chloride concentrations has been obtained. Once these factors have been calibrated, they are used to simulate the transport of other solutes, such as nitrate.

Method of Simulating Tracer Transport

Tracer simulation uses the agri-chemical solute transport subroutines TOPMOV and SUBMOV which are described in section PEST. No reactions are modeled.

Inputs of the tracer substance to the surface and upper soil layers can be simulated using either or both of two methods: 1) as changes to storage variables in the SPEC-ACTIONS block, or 2) as atmospheric deposition.

Atmospheric deposition inputs can be specified in two possible ways depending on the form of the available data. If the deposition is in the form of a flux (mass per area per time), then it is considered "dry deposition". If the deposition is in the form of a concentration in rainfall, then it is considered "wet deposition", and the program automatically combines it with the input rainfall time series to compute the resulting flux. Either type of deposition data can be input as a time series, which covers the entire simulation period, or as a set of monthly values that is used for each year of the simulation. The specific atmospheric deposition time series are documented in the EXTNL table of the Time Series Catalog for PERLND, and are specified in the EXT SOURCES block of the UCI. The monthly values are input in the MONTH-DATA block in the UCI.

If atmospheric deposition data are input to the model, then the soil storage of tracer is updated for both affected soil layers using the formula:

$$T = T + ADFX + \text{PREC} * \text{ADCN} \quad (1)$$

where:

T = storage of tracer in the soil layer (mass/area)
 ADFX = dry or total atmospheric deposition flux (mass/area per interval)
 PREC = precipitation depth
 ADCN = concentration for wet atmospheric deposition (mass/volume)

4.2(2) Simulate an Impervious Land Segment (Module IMPLND)

In an impervious land segment, little or no infiltration occurs. However, land surface processes do occur as illustrated in Figure 4.2(2)-1. Snow may accumulate and melt, and water may be stored or may evaporate. Various water quality constituents accumulate and are removed. Water, solids, and various pollutants flow from the segments by moving laterally to a downslope segment or to a reach/reservoir.

Module IMPLND simulates these processes. The sections of IMPLND and their functions are given in the structure chart shown in Figure 4.2(2)-2. They are executed from left to right. Many of them are similar to the corresponding sections in the PERLND module. In fact, since sections SNOW and ATEMP perform functions that can be applied to pervious or impervious segments, they are shared by both modules. IWATER is analogous to PWATER in module PERLND; SOLIDS is analogous to SEDMNT; IWTGAS is analogous to PWTGAS; and IQUAL is analogous to PQUAL. However, the IMPLND sections are simpler since they contain no infiltration function and consequently no subsurface flows.

4.2(2).3 Simulate the Water Budget for an Impervious Land Segment
(Section IWATER of Module IMPLND)

Purpose

Section IWATER simulates the retention, routing, and evaporation of water from an impervious land segment.

Method

Section IWATER is similar to section PWATER of the PERLND module. However, IWATER is simpler because there is no infiltration and consequently no subsurface processes. IWATER is composed of the parent subroutine plus three subordinate subroutines: RETN, IROUTE, and EVRETN. RETN is analogous to ICEPT, IROUTE is analogous to PROUTE, and EVRETN is analogous to EVICEP in module section PWATER. The time series requirements are the same as for section PWATER.

Figure 4.2(2).3-1 schematically represents the fluxes and storages simulated in module section IWATER. Moisture (SUPY) is supplied by precipitation, or under snow conditions, it is supplied by the rain not falling on the snowpack plus the water yielded by the snowpack. This moisture is available for retention; subroutine RETN performs the retention functions. Lateral surface inflow (SURLI) may also be retained if the user so specifies by setting the flag parameter RTLIFG=1. Otherwise, retention inflow (RETI) equals SUPY. Moisture exceeding the retention capacity overflows the storage and is available for runoff.

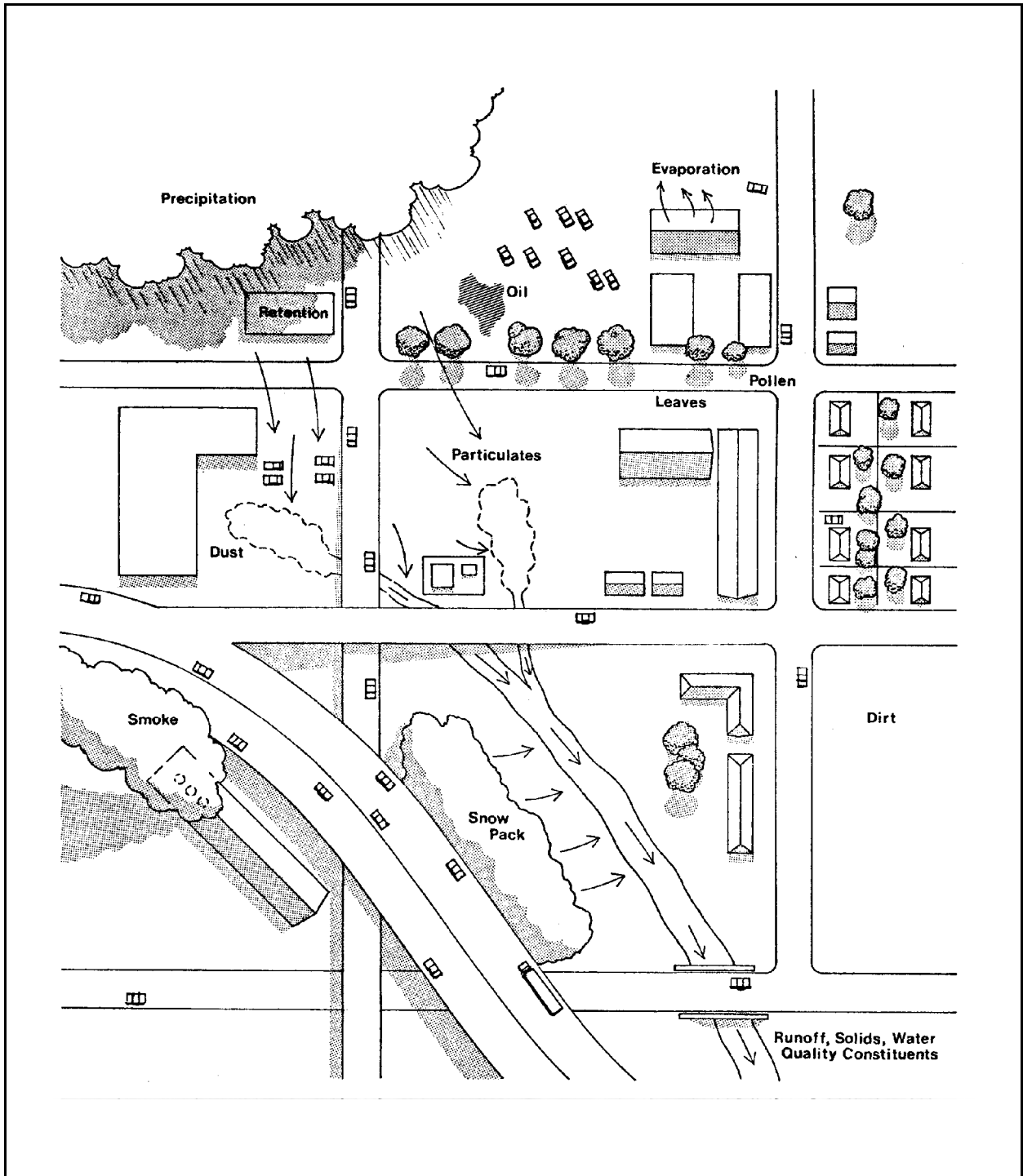


Figure 4.2(2)-1 Impervious land segment processes

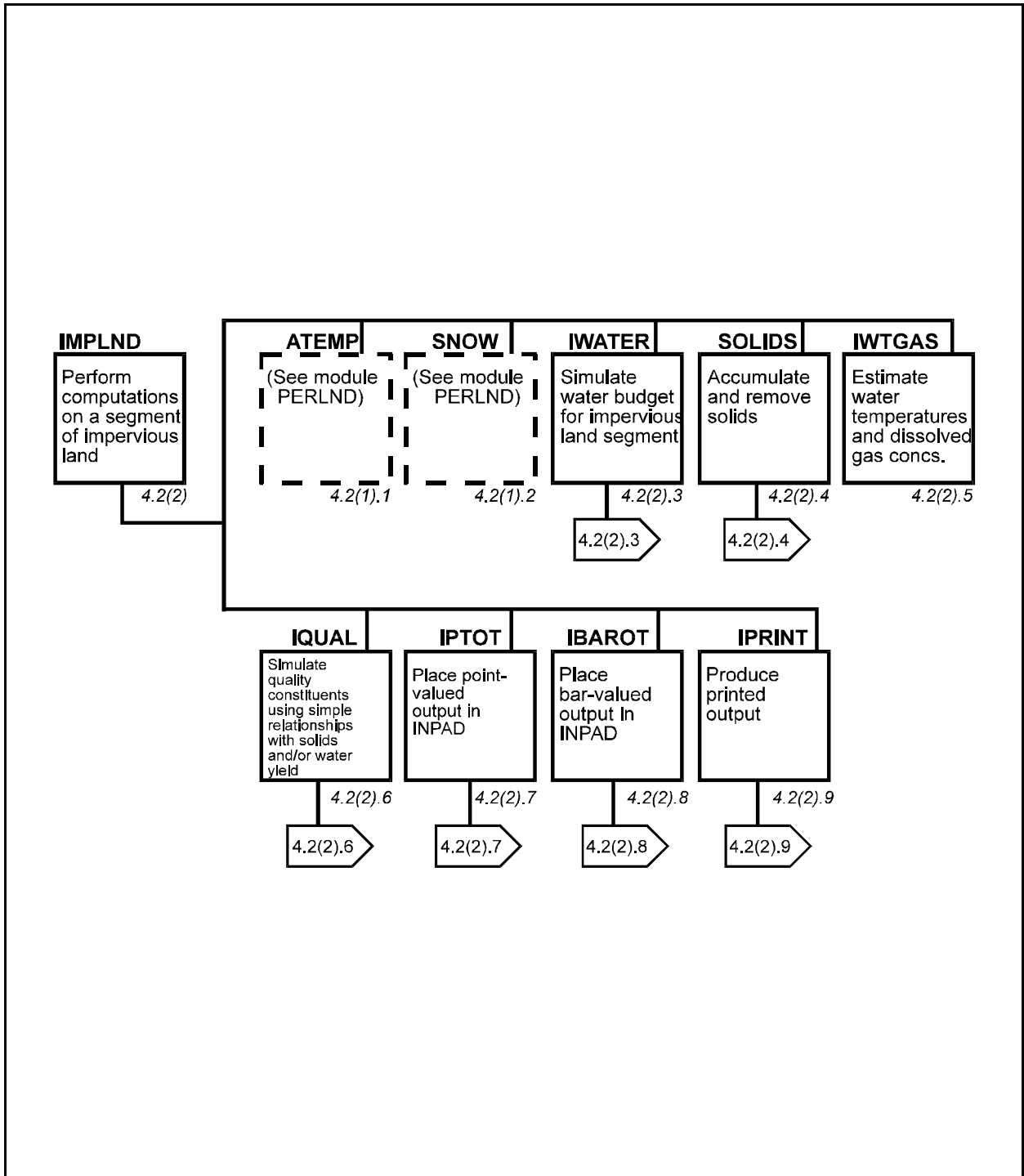


Figure 4.2(2)-2 Structure chart for IMPLND Module

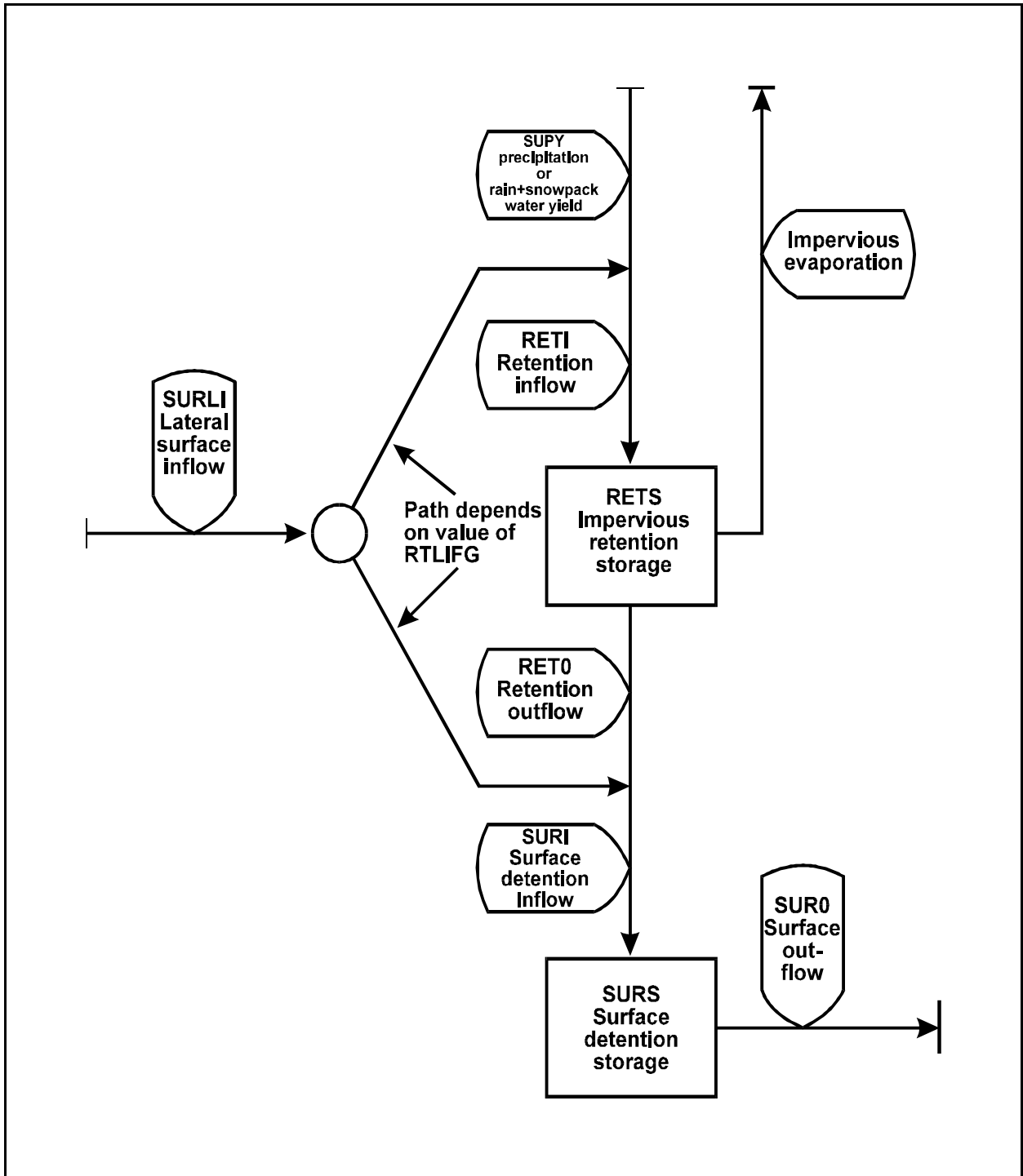


Figure 4.2(2).3-1 Hydrologic Processes

The retention capacity, defined by the parameter RETSC, can be used to designate any retention of moisture which does not reach the overland flow plane. RETSC may be used to represent roof top catchments, asphalt wetting, urban vegetation, improper drainage, or any other containment of water that will never flow from the land segment. The user may supply the retention capacity on a monthly basis to account for seasonal variations, or may supply one value designating a fixed capacity.

Water held in retention storage is removed by evaporation (IMPEV). The amount evaporated is determined in subroutine EVRETN. Potential evaporation is an input time series.

Retention outflow (RETO) is combined with any lateral inflow when RTLIFG=0 producing the total inflow to the detention storage (SURI). Water remaining in the detention storage plus any inflow is considered the moisture supply. The moisture supply is routed from the land surface in subroutine IROUTE.

4.2(2).3.2 Determine How Much of the Moisture Supply Runs Off (subroutine IROUTE)

Purpose

The purpose of subroutine IROUTE is to determine how much of the moisture supply runs off the impervious surface in one simulation interval.

Method of Routing

A method similar to that used in module PERLND (Section 4.2(1).3.2.1.3) is employed to route overland flow.

4.2(2).4 Simulate Accumulation and Removal of Solids (Section SOLIDS of Module IMPLND)

Purpose

Module section SOLIDS simulates the accumulation and removal of solids by runoff and other means from the impervious land segment. The solids outflow may be used in section IQUAL to simulate quality constituents associated with particulates.

Method

The equations used in this section are based on those in the NPS Model (Donigian and Crawford, 1976b). Figure 4.2(2).4-1 schematically represents the fluxes and storages simulated by section SOLIDS. Lateral input of solids by water flow is a user designated option. Washoff of solids may be simulated by one of two ways. One subroutine is similar to the method used in the NPS Model. However, this method is dimensionally nonhomogeneous. That is, a flux and a storage are added making the answer more interval dependent. This technique was designed for 15-min intervals. The other subroutine is dimensionally homogenous, since only a flux term is used in the solution.

The accumulation and removal of solids which occurs independently of runoff (e.g., by atmospheric fallout, street cleaning) is handled in subroutine ACCUM.

4.2(2).4.1 Washoff Solids Using Method 1 (subroutine SOSLD1)

Purpose

Subroutines SOSLD1 and SOSLD2 perform the same task, but by different methods. They simulate the washoff of solids from an impervious land segment.

Method

When simulating the washoff of solids, the transport capacity of the overland flow is estimated and compared to the amount of solids available. The transport capacity is calculated by the equation:

$$STCAP = DELT60 * KEIM * ((SURS + SURO) / DELT60) ** JEIM \quad (1)$$

where:

STCAP = capacity for removing solids (tons/ac per interval)
 DELT60 = hours per interval
 KEIM = coefficient for transport of solids
 SURS = surface water storage (inches)
 SURO = surface outflow of water (in/interval)
 JEIM = exponent for transport of solids

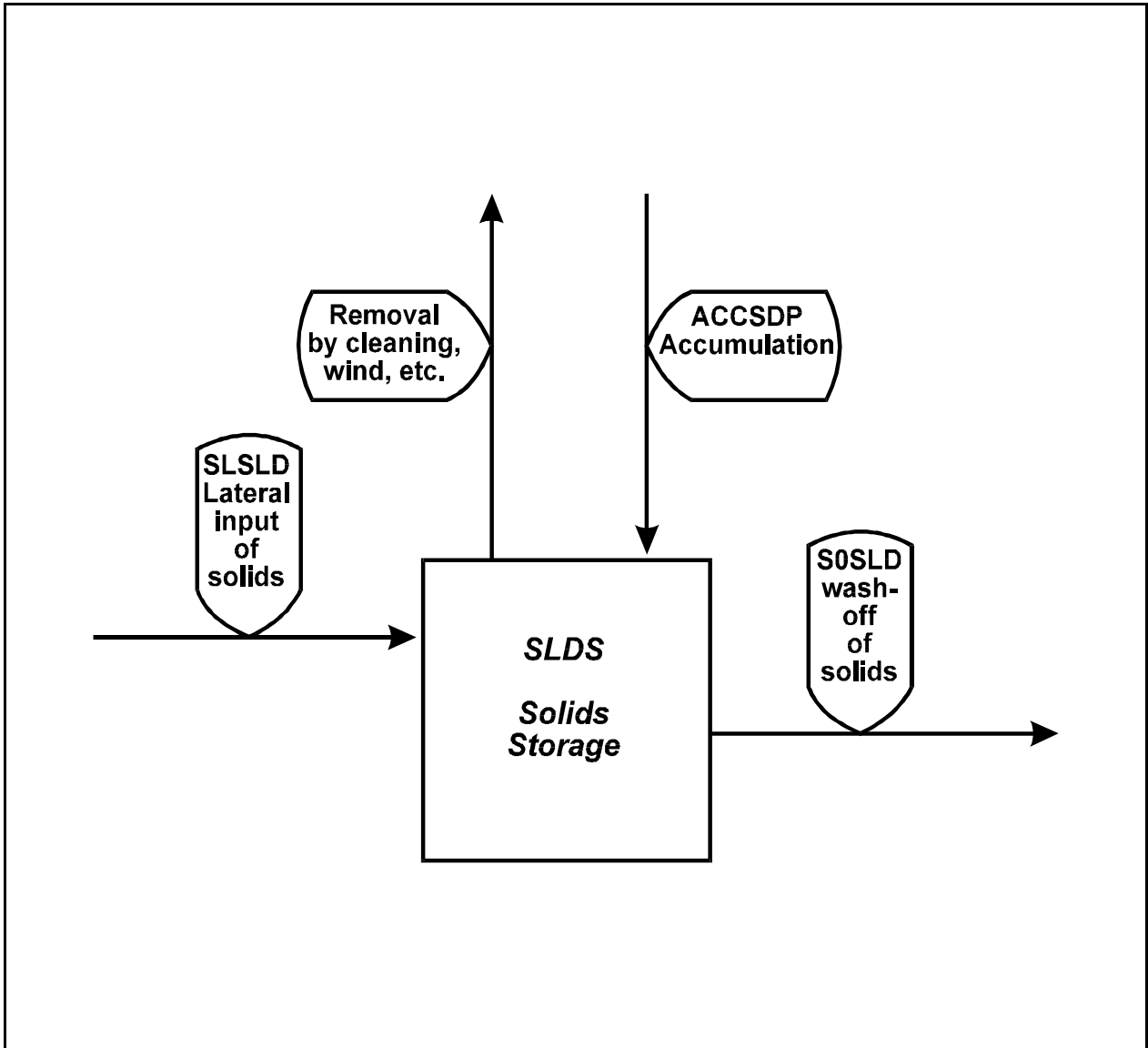


Figure 4.2(2).4-1 Flow diagram of the SOLIDS section of the IMPLND Application Module

When STCAP is greater than the amount of solids in storage, washoff is calculated by:

$$\text{SOSLD} = \text{SLDS} * \text{SURO} / (\text{SURS} + \text{SURO}) \quad (2)$$

If the storage is sufficient to fulfill the transport capacity, then the following relationship is used:

$$\text{SOSLD} = \text{STCAP} * \text{SURO} / (\text{SURS} + \text{SURO}) \quad (3)$$

where:

SOSLD = washoff of solids (tons/ac per interval)

SLDS = solids storage (tons/ac)

SOSLD is then subtracted from SLDS.

Subroutine SOSLD1 differs from SOSLD2 in that it uses the dimensionally nonhomogeneous term $(\text{SURS} + \text{SURO}) / \text{DELT60}$ in the above equations, while SOSLD2 uses the homogeneous term $\text{SURO} / \text{DELT60}$.

4.2(2).4.2 Washoff Solids Using Method 2 (subroutine SOSLD2)

Purpose

The purpose of this subroutine is the same as SOSLD1. It only differs in method.

Method of Determining Removal

Unlike subroutine SOSLD1, this method of determining sediment removal makes use of the dimensionally homogeneous term $\text{SURO} / \text{DELT60}$ instead of $(\text{SURO} + \text{SURS}) / \text{DELT60}$ in the following equation.

$$\text{STCAP} = \text{DELT60} * \text{KEIM} * (\text{SURO} / \text{DELT60}) ** \text{JEIM} \quad (4)$$

When STCAP is more than the amount of solids in storage, the flow washes off all of the solids storage (SLDS). However, when STCAP is less than the amount of solids in storage, the situation is transport limiting, so SOSLD is equal to STCAP.

4.2(2).4.3 Accumulate and Remove Solids Independently of Runoff (subroutine ACCUM)

Purpose

Subroutine ACCUM simulates the accumulation and removal of solids independently of runoff; for example, atmospheric fallout and street cleaning.

Method

The storage is updated once a day, on those days when precipitation did not occur during the previous day, using the equation:

$$SLDS = ACCSDP + SLDSS*(1.0 - REMSDP) \quad (5)$$

where:

ACCSDP = accumulation rate of the solids storage (tons/ac per day)
 SLDS = solids in storage at end of day (tons/ac)
 SLDSS = solids in storage at start of day (tons/ac)
 REMSDP = unit removal rate of solids in storage
 (i.e., fraction removed per day)

ACCSDP and REMSDP may be input on a monthly basis to account for seasonal variations.

Note: if no runoff occurs, Equation 5 will cause the solids storage to asymptotically approach a limiting value. The limit, found by setting SLDS and SLDSS to the same value (SLDSL), is:

$$SLDSL = ACCSDP/REMSDP \quad (6)$$

4.2(2).5 Estimate Water Temperature and Dissolved Gas Concentrations
(Section IWTGAS of Module IMPLND)

Purpose

IWTGAS estimates the water temperature and concentrations of dissolved oxygen and carbon dioxide in the outflow from the impervious land segment.

Method

Outflow temperature is estimated by the following regression equation:

$$\text{SOTMP} = \text{AWTF} + \text{BWTF} * \text{AIRTC} \quad (1)$$

where:

SOTMP = impervious surface runoff temperature (degrees C)
 AWTF = Y-intercept
 BWTF = slope
 AIRTC = air temperature (degrees C)

The parameters AWTF and BWTF may be input on a monthly basis. When snowmelt contributes to the outflow, SOTMP is set equal to 0.5.

The dissolved oxygen and carbon dioxide concentrations of the overland flow are assumed to be at saturation and are calculated as direct functions of water temperature. IWTGAS uses the following empirical nonlinear equation to relate dissolved oxygen at saturation to water temperature (Committee on Sanitary Engineering Research, 1960):

$$\text{SODOX} = (14.652 + \text{SOTMP} * (-0.41022 + \text{SOTMP} * (0.007991 - 0.000077774 * \text{SOTMP}))) * \text{ELEVGC} \quad (2)$$

where:

SODOX = concentration of dissolved oxygen in surface outflow (mg/l)
 SOTMP = surface outflow temperature (degrees C)
 ELEVGC = correction factor for elevation above sea level
 (ELEVGC is calculated by the Run Interpreter dependent upon mean elevation of the segment)

The empirical equation for dissolved carbon dioxide concentration of the overland flow (Harnard and Davis, 1943) is:

$$\text{SOCO2} = (10 ** (2385.73 / \text{ABSTMP} - 14.0184 + 0.0152642 * \text{ABSTMP})) * 0.000316 * \text{ELEVGC} * 12000.0 \quad (3)$$

where:

SOCO2 = concentration of dissolved carbon dioxide in surface outflow (mg C/l)
 ABSTMP = absolute temperature of surface outflow (degrees K)

4.2(2).6 Simulate Washoff of Quality Constituents Using Simple Relationships with Solids and Water Yield (Section IQUAL of Module IMPLND)

Purpose

The IQUAL module section simulates water quality constituents or pollutants in the outflows from an impervious land segment using simple relationships with water yield and/or solids. Any constituent can be simulated by this module section. The user supplies the name, units and parameter values appropriate to each of the constituents that are needed in the simulation. Note that more detailed methods of simulating solids, heat, dissolved oxygen, and dissolved carbon dioxide removal from the impervious land segment are available in other sections of IMPLND.

Approach

The basic algorithms used to simulate quality constituents are a synthesis of those used in the NPS Model (Donigian and Crawford, 1976b) and HSP QUALITY (Hydrocomp, 1977). However, some options and combinations are unique to HSPF.

Figure 4.2(2).6-1 shows schematically the fluxes and storages represented in module section IQUAL. A quality constituent may be simulated by two methods. One approach is to simulate the constituent by association with solids removal. The other approach is to simulate it by using atmospheric deposition and/or basic accumulation and depletion rates together with depletion by washoff; that is, constituent outflow from the surface is a function of the water flow and the constituent in storage. A combination of the two methods may be used in which the individual fluxes are added to obtain the total surface outflow. These approaches will be discussed further in the descriptions of the corresponding subroutines.

IQUAL allows the user to simulate up to 10 quality constituents at a time. If a constituent is considered to be associated with solids, it is called a QUALSD. The corresponding term for constituents associated directly with overland flow is QUALOF. Each of the 10 constituents may be defined as either a QUALSD or a QUALOF or both. Note that only a QUALOF may receive atmospheric deposition, since it is the only type to maintain a storage. However, no more than seven of any one of the constituent types (QUALSD or QUALOF) may be simulated in one operation. The program uses a set of flag pointers to keep track of these associations. For example, QSDFP(3)=0 means that the third constituent is not associated with solids, whereas QSDFP(6)=4 means that the sixth constituent is the fourth solids associated constituent (QUALSD). Similar flag pointer arrays are used to indicate whether or not a quality constituent is a QUALOF.

4.2(2).6.1 Remove by Association with Solids (subroutine WASHSD)

Purpose

WASHSD simulates the removal of a quality constituent from the impervious land surface by association with the solids removal determined in section SOLIDS.

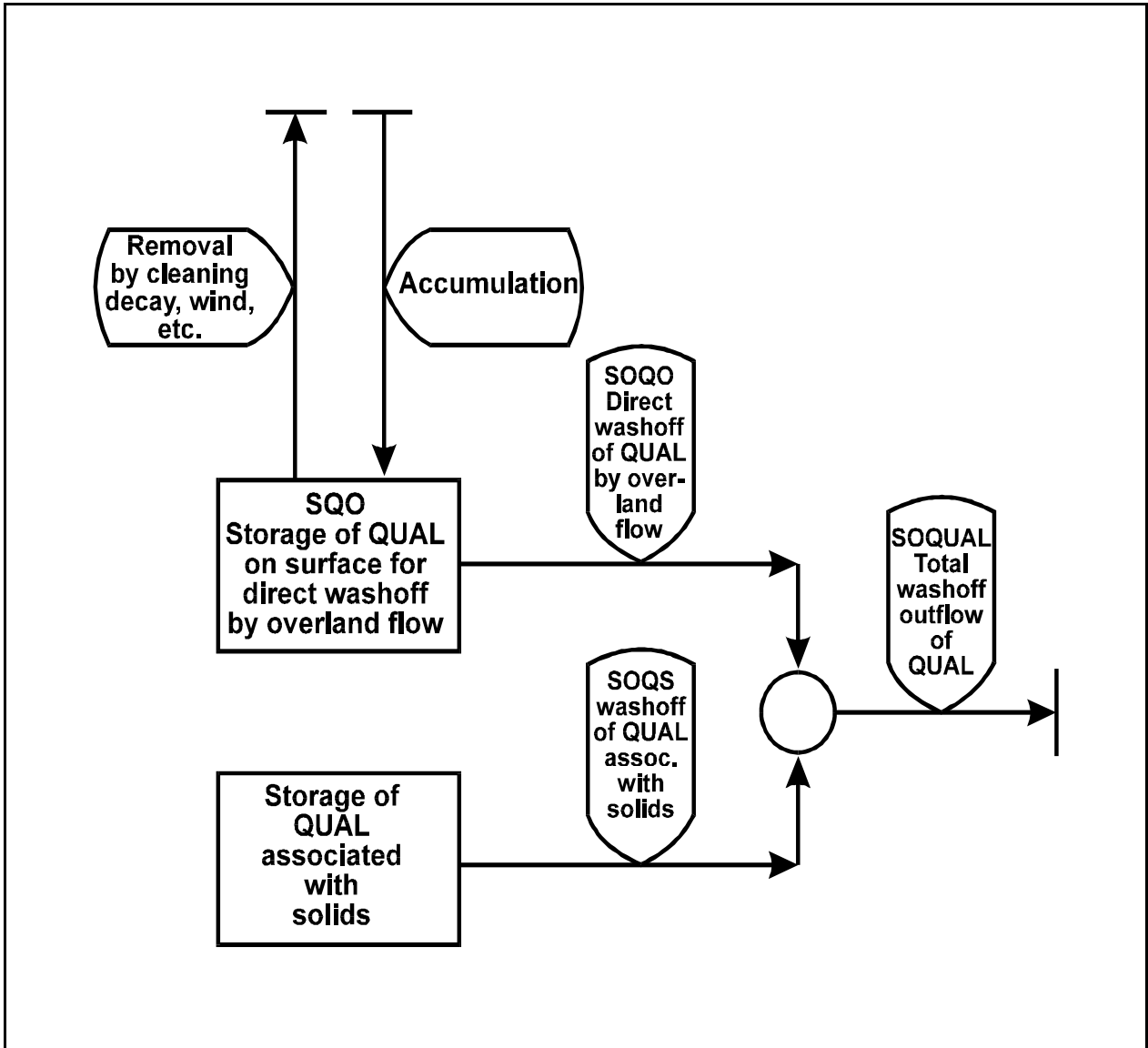


Figure 4.2(2).6-1 Flow diagram for IQUAL section of IMPLND Application Module

Method

This approach assumes that the particular quality constituent removed from the land surface is in proportion to the solids removal. The relation is specified by user-input "potency factors." Potency factors indicate the constituent strength relative to the solids removal from the surface. For each quality constituent associated with solids, the user supplies separate potency factors. The user is also able to supply monthly potency factors for constituents that vary somewhat consistently throughout the year.

Removal of the solids associated constituent by solids washoff is simulated by:

$$SOQS = SOSLD * POTFW \quad (1)$$

where:

SOQS = flux of constituent associated with solids washoff
(quantity/ac per interval)
SOSLD = washoff of detached solids (tons/ac per interval)
POTFW = washoff potency factor (quantity/ton)

The unit "quantity" refers to mass units (pounds or tons in the English system) or some other quantity, such as number of organisms for coliforms. The user specifies the units of "quantity."

4.2(2).6.2 Accumulate and Remove by a Constant Unit Rate and by Overland Flow (subroutine WASHOF)

Purpose

WASHOF simulates the accumulation of a quality constituent on the impervious land surface and its removal by a constant unit rate and by overland flow.

Method

This subroutine differs from subroutine WASHSD in that the storage of the quality constituent is simulated. The stored constituent can be accumulated and removed by processes which are independent of storm events, such as cleaning, decay, and wind deposition, and it is washed off by overland flow. The accumulation and removal rates can have monthly values to account for seasonal fluctuations. The constituent may, alternatively or additionally, receive atmospheric deposition.

Atmospheric deposition inputs can be specified in two possible ways depending on the form of the available data. If the deposition is in the form of a flux (mass per area per time), then it is considered "dry deposition". If it is in the form of a concentration in rainfall, then it is considered "wet deposition", and HSPF automatically combines it with the input rainfall time series to compute the resulting flux. Either type of deposition data can be input as a time series, which covers the entire simulation period, or as a set of monthly values that is used for each year of the simulation. The atmospheric deposition time series are documented in the EXTNL table of the Time Series Catalog for IMPLND, and are input in the EXT SOURCES block. The monthly values are input in the MONTH-DATA block.

If atmospheric deposition data are input, the surface storage is updated:

$$SQO = SQO + ADFX + PREC*ADCN \quad (1)$$

where:

SQO = storage of available quality constituent on the surface
(mass/area)
ADFX = dry or total atmospheric deposition flux (mass/area per interval)
PREC = precipitation depth
ADCN = concentration for wet atmospheric deposition (mass/volume)

When there is surface outflow and some quality constituent is in storage, then washoff is simulated using the commonly used relationship:

$$SQOQ = SQO*(1.0 - EXP(-SURO*WSFAC)) \quad (2)$$

where:

SQOQ = washoff of the quality constituent from the land
surface (quantity/ac per interval)
SQO = storage of the quality constituent on the surface (quantity/ac)
SURO = surface outflow of water (in/interval)
WSFAC = susceptibility of the quality constituent to washoff (/inch)
EXP = exponential function

The storage is updated once a day to account for accumulation and removal which occurs independent of runoff by the equation:

$$SQO = ACQOP + SQOS*(1.0 - REMQOP) \quad (3)$$

where:

ACQOP = accumulation rate of the constituent (quantity/ac per day)
SQOS = SQO at the start of the interval
REMQOP = unit removal rate of the stored constituent (per day)

The Run Interpreter computes REMQOP and WSFAC for this subroutine according to:

$$REMQOP = ACQOP/SQOLIM \quad (4)$$

where:

SQOLIM = asymptotic limit for SQO as time approaches infinity,
if no washoff occurs (quantity/ac),

and

$$WSFAC = 2.30/WSQOP \quad (5)$$

where:

WSQOP = rate of surface runoff that results in 90% washoff in 1 hour (in/hr)

Since the unit removal rate (REMQOP) is computed from two other parameters, it is not supplied directly by the user.

4.2(3) Simulate a Free-flowing Reach or Mixed Reservoir (Module RCHRES)

This module simulates the processes which occur in a single reach of open or closed channel or a completely mixed lake. For convenience, such a processing unit is referred to as a RCHRES throughout this documentation. In keeping with the assumption of complete mixing, the RCHRES consists of a single zone situated between two nodes, which are the extremities of the RCHRES.

Flow through a RCHRES is assumed to be unidirectional. The inflow and outflow of materials through a RCHRES are illustrated in Figure 4.2(3)-1. Water and other constituents which arrive from other RCHRES's and local sources enter the RCHRES through a single gate (INFLO). Outflows may leave the RCHRES through one of several gates or exits (OFLO). A RCHRES can have up to five OFLO exits. Precipitation, evaporation, and other fluxes also influence the processes which occur in the RCHRES, but do not pass through the exits.

The ten major subdivisions of the RCHRES module and their functions are shown in Figure 4.2(3)-2. RPTOT, RBAROT, and RPRINT perform the storage and printout of results from the other module sections of RCHRES (HYDR through RQUAL). Within a module section, simulation of physical processes (longitudinal advection, sinking, benthic release) is always performed before simulation of biochemical processes.

The user specifies which module sections are active. If any "quality" sections (CONS through RQUAL) are active, section ADCALC must also be active; it computes certain quantities needed to simulate advection of the quality constituents. Besides fulfilling this requirement, the user must ensure that all the time series required by the active sections are available, either as supplied input time series or as data computed by another module section. For example, if RQUAL is active, the water temperature must be supplied, either as an input time series or by activating section HTRCH which will compute it.

Water Rights Categories

The HYDR section of RCHRES allows the optional simulation of water "categories", which are used to facilitate the modeling of water rights or ownership. If this option is turned on (by including the CATEGORY block in the UCI), each RCHRES in the run keeps track of the user-defined categories of all inflows, storages, and outflows, as well as precipitation and evaporation fluxes. Up to 100 categories can be specified in the CATEGORY block. Details of this option are provided in the discussion of HYDR below (Section 4.2(3).1), and the CATEGORY block documentation (Section 4.12 of Part F). Also, refer to the description of HYDR inputs in Section 4.4(3).2 of Part F.

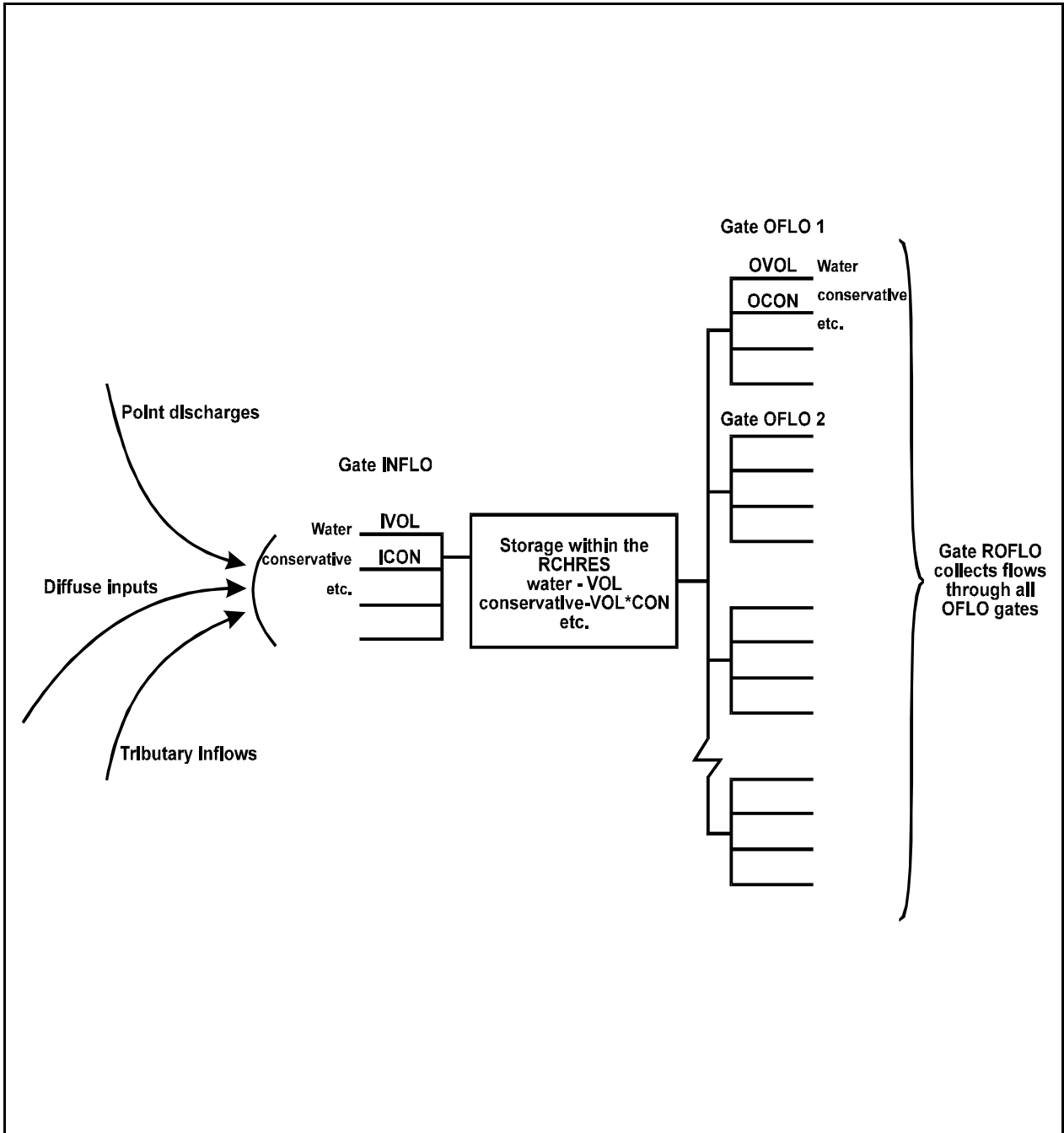


Figure 4.2(3)-1 Flow of materials through a RCHRES

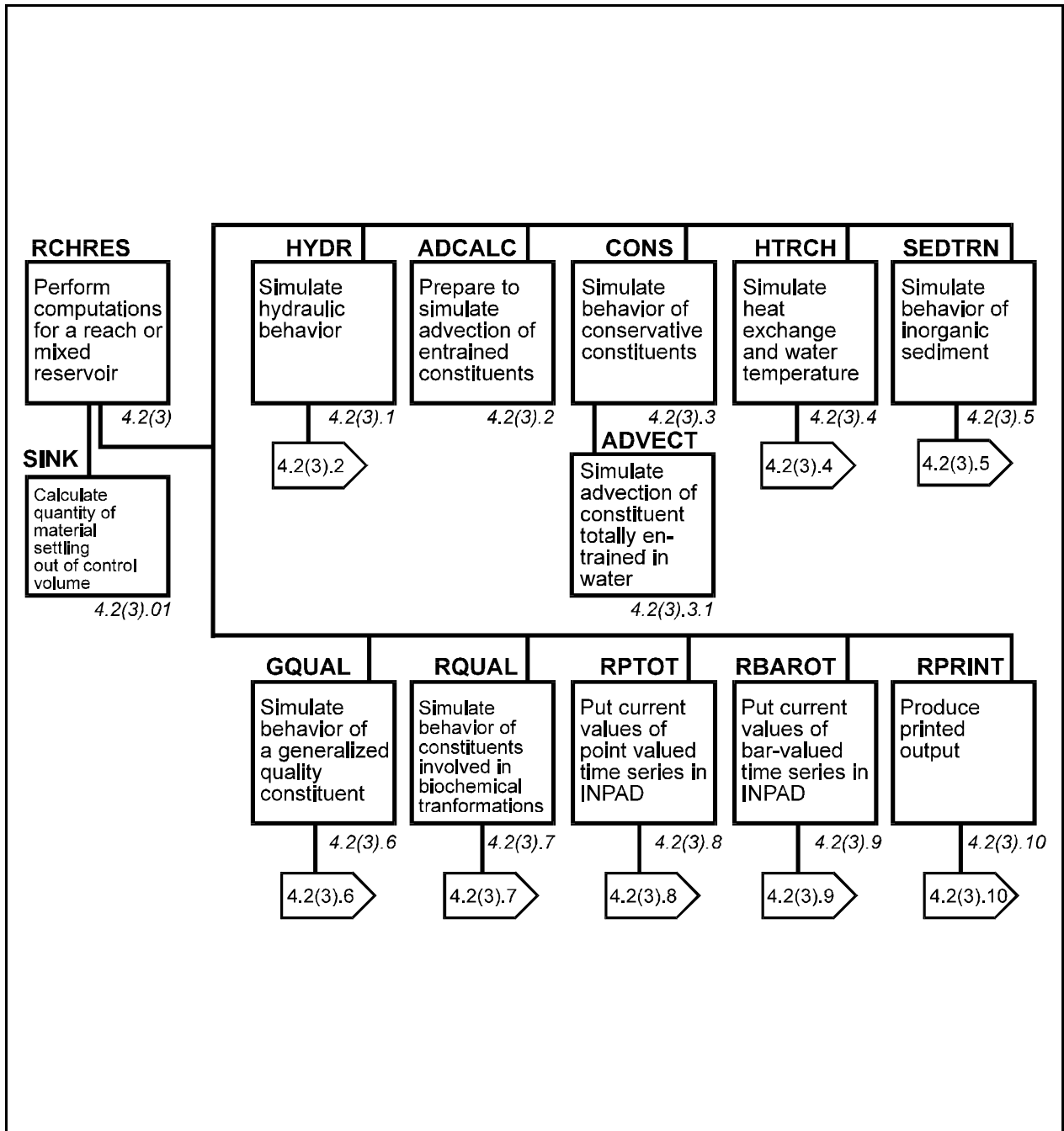


Figure 4.2(3)-2 Structure chart for RCHRES Module

4.2(3).01 Simulate Sinking of Suspended Material
(subroutine SINK)

Purpose

SINK calculates the quantity of material settling out of a RCHRES and determines the resultant change in concentration of the material within the RCHRES.

Method

The portion of material settling out of a RCHRES during an interval is calculated by the equation:

$$\text{SNKOUT} = \text{CONC} * (\text{KSET} / \text{AVDEPE}) \quad (1)$$

where:

SNKOUT = fraction of material which settles out (reduction of concentration/interval)

CONC = concentration of material before deposition

KSET = sinking rate (ft/interval) (dependent upon RCHRES characteristics and type of material)

AVDEPE = average depth of water (feet)

In any interval in which KSET is greater than AVDEPE, all the material in the RCHRES sinks out of the water.

The mass of material sinking out of the RCHRES is calculated as:

$$\text{SNKMAT} = \text{SNKOUT} * \text{VOL} \quad (2)$$

where:

SNKMAT = mass of material that settles out during the interval
(mass.ft³/l/interval or mass.m³/l/interval)

VOL = volume of water in RCHRES (ft³ or m³)

4.2(3).1 Simulate Hydraulic Behavior (Section HYDR of Module RCHRES)

Purpose

The purpose of this code is to simulate the hydraulic processes occurring in a reach or a mixed reservoir (RCHRES). The final goal of the process may be to route floods, study reservoir behavior, or analyze constituents dissolved in the water.

Schematic View of Fluxes and Storage

Figure 4.2(3).1-1 shows the principal state variable (stored volume) and fluxes with which this part of HSPF deals.

All water entering the RCHRES from surface and subsurface sources arrives through "gate" INFLO; this quantity is called IVOL. The user indicates the time series which enter this gate in the EXT SOURCES or NETWORK Block in the User's Control Input (UCI). If no time series are specified, the system assumes the RCHRES has zero inflow.

The volume of water which leaves the RCHRES during a simulation time interval, through gate OFLO(N), is called OVOL(N). The total outflow is ROVOL.

The input of water from precipitation falling directly on the water surface and the loss of water by evaporation from the surface can also be considered. The user activates these options by supplying the time series PREC and/or POTEV in the User's Control Input (External Sources block). These time series are in units of depth/interval. The code multiplies these quantities by the current surface area of the RCHRES to obtain volumes of input or output. If either time series is absent from the UCI it is assumed that the option is inactive and the corresponding flux is zero.

The basic equation is that of continuity:

$$\text{VOL} - \text{VOLS} = \text{IVOL} + \text{PRSUPY} - \text{VOLEV} - \text{ROVOL} \quad (1)$$

where:

VOL = volume at the end of the interval
VOLS = volume at the start of the interval

This can be written as:

$$\text{VOL} = \text{VOLT} - \text{ROVOL} \quad (2)$$

where:

VOLT = IVOL + PRSUPY - VOLEV + VOLS

The principal task of this subroutine is to estimate ROVOL and, hence, the volume at the end of the interval (VOL).

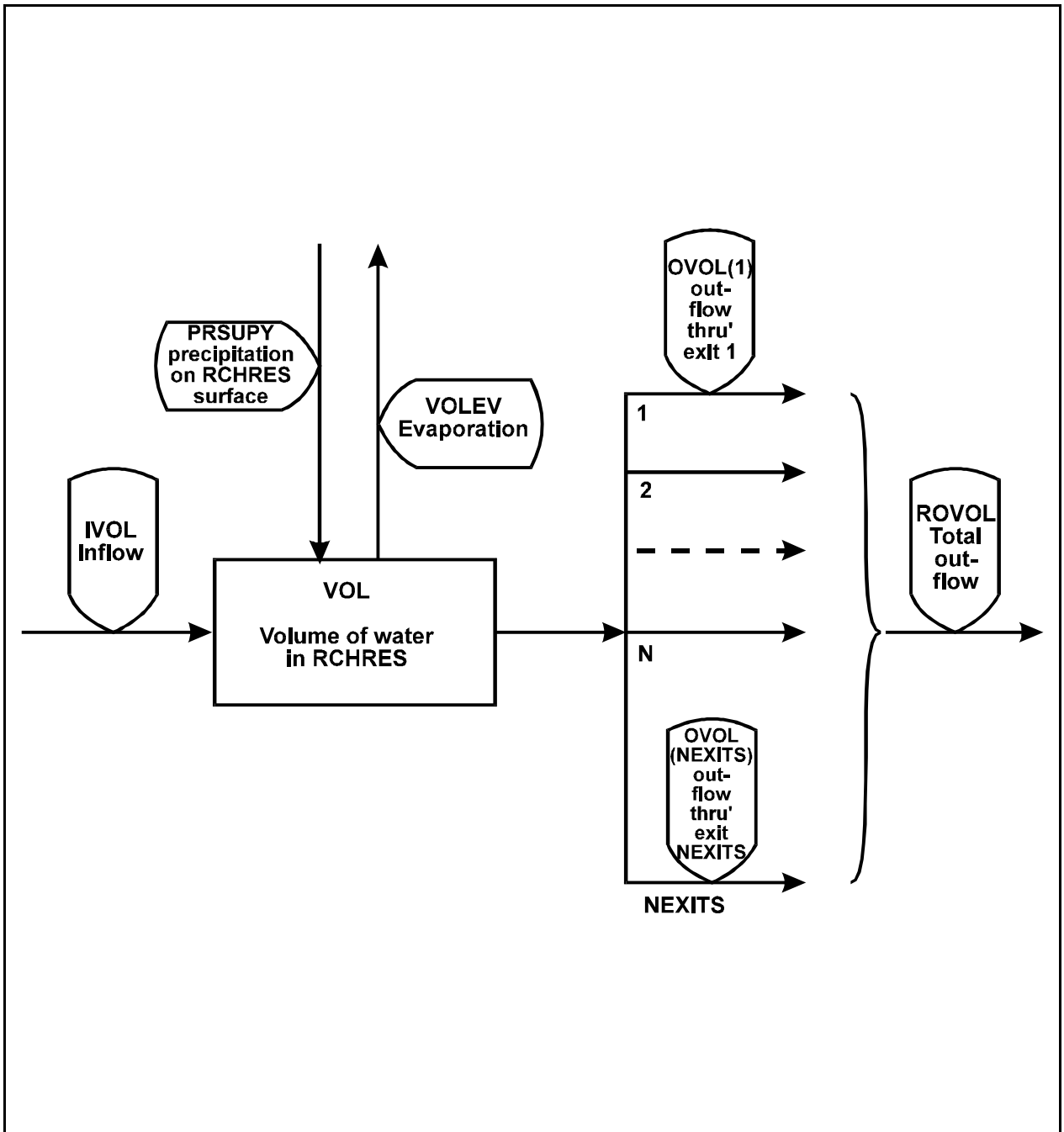


Figure 4.2(3).1-1 Flow diagram for the HYDR Section of the RCHRES Application Module

Calculation of Outflows and VOL

If water is available, it is assumed that the total volume of water leaving a RCHRES in an interval is:

$$\text{ROVOL} = (\text{KS} * \text{ROS} + \text{COKS} * \text{ROD}) * \text{DELTS} \quad (3)$$

where:

KS = weighting factor ($0 \leq \text{KS} \leq 0.99$)
 COKS = $1.0 - \text{KS}$ (complement of KS)
 ROS = total rate of outflow from the RCHRES at the start of the interval
 ROD = total rate of demanded outflow for the end of the interval
 DELTS = simulation interval in seconds

That is, the mean rate of outflow is assumed to be a weighted mean of the rates at the start and end of the interval. The weighting factor KS is supplied either by the user or by default. Care should be exercised in selecting a value because, as KS increases from 0.0 to 1.0, there is an increasing risk that the computation of outflow rates will become unstable. Theoretically, a value of 0.5 gives the most accurate results, provided oscillations do not occur. The default value of 0.0 has zero risk, but gives less accurate results. Users are advised to be very careful if a nonzero value is used; users should not select a value greater than 0.5.

Combination of Equations 2 and 3 yields:

$$\text{VOL} = \text{VOLT} - (\text{KS} * \text{ROS} + \text{COKS} * \text{ROD}) * \text{DELTS} \quad (4)$$

There are two unknown values in this equation: VOL and ROD. Thus, a second relation is required to solve the problem. To provide this function, it is assumed that outflow demands for the individual exits are of the form:

$$\begin{aligned} \text{OD}(1) &= f_1(\text{VOL}, t) \\ \text{OD}(2) &= f_2(\text{VOL}, t) \\ &\cdot \\ &\cdot \\ \text{OD}(\text{NEXIT}) &= f_{\text{NEXIT}}(\text{VOL}, t) \end{aligned} \quad (5)$$

That is, the outflow demand for each exit is a function of volume or time or a combination. This topic is discussed in greater detail in Section 4.2(3).1.1.2. It follows that the total outflow demand is of similar form:

$$\text{ROD} = \text{funct}(\text{VOL}, t) \quad (6)$$

At a given time in the simulation, t is known and the above functions reduce to:

$$\text{OD}(N) = f_N(\text{VOL}) \quad (7)$$

$$\text{ROD} = \text{funct}(\text{VOL}) \quad (8)$$

Equation 8 provides the second relation required to solve the problem.

Equations 4, 7, and 8 are shown in Figure 4.2(3).1-2. The point of intersection of Equations 4 and 8 gives the values RO, VOL, and hence O(1), O(2), etc.

where:

RO = total rate of outflow from the RCHRES at the end of the interval
 O(N) = rate of outflow through exit N at the end of the interval

In HSPF, it is assumed that each outflow demand can be represented by one or both of the following types of components:

Component = function(VOL). This is most useful in simulating RCHRES's where there is no control over the flow or where gate settings are only a function of water level. This component is supplied to the program in the form of an FTABLE.

Component = function(time). This is most useful for handling demands for municipal, industrial, or agricultural use. The function may be cyclic (for example, annual cycle) or general (for example, annual cycle superimposed on an increasing trend). The user must supply this component in the form of an input time series.

If a user indicates that both types of component are present in an outflow demand, then the user must also specify how they are to be combined to get the demand. HSPF allows the following options:

1. $OD(N) = \text{Min} [fN(VOL), gN(t)]$. This is useful in cases such as the following:

Suppose a water user has an optimum demand which may be expressed as a function of time ($g(t)$); however, his pump has a limited capacity to deliver water. This capacity is a function of the water level in the RCHRES from which the pump is drawing the water. Thus, it can be expressed as a function of the volume in the RCHRES ($f(VOL)$). Then, his actual demand for water will be the minimum of the two functions. Note that $g(t)$ is an input time series (OUTDGT). See the Time Series Catalog (Section 4.7).

2. $OD(N) = \text{Max} [fN(VOL), gN(t)]$

3. $OD(N) = fN(VOL) + gN(t)$

If one or more outflow demands have an $f(VOL)$ component (Fig.4.2(3).1-2a), subroutine ROUTE is called to solve the routing equations. In this case, the evaluation of the outflow demands and the solution of the equations can be quite complicated.

If there is no $f(VOL)$ component in any demand, the process is much simpler (Figure 4.2(3).1-2b). Subroutine NOROUT is called in this case.

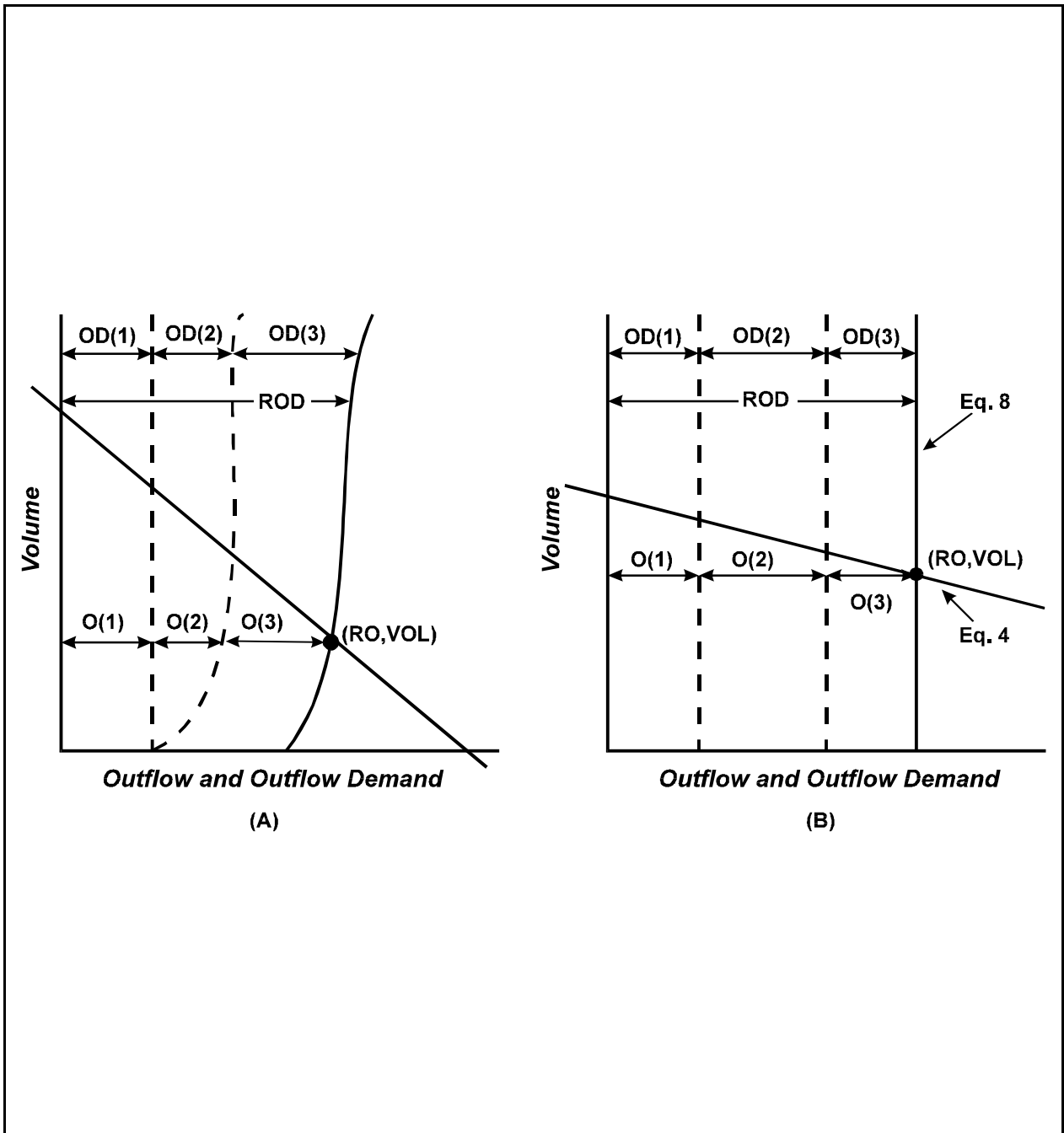
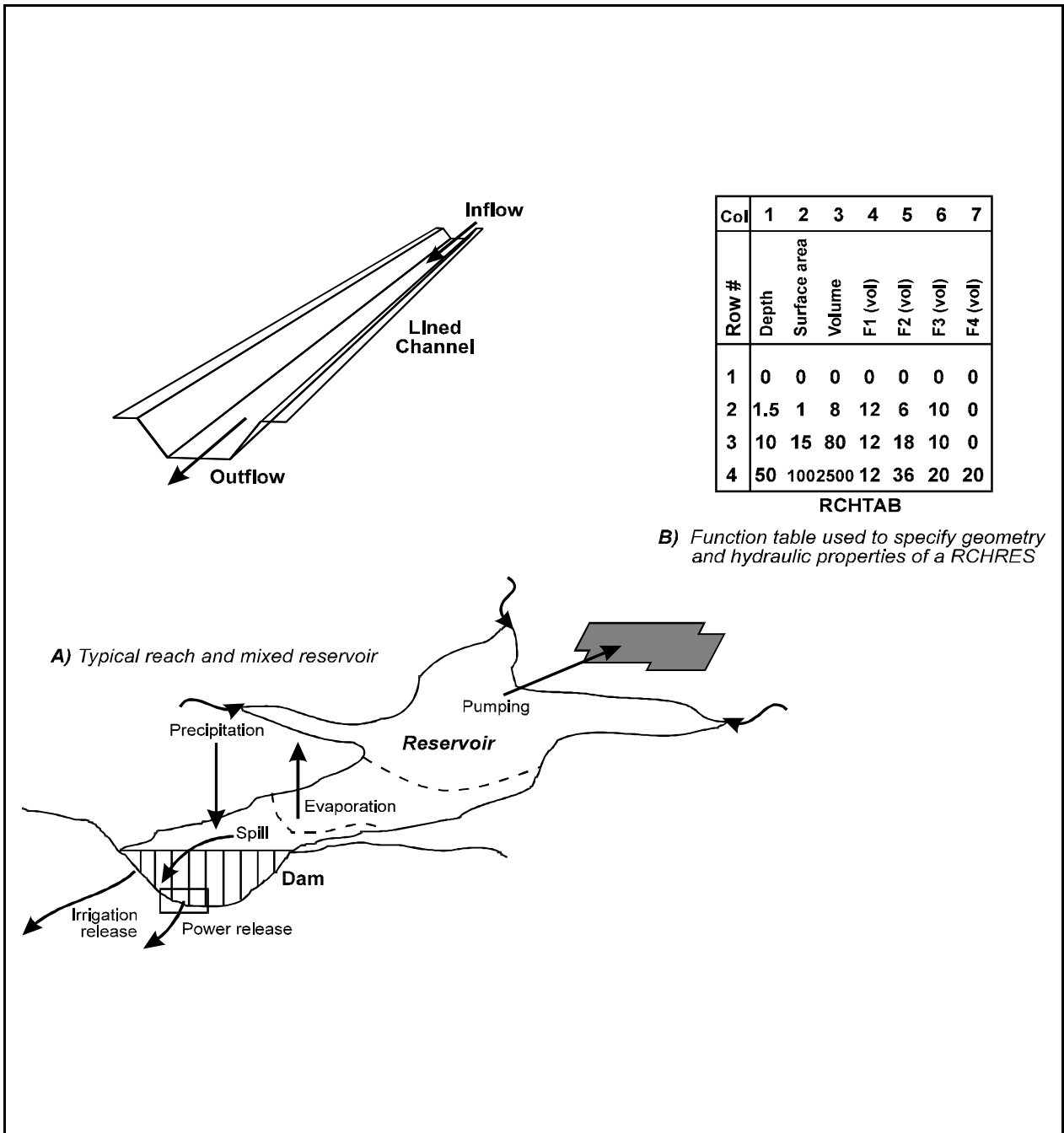


Figure 4.2(3).1-2 Graphical representation of the equations used to compute outflow rates and volume



Col	1	2	3	4	5	6	7
Row #	Depth	Surface area	Volume	F1 (vol)	F2 (vol)	F3 (vol)	F4 (vol)
1	0	0	0	0	0	0	0
2	1.5	1	8	12	6	10	0
3	10	15	80	12	18	10	0
4	50	100	2500	12	36	20	20

RCHTAB

B) Function table used to specify geometry and hydraulic properties of a RCHRES

Figure 4.2(3).1-3 Typical RCHRES configurations and the method used to represent geometric and hydraulic properties

Representing the Geometry and Hydraulic Properties of a RCHRES

HSPF makes no assumptions regarding the shape of a RCHRES. It does not require that the cross-section be trapezoidal or even that the shape be prismoidal. This is one reason why both free flowing reaches and reservoirs can be handled by the same application module. Both of the shapes shown in Figure 4.2(3).1-3a are acceptable. However, HSPF does assume that:

1. There is a fixed relation between depth (at the deepest point in the RCHRES), surface area, and volume.
2. For any outflow demand with an $f(\text{VOL})$ component, the functional relation is constant in time (with the exception discussed in Section 4.2(3).2.1.1).

These assumptions rule out cases where the flow reverses direction or where one RCHRES influences another upstream of it in a time-dependent way. No account is taken of momentum. The routing technique falls in the class known as "storage routing" or "kinematic wave" methods.

The user specifies the properties of a RCHRES in a table called RCHTAB (Figure 4.2(3).1-3b). It has columns for the depth, surface area, volume, and volume dependent functions ($fN(\text{VOL})$). Each row contains values appropriate to a specified water surface elevation. The system obtains intermediate values by interpolation. Thus, the number of rows in RCHTAB depends on the size of the cross section and the desired resolution. The table is either included in the User's Control Input (in the function tables (FTABLES) block) or it may be stored in a Watershed Data Management (WDM) file. A subsidiary, stand-alone program can be used to generate this table for RCHRES's with simple properties (for prismoidal channels with uniform flow, use Manning's equation).

Auxiliary Variables

Besides calculating outflow rates and the volume in a RCHRES, HSPF can compute the values of some auxiliary state variables:

1. If $\text{AUX1FG}=1$, DEP, STAGE, SAREA, AVDEP, TWID, and HRAD are computed, where: DEP is the depth at the deepest point; STAGE is the water stage at a related point; SAREA is the surface area of water in the RCHRES; AVDEP is the average depth (volume/surface area); TWID is the top width (surface area/length); HRAD is the hydraulic radius.
2. If $\text{AUX2FG}=1$, AVSECT and AVVEL are computed, where: AVSECT is the average cross section (volume/length); AVVEL is the average velocity (discharge/AVSECT).
3. If $\text{AUX3FG}=1$, USTAR and TAU are computed, where: USTAR is the bed shear velocity; TAU is the bed shear stress.

Note that these are point-valued time series; that is, they apply at the boundaries (start or end) of simulation time intervals.

The user specifies whether AUX1FG, AUX2FG, and AUX3FG are ON or OFF. If certain

constituents are being simulated, one or more of these flags might be required to be ON. For example, simulation of oxygen (group OXRX) requires that both AUX1FG and AUX2FG be ON. AUX3FG must be ON if sediment is simulated (group SEDTRN).

4.2(3).1.1 Calculate Outflows Using Hydraulic Routing (subroutine ROUTE)

Purpose

ROUTE computes the rates and volumes of outflow from a RCHRES and the new volume in cases where at least one outflow demand has an $f(VOL)$ component.

Method

The problem is to solve simultaneously Equations 4 and 8. The cases which arise are shown graphically in Figure 4.2(3).1-4. Equations 7 and 8 are represented by a series of straight line segments. The breakpoints in the lines correspond to a row of entries in RCHTAB (the FTABLE). A segment of Equation 8 can be represented by the equation:

$$(VOL - V1)/(ROD - ROD1) = (V2 - V1)/(ROD2 - ROD1) \quad (9)$$

where $V1, V2$ are volumes specified in adjacent rows of RCHTAB, for the lower and upper extremities of the straight-line segment, respectively. $ROD1$ and $ROD2$ are the corresponding total outflow demands.

The first step is to find the intercept of Equation 4 on the volume axis:

$$VOLINT = VOLT - KS*ROS*DELTS \quad (10)$$

If $VOLINT$ is less than zero, the equations cannot be solved (case 3). Equation 4 will give a negative value for VOL , even if ROD is zero. Physically, this means that we started the interval with too little water to satisfy the projected outflow demand, even if the outflow rate at the end of the interval is zero. Accordingly, the code does the following:

```
VOL   = 0.0
RO    = 0.0
O(*)  = 0.0
ROVOL = VOLT
```

If $VOLINT$ is greater than or equal to zero, the outflow rate at the end of the interval will be nonzero (case 1 or 2). To determine the case:

1. The intercept of Equation 4 on the Volume axis is found:

$$OINT = VOLINT/(DELTS*COKS) \quad (11)$$

2. The maximum outflow demand for which the volume is still zero ($RODZ$) is found.

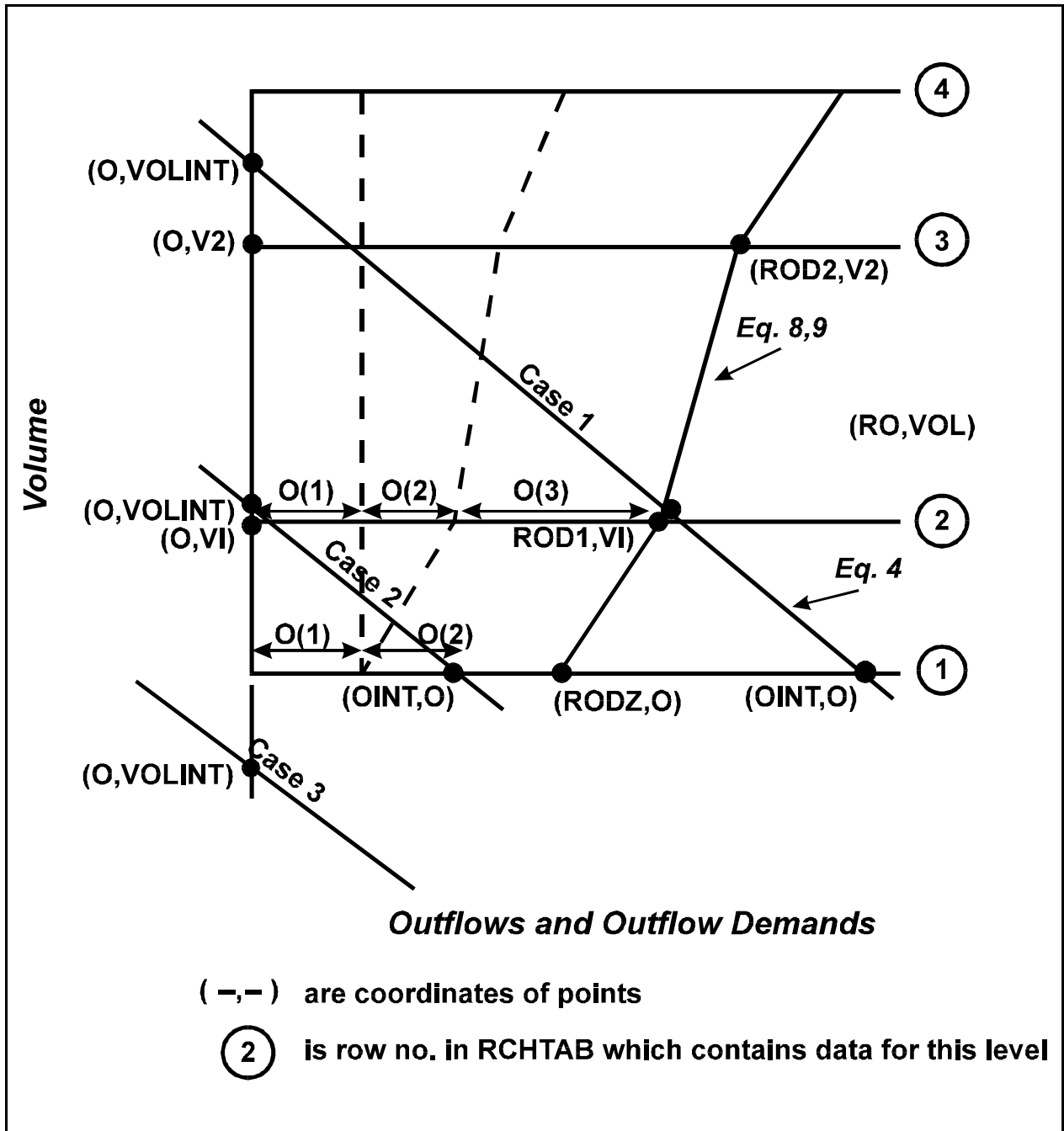


Figure 4.2(3).1-4 Graphical representation of the work performed by subroutine ROUTE

If OINT is greater than RODZ, Equations 4 and 8 can be solved (case 1). The solution involves searching for the segment of Equation 8 which contains the point of intersection of the graphs, and finding the coordinates of the point (RO,VOL). This is done by subroutine SOLVE.

If OINT is less than or equal to RODZ, Equations 4 and 8 cannot be solved (case 2). Physically this means that the RCHRES will instantaneously go dry at the end of the interval with total outflow rate at that time equal to OINT. Accordingly, the code assigns a zero value to the RCHRES volume, and the total outflow is equal to the intercept of Equation 4 on the volume axis in Figure 4.2(3).1-4. As many of the individual demands (O(*)) as possible are satisfied in full by the available water. The remaining water is used to partially satisfy the demand of next highest priority, and any others are not satisfied at all.

4.2(3).1.1.2 Find the Outflow Demands which Correspond to a Specified Row in RCHTAB (subroutine DEMAND)

Purpose

DEMAND finds the individual and total outflow demands which apply at the end of the present interval for a specified level (row) in RCHTAB.

General Method

The approach is to determine the outflow demand for each active exit and accumulate them to find the total demand.

Evaluating the Demand for Exit N

The outflow demand for an individual exit consists of one or both of two components. Their presence or absence is indicated by two flags:

Component	Flag
fN(VOL)	ODFVFG(N)
gN(t)	ODGTFG(N)

Finding the fN(VOL) Component

If ODFVFG(N) is zero, there is no fN(VOL) component.

If ODFVFG(N) is greater than zero, there is a fN(VOL) component. The value of the flag is the column number in RCHTAB containing the value to be used to find the component:

$$\begin{aligned} \text{col} &= \text{ODFVFG}(N) \\ \text{ODFV} &= \text{fN}(\text{VOL}) = (\text{column value}) * \text{CONVF} \end{aligned} \quad (12)$$

where CONVF is a conversion factor which can vary throughout the year. It is supplied by the user in the RCHRES Block of the User's Control Input. It can be used to incorporate effects into the simulation of, for example, seasonal variation in channel roughness.

If ODFVFG(N) is less than zero, there is an fN(VOL) component, but the function fN is time varying. In this case the determination of the component is less direct. The absolute value of ODFVFG(N), say I, gives the element number of a vector COLIND() which contains a user-supplied time series. The values in this time series indicate which pair of columns in RCHTAB are used to interpolate fN(VOL). For example, if COLIND(I) = 4.6 for a given time step, then the value is interpolated between those in columns 4 and 5:

$$\text{ODFV} = \text{fN}(\text{VOL}) = [0.6 * (\text{column5 value}) + 0.4 * (\text{column4 value})] * \text{CONVF} \quad (13)$$

If the user has selected this option, the time series COLIND(I) must be supplied in the EXT SOURCES Block of the UCI.

This method of outflow demand specification is useful where a set of rule curves (f(VOL)) are specified for releases from a reservoir, and it is necessary to move from one curve to another (gradually or suddenly) as time progresses in the simulation.

Finding the gN(t) Component

If ODGTFG(N) is zero, there is no gN(t) component. If ODGTFG(N) is greater than zero, there is a gN(t) component. The value of this flag is the element number of vector OUTDGT() which contains the required time series:

$$\begin{aligned} \text{FG2} &= \text{ODGTFG}(N) \\ \text{ODGT} &= \text{gN}(t) = \text{OUTDGT}(\text{FG2}) \end{aligned} \quad (14)$$

Combining the fN(VOL) and gN(t) Components

If an outflow demand has both of the components described above, the system expects the user to indicate which of the following options to use in combining them:

1. $\text{OD}(N) = \text{Min} [\text{fN}(\text{VOL}), \text{gN}(t)]$
 2. $\text{OD}(N) = \text{Max} [\text{fN}(\text{VOL}), \text{gN}(t)]$
 3. $\text{OD}(N) = \text{fN}(\text{VOL}) + \text{gN}(t)$
- (15)

4.2(3).1.1.3 Solve Routing Equations used in Case 1. (subroutine SOLVE)

Purpose

SOLVE finds the point where Equations 4 and 8 intersect (case 1 in Figure 4.2(3).1-4).

General Approach

The general idea is to select a segment of Equation 8, and determine the point of intersection with Equation 4. If this point lies outside the selected segment, the code will select the adjacent segment (in the direction in which the point of intersection lies) and repeat the process. This continues until the point lies within the segment under consideration. To minimize searching, the segment in which the point of intersection was last located is used to start the process.

Solving the Simultaneous Linear Equations

Equations 4 and 9 can be written as:

$$A1*VOL+ B1*ROD = C1 \quad (16)$$

$$A2*VOL+ B2*ROD = C2 \quad (17)$$

These equations can be solved by evaluating the determinants:

$$\begin{array}{ccc} \begin{array}{cc} *A1 & B1* \\ *A2 & B2* \end{array} & \begin{array}{cc} *C1 & B1* \\ *C2 & B2* \end{array} & \begin{array}{cc} *A1 & C1* \\ *A2 & C2* \end{array} \\ \text{DET} = * & \text{DETV} = * & \text{DETO} = * \\ & & \end{array} \quad (18)$$

In the code of this subroutine:

$$\text{FACTA1} = A1 = 1.0/(\text{COKS}*\text{DELTS}) \quad (19)$$

$$\text{FACTA2} = A2 = \text{ROD1} - \text{ROD2} \quad (20)$$

$$\text{FACTB1} = B1 = 1.0 \quad (21)$$

$$\text{FACTB2} = B2 = V2 - V1 \quad (22)$$

$$\text{FACTC1} = C1 = \text{OINT} \quad (23)$$

$$\text{FACTC2} = C2 = (V2*\text{ROD1}) - (V1*\text{ROD2}) \quad (24)$$

By substituting Equations 19 through 24 in Equation 18, the determinants are evaluated as:

$$\text{DET} = \text{FACTA1}*\text{FACTB2} - \text{FACTA2} \quad (25)$$

$$\text{DETV} = \text{OINT}*\text{FACTB2} - \text{FACTC2} \quad (26)$$

$$\text{DETO} = \text{FACTA1}*\text{FACTC2} - \text{FACTA2}*\text{OINT} \quad (27)$$

The coordinates of the point of intersection are:

$$\text{VOL} = \text{DETV}/\text{DET} \quad (28)$$

$$\text{RO} = \text{DETO}/\text{DET} \quad (29)$$

4.2(3).1.2 Calculate Outflows Without Using Hydraulic Routing (subroutine NOROUT)

Purpose

NOROUT is used to compute the rates and volumes of outflow from a RCHRES and the new volume in cases where no outflow demand has an $f(VOL)$ component; that is, where all outflow demands are functions of time only.

Method

Equations 4 and 8 are illustrated for this situation in Figure 4.2(3).1-5. The solution procedure is similar to that used in subroutine ROUTE, except that: because no outflow demands depend on volume, no table look-up and interpolation is required to evaluate them, and the simultaneous solution of Equations 4 and 8 is easier.

The intercept of Equation 4 on the volume axis is found, as before, using Equation 10. If VOLINT is less than 0.0, there is no solution (case 3). The code takes similar action to that taken by subroutine ROUTE for this case.

If VOLINT is greater than or equal to 0.0, the solution is either case 1 or case 2, as before. In either case, the first step is to evaluate the outflow demands:

$$\begin{aligned} FG &= ODGTFG(N) \\ OD(N) &= OUTDGT(FG) \end{aligned} \quad (30)$$

$$ROD = OD(1) + \dots OD(NEXITS) \quad (31)$$

The intercept of Equation 4 on the volume axis (OINT) is found using Equation 11. If OINT is greater than ROD, Equations 4 and 8 can be solved (case 1):

$$\begin{aligned} RO &= ROD \\ O(*) &= OD(*) \end{aligned} \quad (32)$$

And from Equations 4 and 10,

$$VOL = VOLINT - COKS*RO*DELTS \quad (33)$$

If OINT is less than or equal to ROD, Equations 4 and 8 cannot be solved (case 2). The physical meaning and the action taken by the code are identical to that described for subroutine ROUTE.

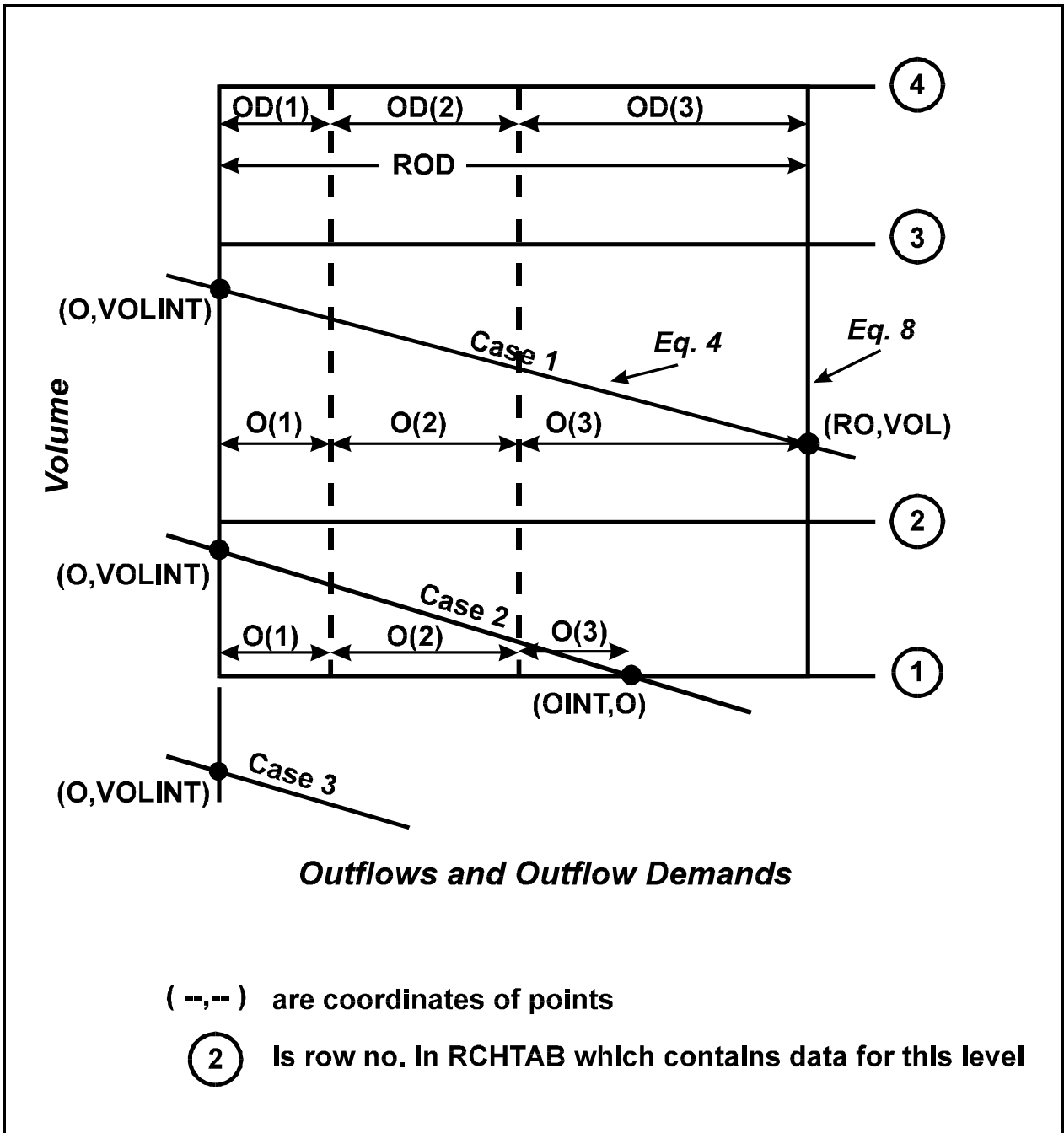


Figure 4.2(3).1-5 Graphical representation of the work performed by subroutine NOROUT

4.2(3).1.3 Compute Values of Auxiliary State Variables (subroutine AUXIL)

Purpose

AUXIL is used to compute the depth, stage, surface area, average depth, top width, and hydraulic radius corresponding to a given volume of water in a RCHRES.

Method of Computing Depth

The basic problem is to interpolate a depth value between those given for discrete values of volume in RCHTAB. This raises the question of how the interpolation should be performed; for example, linear or quadratic. Whatever method is used, it should be consistent with the fact that volume is the integral of surface area with respect to depth.

Most RCHRES's are long and relatively narrow (Figure 4.2(3).1-6). To perform interpolation, it is assumed that surface area varies linearly with depth between neighboring levels (rows) in RCHTAB:

$$SAREA = SA1 + (SA2 - SA1)*RDEP \quad (34)$$

where SAREA is the surface area at depth DEP; SA1, SA2 are the tabulated values of surface area immediately above and below SAREA; RDEP is the relative depth $(DEP-DEP1)/(DEP2-DEP1)$; DEP1, DEP2 are the tabulated values of depth immediately above and below DEP.

By integrating the above equation with respect to depth and equating the result to volume:

$$(A*RDEP**2) + (B*RDEP) + C = 0.0 \quad (35)$$

where:

$$A = SA2 - SA1$$

$$B = 2.0*SA1$$

$$C = -(VOL - VOL1)/(VOL2 - VOL1)*(B + A)$$

Equation 35 provides a means of interpolating depth, given volume. There is a quadratic relation between RDEP and VOL. The equation can be solved for RDEP analytically, but, in HSPF, Newton's method of successive approximations is used because it is generally faster in execution:

1. Calculation starts with an estimate of RDEP: $RDEP1 = 0.5$
2. The function $FRDEP = (A*RDEP1**2) + (B*RDEP1) + C$ is evaluated
3. The derivative $DFRDEP = 2.0*A*RDEP1 + B$ is evaluated
4. A new value $RDEP2 = RDEP1 - FRDEP/DFRDEP$ is calculated
5. Steps 2-4 are repeated with $RDEP1 = RDEP2$ until the change in RDEP is small

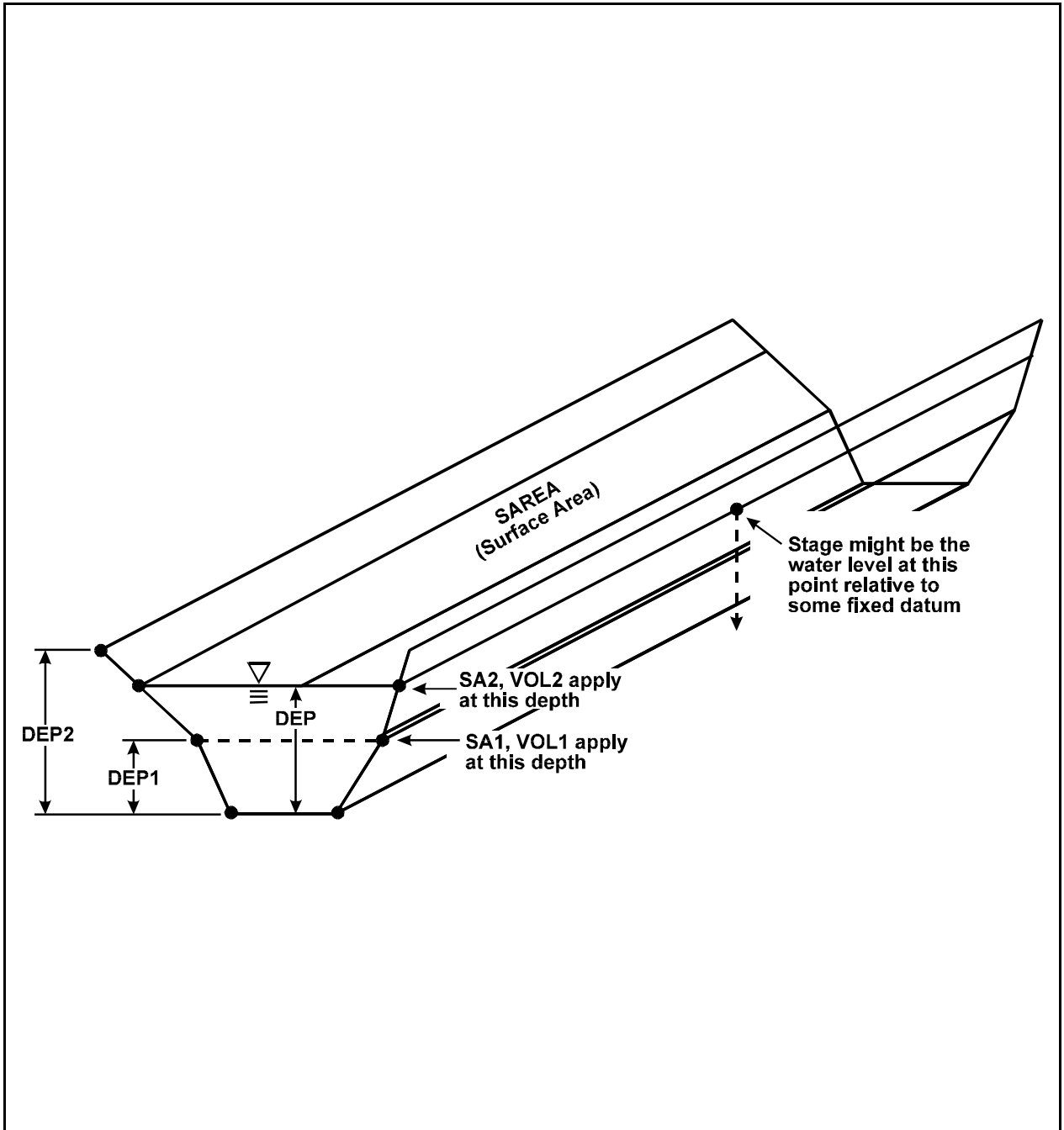


Figure 4.2(3).1-6 Illustration of quantities involved in calculation of depth

The depth is found using:

$$DEP = DEP1 + RDEP2*(DEP2 - DEP1) \quad (36)$$

Computation of Other State Variables

STAGE is the name for any quantity which differs from DEP by a constant:

$$STAGE = DEP + STCOR \quad (37)$$

where:

STCOR = the difference, supplied by the user

Surface area is computed using a formula based on Equation 34:

$$SAREA = SA1 + A*RDEP2 \quad (38)$$

Average depth is computed as:

$$AVDEP = VOL/SAREA \quad (39)$$

The mean top width is found using:

$$TWID = SAREA/LEN \quad (40)$$

where:

LEN = length of the RCHRES, supplied by the user

The hydraulic radius is calculated as a function of average water depth (AVDEP) and mean top width (TWID):

$$HRAD = (AVDEP*TWID)/(2.*AVDEP + TWID) \quad (41)$$

4.2(3).1.4 Calculate Bed Shear Stress and Shear Velocity (subroutine SHEAR)

Purpose

SHEAR is used to compute the bed shear velocity and shear stress, based on the mean particle size of bed sediment and the hydraulic properties of the RCHRES (i.e., average water depth, average velocity, hydraulic radius, and slope).

The method of calculating shear velocity and shear stress depends on whether the RCHRES is a lake or a river. If the RCHRES is a lake (LKFG=1), shear velocity is computed using Equation 8.49 from "Hydraulics of Sediment Transport", by W. H. Graf:

$$USTAR = AVVEL / (17.66 + (ALOG10 (AVDEP / (96.5 * DB50))) * 2.3 / AKAPPA) \quad (42)$$

where:

USTAR = shear velocity (ft/s or m/s)
 AVVEL = average flow velocity (ft/s or m/s)
 AVDEP = average water depth (ft or m)
 DB50 = median diameter of bed material (ft or m)
 AKAPPA = Karman constant (AKAPPA = 0.4)

The shear stress (TAU) on a lake bed is calculated as:

$$TAU = GAM * (USTAR ** 2) / GRAV \quad (43)$$

where:

TAU = bed shear stress (lb/ft² or kg/m²)
 GAM = unit weight, or density, of water (62.4 lb/ft³ or 1000 kg/m³)
 GRAV = acceleration due to gravity (32.2 ft/sec² or 9.81 m/sec²)

If the RCHRES being simulated is a stream or river, both shear velocity and shear stress are determined as functions of the slope and hydraulic radius of the reach:

$$USTAR = SQRT(GRAV * SLOPE * HRAD) \quad (44)$$

where:

SLOPE = slope of the RCHRES (-)
 HRAD = hydraulic radius (ft or m)

and

$$TAU = SLOPE * GAM * HRAD \quad (45)$$

where:

TAU = stream bed shear stress (lb/ft² or kg/m²)

Water Rights Categories

Categories can be used to facilitate the modeling of water rights in a RCHRES. If categories are being simulated (NCAT > 0) in the CATEGORY block), each RCHRES in the run keeps track of the categories of all inflows, storages, and outflows, as well as precipitation and evaporation fluxes. Up to 100 categories may be specified in the CATEGORY block.

The storage of each category of water in a RCHRES is called CVOL(C). The inflows of each category are CIVOL(C). The category outflows from exit gate OFLO(N) are called COVOL(C,N), and the total outflow of each category is CROVOL(C). These quantities are illustrated in Figure 4.2(3).1-7.

The initial storage of water in a RCHRES may be assigned to a single category, or fractions of the storage can be assigned to specified categories. The default is to divide the storage equally among all active categories.

All water entering a RCHRES must be assigned a category. The inflow to each category is input as time series CIVOL, and IVOL is computed as the sum.

By default, precipitation is divided proportionally among all categories present in a RCHRES according to their current storage fraction CFRAC(C), which is calculated as CVOL(C) divided by VOL. Optionally, it may be assigned to either a single category or to several categories by user-defined fractions.

Assigning evaporation losses to categories is somewhat more complicated. By default, evaporation is taken from all categories proportionally based on CFRAC. If a single category is specified, evaporation is taken from that category as long as sufficient water is present. For more complex situations, a priority may be assigned to each of several categories. Multiple categories may be given the same priority, and losses may be divided among them by either user-specified fractions or by CFRAC (the default). When all specified categories are exhausted, any remaining loss is distributed among the other categories by CFRAC.

F(VOL) outflows are calculated from the FTABLE normally. Most free-flowing reaches will use the default algorithm, which is to pass all categories downstream unchanged, i.e. according to CFRAC. For more complex situations, categories can be assigned in the same way as for evaporation, with separate priorities and categories specified for each exit.

Time series demands (g(t) releases) are handled differently. The time series OUTDGT is replaced by COTDGT, which is an array specifying the demand from each category for each exit. If there is not enough water in a category to satisfy the demand, the release is cut back, and the storage of that category is reduced to zero. Water is not "borrowed" from other categories to make up the flow. Any deficit in the demand is accumulated throughout the run in the time series CDFVOL. If a category is drawn from more than one exit, a priority may be established for each demand. The priority may be specified as either a real number or a date, such as an ownership date.

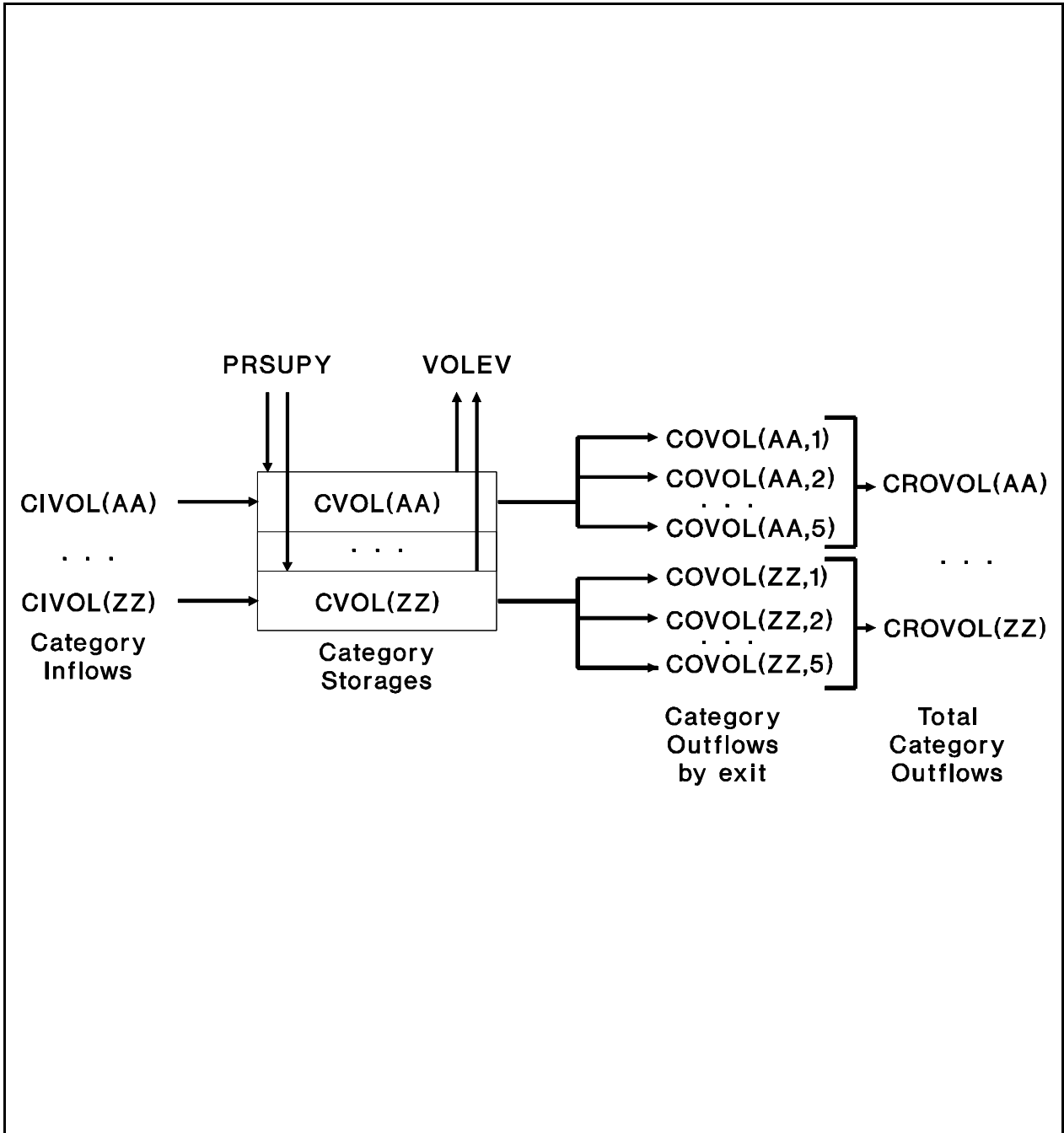


Figure 4.2(3).1-7 Flow diagram for water categories in the HYDR Section of the RCHRES Application Module

If an exit uses FUNCT to combine $f(VOL)$ and $g(t)$ demands, then OUTDGT is calculated as the sum of COTDGT for that exit, and the combining function is applied normally.

COVOL is then the result of the actual releases of $g(t)$ demands COTDGT and the apportionment of $f(VOL)$ flows by category. The outflow rate is called $CO(C,N)$. The total category outflow volume and rate are CROVOL and CRO, respectively.

4.2(3).2 Prepare to Simulate Advection of Fully Entrained Constituents (Section ADCALC of Module RCHRES)

Purpose

ADCALC calculates values for variables which are necessary to simulate longitudinal advection of dissolved or entrained constituents. These variables are dependent upon the volume and outflow values calculated in the hydraulics section (HYDR).

Approach

The outflow of an entrained constituent is a weighted mean of two quantities: one is an estimate based on conditions at the start of the time step, the other reflects conditions at the end of the time step. The weighting factors are called JS and COJS (complement of JS), respectively. The values of the weighting coefficients depend on (1) the relative volume of stored water in the RCHRES compared to the volume leaving in a single time step and (2) the uniformity of the velocity across a cross-section of the RCHRES. In order to represent these factors, two variables are defined: RAT and CRRAT. RAT is the ratio of RCHRES volume at the start of the interval to the outflow volume based on the outflow rate at the start of the interval:

$$\text{RAT} = \text{VOLS}/(\text{ROS}*\text{DELTS}) \quad (1)$$

where:

VOLS = volume of water at the start of interval (ft³ or m³)
 ROS = outflow rate at start of interval (ft³/s or m³/s)
 DELTS = number of seconds in interval

The parameter CRRAT is defined as the ratio of maximum velocity to mean velocity in the RCHRES cross-section under typical flow conditions. CRRAT must always have a value of 1.0 or greater. A value of 1.0 corresponds to a totally uniform velocity (plug flow) across the RCHRES.

Determination of JS and COJS

If the value of RAT is greater than that of CRRAT, it is assumed that all outflow over a given time interval was contained in the RCHRES at the start of the interval, and the mean rate of outflow of material is entirely dependent upon the rate of outflow at the start of the interval (JS = 1.0). If the value of RAT is less than CRRAT, it is assumed that part of the water in the outflow entered the RCHRES as inflow during the same interval; in this case, the concentration of inflowing material will affect the outflow concentration in the same interval, and JS will have a value less than 1.0. The relationship of RAT, CRRAT, and JS is illustrated in Figure 4.2(3).2-1. COJS is (1.0 - JS).

Another way to interpret the relationship of these variables is that no inflowing material is present in the outflow in the same interval if the outflow volume is less than (VOLS/CRRAT).

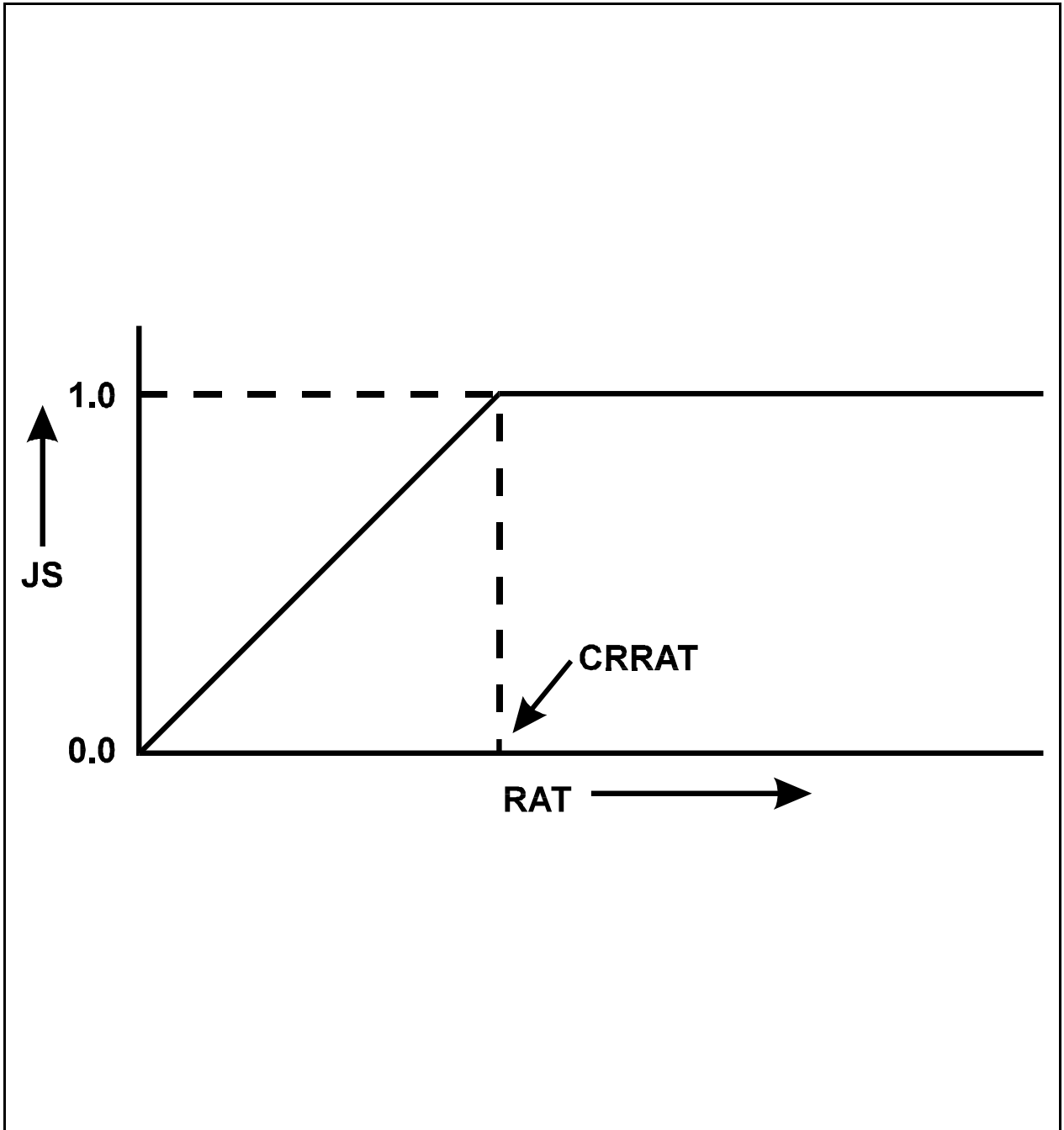


Figure 4.2(3).2-1 Determination of weighting factors for advection calculations

Calculation of Components of Outflow Volume

Components of outflow volume based on conditions at the start of the interval (SROVOL) and the end of the interval (EROVOL) are calculated as:

$$\begin{aligned} \text{SROVOL} &= \text{JS} * \text{ROS} * \text{DELTS} \\ \text{EROVOL} &= \text{COJS} * \text{RO} * \text{DELTS} \end{aligned} \quad (2)$$

where:

SROVOL = outflow volume component based on start of interval
(ft³/interval or m³/interval)
 EROVOL = outflow volume component based on end of interval
(ft³/interval or m³/interval)
 ROS = outflow rate at start of interval (ft³/s or m³/s)
 RO = outflow rate at end of interval (ft³/s or m³/s)
 DELTS = number of seconds in interval

Likewise, if there is more than one exit gate for the RCHRES, the corresponding outflow components for each unit, based on conditions at the start and end of each interval, are calculated as:

$$\begin{aligned} \text{SOVOL}(N) &= \text{JS} * \text{OS}(N) * \text{DELTS} \\ \text{EOVOL}(N) &= \text{COJS} * \text{O}(N) * \text{DELTS} \end{aligned} \quad (3)$$

where:

SOVOL(N) = outflow volume component based on start of interval for exit
gate N (ft³/interval or m³/interval)
 EOVOL(N) = outflow volume component based on end of interval for exit gate N
(ft³/interval or m³/interval)
 OS(N) = outflow rate at start of interval for exit gate N (ft³/s or m³/s)
 O(N) = outflow rate at end of interval for exit gate N (ft³/s or m³/s)
 DELTS = number of seconds in interval

It should be noted that SROVOL, EROVOL, SOVOL(N), and EOVL(N) are not actual outflows from the RCHRES, but instead are components of outflow based on conditions at the start or end of the interval. These variables are used in subroutine ADVECT to estimate the advection of constituents.

4.2(3).3 Simulate Conservative Constituents (Section CONS of Module RCHRES)

Purpose

CONS simulates constituents which, for all practical purposes, do not decay with time or leave the RCHRES by any mechanism other than advection. Examples include: total dissolved solids, chlorides, and pesticides and herbicides which decay very slowly. Figure 4.2(3).3-1 illustrates the fluxes of conservative material that are modeled in CONS.

Method

Subroutine CONS performs three functions. First, a value for inflow of material (INCON) is obtained and converted to internal units. The inflow is the sum of inputs from upstream reaches, tributary land areas, and atmospheric deposition:

$$\text{INCON} = \text{ICON} + \text{SAREA} * \text{ADFX} + \text{SAREA} * \text{PREC} * \text{ADCN} \quad (1)$$

where:

INCON = total input to reach (mass/interval)
 ICON = input from upstream reaches and tributary land (mass/interval)
 SAREA = surface area of reach (area)
 ADFX = dry or total atmospheric deposition flux (mass/area per interval)
 PREC = precipitation (depth)
 ADCN = concentration for wet atmospheric deposition in mass/volume

The atmospheric deposition inputs can be specified in two possible ways depending on the form of the available data. If the deposition is in the form of a flux (mass per area per time), then it is considered "dry deposition". If the deposition is in the form of a concentration in rainfall, then it is considered "wet deposition", and the program automatically combines it with the input rainfall time series to compute the resulting flux. Either type of deposition data can be input as a time series, or as a set of monthly values. The atmospheric deposition time series are documented in the EXTNL table of the Time Series Catalog for RCHRES, and are specified in the EXT SOURCES block of the UCI. Monthly values are input in the MONTH-DATA block.

After computing inflows, CONS calls subroutine ADVECT to perform longitudinal advection of this material and the material already contained in the RCHRES. Finally, CONS calculates the mass of material remaining in the RCHRES after advection; this value, RCON, is necessary for the mass balance checks on conservatives and is calculated as:

$$\text{RCON} = \text{CON} * \text{VOL} \quad (2)$$

where:

RCON = mass of material in RCHRES after advection
 CON = concentration of conservative after advection
 VOL = volume of water in RCHRES at end of interval (ft³ or m³)

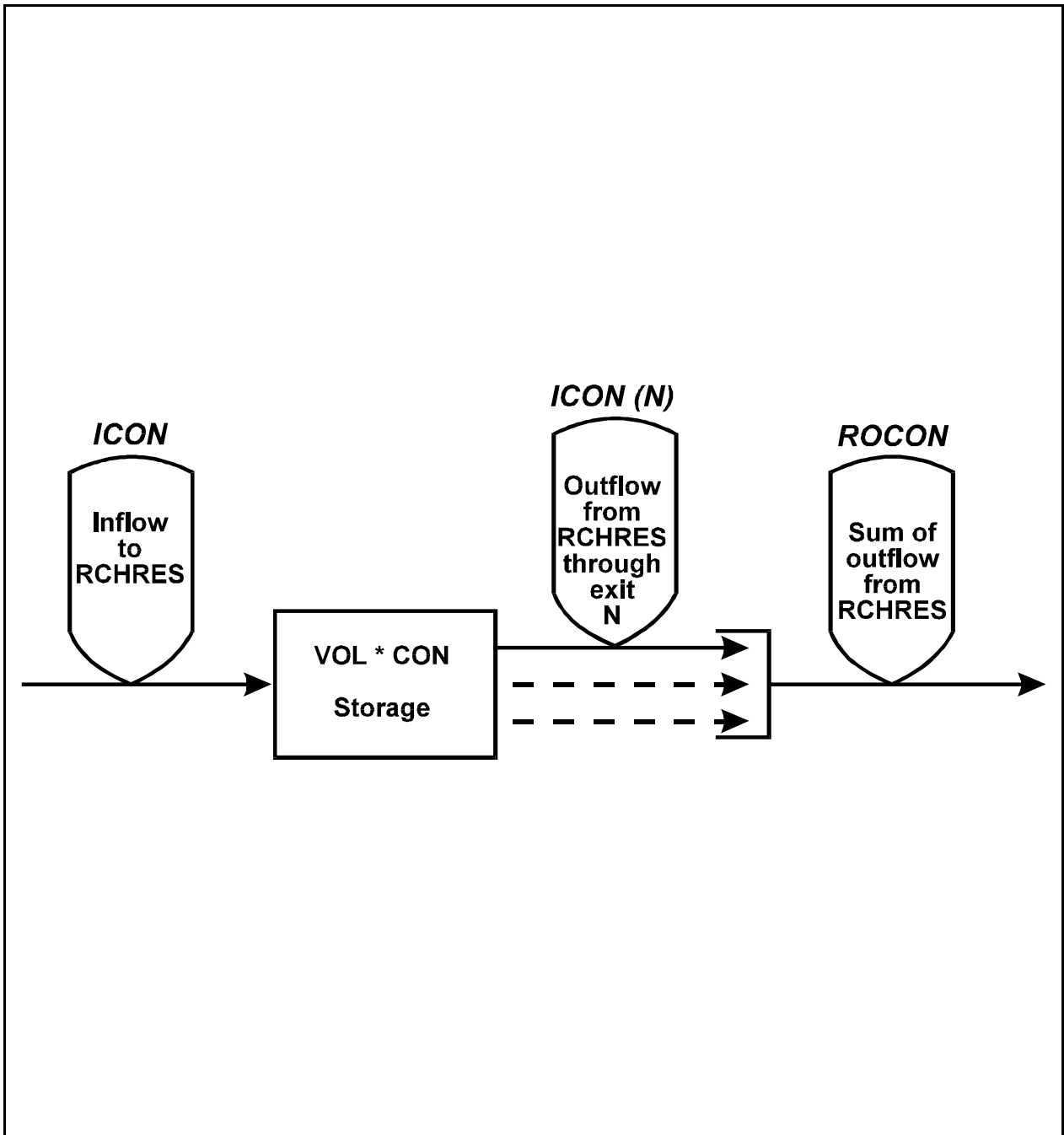


Figure 4.2(3).3-1 Flow diagram for conservative constituents in the CONS section of the RCHRES Application Module

Additional Requirements

HSPF allows a maximum of ten conservative constituents. The user selects the units for each constituent; thus, different conservative constituents may have different units. However, in order to provide this flexibility, additional input is required. For each constituent the following information must be provided in the User's Control Input:

1. CONID: the name of the constituent (up to 20 characters long)
2. QTYID: this string (up to 8 characters) contains the units used to describe the quantity of constituent entering or leaving the RCHRES, or the total quantity of material stored in it. Examples of possible units for QTYID are 'kg' for kilograms or 'lbs' for pounds
3. CONCID: the concentration units for each conservative (up to 8 characters long); examples are 'mg/l' or 'lbs/ft3'
4. CONV: conversion factor from QTYID/VOL to desired concentration units: $CONC = CONV * (QTY/VOL)$ (in English system, VOL is expressed in ft3) (in metric system, VOL is expressed in m3)
For example, if:
 CONCID is mg/l
 QTYID is kg
 VOL is in m3
 then $CONV = 1000.0$

4.2(3).3.1 Simulate Advection of Constituent Totally Entrained in Water (subroutine ADVECT)

Purpose

ADVECT computes the concentration of material in a RCHRES and the quantities of material that leave the RCHRES due to longitudinal advection through active exits. ADVECT is a generalized subroutine, and is called by each module section which simulates constituents which undergo normal longitudinal advection.

Assumptions

Two assumptions are made in the solution technique for normal advection:

1. Each constituent advected by calling subroutine ADVECT is uniformly dispersed throughout the waters of the RCHRES.
2. Each constituent is completely entrained by the flow; that is, the material moves at the same horizontal velocity as the water.

Method

The equation of continuity may be written as:

$$IMAT - ROMAT = (CONC * VOL) - (CONCS * VOLS) \quad (2)$$

where:

IMAT = inflow of material over the interval
 ROMAT = total outflow of material over the interval
 CONCS = concentration at the start of the interval
 CONC = concentration at the end of the interval
 VOLS = volume of water stored in the RCHRES at the start of the interval
 VOL = volume of water stored in the RCHRES at the end of the interval

The other basic equation states that the total outflow of material over the time interval is a weighted mean of two estimates; one based on conditions at the start of the interval, the other on ending conditions:

$$ROMAT = ((JS * ROS * CONCS) + (COJS * RO * CONC)) * DELTS \quad (3)$$

where:

JS = weighting factor
 COJS = 1.0 - JS
 ROS = rates of outflow at the start of the interval (m³/s or ft³/s)
 RO = rates of outflow at the end of the interval (m³/s or ft³/s)
 DELTS = length of interval (seconds)

Using Equations (2) in Section 4.2(3).2 (Subroutine ADCALC), Equation (3) can be written:

$$ROMAT = (SROVOL * CONCS) + (EROVOL * CONC) \quad (4)$$

where SROVOL and EROVOL are as defined earlier.

By combining Equations (2) and (4) we can solve for CONC:

$$\text{CONC} = (\text{IMAT} + \text{CONCS} * (\text{VOLS} - \text{SROVOL})) / (\text{VOL} + \text{EROVOL}) \quad (5)$$

The total amount of material leaving the RCHRES during the interval is calculated from equation (4).

If there is more than one active exit from the RCHRES, the amount of material leaving through each exit is calculated as:

$$\text{OMAT} = \text{SOVOL} * \text{CONCS} + \text{EOVOL} * \text{CONC} \quad (6)$$

where:

OMAT = amount of material leaving RCHRES through individual exit
 SOVOL = outflow volume component for individual exit based on start of interval
 EOVL = outflow volume component for individual exit based on end of interval

(SOVOL and EOVL are defined in Section 4.2(3).2)

If the RCHRES goes dry during the interval, the concentration at the end of the interval is undefined. The total amount of material leaving the RCHRES is:

$$\text{ROMAT} = \text{IMAT} + (\text{CONCS} * \text{VOLS}) \quad (7)$$

If there is more than one active exit from the RCHRES, the amount of material leaving through each exit from a RCHRES which has gone dry during the interval is calculated as:

$$\text{OMAT} = (\text{SOVOL} / \text{SROVOL}) * \text{ROMAT} \quad (8)$$

The units in the preceding equations are:

VOLS,VOL	m3 or ft3 (call these volunits)
SROVOL,etc	volunits/interval
CONCS,CONC	user defined (call these concunits)
IMAT,ROMAT,etc	concunits * volunits/interval

4.2(3).4 Simulate Heat Exchange and Water Temperature (Section HTRCH of Module RCHRES)

Purpose

The purpose of this code is to simulate the processes which determine the water temperature in a reach or mixed reservoir. Water temperature is one of the most fundamental indices used to determine the nature of an aquatic environment. Most processes of functional importance to an environment are affected by temperature. For example, the saturation level of dissolved oxygen varies inversely with temperature. The decay of reduced organic matter, and hence oxygen demand caused by the decay, increases with increasing temperature. Some form of temperature dependence is present in nearly all processes. The prevalence of individual phytoplankton and zooplankton species is often temperature dependent.

Required Time Series

Five time series of meteorological data are required to simulate the temperature balance within a RCHRES. These are:

1. solar radiation in langleys/interval
2. cloud cover expressed as tenths
3. air temperature in degrees F (English) or degrees C (Metric)
4. dewpoint temperature in degrees F (English) or degrees C (Metric)
5. wind speed in miles/interval (English) or km/interval (Metric)

Note that solar radiation data are usually available as daily totals. The user must generally convert these data to hourly or two hourly values before using them in HSPF. If the standard HSPF disaggregation rule were used, a daily value would be divided into equal increments for each interval of the day; this would not account for the rising and setting of the sun. A similar kind of preprocessing needs to be done if daily max/min air temperatures are used.

Schematic View of Fluxes and Storages

Figure 4.2(3).4-1 illustrates the fluxes involved in this module section. There are no significant internal sources or sinks of temperature within a RCHRES. Changes in heat content are due only to transport processes across the RCHRES boundaries. Module section HTRCH considers three major processes: heat transfer by advection, heat transfer across the air-water interface, and optionally, heat transfer across the water-sediment (bed) interface. The processes of diffusion and dispersion are not considered in HSPF.

Heat transfer by advection is simulated by treating water temperature as a thermal concentration. This enables the use of subroutine ADVECT, a standard subroutine which calculates advective transport of constituents totally entrained in the moving water.

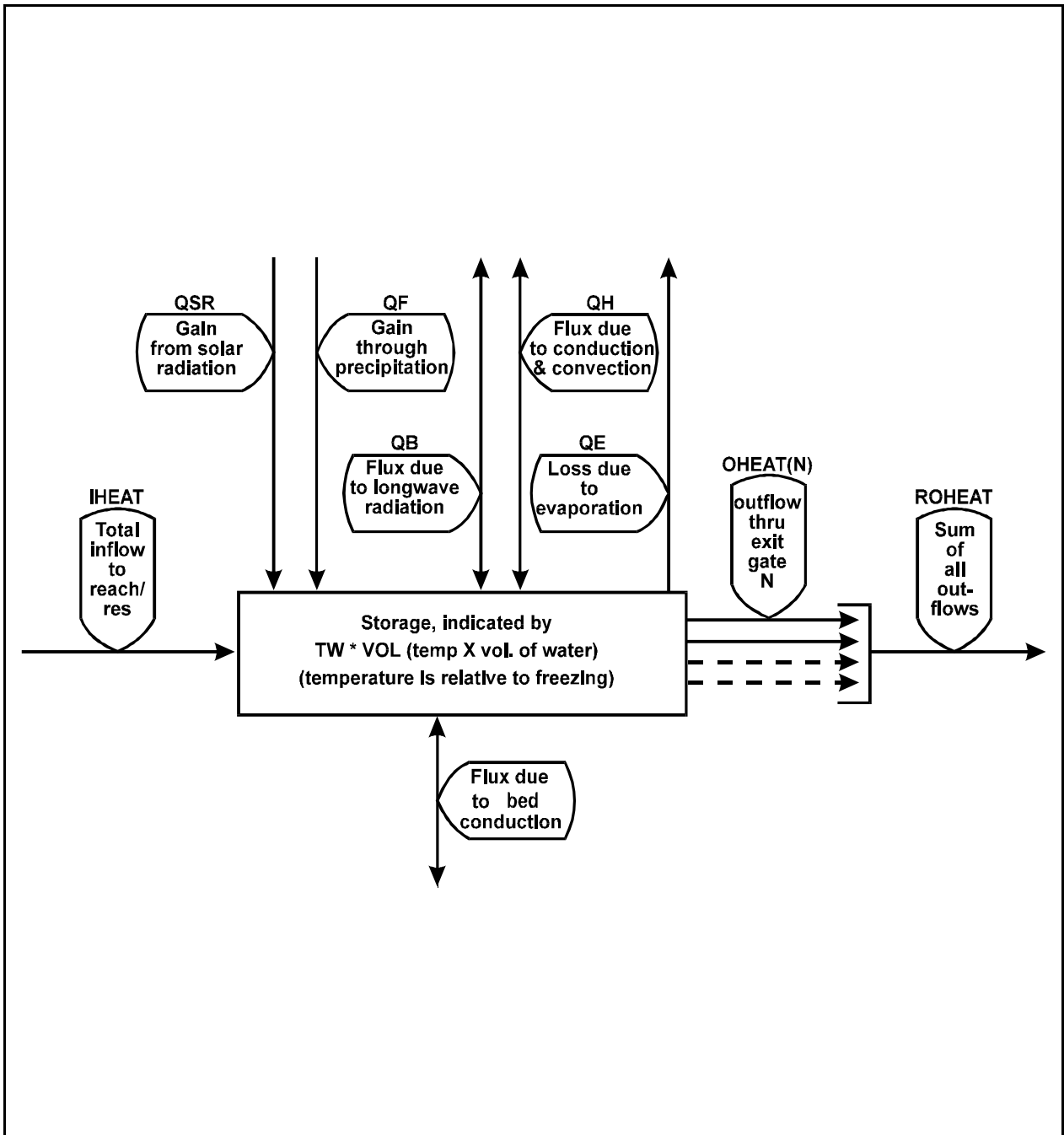


Figure 4.2(3).4-1 Flow diagram for HTRCH section of the RCHRES Application Module

Heat is transported across the air-water interface by a number of mechanisms, and each must be evaluated individually. The net transport across the air-water interface is the sum of the individual effects. Mechanisms which can increase the heat content of the water are absorption of solar radiation, absorption of longwave radiation, and conduction-convection. Mechanisms which decrease the heat content are emission of longwave radiation, conduction-convection, and evaporation.

Shortwave Solar Radiation

The shortwave radiation absorbed by a RCHRES is approximated by the following equation:

$$QSR = 0.97 * CFSAX * SOLRAD * 10.0 \quad (1)$$

where:

QSR = shortwave radiation (kcal/m²/interval)
 0.97 = fraction of incident radiation which is assumed absorbed
 (3 percent is assumed reflected)
 CFSAX = ratio of radiation incident to water surface to radiation
 incident to gage where data were collected. This factor also
 accounts for shading of the water body, e.g., by trees
 SOLRAD = solar radiation (langleys/interval)
 10.0 = conversion factor from langleys to kcal/m²

Longwave Radiation

All terrestrial surfaces, as well as the atmosphere, emit longwave radiation. The rate at which each source emits longwave radiation is dependent upon its temperature. The longwave radiation exchange between the atmosphere and the RCHRES is estimated using the formula:

$$QB = SIGMA * ((TWKELV^{**4}) - KATRAD * (10^{**-6}) * CLDFAC * (TAKELV^{**6})) * DELT60 \quad (2)$$

where:

QB = net transport of longwave radiation (kcal/m²/interval)
 SIGMA = Stephan-Boltzman constant multiplied by 0.97 to account
 for emissivity of water
 TWKELV = water temperature (degrees Kelvin)
 KATRAD = atmospheric longwave radiation coefficient with a typical
 value of 9.0
 CLDFAC = 1.0 + (.0017 * C ** 2)
 TAKELV = air temperature corrected for elevation difference (deg K)
 C = cloud cover, expressed as tenths (range = 0 - 10)
 DELT60 = DELT(minutes) divided by 60

Both atmospheric radiation to the water body and back radiation from the water body to the atmosphere are considered in this equation. QB is positive for transport of energy from the water body to the atmosphere.

Conduction-Convection

Conductive-convective transport of heat is caused by temperature differences between the air and water. Heat is transported from the warmer medium to the cooler medium; heat can therefore enter or leave a water body, depending upon its temperature relative to air temperature. HSPF assumes that the heat transport is proportional to the temperature difference between the two media. The equation used is:

$$QH = CFPRES*(KCOND*10**{-4})*WIND*(TW - AIRTMP) \quad (3)$$

where:

QH = conductive-convective heat transport (kcal/m2/interval)
 CFPRES = pressure correction factor (dependent on elevation)
 KCOND = conductive-convective heat transport coefficient
 (typically in the range 1 - 20)
 WIND = wind speed (m/interval)
 TW = water temperature (deg C)
 AIRTMP = air temperature (deg C)

QH is positive for heat transfer from the water to the air.

Evaporative Heat Loss

Evaporative heat transport occurs when water evaporates from the water surface. The amount of heat lost depends on the latent heat of vaporization for water and on the quantity of water evaporated. For purposes of water temperature simulation, HSPF uses the following equation to calculate the amount of water evaporated:

$$EVAP = (KEVAP*10**{-9})*WIND*(VPRESW - VPRESA) \quad (4)$$

where:

EVAP = quantity of water evaporated (m/interval)
 KEVAP = evaporation coefficient with typical values of 1 - 5
 WIND = wind movement 2 m above the water surface (m/interval)
 VPRESW = saturation vapor pressure at the water surface (mbar)
 VPRESA = vapor pressure of air above water surface (mbar)

The heat removed by evaporation is then calculated:

$$QE = HFACT*EVAP \quad (5)$$

where:

QE = heat loss due to evaporation (kcal/m2/interval)
 HFACT = heat loss conversion factor (latent heat of vaporization multiplied by density of water)

Heat Content of Precipitation

In module section HYDR, an option exists to include the input of water from precipitation falling directly on the water surface. If this option is activated, it is necessary to assign a temperature to the water added to the RCHRES in this manner. HSPF assumes that precipitation has the same temperature as the water surface on which it falls.

Bed conduction

Heat movement between water and bed sediment contributes significantly to the diurnal variation of water temperature, especially in shallow streams and rivers. Simulation of bed conduction is optional, and the user may select from three alternative methods to represent this process.

Method 1:

If BEDFLG = 1, streambed conduction is computed as a simple function of the difference in temperature between the water-streambed interface (temperature = water temperature) and the streambed at an equilibrium ground temperature at some depth below the bed. The equation is:

$$QBED = KMUD * (TGRND - TW)$$

where:

QBED = heat flux from ground to water (kcal/m²/interval)
 TGRND = equilibrium ground temperature (C)
 TW = water temperature (C)
 KMUD = water-ground heat conduction coefficient (kcal/m²/C/interval)

KMUD can be estimated as the thermal conductivity of the streambed material divided by the depth (below the water-sediment interface) where equilibrium temperature is assumed to occur.

Method 2:

If BEDFLG = 2, bed conduction is based on the method of Caupp et al. (1994) that was used in modeling the Truckee River. The method is an extension of Method 1 to include a finite sediment or mud layer (consisting of water-saturated sediment) overlying the ground, which is at an equilibrium temperature. Heat fluxes between the ground and sediment and between the sediment and water are computed, as well as sediment and water temperatures. The algorithm, which includes a differencing scheme for updating the sediment temperature is described below:

The heat transfer between the ground and sediment is computed as follows:

$$QGRMUD = KGRND * (TGRND - TMUD)$$

where:

QGRMUD = heat transfer from ground to sediment layer (kcal/m²/interval)
 KGRND = ground-sediment heat conduction coefficient
 (kcal/m²/C/interval); (default value = 1.419)
 TGRND = equilibrium ground temperature (C)
 TMUD = sediment temperature (C)

This heat transfer is used to update the sediment temperature as follows:

$$TMUD = TMUD + QGRMUD/CPR/MUDDP$$

where:

CPR = heat capacity of sediment (1000 kcal/m³/C)
 (CPR is assumed to be the heat capacity of water)
 MUDDP = depth of sediment layer (m)

Finally, the new sediment temperature is used to compute the heat transfer between the sediment and water column:

$$QBED = KMUD*(TMUD - TW)$$

where:

QBED = heat flux from sediment to water (kcal/m²/hr)
 KMUD = water-sediment heat conduction coefficient (kcal/m²/C/hr)
 TW = water temperature (C)

Method 3:

If BEDFLG = 3, the bed conduction computation is based on the method proposed by Jobson (1977, 1979) in which the advection-dispersion equation for heat is solved analytically. Jobson's solution reduces the bed conduction to a convergent series consisting of the product of the following quantities:

1. Temperature change (deg C) of the water over a specific period (TSTOP intervals) prior to the current time interval. ()T
2. Heat flux per degree C between the bed and water (over the TSTOP time period). The units are kcal/m²/C/interval. ()H

Assuming time intervals of one hour, the equation is:

$$QBED = \sum_{(I=1, TSTOP)} [DELH(I) * DELTT(I)]$$

where:

$\sum_{(I=1, TSTOP)}$ = summation over the past TSTOP hours
 DELH(I) = heat flux from bed to water at current interval resulting from a 1.0 degree C temperature increase at hour I (kcal/m²/C/hr)
 DELTT(I) = temperature change over hour I

Therefore, at each time step, the total bed conduction flux is simply the summation, over TSTOP, of the product of these two arrays. As implemented in HSPF, the temperature change at the current time step is computed twice. The first computation includes all heat flux components except bed conduction; then the resulting temperature change is used to compute the bed conduction flux, which is used to compute the final water temperature change.

Values of DELH and TSTOP can be developed from Jobson's equations; a utility program is available to compute these inputs as a function of the thickness and thermal properties of the bed. Note: The input values of DELH depend upon time-step, i.e., the units are kcal/m²/C/interval. Also, DELH values are negative.

Net heat exchange

The net heat exchange at the water surface is represented as:

$$QT = QSR - QB - QH - QE + QP + QBED \quad (6)$$

where:

QT = net heat exchange in kcal/m²/interval
 QSR = net heat transport from incident shortwave radiation
 QB = net heat transport from longwave radiation
 QH = heat transport from conduction-convection
 QE = heat transport from evaporation
 QP = heat content of precipitation
 QBED = net heat exchange with bed

Calculation of Water Temperature

Of the five heat transport mechanisms across the air-water interface, three are significant and dependent upon water temperature. In order to obtain a stable solution for water temperature, these three terms (QB, QH, QE) are evaluated for the temperature at both the start and end of the interval, and the average of the two values is taken (trapezoidal approximation). For this purpose, the unknown ending temperature is approximated by performing a Taylor series expansion about the starting temperature, and ignoring nonlinear terms. This formulation leads to the following equation for the change in water temperature over the interval:

$$DELTTW = CVQT*QT/(1.0 + SPD*CVQT) \quad (7)$$

where:

DELTTW = change in water temperature (deg C)
 CVQT = conversion factor to convert total heat exchange expressed in kcal/m²/interval to deg C/interval (volume dependent)
 QT = net heat exchange in kcal/m²/interval (with terms evaluated at starting temperature)
 SPD = sum of partial derivatives of QB, QH, and QE with respect to water temperature

The heat exchange calculations do not give realistic results when the water body becomes excessively shallow. Consequently, heat transport processes are not considered if the average depth of water in the RCHRES falls below 2 inches. When this happens, the water temperature is set equal to the air temperature.

4.2(3).4.1 Correct Air Temperature for Elevation Difference (subroutine RATEMP)

Purpose

The purpose of this code is to correct air temperature for any elevation difference between the RCHRES and the temperature gage.

Approach

The lapse rate for air temperature is dependent upon whether or not precipitation occurs during the time interval. If precipitation does occur, a wet lapse rate of 1.94E-3 degrees C/ft is assumed. Otherwise, a dry lapse rate which is a function of the time of day is used. A table of 24 hourly dry lapse rates is built into HSPF. The corrected air temperature is:

$$\text{AIRTMP} = \text{GATMP} - \text{LAPS} * \text{ELDAT} \quad (8)$$

where:

AIRTMP = corrected air temperature (deg C)
 GATMP = air temperature at gage
 LAPS = lapse rate (degrees C/ft)
 ELDAT = elevation difference between mean RCHRES elevation and gage elevation (feet) (ELDAT is positive if the mean RCHRES elevation is greater than the gage elevation)

4.2(3).5 Simulate Behavior of Inorganic Sediment (Section SEDTRN of Module RCHRES)

Purpose

The purpose of this code is to simulate the transport, deposition, and scour of inorganic sediment in free-flowing reaches and mixed reservoirs. The modeling of sediment in channels may be needed for analysis of such problems as:

1. Structural instability of bridge piers or water intakes caused by scouring.
2. Reduction of reservoir capacity and clogging of irrigation canals and navigable waterways due to deposition.
3. Reduction of light available to aquatic organisms caused by suspended sediment.
4. Transport of adsorbed pollutants such as fertilizers, herbicides, and pesticides.

Schematic View of Fluxes and Storages

Figure 4.2(3).5-1 shows the principal state variables and fluxes with which module section SEDTRN deals.

Both the migration characteristics and the adsorptive capacities of sediment vary significantly with particle size. Consequently, HSPF divides the inorganic sediment load into three components (sand, silt, and clay), each with its own properties. Parametric information required for cohesive sediments (silt and clay) include:

1. particle diameter - D
2. particle settling velocity in still water - W
3. particle density - RHO
4. critical shear stress for deposition - TAUCD
5. critical shear stress for scour - TAUCS
6. erodibility coefficient - M

Parameter values required for noncohesive, or sand, particles depend on the method used to compute sandload (alternate methods are described in the functional description of subroutines SANDLD, TOFFAL, and COLBY). If the Toffaleti method is used, values must be defined for median bed sediment diameter (DB50) and particle settling velocity (W). The Colby method requires a value for DB50, and the power function method requires both a coefficient (KSAND) for the power function and an exponent (EXPSND).

As Figure 4.2(3).5-1 indicates, the same material fluxes are modeled for all three fractions of sediment. Only the methodology used to determine fluxes between suspended storage and bed storage differ.

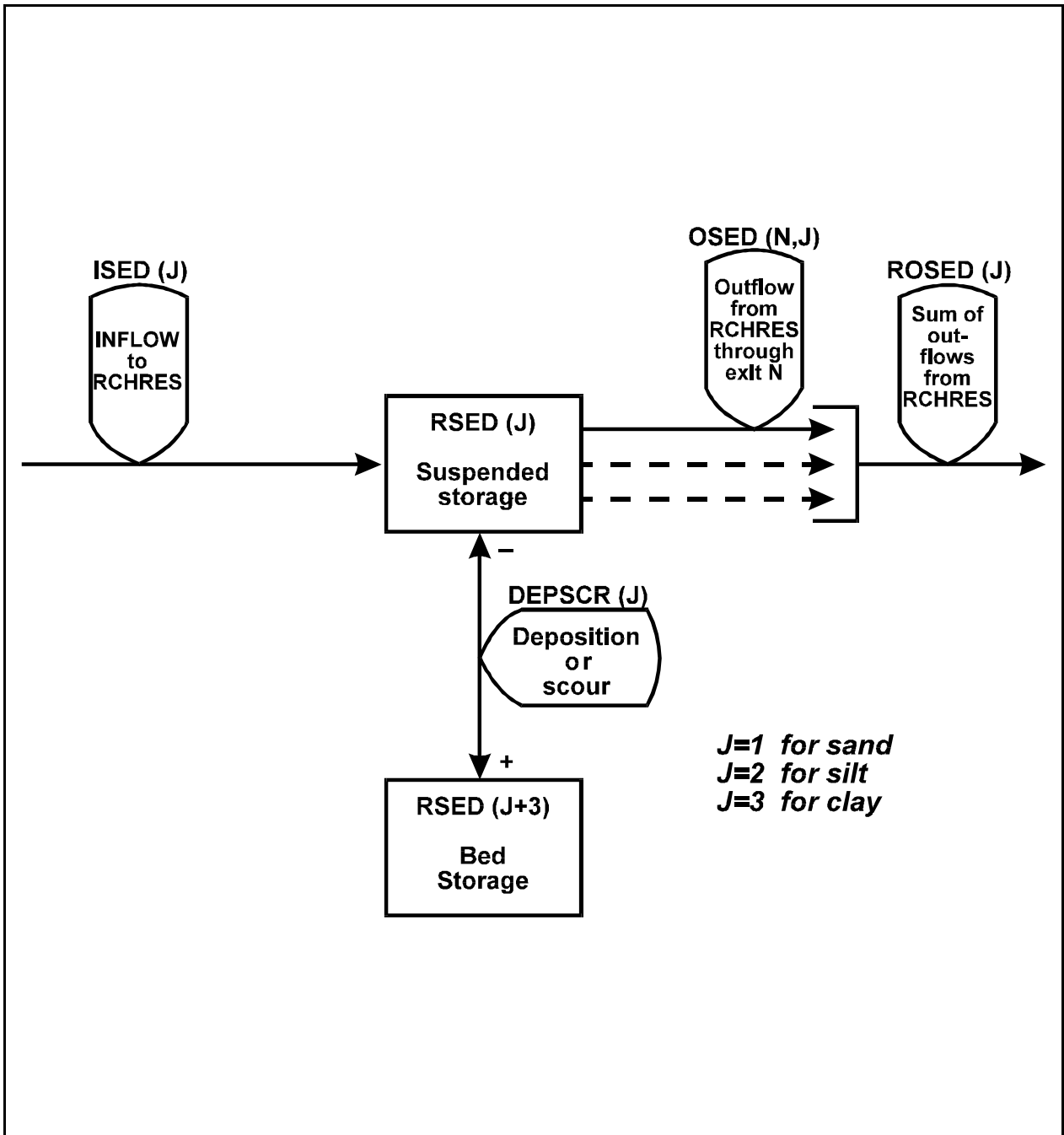


Figure 4.2(3).5-1 Flow diagram of inorganic sediment fractions in the SEDTRN section of the RCHRES Application Module

HSPF assumes that scour or deposition of inorganic sediment does not affect the hydraulic properties of the channel. Furthermore, it is assumed that sand, silt, and clay deposit in different areas of the RCHRES bed; consequently, the deposition or scour of each material is not linked to the other fractions (i.e., "armoring" is not modeled). Longitudinal movement of bed sediments is not modeled.

The details of the transport, deposition, and scour techniques are outlined in the functional descriptions of the lower level routines of the SEDTRN module section. Following these calculations, the depth of sediment in the RCHRES bed is determined in order to warn the user whenever the deposited sediment exceeds a pre-specified level. First, the volume occupied by each fraction of bed sediment is calculated:

$$\text{VOLSED}(J) = \text{RSED}(J+3)/\text{RHO}(J)*1.0\text{E}06 \quad (1)$$

where:

VOLSED(J) = volume occupied by bed sediment of fraction J (m³ or ft³)
 RSED(J+3) = bed storage of sediment fraction J (mg.m³/l or mg.ft³/l)
 RHO(J) = particle density of fraction J (gm/cm³)

The volumes of the three fractions of bed sediment are summed, and the total bed volume is adjusted to account for the fraction of the volume which is void of sediment (i.e., the porosity):

$$\text{VOLSEDA} = \text{VOLSED}/(1.0 - \text{POR}) \quad (2)$$

where:

VOLSEDA = volume of bed adjusted to account for volume occupied
 by materials other than sediment
 VOLSED = volume of sediment contained in the bed (sand + silt + clay)
 POR = porosity of bed sediment (ratio of pore volume to total volume)

Finally, the depth of bed sediment is calculated for use as an indicator of excessive deposition:

$$\text{BEDDEP} = \text{VOLSEDA}/(\text{LEN}*\text{BEDWID}) \quad (3)$$

where:

BEDDEP = depth of bed (m or ft)
 VOLSEDA = volume of bed (m³ or ft³)
 LEN = length of RCHRES (m or ft)
 BEDWID = effective width of bed for calculation of bed thickness
 (an input parameter expressed in m or ft)

If the calculated value for BEDDEP exceeds a user specified value, a warning message is printed to alert the user to potential modeling problems.

The PERLND module of HSPF simulates removal of total inorganic sediment due to washoff from the land surface and erosion from gullies. Therefore, the user must divide this total sediment into the three components (sand, silt, and clay) so that this material can be routed through the channel system in the RCHRES module.

4.2(3).5.1 Simulate Cohesive Sediments (subroutine COHESV)

Purpose

COHESV simulates the deposition, scour, and transport processes of cohesive sediments (silt and clay).

Method

The modeling effort consists of two steps. First, subroutine ADVECT is called to perform advective transport (see section 4.2(3).3.1). Then subroutine BDEXCH is called, and deposition or scour is calculated based on the bed shear stress and the Krone and Partheniades equations. (see section 4.2(3).5.1.1).

4.2(3).5.1.1 Simulate Exchange with Bed
(subroutine BDEXCH)

Purpose

BDEXCH simulates the deposition and scour of cohesive sediment fractions (silt and clay).

Approach

Exchange of cohesive sediments with the bed is dependent upon the shear stress exerted upon the bed surface. The shear stress within the RCHRES is calculated in subroutine SHEAR of the HYDR section. Whenever shear stress (TAU) in the RCHRES is less than the user-supplied critical shear stress for deposition (TAUCD), deposition occurs; whenever shear stress is greater than the user-supplied critical shear stress for scour (TAUCS), scouring of cohesive bed sediments occurs. The rate of deposition for a particular fraction of cohesive sediment is based on a simplification of Krone's (1962) equation to the following form:

$$D = W*CONC*(1.0 - TAU/TAUCD) \quad (4)$$

where:

- D = rate at which sediment fraction settles out of suspension (mass/len2.iv1)
- W = settling velocity for cohesive sediment fraction (len/iv1)
- CONC = concentration of suspended sediment fraction (mass/len3)
- TAU = shear stress (lb/ft2 or kg/m2)
- TAUCD = critical shear stress for deposition (lb/ft2 or kg/m2)

The rate of change of suspended sediment fraction concentration in the RCHRES due to deposition can be expressed as:

$$d(CONC)/dt = -(D/AVDEPM) \quad (5)$$

where:

AVDEPM = average depth of water in RCHRES (m)

By substituting the expression for deposition rate (D) from Equation 4, the following equation is obtained:

$$d(\text{CONC})/dt = -(W*\text{CONC}/\text{AVDEPM})*(1 - \text{TAU}/\text{TAUCD}) \quad (6)$$

By integrating and rearranging this equation, a solution may be obtained for the concentration of suspended sediment lost to deposition during a simulation interval (DEPCONC):

$$\text{DEPCONC} = \text{CONC}*(1.0 - \text{EXP}((-W/\text{AVDEPM})*(1.0 - \text{TAU}/\text{TAUCD})) \quad (7)$$

where:

CONC = concentration of suspended sediment at start of interval (mg/l)

W = settling velocity for sediment fraction (m/ivl)

AVDEPM = average depth of water in RCHRES in meters (calculated in HYDR)

TAU = shear stress (lb/ft² or kg/m²)

TAUCD = critical shear stress for deposition (lb/ft² or kg/m²)

The user must supply values for settling velocity (W) and critical shear stress for deposition (TAUCD) for each fraction of cohesive sediment (silt and clay).

Following the calculation of DEPCONC, the storage of sediment in suspension and in the bed is updated:

$$\text{SUSP} = \text{SUSP} - (\text{DEPCONC}*\text{VOL}) \quad (8)$$

$$\text{BED} = \text{BED} + (\text{DEPCONC}*\text{VOL}) \quad (9)$$

where:

SUSP = suspended storage of sediment fraction (mg.ft³/l or mg.m³/l)

BED = storage of sediment fraction in bed (mg.ft³/l or mg.m³/l)

VOL = volume of water in RCHRES (ft³ or m³)

The rate of resuspension, or scour, of cohesive sediments from the bed is derived from a modified form of Partheniades'(1962) equation:

$$S = M*(\text{TAU}/\text{TAUCS} - 1.0) \quad (10)$$

where:

S = rate at which sediment is scoured from the bed (mass/len².ivl)

M = erodibility coefficient for the sediment fraction (kg/m².ivl)

TAUCS = critical shear stress for scour (lbs/ft² or kg/m²)

The rate of change of suspended sediment fraction concentration in the RCHRES due to scour can be expressed as:

$$d(\text{CONC})/dt = S/\text{AVDEPM} \quad (11)$$

By substituting the expression for scour rate (S) from Equation 10 the following equation is obtained:

$$d(\text{CONC})/dt = (M/\text{AVDEPM}) * (\text{TAU}/\text{TAUCS} - 1.0) \quad (12)$$

By integrating and rearranging this equation, a solution may be obtained for the concentration of suspended sediment added to suspension by scour during a simulation interval (SCRCONC):

$$\text{SCRCONC} = M/\text{AVDEPM} * 1000 * (\text{TAU}/\text{TAUCS} - 1.0) \quad (13)$$

where:

M = erodibility coefficient (kg/m².ivl)
 AVDEPM = average depth of water (m)
 1000 = conversion from kg/m³ to mg/l

The user is required to supply values for the erodibility coefficient (M) and critical shear stress for scour (TAUCS) for each fraction of cohesive sediment (silt and clay) which is modeled.

Following the calculation of SCRCONC, the storage of sediment in suspension and in the bed is updated:

$$\text{BED} = \text{BED} - (\text{SCRCONC} * \text{VOL}) \quad (14)$$

$$\text{SUSP} = \text{SUSP} + (\text{SCRCONC} * \text{VOL}) \quad (15)$$

If the amount of scour calculated is greater than available storage in the bed, the bed scour is set equal to the bed storage, and the bed storage is set equal to zero. Since the value specified for TAUCS should be greater than that for TAUCD, only one process (deposition or scour) occurs during each simulation interval.

4.2(3).5.2 Simulate Behavior of Sand/Gravel (subroutine SANDLD)

Purpose

SANDLD simulates the deposition, scour, and transport processes of the sand fraction of inorganic sediment.

Method

Erosion and deposition of sand, or noncohesive sediment, is affected by the amount of sediment the flow is capable of carrying. If the amount of sand being transported is less than the flow can carry for the hydrodynamic conditions of the RCHRES, sand will be scoured from the bed. This occurs until the actual sand transport rate becomes equal to the carrying capacity of the flow or until the available bed sand is all scoured. Conversely, deposition occurs if the sand transport rate exceeds the flow's capacity to carry sand.

Subroutine SANDLD allows the user to calculate sand transport capacity for a RCHRES by any one of three methods. Depending on the value of SANDFG specified in the User's Control Input, either the Toffaleti equation (SANDFG=1), the Colby method (SANDFG=2), or an input power function of velocity (SANDFG=3) is used. If sand transport capacity is calculated using the Toffaleti or Colby methods, the potential sandload concentration is determined by the following conversion:

$$PSAND = (GSI * TWIDE * 10.5) / ROM \quad (16)$$

where:

PSAND = potential sandload (mg/l)
 GSI = sand transport capacity (tons/day/ft of width)
 (calculated in COLBY or TOFFAL)
 TWIDE = width of RCHRES (ft)
 10.5 = conversion factor
 ROM = total rate of outflow of water from the RCHRES (m³/sec)

If carrying capacity is a power function of velocity, PSAND is calculated as:

$$PSAND = KSAND * AVVELE ** EXPSND \quad (17)$$

where:

KSAND = coefficient in the sandload suspension equation (input parameter)
 EXPSND = exponent in sandload suspension equation (input parameter)
 AVVELE = average velocity (ft/sec)

The potential outflow of sand during the interval is:

$$PROSND = (SANDS * SROVOL) + (PSAND * EROVOL) \quad (18)$$

where:

PROSND = potential sand outflow
 SANDS = concentration of sand at start of interval (mg/l)
 SROVOL and EROVOL are as defined in Section 4.2(3).2

The potential scour from, or deposition to, the bed storage is found using the continuity equation:

$$PSCOUR = (VOL * PSAND) - (VOLS * SANDS) + PROSND - ISAND \quad (19)$$

where:

PSCOUR = potential scour (+) or deposition (-)
 VOL = volume of water in RCHRES at the end of the interval (ft³ or m³)
 VOLS = volume of water in RCHRES at the start of interval (ft³ or m³)
 ISAND = total inflow of sand into RCHRES during interval

The terms in Equations 18 and 19 have the units of concentration. The potential scour is compared to the amount of sand material on the bottom surface available for resuspension. If scour demand is less than available bottom sands, the demand is satisfied in full, and the bed storage is adjusted accordingly. The new suspended concentration is PSAND. If the potential scour cannot be satisfied by bed storage, all of the available bed sand is suspended, and bed storage is exhausted. The concentration of suspended sandload is calculated as:

$$\text{SAND} = (\text{ISAND} + \text{SCOUR} + \text{SANDS} * (\text{VOLS} - \text{SROVOL})) / (\text{VOL} + \text{EROVOL}) \quad (20)$$

where:

SAND = concentration of sand at end of interval
 SCOUR = sand scoured from, or deposited to, the bottom
 SANDS = concentration of sand at start of interval

The total amount of sand leaving the RCHRES during the interval is:

$$\text{ROSAND} = \text{SROVOL} * \text{SANDS} + \text{EROVOL} * \text{SAND} \quad (21)$$

If a RCHRES goes dry during an interval, or if there is no outflow from the RCHRES, all the sand in suspension at the beginning of the interval is assumed to settle out, and the bed storage is correspondingly increased.

4.2(3).5.2.1 Calculate Sand Transport Capacity by Using Toffaleti's Method (subroutine TOFFAL)

Purpose

TOFFAL uses Toffaleti's method to calculate the capacity of the RCHRES flow to transport sand.

Method

In Toffaleti's methodology, the actual stream for which the sand discharge is to be calculated is assumed to be equivalent to a two-dimensional stream of width equal to that of the real stream and of depth equal to the hydraulic radius of the real stream (FHRAD).

For the purposes of calculation, the depth, FHRAD, of the hypothetical stream is divided into four zones shown in Figure 4.2(3).5-2. These are: (1) the bed zone of relative thickness $Y/\text{FHRAD} = 2 * \text{FDIAM}/\text{FHRAD}$; (2) the lower zone extending from $Y/\text{FHRAD} = 2 * \text{FDIAM}/\text{FHRAD}$ to $Y/\text{FHRAD} = 1/11.24$; (3) the middle zone extending from $Y/\text{FHRAD} = 1/11.24$ to $Y/\text{FHRAD} = 1/2.5$; and (4) the upper zone extending from $Y/\text{FHRAD} = 1/2.5$ to the surface. (FDIAM is the median bed sediment diameter). The velocity profile is represented by the power relation:

$$U = (1 + \text{CNV}) * V * (Y/\text{FHRAD}) ** \text{CNV} \quad (22)$$

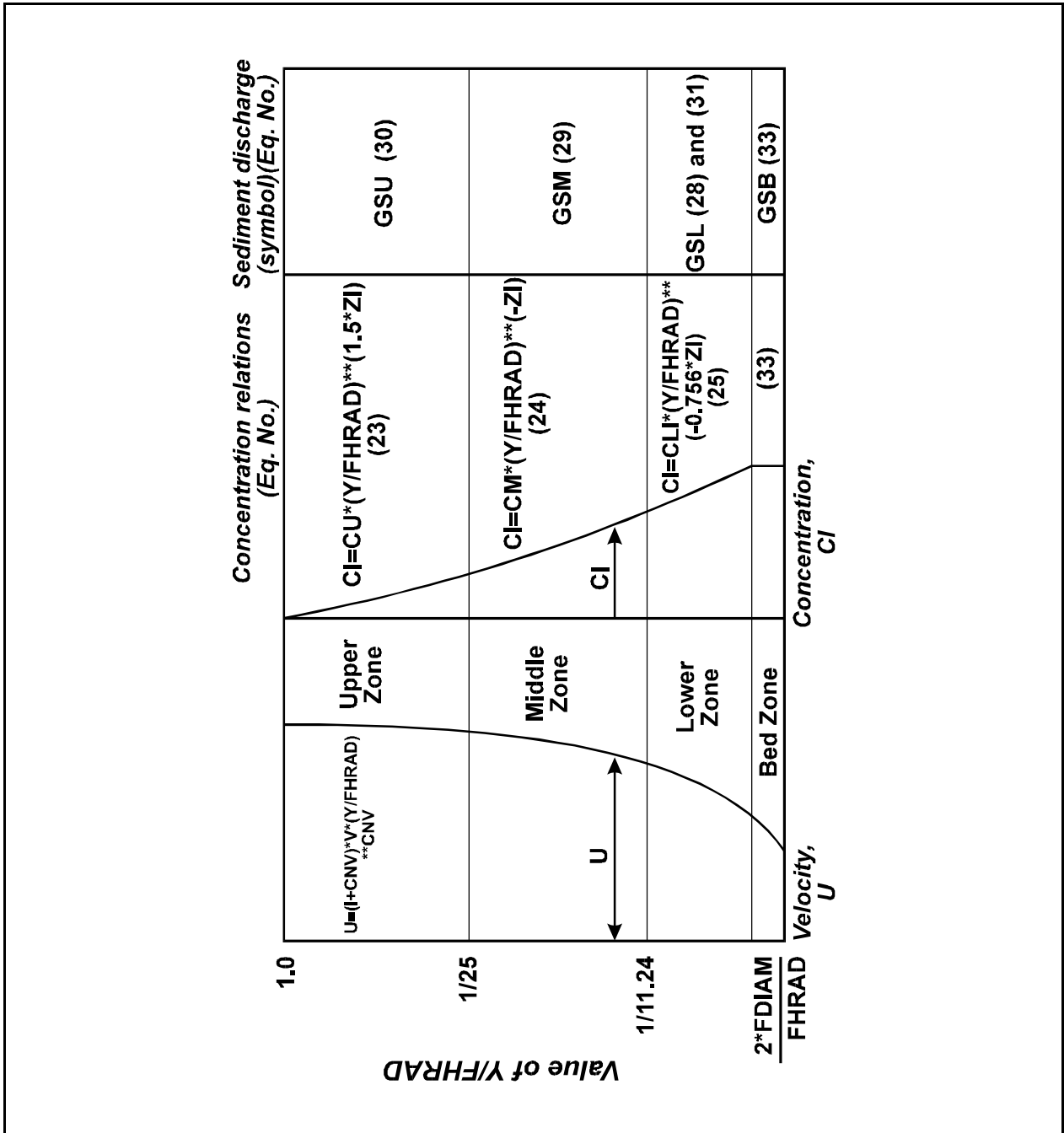


Figure 4.2(3).5-2 Toffaleti's velocity, concentration, and sediment discharge relations

where:

U = flow velocity at distance Y above the bed (ft/sec)
 V = mean stream velocity (ft/sec)
 CNV = exponent derived empirically as a function of water temperature ($0.1198 + 0.00048 \cdot \text{TMPR}$)
 TMPR = water temperature (degrees F)

The concentration distribution of sand is given by a power relation for each of the three upper zones; i.e., by Equations 23-25 in Figure 4.2(3).5-2. The exponent, ZI, in Equations 23-25 is given by:

$$\text{ZI} = (\text{VSET} \cdot \text{V}) / (\text{CZ} \cdot \text{FHRAD} \cdot \text{SLOPE}) \quad (26)$$

where:

VSET = settling velocity for sand (ft/s)
 SLOPE = slope of RCHRES (ft/ft)
 CZ = empirical factor derived as a function of water temperature ($260.67 - 0.667 \cdot \text{TMPR}$)

Expressions for the sand transport capacity of the lower (GSL), middle (GSM), and upper (GSU) zones are obtained by substituting U from Equation 22 and the appropriate value for sand particle concentration (CI) for each zone into the following equation and integrating between the vertical limits of the zone:

$$\text{GSI} = \text{INT} [\text{LLI to ULI}] (\text{CI} \cdot \text{Udy}) \quad (27)$$

where:

GSI = sand transport capacity for zone I
 INT = integral of function in () over limits in []
 ULI = depth Y at upper limit of zone I
 LLI = depth Y at lower limit of zone I
 CI = concentration of sand in zone I

The resulting equations for sand transport capacity in the three zones are:

$$\text{GSL} = \text{CMI} \cdot \left(\left(\frac{\text{HRAD}}{11.24} \right)^{1.0 + \text{CNV} - 0.758 \cdot \text{ZI}} - \left(2 \cdot \text{FDIAM} \right)^{1.0 + \text{CNV} - 0.756 \cdot \text{ZI}} \right) / (1.0 + \text{CNV} - 0.756 \cdot \text{ZI}) \quad (28)$$

$$\text{GSM} = \text{CMI} \cdot \left(\left(\frac{\text{HRAD}}{11.24} \right)^{0.244 \cdot \text{ZI}} \cdot \left(\frac{\text{HRAD}}{2.5} \right)^{1.0 + \text{CNV} - \text{ZI}} - \left(\frac{\text{HRAD}}{11.24} \right)^{1.0 + \text{CNV} - \text{ZI}} \right) / (1.0 + \text{CNV} - \text{ZI}) \quad (29)$$

$$\text{GSU} = \text{CMI} \cdot \left(\left(\frac{\text{HRAD}}{11.24} \right)^{0.244 \cdot \text{ZI}} \cdot \left(\frac{\text{HRAD}}{2.5} \right)^{0.5 \cdot \text{ZI}} \cdot \left(\frac{\text{HRAD}}{2.5} \right)^{1.0 + \text{CNV} - 1.5 \cdot \text{ZI}} - \left(\frac{\text{HRAD}}{11.24} \right)^{1.0 + \text{CNV} - 1.5 \cdot \text{ZI}} \right) / (1.0 + \text{CNV} - 1.5 \cdot \text{ZI}) \quad (30)$$

in which

$$\text{CMI} = 43.2 \cdot \text{CLI} \cdot (1.0 + \text{CNV}) \cdot \text{V} \cdot \text{HRAD}^{0.758 \cdot \text{ZI} - \text{CNV}} \quad (31)$$

A value for CLI, the concentration of sand in the lower zone, can be obtained by setting the expression for GSL in Equation 28 equal to the following empirical expression and solving for CLI:

$$GSL = 0.6 / ((TT * AC * K4 / V^{**2})^{**1.67} * FDIAM / 0.00058)^{**1.67} \quad (32)$$

where:

- GSL = sand transport capacity
- TT = empirical factor derived as a function of water temperature ($1.10 * (0.051 + 0.00009 * T_{MPR})$)
- AC = empirical factor derived as a function of the kinematic viscosity of water (VIS) and shear velocity based on shear stress due to sand grain roughness (USTAR)
- K4 = empirical factor derived as a function of AC, slope of the RCHRES (SLOPE), and particle diameter for which 65% by weight of sediment is finer (D65).
- V = mean stream velocity (ft/sec)
- FDIAM = median bed sediment diameter (ft)

Values for factors AC and K4 are given in Figure 4.2(3).5-3. The dimensions of AC are such that GSL is expressed in tons per day per foot of width. Consequently, when CLI is evaluated and substituted back into Equations 28-30 the resulting units of sand transport capacity for all three zones are tons per day per foot of width.

Prior to calculation of sand transport capacity for the zones, Equation 25 is solved to be sure that the value for concentration at $Y=2*FDIAM$ does not exceed 100 lbs/ft³. If it does, the concentration at this depth is set equal to 100 lbs/ft³ and an adjusted value of CLI is calculated and used in Equations 28-30. The transport capacity of the final zone, the bed zone (Figure 4.2(3).5-2), is also determined using the adjusted value of CLI and the following equation:

$$GSB = CMI * (2 * FDIAM)^{**1.0 + CNV - 0.758 * ZI} \quad (33)$$

The total sand transport capacity (GSI) for the RCHRES is the sum of the transport capacities for the four zones:

$$GSI = GSB + GSL + GSM + GSU \quad (34)$$

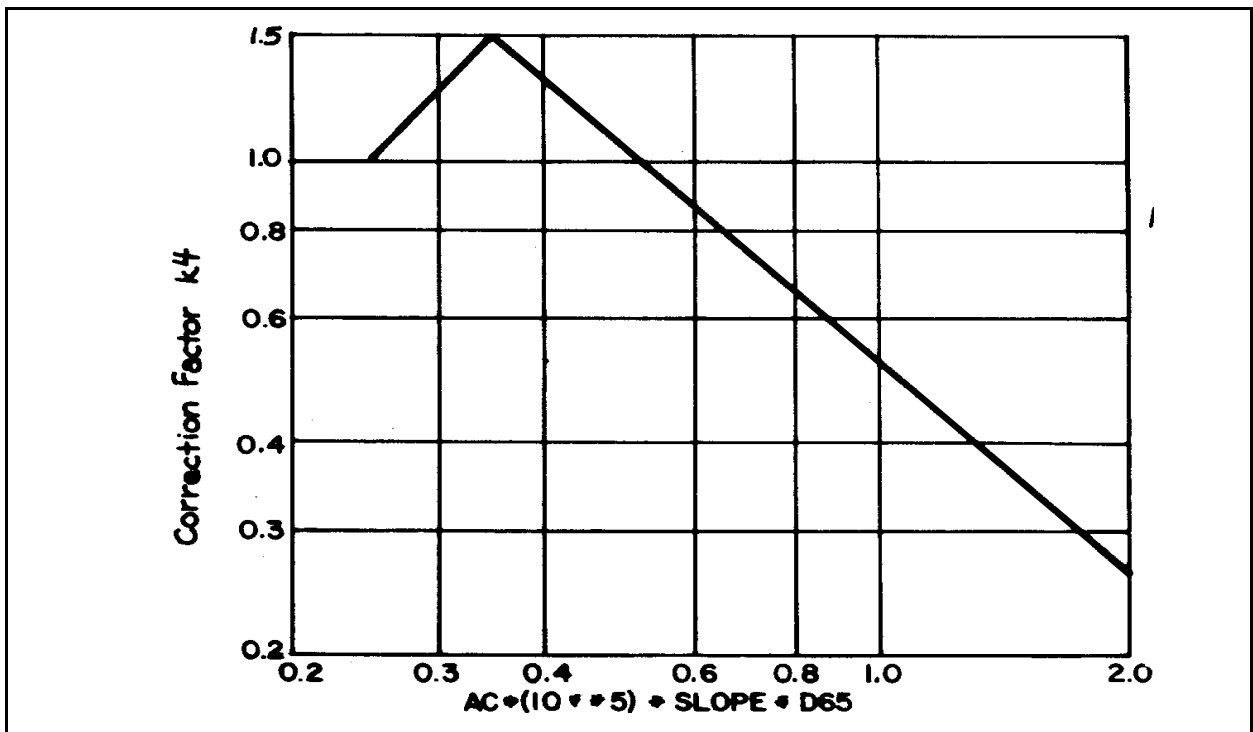
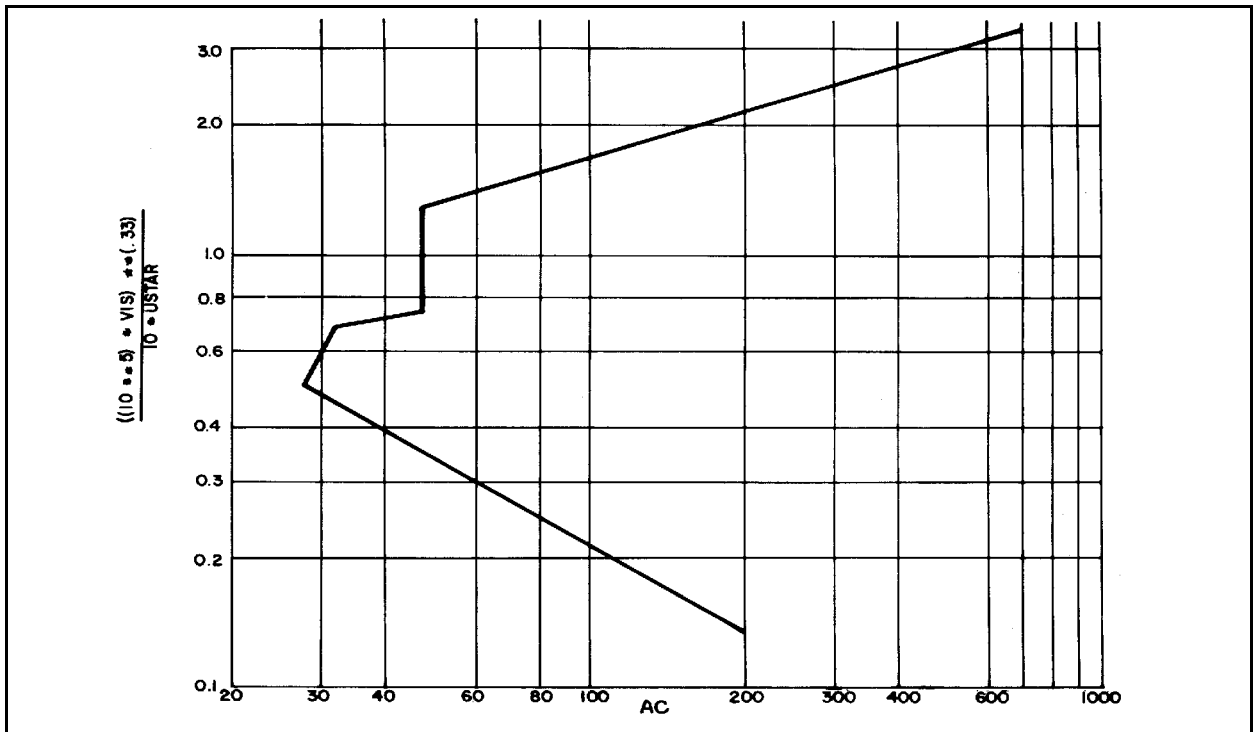


Figure 4.2(3).5-3 Factors in Toffaleti relations

4.2(3).5.2.2 Calculate Sand Transport Capacity by Using Colby's Method (subroutine COLBY)

Purpose

COLBY calculates the capacity of the RCHRES to transport sand based on the median bed sediment diameter (DB50), average stream velocity (V), hydraulic radius (HRAD), fine sediment load concentration (FSL), and water temperature (TEMPR).

Method

The solution technique used in this subroutine is based on empirical relationships developed from Figures 4.2(3).5-4 and 4.2(3).5-5. In general terms, the solution consists of three operations:

1. Obtain one value for sediment transport capacity from a matrix of values by interpolation. The dimensions of the matrix (G) are 4x8x6 and correspond to ranges of hydraulic radius, velocity, and mean diameter of bed sediment, respectively. Since Colby's curves were developed on a log-log scale, it is necessary to perform a series of three linear interpolations of logarithmic values to derive the value for sediment transport appropriate for the hydraulic parameters in the RCHRES. This value (GTUC) is not corrected for the effects of fine sediment concentration or water temperature.
2. Correct sand transport capacity value to account for water temperature in RCHRES. A multiplier is obtained from a matrix of values by interpolation. The dimensions of the matrix (T) are 7x4 and correspond to ranges of water temperature and hydraulic radius, respectively. A linear interpolation of logarithmic values is performed to derive the appropriate temperature correction factor. Generally speaking sand transport capacity, measured in tons per day per foot of stream width, decreases with increasing stream width (see Figure 4.2(3).5-5).
3. Correct sand transport capacity value to account for fine sediment load in RCHRES. A multiplier is obtained from a matrix of values by interpolation. The dimensions of the matrix (F) are 5x9 and correspond to ranges of fine sediment load concentration and hydraulic radius, respectively. Again, a linear interpolation of logarithmic values is performed to derive the appropriate correction factor. Sand transport capacity increases with increasing fine sediment load and with increasing stream width (Figure 4.2(3).5-5). It should be noted, however, that the correction factor is not large for typical stream conditions. For example, the multiplier corresponding to a fine sediment load of 10,000 ppm (with hydraulic radius of 1 foot) is 1.17.

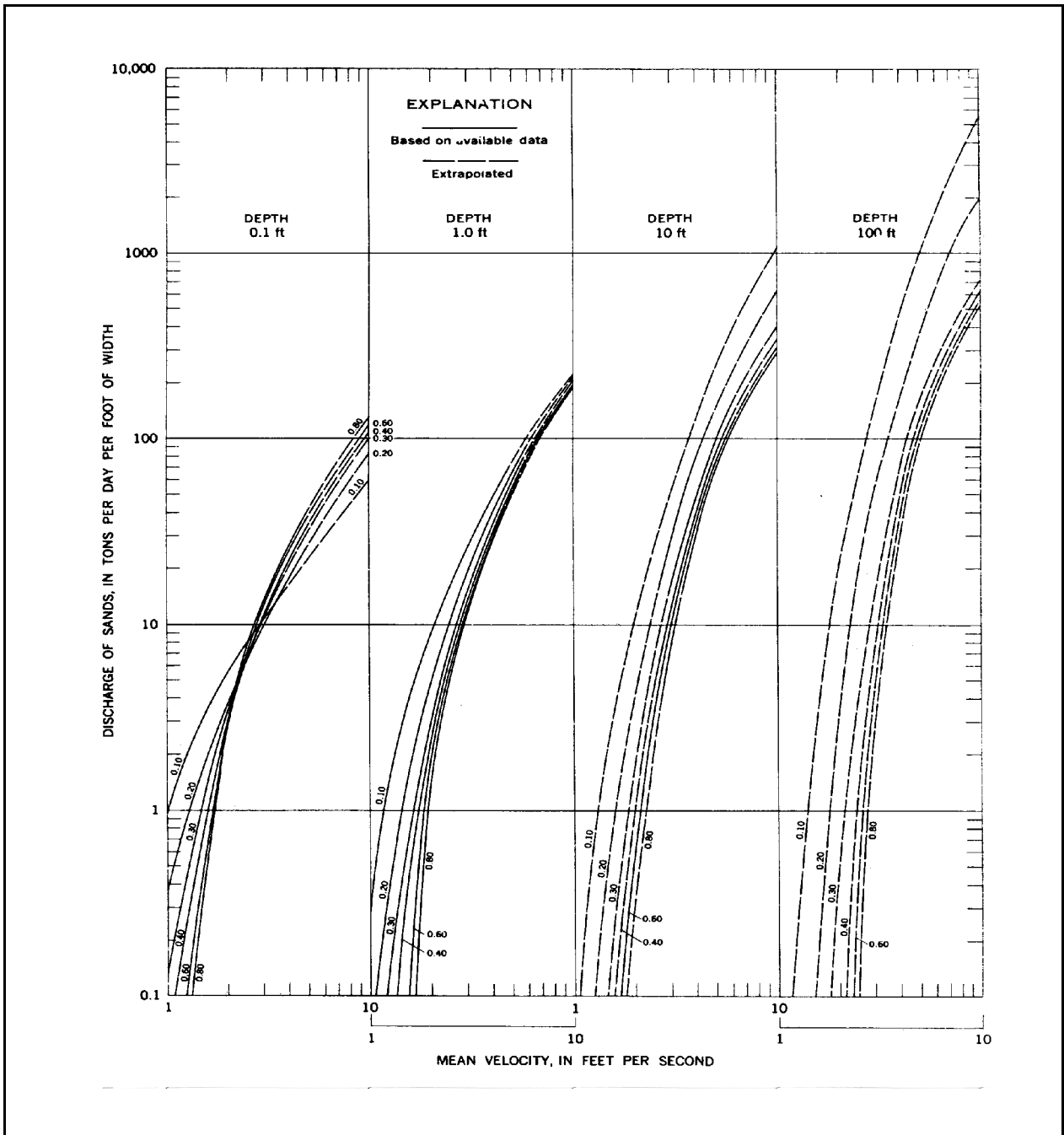


Figure 4.2(3).5-4 Colby's relationship for discharge of sands in terms of mean velocity for six median sizes of bed sands, four depths of flow, and water temperature of 60 F

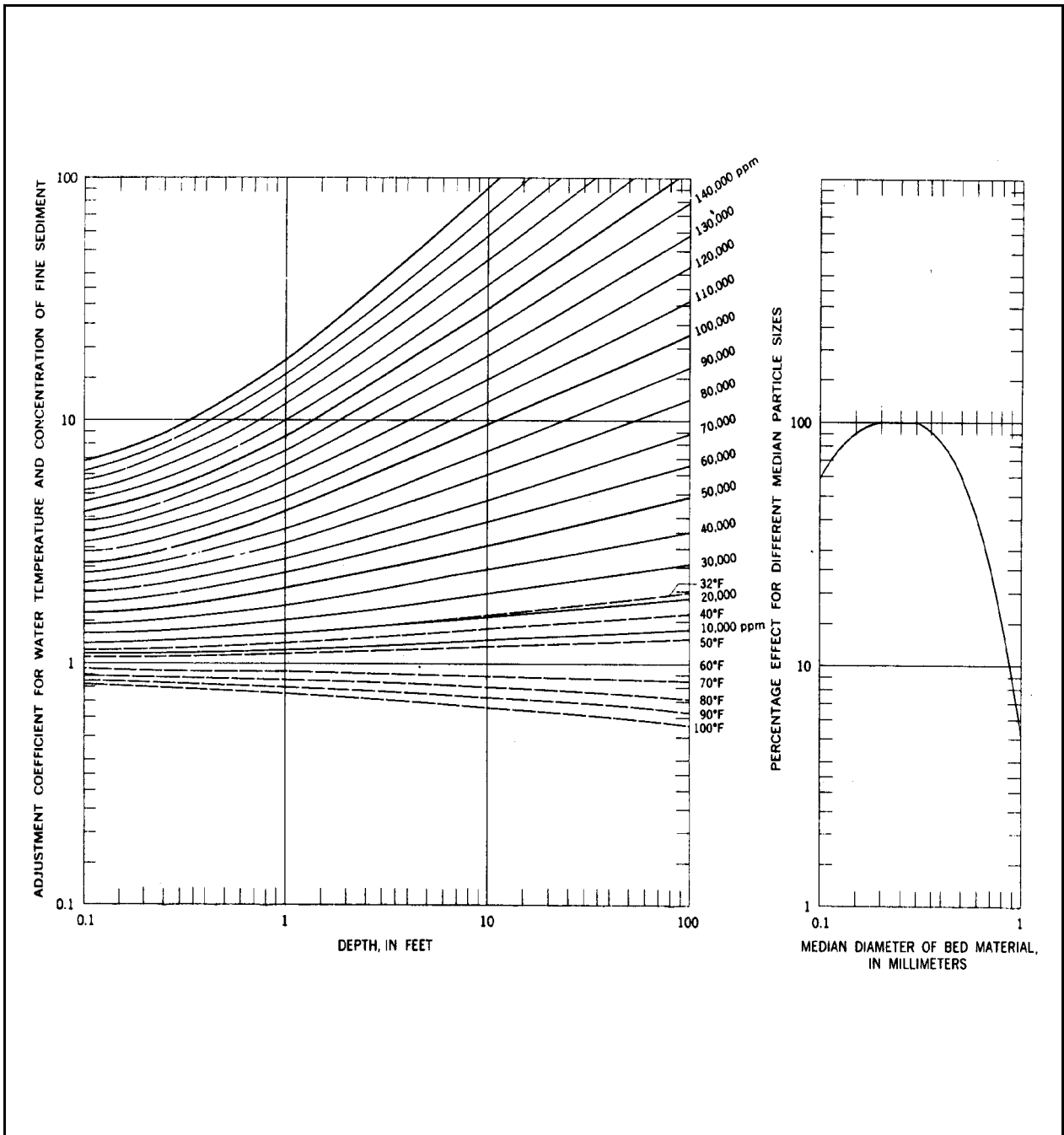


Figure 4.2(3).5-5 Colby's correction factors for effect of water temperature, concentration of fine sediment, and sediment size; applied to uncorrected discharge of sand given by Figure 4.2(3).5-4

The following additional comments are important to understanding and using the COLBY subroutine in HSPF:

1. Fine sediment load is defined as the sum of suspended silt and clay.
2. If the value for median bed sediment diameter, hydraulic radius, or average velocity for the RCHRES for a given simulation interval falls outside the range of values considered in Colby's graphs, a solution for sand transport capacity cannot be obtained by the Colby method. In this case, an error message is printed which specifies which parameter is out of range, and subroutine TOFFAL is automatically called to obtain a solution using the Toffaleti method.

Acceptable ranges of parameter values for COLBY are:

- | | |
|----------------------------------|---------------|
| (a) median bed sediment diameter | 0.1-0.8 mm |
| (b) hydraulic radius | 0.1-100 ft |
| (c) average velocity | 1.0-10.0 ft/s |

3. Both the Colby and Toffaleti formulations equate depth of flow to hydraulic radius. This approximation is best for wide rivers. Subroutines COLBY and TOFFAL were obtained and modified from Battelle Northwest Laboratories' SERATRA model (Onishi and Wise, 1979). In this model, the depth of flow values in Figures 4.2(3).5-4 and 4.2(3).5-5 are equated to hydraulic radius values, and the HSPF version of COLBY has done the same. To the best of our knowledge the accuracy of this approximation for narrow streams has not been documented.

4.2(3).6 Simulate the Behavior of a Generalized Quality Constituent (Module Section GQUAL)

Purpose

The purpose of this code is to enable the model user to simulate the behavior of a generalized constituent. The constituent which is modeled may be present in the RCHRES only in a dissolved state, or it may also be sediment-associated. If the generalized quality constituent, which will be called a "qual" throughout this discussion, is not associated with sediment, module section GQUAL only considers the following processes:

1. Advection of dissolved material
2. Decay processes. One or more of the following can be modeled:
 - a. hydrolysis
 - b. oxidation by free radical oxygen
 - c. photolysis
 - d. volatilization
 - e. biodegradation
 - f. generalized first-order decay
3. Production of one generalized quality constituent as a result of decay of another generalized quality constituent by any of the listed decay processes except volatilization. This capability is included to allow for situations in which the decay products of a chemical are of primary interest to the user.

The following additional processes are considered if the generalized quality constituent being modeled is sediment-associated:

4. Advection of adsorbed suspended material
5. Deposition and scour of adsorbed material with sediment
6. Decay of suspended and bed material
7. Adsorption/desorption between dissolved and sediment-associated phase.

Schematic View of Fluxes and Storage

Figure 4.2(3).6-1 illustrates the fluxes and storages modeled in section GQUAL. Note that the arrows indicating fluxes from each of the sediment fraction storages are not all labeled. For instance, although deposition and scour transfer materials between the suspended storage and bed storage of all three sediment fractions (sand, silt, clay), only the flux arrow for deposition/scour of clay is labeled. Deposition/scour flux arrows for sand and silt are left unlabeled so that the flow diagram does not become overly cluttered and incomprehensible. The same convention is used for the other fluxes contained in the flow diagram (i.e., an unlabeled flux arrow indicates that a flux of the same nature as a parallel labeled flux occurs).

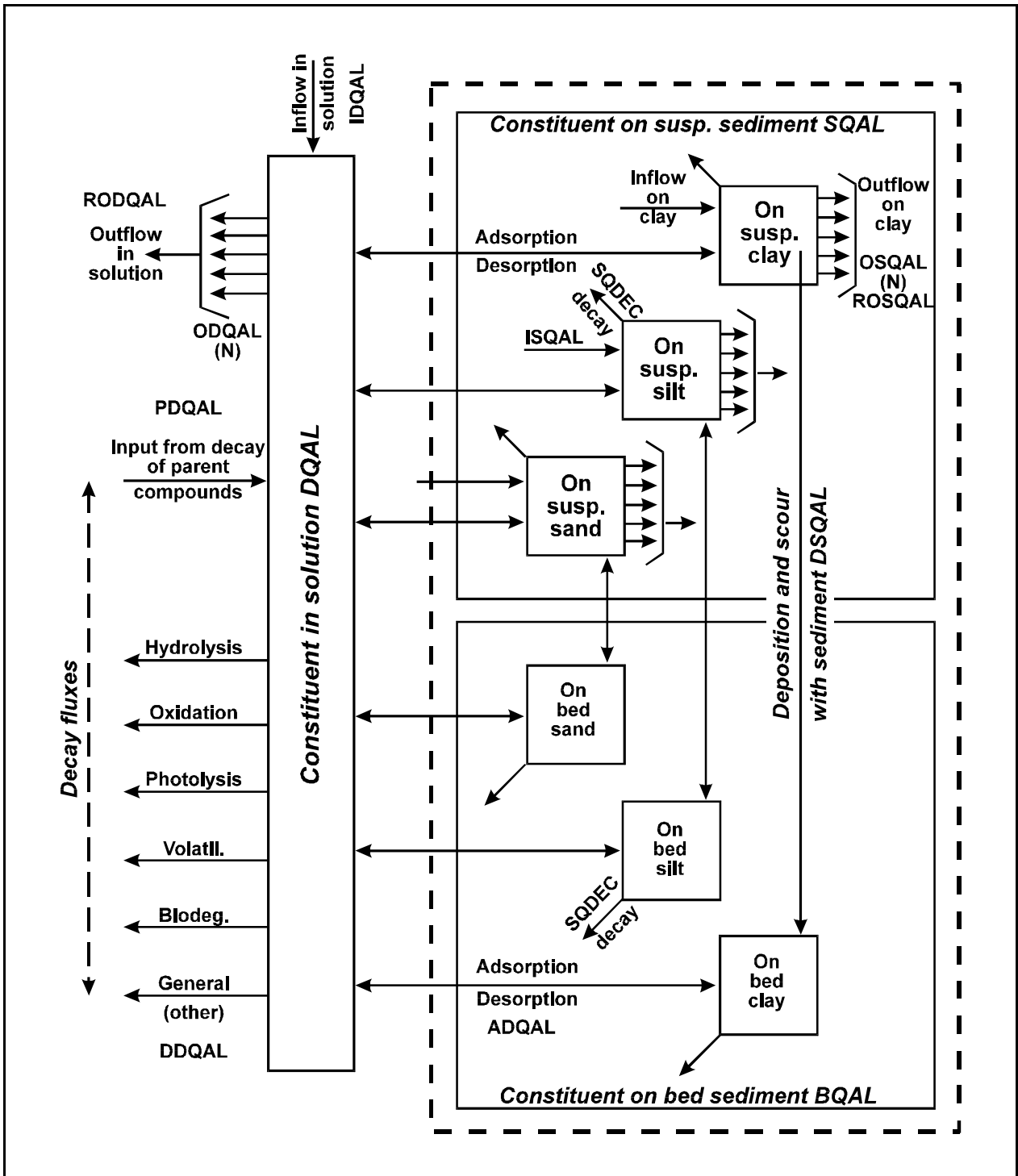


Figure 4.2(3).6-1 Flow diagram for generalized quality constituent in the GQUAL section of the RCHRES Application Module

Approach

The first portion of GQUAL evaluates the nature of the data which will be used for the GQUAL simulation. Since it is anticipated that some users of section GQUAL will be using this section independently of many of the other sections of the RCHRES application module, a variety of data types are allowed. In particular, most data required for simulation of individual decay processes can be supplied in the form of a single constant, 12 monthly constants, a time series value from the INPAD, or in cases where the data value is calculated in another active section of RCHRES, the last computed value may be used. Data types which may be obtained from any one of these sources include:

1. water temperature
2. pH (for hydrolysis)
3. free radical oxygen (for oxidation)
4. total suspended sediment (for photolysis)
5. phytoplankton (for photolysis)
6. cloud cover (for photolysis)
7. wind (for volatilization on lakes)

GQUAL utilizes six routines to perform the simulation of a generalized quality constituent. These six routines and their functions are:

1. OXREA: compute oxygen reaeration rate (used to simulate volatilization)
2. ADVECT: simulate advection of dissolved material
3. DDECAY: simulate decay of dissolved material
4. ADVQAL: advect sediment-associated material
5. ADECAY: simulate decay of qual adsorbed to suspended and bed sediment
6. ADSDES: simulate exchange of materials due to adsorption and desorption

Details on the methods used by these routines are provided in functional descriptions 4.2(3)3.1, 4.2(3).7.1.2, and 4.2(3).6.1 through 4.2(3).6.4, respectively.

Before ADVECT is called, GQUAL sums the inputs of dissolved qual from upstream reaches, tributary land areas, and atmospheric deposition:

$$\text{INDQAL} = \text{IDQAL} + \text{SAREA} * \text{ADFX} + \text{SAREA} * \text{PREC} * \text{ADCN} \quad (1)$$

where:

- INDQAL = total input of dissolved qual to reach
- IDQAL = input of dissolved qual from upstream reaches and tributary land
- SAREA = surface area of reach
- ADFX = dry or total atmospheric deposition flux in mass/area per interval
- PREC = precipitation depth
- ADCN = concentration for wet atmospheric deposition in mass/volume

Atmospheric deposition inputs can be specified in two possible ways depending on the form of the available data. If the deposition is in the form of a flux (mass per area per time), then it is considered "dry deposition". If the deposition is in the form of a concentration in rainfall, then it is considered "wet deposition", and the program automatically combines it with the input rainfall time series to compute the resulting flux. Either type of deposition data can be input as a time series, which covers the entire simulation period, or as a set of monthly values that is used for each year of the simulation. The specific atmospheric deposition time series are documented in the EXTNL table of the Time Series Catalog for RCHRES, and are specified in the EXT SOURCES block of the UCI. The monthly values are input in the MONTH-DATA block in the UCI.

GQUAL is also responsible for the calculation of increases in qual resulting from decay of a "parent" chemical. The HSPF code is designed so that a user may specify that a "daughter" chemical is produced by any or all of the six decay processes (except volatilization) which degrade a parent qual. However, certain restrictions are placed on the daughter/parent relationship. Simulation of up to three generalized quality constituents is allowed. Qual #2 may be produced by decay of qual #1. Qual #3 may be produced by decay of qual #1 and/or qual #2. Other relationships are not allowed. The user should sequence quality constituents accordingly. The amount of daughter qual produced by decay of a parent by a particular decay process is computed as:

$$PDQAL(I) = DDQAL(K,J)*C(I,J,K) \quad (1)$$

where:

PDQAL(I) = amount of daughter qual I produced by decay of parent qual J through process K (concu/l)*(ft3/ivl) or (concu/l)*(m3/ivl)
 DDQAL(K,J) = amount of parent material decayed by process K expressed in same units as PDQAL(I)
 C(I,J,K) = amount of qual I produced per unit of qual J degraded by process K in units of concu I/concu J

After the amount of decay resulting from all active decay processes and the amount of input of qual produced by decay of parent qual(s) have been calculated, the new dissolved concentration of a qual is computed as:

$$DQAL(I) = DQAL(I) + (PDQAL(I) - DDQAL(7,I))/VOL \quad (2)$$

where:

DQAL(I) = concentration of dissolved qual I
 PDQAL(I) = amount of qual I produced by decay of parent qual(s)
 DDQAL(7,I) = total amount of qual I degraded by the decay processes
 VOL = volume of water in the RCHRES

Additional Requirements

HSPF allows a maximum of 3 general quality constituents. The user selects the units for each constituent; thus, different constituents may have different units. For example, the user may simulate fecal and total coliforms expressed in organisms per ml and a pesticide expressed in milligrams per liter in the same simulation. In order to provide this flexibility, additional input is required. For each constituent the following information must be provided in the User's Control Input:

- GQID: the name of the constituent (up to 20 characters long)
- QTYID: this string (up to 8 characters) contains the units used to describe the quantity of constituent entering or leaving the RCHRES, and the total quantity of material stored in it. Examples of possible units for QTYID are 'Morg' for millions of organisms or 'lbs' for pounds
- CONCID: the concentration units for each decay constituent (up to 4 characters long); examples are '#' or 'mg'. It is implied that these units are "per l".
- CONV: conversion factor from QTYID/VOL to desired concentration units: $CONC = CONV * (QTY/VOL)$ (in English system, VOL is expressed in ft³; in metric system, VOL is expressed in m³)

For example, if:
 CONCID is mg/l,
 QTYID is kg, and
 VOL is m³,
 then $CONV = 1000$.

4.2(3).6.1 Simulate Decay of Dissolved Material (subroutine DDECAY)

Purpose

DDECAY simulates the degradation of generalized quality constituents by chemical and/or biological means. Six processes are considered:

1. hydrolysis
2. oxidation by free radical oxygen
3. photolysis
4. volatilization
5. biodegradation
6. generalized first-order decay

Discussion

HSPF includes detailed degradation methods only for the dissolved state of the quality constituent (qual); decay of qual material in the adsorbed state is handled by a lumped first-order decay function in subroutine ADECAY. Formulations of the degradation processes are based on studies conducted by Smith et al. (1977, 1979), Zepp and Cline (1977), Falco et al. (1976), and Mill et al. (1980). Most formulations are similar to those included in the SERATRA model (Onishi and Wise, 1979). All degradation processes modeled in DDECAY contain a temperature correction factor.

Methods

Hydrolysis

Hydrolysis is defined as any reaction that takes place in water, without the aid of light or microorganisms, in which a compound is transformed to a different compound as a result of reaction with water. The rate of change of dissolved qual concentration due to hydrolysis is sensitive to changes in pH and water temperature. In HSPF, the equation presented by Smith et al. (1977) is modified to include a temperature correction factor and rewritten as:

$$\text{KHYD} = (\text{KA} * 10.0^{**(-\text{PHVAL})} + \text{KB} * 10.0^{**(\text{PHVAL} - 14.0)} + \text{KN}) * \text{THHYD}^{**\text{TW20}} \quad (3)$$

where:

KHYD = hydrolysis rate constant for qual adjusted for pH and water temperature conditions of RCHRES
 KA = hydrolysis rate coefficient for qual in acidic solution (pH5)
 KB = hydrolysis rate coefficient for qual in basic solution (pH9)
 KN = hydrolysis rate coefficient for qual in neutral solution (pH7)
 PHVAL = pH of water in RCHRES
 THHYD = temperature correction parameter for hydrolysis
 TW20 = TW (water temperature in degrees C) - 20.0

The hydrolysis rate coefficients (KA, KB, KN) for a particular qual are determined by standard laboratory tests (ASTM, 1980). Depending on the availability of data and the needs of the model user, pH information for the hydrolysis equation can be supplied as (1) one constant value, (2) twelve monthly values, or (3) a time series. The time series can either be an input time series or the results of pH simulation if section RQUAL is active and pH is simulated.

Oxidation by Free Radical Oxygen

Two general types of oxidation reactions can be distinguished for evaluating chemical oxidation processes in an aquatic environment (Mill et al., 1980):

1. Reaction of an excited state of a molecule with oxygen, in which the excited state is produced by direct photolysis or by interaction with a photosensitizer; this process is termed photo-oxidation.

2. Reaction of the ground state of the chemical with oxidants in solution, in which the oxidants are formed by reactions of dissolved or suspended natural materials in solution; these reactions are termed thermal oxidation, autoxidation, or simply oxidation. The ultimate driving force for oxidant formation may, however, often be photochemical reactions of the natural materials.

In HSPF, photo-oxidation is considered as one of the photo-initiated degradation processes collectively labelled as photolysis. Consequently, only thermal oxidation is considered in the following formulation. The rate of oxidation of dissolved qual is expressed as a function of free radical oxygen concentration (ROC) and water temperature:

$$KROX = KOX * ROC * (THOX ** TW20) \quad (4)$$

where:

KROX = oxidation rate constant for qual adjusted for free radical oxygen concentration and water temperature
 KOX = base oxidation rate coefficient for qual
 ROC = free radical oxygen concentration (moles/l (M))
 THOX = temperature correction parameter for oxidation
 TW20 = TW (water temperature in degrees C) - 20.0

The oxidation rate coefficient (KOX) for a qual is determined from laboratory tests. Mill et al. (1980) cites two groups of oxidants which are likely to be important in natural waters: alkylperoxy radicals and singlet molecular oxygen. The overall free radical oxygen concentration can be specified by the user as a constant value, twelve monthly values, or a time series.

Photolysis

Photochemical transformation of chemicals can occur when energy in the form of light is absorbed by a molecule, placing it in an excited state from which reaction can occur. Direct photolysis of chemicals occurs when the chemical molecule itself absorbs light and undergoes reaction from its excited state. Indirect photolysis occurs when another chemical species, called a sensitizer, absorbs light and the sensitizer transfers energy from its excited state to another chemical, which then undergoes reaction. There are many types of photochemical reactions, including oxidation, reduction, hydrolysis, substitution, and rearrangement. In practice it is possible to measure the rate constant for photochemical reaction or a reaction quantum yield without knowing the types of reactions which are occurring (Mill et al., 1980). The formulation of photolysis developed for HSPF is intended to measure the net degradation of a generalized quality constituent which results from photochemical reactions.

The basic equation for rate of loss of a qual in dilute solution in an environmental water body due to absorbance of light of wavelength lambda is given by:

$$KPHOL = ((PHI * INLITL) / DEP) * FSLAM * FQLAM \quad (5)$$

where:

KPHOL = rate of loss of qual due to photolysis by light of wavelength lambda
 PHI = reaction quantum yield for photolysis of qual (moles/einstein)
 INLITL = incident light intensity of wavelength lambda (einsteins/cm2.day)
 DEP = depth of water
 FSLAM = fraction of light absorbed by the system
 FQLAM = fraction of absorbed light that is absorbed by qual

The solution technique outlined by Mill and implemented in HSPF uses seasonal day-averaged, 24-hour light intensity values (LLAM) for 18 wavelength intervals from 300 nm to 800 nm. In order to use these values, the relationship between the light intensity variable (INLITL) in Equation 5 and the tabulated values for LLAM must be defined. The relationship derived by Mill for relatively clear water or shallow depths can be written as:

$$\text{INLITL} = \text{LLAM}/2.3*\text{BETA} \quad (6)$$

where:

BETA = LLIT/DEP
 LLIT = path length of light through water
 DEP = depth of water

Further, the effects of cloud cover on light intensity are introduced by adding factor CLDLAM:

$$\text{INLITL} = (\text{LLAM}/2.3*\text{BETA})*\text{CLDLAM} \quad (7)$$

where:

CLDLAM = fraction of total light intensity of wavelength lambda which is not absorbed or scattered by clouds

CLDLAM is calculated as:

$$\text{CLDLAM} = (10.0 - \text{CC}*\text{KCLDL})/10.0 \quad (8)$$

where:

CC = cloud cover in tenths
 KCLDL = efficiency of cloud cover in intercepting light of wavelength lambda, a user supplied parameter (default value 0.0)

By substitution of Equation 7 into Equation 5, the general equation for the photolysis rate of a qual due to absorbance of light of wavelength lambda can be expressed as:

$$\text{KPHOL} = ((\text{PHI}*\text{LLAM}*\text{CLDLAM})/2.3*\text{BETA}*\text{DEP})*\text{FSLAM}*\text{FQLAM} \quad (9)$$

The general mathematical expression for the fraction of light absorbed by the water system (FSLAM) is:

$$\text{FSLAM} = 1.0 - 10^{**}(-\text{KLAM}*\text{LLIT}) \quad (10)$$

The exponential coefficient, KLAM, in this equation has two components for laboratory conditions:

$$KLAM = ALPHL + EPSLAM * C \quad (11)$$

where:

ALPHL = base absorbance term for light of wavelength lambda for the system (/cm)

EPSLAM = absorbance term for light of wavelength lambda absorbed by qual (l/mole.cm)

C = concentration of qual (moles/l)

For environmental systems, the effects of light absorbance by suspended sediment and phytoplankton are introduced to the formulation, and KLAM is expanded to:

$$KLAM = ALPHL + EPSLAM * C + GAMLAM * SED + DELLAM * PHYTO \quad (12)$$

where:

GAMLAM = absorbance term for light absorbed by suspended sediment (l/mg/cm)

SED = total suspended sediment (mg/l)

DELLAM = absorbance term for light absorbed by phytoplankton (l/mg/cm)

PHYTO = phytoplankton concentration (mg/l)

Because the concentration of qual is assumed small, the fraction of total absorbance of light in the water system resulting from absorbance by the qual is assumed negligible, and the term (EPSLAM*C) is dropped from Equation 12. By substituting the modified value of KLAM into Equation 9, setting LLIT = BETA*DEP (from Equation 6), and assuming that BETA = 1.2 (Mill, 1980), the final form of the expression for FSLAM is obtained:

$$FSLAM = 1.0 - 10^{**}(-1.2 * KLAM * DEP) \quad (13)$$

The remaining term of the general equation for photolysis (Equation 9) which must be evaluated is FQLAM, the fraction of total absorbed light that is absorbed by the qual. This term is evaluated as:

$$FQLAM = (EPSLAM * C) / KLAM \quad (14)$$

Equation 9 can be rewritten as:

$$PHOFXL = ((PHI * LLAM * CLDLAM) / 2.3 * BETA * DEP) * (1.0 - 10^{**}(-1.2 * KLAM * DEP)) * (EPSLAM * C / KLAM) \quad (15)$$

To obtain the rate of loss of qual due to photolysis from absorption of light of all wavelength intervals, Equation 15 must be summed over LLAM:

$$KPHO = (PHI / (2.76 * DEP)) * (SUM [1 to 18] ((LLAM * CLDLAM * EPSLAM / KLAM) * (1.0 - EXP(-2.76 * KLAM * DEP))) \quad (16)$$

The equation for the degradation rate due to photolysis used in HSPF is further complicated by correction factors for surface shading and water temperature. The final rearranged and expanded formulation is:

$$KPHO = (CF*DELT60/24.)*PHI*(SUM [1 to 18] ((LLAM*CLDLAM/2.76*KLAM*DEP)*(1.0 - EXP(-2.76*KLAM*DEP))*EPSLAM))*THPHO**TW20 \quad (17)$$

where:

SUM = summation of function in () over limits in []
 CF = factor accounting for surface shading
 DELT60/24 = conversion from day to interval
 THPHO = temperature correction parameter for photolysis
 TW20 = TW (water temperature in degrees C) - 20.0

For simulation intervals of less than 24 hours, photolysis is assumed to occur only between 6:00 AM and 6:00 PM during approximate daylight hours. In order to obtain a solution which is reasonably consistent with the input seasonal, day-averaged, 24-hour light intensity values, the daily light intensity is assumed to be uniformly distributed over the 12 hours from 6:00 AM to 6:00 PM. Consequently, calculated photolysis rates are doubled during daylight hours and set equal to zero for non-daylight hours. It should be noted that five look-up tables for solar intensity values (LLAM) are incorporated into HSPF. Tables 4.2(3).6-1 through 4.2(3).6-5 show the values for seasonal day-averaged, 24 hour light intensity at 10, 20, 30, 40, and 50 degrees latitude. The Run Interpreter checks the input latitude for the study area and selects the appropriate table from which to extract values. Additional input required to simulate photolysis in subroutine DDECAY include:

1. Molar absorption coefficients for each of the 18 wavelengths
2. Reaction quantum yield for qual (PHI)
3. Temperature correction parameter for photolysis (THPHO)
4. 18 values for base absorbance term for water system (ALPHL)
5. 18 values for absorbance for light absorbed by suspended sediment (GAMLAM)
6. 18 values for absorbance for light absorbed by phytoplankton (DELLAM)
7. Cloud cover values. Either a time series or 12 monthly values may be supplied.
8. Total suspended sediment values. Either a time series or 12 monthly values.
9. Phytoplankton values. Either a time series or 12 monthly.

Table 4.2(3).6-1 Solar Intensity Values for Latitude 10 N

Wavelength, Nanometers	Solar Intensity, milli-einsteins/cm ² /day			
	Spring	Summer	Fall	Winter
300	1.02E-2	4.66E-4	4.19E-4	3.20E-4
303.75	1.78E-2	3.16E-3	2.87E-3	2.39E-3
308.75	2.85E-2	9.37E-3	8.51E-3	7.26E-3
313.75	3.27E-2	1.90E-2	1.73E-3	1.51E-2
318.75	4.18E-2	2.91E-2	2.66E-2	2.38E-2
323.1	3.70E-2	2.65E-2	2.91E-2	2.36E-2
346	3.39E-1	3.29E-1	2.99E-1	2.92E-1
370	4.33E-1	4.38E-1	3.85E-1	3.44E-1
400	8.40E-1	8.37E-1	7.64E-1	6.96E-1
430	1.16	1.17	1.07	9.80E-1
460	1.47	1.47	1.36	1.23
490	1.50	1.50	1.37	1.27
536.25	2.74	2.69	2.46	2.26
587.5	2.90	2.79	2.52	2.35
637.5	2.90	2.80	2.60	2.43
687.5	2.80	2.80	2.60	2.30
756	2.70	2.70	2.50	2.40
800	3.00	2.50	2.30	2.10

Table 4.2(3).6-2 Solar Intensity Values for Latitude 20 N

Wavelength, Nanometers	Solar Intensity, milli-einsteins/cm ² /day			
	Spring	Summer	Fall	Winter
300	3.51E-4	4.44E-4	2.74E-4	1.47E-4
303.75	2.51E-3	3.15E-3	2.20E-3	1.47E-3
308.75	8.09E-3	9.61E-3	6.89E-3	5.34E-3
313.75	1.81E-2	1.97E-2	1.48E-2	1.15E-2
318.75	2.82E-2	3.02E-2	2.33E-2	1.88E-2
323.1	2.83E-2	3.03E-2	2.33E-2	1.88E-2
340	3.29E-1	3.47E-1	2.68E-1	2.21E-1
370	4.24E-1	4.47E-1	3.45E-1	2.86E-1
406	8.41E-1	8.83E-1	6.96E-1	5.97E-1
430	1.17	1.23	9.80E-1	8.40E-1
460	1.47	1.55	1.24	1.06
490	1.50	1.58	1.26	1.09
536.25	2.68	2.81	2.30	1.95
587.5	2.80	2.96	2.35	2.03
637.5	2.80	2.90	2.42	2.07
687.5	2.80	3.00	2.40	2.10
750	2.76	2.80	2.20	2.36
800	2.50	2.70	2.26	1.60

Table 4.2(3).6-3 Solar Intensity Values for Latitude 30 N

Wavelength, Nanometers	Solar Intensity, milli-einsteins/cm ² /day			
	Spring	Summer	Fall	Winter
300	2.30E-4	3.65E-4	1.35E-4	4.10E-5
303.75	2.13E-3	2.32E-3	1.44E-3	6.50E-4
308.73	7.26E-3	9.02E-3	4.84E-3	2.76E-3
313.75	1.65E-2	1.92E-2	1.16E-2	7.55E-3
318.75	2.64E-2	3.02E-2	1.89E-2	1.31E-2
323.1	2.69E-2	3.04E-2	2.30E-2	1.34E-2
340	3.20E-1	3.74E-1	2.23E-1	1.70E-1
370	4.14E-1	4.37E-1	2.84E-1	2.19E-1
400	8.27E-1	9.07E-1	6.23E-1	4.75E-1
430	1.15	1.34	8.50E-1	6.69E-1
460	1.45	1.59	1.09	8.50E-1
490	1.48	1.62	1.11	8.80E-1
536.25	2.64	2.89	2.00	1.57
587.5	2.74	3.03	2.07	1.63
637.5	2.76	3.00	2.09	1.67
687.5	2.80	3.00	2.10	1.73
750	2.70	2.90	2.10	1.63
800	2.50	2.80	1.90	1.60

Table 4.2(3).6-4 Solar Intensity Values for Latitude 40 N

Wavelength, Nanometers	Solar Intensity, milli-einsteins/cm ² /day			
	Spring	Summer	Fall	Winter
300	1.09E-4	2.49E-4	1.09E-4	5.38E-6
303.75	1.37E-3	2.32E-3	1.37E-3	1.56E-4
308.75	2.96E-3	7.93E-3	5.35E-3	1.02E-3
313.75	7.99E-3	1.81E-2	1.38E-2	3.79E-3
318.75	1.38E-2	2.91E-2	2.319E-2	7.53E-3
323.1	1.42E-2	2.97E-2	2.39E-2	8.10E-3
340	1.78E-1	3.54E-1	1.08E-1	7.52E-2
370	2.30E-1	4.58E-1	3.84E-1	1.47E-1
400	5.26E-1	9.71E-1	7.91E-1	3.38E-1
430	6.76E-1	1.28	1.11	4.80E-1
460	8.90E-1	1.43	1.39	6.10E-1
490	9.23E-1	1.63	1.42	6.20E-1
536.25	1.69	2.92	2.52	1.12
587.5	1.73	3.05	2.62	1.16
637.5	1.78	3.00	2.60	1.19
687.5	1.50	3.10	4.70	1.39
750	1.70	2.90	2.60	1.20
800	1.60	2.90	2.50	1.16

Table 4.2(3).6-5 Solar Intensity Values for Latitude 50 N

Wavelength, Nanometers	Solar Intensity, milli-einsteins/cm ² /day			
	Spring	Summer	Fall	Winter
300	3.71E-5	7.88E-6	1.52E-4	4.00E-7
303.75	7.10E-4	1.75E-3	2.25E-4	1.57E-5
308.75	3.55E-3	6.53E-3	1.29E-3	1.78E-4
313.75	7.30E-3	1.63E-2	4.39E-3	1.20E-3
318.75	1.84E-3	2.67E-2	8.64E-3	2.93E-3
323.1	1.96E-2	2.77E-2	9.20E-3	3.68E-3
340	2.66E-1	3.43E-1	1.24E-1	6.29E-2
370	3.48E-1	4.44E-1	1.66E-1	8.21E-2
400	7.24E-1	9.04E-1	3.65E-1	1.96E-1
430	1.02	1.26	5.17E-1	2.75E-1
460	1.29	1.60	6.60E-1	3.51E-1
470	1.32	1.63	6.80E-1	3.55E-1
536.25	2.34	2.90	1.22	6.30E-1
587.5	2.40	3.04	1.25	6.40E-1
637.5	2.44	3.00	1.31	6.90E-1
687.5	2.50	3.10	1.34	7.10E-1
750	2.50	2.90	1.31	7.10E-1
800	2.30	2.90	1.24	6.90E-1

Volatilization

Volatilization of a chemical that is dissolved in water is defined as the transport of the chemical from the water to the atmosphere. The concentration of the chemical in water decreases even though a transformation does not occur. Thus, volatilization is not a degradation process in the strict sense, since the chemical which leaves a water body by volatilization is not biologically or chemically degraded. Current evidence suggests that volatilization is likely to be the major aquatic fate of low molecular weight, nonpolar compounds that are not rapidly biodegraded or chemically transformed. Volatilization rates of higher molecular weight compounds can also be significant under certain conditions (Smith, 1979).

In HSPF, the volatilization rate of a qual is tied to the oxygen reaeration coefficient:

$$KVOL = KOREA * CFGAS \quad (18)$$

where:

KVOL = rate of loss of qual from water due to volatilization
 KOREA = oxygen reaeration coefficient calculated by subroutine OXREA
 CFGAS = ratio of volatilization rate of qual to oxygen reaeration rate, an input parameter.

The value for input parameter CFGAS can be determined as the ratio of the molecular diameter of oxygen to the molecular diameter of the qual.

Biodegradation

Biodegradation is one of the most important processes for transformation of chemical compounds when they enter natural environments. Many organic chemicals are used by living cells for carbon and energy sources. Microorganisms metabolize a wide variety of organic compounds, including many man-made chemicals (Chou, 1980). The rate of biodegradation of a dissolved qual is expressed as a function of the concentration of biomass which degrades the qual (BIO) and water temperature:

$$KBIO = KBMASS * BIO * (THBIO ** TW20) \quad (19)$$

where:

KBIO = biodegradation rate constant for qual adjusted for biomass concentration and water temperature
 BIOCON = base biodegradation rate coefficient for qual
 BIO = concentration of biomass that is involved in qual degradation
 THBIO = temperature correction parameter for biodegradation
 TW20 = TW (water temperature in degrees C) - 20.0

Biomass data may be supplied as a constant, 12 monthly values, or a time series. HSPF allows for the fact that a different population of microorganisms can be involved in the biodegradation of each different generalized quality constituent by requiring the user to specify a unique set of biomass data for each constituent which is simulated.

Generalized First-order Decay

Generalized first-order decay of dissolved qual may be simulated in addition to, or instead of, the individual decay processes outlined above. The equation used to calculate rate of decay is:

$$KGEN = KGEND * THGEN ** TW20 \quad (20)$$

where:

KGEN = generalized first-order decay rate for a qual
corrected for temperature
KGEND = base first-order decay rate for a qual
THGEN = temperature correction parameter for first-order decay

After decay rates for all of the processes which are active for a qual have been calculated, they are summed to determine a total decay rate. At this point the total loss of qual material resulting from decay is evaluated:

$$DDQALT = DQAL * (1.0 - \text{EXP}(-KTOTD)) * VOL \quad (21)$$

where:

DDQALT = loss of qual due to all forms of degradation,
expressed in (concu/l)*(ft³/ivl) or (concu/l)*(m³/ivl)
DQAL = concentration of dissolved qual (concu/l)
KTOTD = total decay rate of qual per interval
VOL = volume of water in the RCHRES

Finally, to determine the amount of material degraded by each individual process, a linear proration is performed based on the total decay of material:

$$DDQAL(I) = (K(I)/KTOTD) * DDQALT \quad (22)$$

where:

DDQAL(I) = loss of qual due to decay by process I, expressed
in (concu/l)*(ft³/ivl) or (concu/l)*(m³/ivl)
K(I) = decay rate due to process I (/ivl)

4.2(3).6.2 Simulate Advection of Material on Sediment (subroutine ADVQAL)

Purpose

ADVQAL simulates the advective processes for the quality constituent attached to one sediment size fraction. Processes handled in this subroutine include:

1. Inflow to the RCHRES of qual attached to suspended sediment.
2. Migration of qual from suspension in the water to the bed as a result of deposition of the sediment to which the qual is adsorbed.
3. Migration of qual from the bed into suspension in the water as a result of scour of the bed sediments to which the qual is adsorbed.
4. Outflow from the RCHRES of qual attached to suspended sediment.

Method

The movement of adsorbed qual is completely determined by the movement of the sediment to which it is attached. All fluxes of adsorbed qual are expressed as the product of the flux of a sediment fraction (sand, silt, or clay) and the concentration of qual associated with that fraction (expressed in concu per mg of sediment). Likewise, storages of adsorbed qual are expressed as the product of the sediment fraction storage and the associated concentration of qual. A simplified flow diagram of sediment and associated qual fluxes and storages is provided in Figure 4.2(3).6-2 to facilitate the following discussion. Note that ADVQAL is designed to operate on one sediment fraction and one qual each time it is called by GQUAL.

If the sediment simulation in module section SEDTRN indicates that scour of bed storage of a sediment fraction occurs, the following actions are taken in ADVQAL:

1. Bed storage of adsorbed qual is updated.
2. Flux of qual from bed to suspension (DSQAL) is set equal to the bed storage of the qual (BQAL) if the entire bed storage of the sediment fraction is scoured.
3. If only part of the bed storage of the sediment fraction is scoured, the flux of qual from bed to suspension is calculated as:

$$DSQAL = BQAL * DEPSCR \quad (23)$$

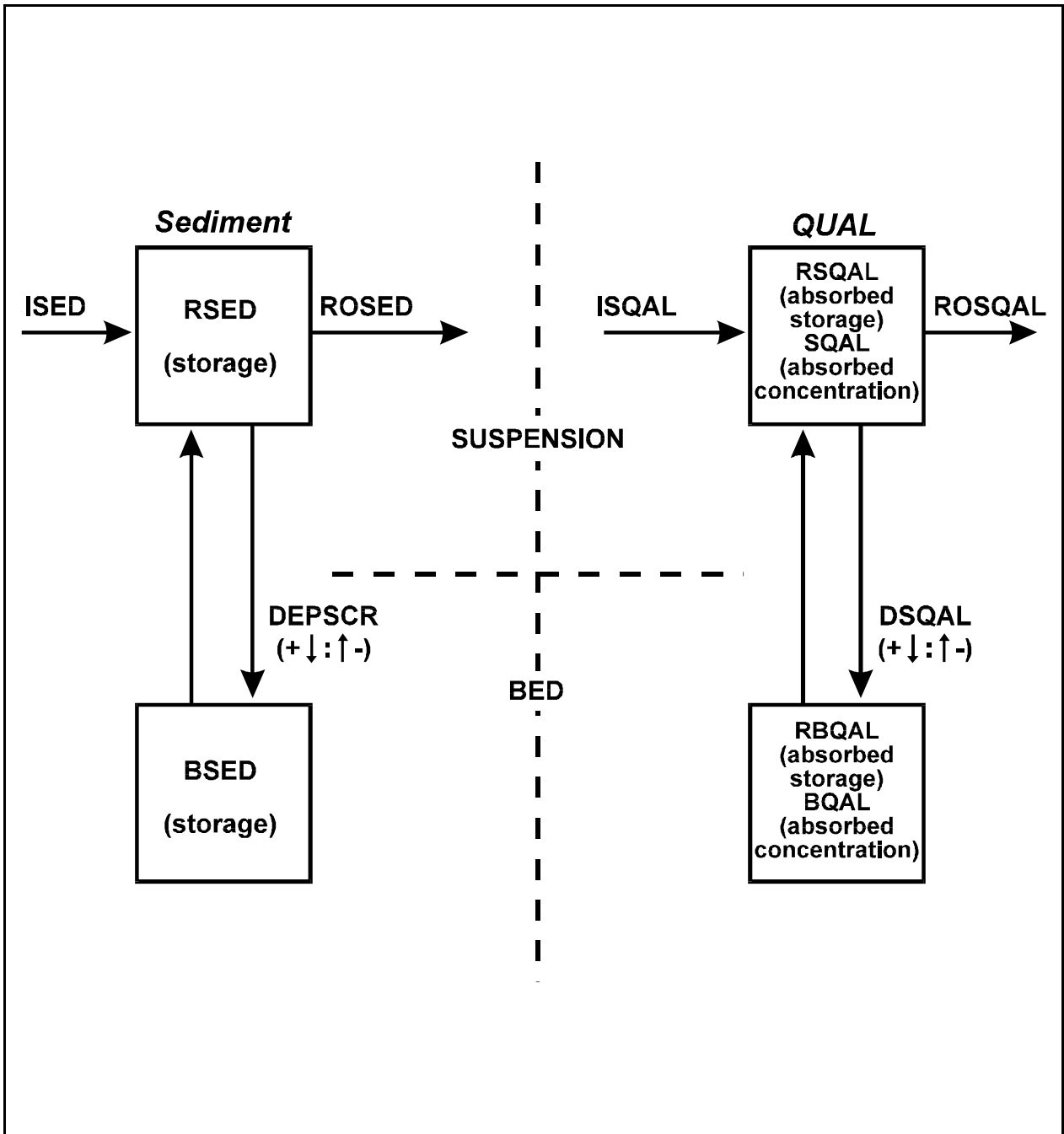


Figure 4.2(3).6-2 Simplified flow diagram for important fluxes and storages of sediment and associated qual used in subroutine ADVQAL

where:

DSQAL = amount of qual scoured from bed and added to suspension
 expressed in (concu/l)*(ft3/ivl) or (concu/l)*(m3/ivl)
 BQAL = concentration of qual on bed sediment fraction
 under consideration in concu/mg sediment
 DEPSCR = amount of sediment fraction which is scoured from
 the bed expressed in mg.ft3/l.ivl or mg.m3/l.ivl

4. Concentration of adsorbed qual in suspension is updated to account for scour:

$$SQAL = (ISQAL + RSQALS - DSQAL)/(RSED + ROSED) \quad (24)$$

where:

SQAL = concentration of adsorbed qual in suspension
 expressed as concu/mg suspended sediment fraction
 ISQAL = inflow of qual to the RCHRES as a result of inflowing sediment
 fraction, expressed as (concu/l)*(ft3/ivl) or (concu/l)*(m3/ivl)
 RSQALS = storage of qual on suspended sediment fraction
 expressed in (concu/l)*ft3 or (concu/l)*m3
 RSED = amount of sediment fraction in suspension at end of interval
 expressed in mg.ft3/l or mg.m3/l
 ROSED = amount of sediment fraction contained in outflow from the RCHRES
 during the interval expressed in mg.ft3/l.ivl or mg.m3/l.ivl

5. Amount of qual leaving the RCHRES as outflow is determined as:

$$ROSQAL = ROSED * SQAL \quad (25)$$

If the sediment simulation in module section SEDTRN indicates that deposition of suspended sediment occurs, ADVQAL performs the following operations:

1. Concentration of qual on total suspended sediment fraction (inflow + suspended storage) for the RCHRES is calculated:

$$SQAL = (ISQAL + RSQALS)/(RSED + DEPSCR + ROSED) \quad (26)$$

2. Amount of qual leaving the RCHRES due to outflow of sediment fraction is determined:

$$ROSQAL = ROSED * SQAL \quad (27)$$

3. Amount of qual leaving suspension due to deposition of the sediment to which it is adsorbed is found by:

$$DSQAL = DEPSCR * SQAL \quad (28)$$

4. The concentration of qual on sediment in suspension is set equal to zero if the suspended storage of sediment is zero.
5. The concentration of qual on bed sediment is set equal to zero if the storage of bed sediment at the end of the interval is zero.
6. If there is bed sediment at the end of the interval, the bed storage of qual associated with the sediment fraction is calculated as:

$$RBQAL = DSQAL + RBQALS \quad (29)$$

7. The concentration of qual on bed sediment is determined:

$$BQAL = RBQAL/BSED \quad (30)$$

where:

BSED = storage of sediment fraction (sand, silt, or clay)
in the bed, expressed as mg.ft³/l or mg.m³/l

The final operation which ADVQAL performs is the computation of outflow of adsorbed qual through individual exits (when more than one exit is specified). The algorithm is:

$$OSQAL(I) = ROSQAL*OSED(I)/ROSED \quad (31)$$

where:

OSQAL(I) = outflow of adsorbed qual through exit gate I
ROSQAL = total outflow of adsorbed qual from RCHRES
OSED(I) = outflow of sediment fraction through exit gate I

4.2(3).6.3 Simulate Decay of Adsorbed Material (subroutine ADECAY)

Purpose

ADECAY is a generalized subroutine which calculates the amount of decay experienced by a generalized quality constituent (qual) adsorbed to inorganic sediment. This subroutine is called twice (once for decay on suspended sediment and once for decay on bed sediment) for each generalized quality constituent which is sediment-associated. (The user specifies that a qual is sediment-associated by setting QALFG(7)=1 for the qual in the User's Control Input.) HSPF assumes that the decay rate of a particular adsorbed qual is the same for all fractions of sediment (sand, silt, and clay), but may be different for suspended sediment than it is for bed sediment.

Method

Necessary information which must be supplied to the subroutine includes:

1. ADDCPM(1) - decay rate for qual on sediment being considered (suspended or bed)
2. ADDCPM(2) - temperature correction coefficient for decay
3. RSED(1-3) - the storage of each sediment fraction expressed in mg.ft3/l or mg.m3/l (for either suspended or bed sediment)
4. SQAL(1-3) - the concentration of qual associated with the 3 fractions of sediment (concu/mg)

First, the temperature-adjusted decay rate is calculated:

$$DK = \text{ADDCPM}(1) * \text{ADDCPM}(2) ** \text{TW20} \quad (32)$$

where:

$$\text{TW20} = \text{TW (water temperature)} - 20.0 \text{ in degrees C.}$$

Next, the fraction of adsorbed qual which decays during the simulation interval (FACT) is calculated using the general form for first-order decay:

$$\text{FACT} = 1.0 - \text{EXP}(-DK) \quad (33)$$

The concentration of qual decayed from each sediment fraction (DCONC) is determined, and the concentration of qual associated with each fraction is updated:

$$\text{DCONC} = \text{SQAL}(I) * \text{FACT} \quad (34)$$

$$\text{SQAL}(I) = \text{SQAL}(I) - \text{DCONC} \quad (35)$$

Finally, the mass of qual decayed from each sediment fraction is calculated:

$$\text{SQDEC}(I) = \text{DCONC} * \text{RSED}(I) \quad (36)$$

where:

$\text{SQDEC}(I)$ = amount of qual decayed from sediment fraction I expressed in (concu/l)*(ft3/ivl) or (concu/l)*(m3/ivl)

DCONC = concentration of qual decayed from sediment fraction (concu/mg)

$\text{RSED}(I)$ = storage of sediment fraction I (mg.ft3/l or mg.m3/l)

4.2(3).6.4 Simulate Adsorption/Desorption of a Generalized Quality Constituent (subroutine ADSDES)

Purpose

ADSDES simulates the exchange of a generalized quality constituent (qual) between the dissolved state and adsorbed state. Kinetic equilibrium between dissolved state and six adsorption sites is modeled: suspended sand, silt, and clay, and bed sand, silt, and clay.

Method

The basic equation (Onishi and Wise, 1979) for the transfer of a chemical between the dissolved state and an adsorbed state on sediment type J is:

$$-d(\text{RSEDJ} \cdot \text{SQALJ})/dt + \text{RSEDJ} \cdot \text{KJT} \cdot (\text{KDJ} \cdot \text{DQAL} - \text{SQALJ}) = 0 \quad (37)$$

where:

RSEDJ = total quantity of sediment type J in the RCHRES
(mg.ft³/l or mg.m³/l)
 SQALJ = concentration of qual on sediment type J (concu/mg)
 DQAL = concentration of dissolved qual (concu/l)
 KDJ = distribution coefficient between dissolved state and sediment type J (liters/mg) (adsorbed concentration/dissolved concentration)
 KJT = temperature corrected transfer rate between dissolved state and sediment type J

Thus, adsorption of a qual by sediment or desorption from sediment is assumed to occur toward an equilibrium condition with transfer rate KJT if the particulate qual concentration differs from its equilibrium value. Equation 37 is actually 6 equations (one for each sediment type J) with 7 unknowns (DQAL and 6 values of SQALJ). The necessary seventh equation is that of conservation of material. The following relation gives the total quantity of qual in the RCHRES, both before and after exchange due to adsorption/desorption:

$$\text{SUM [1 to 6]}(\text{RSEDJ} \cdot \text{SQALJ}) + \text{VOL} \cdot \text{DQAL} = \text{TOT} \quad (38)$$

where:

VOL = volume of water in the RCHRES

To solve numerically, Equation 37 is expressed in finite difference form:

$$\begin{aligned} & -\text{RSEDJ} \cdot (\text{SQALJ} - \text{SQALJO}) + \text{RSEDJ} \cdot \text{KJT} \cdot \text{KDJ} \cdot \text{DQAL} \cdot \text{DELT} \\ & - \text{RSEDJ} \cdot \text{KJT} \cdot \text{SQALJ} \cdot \text{DELT} = 0 \end{aligned} \quad (39)$$

where:

SQALJ = concentration of qual on sediment type J at end of simulation interval (subsequent to adsorption/desorption)
 SQALJO = concentration of qual on sediment type J at start of interval
 DELT = simulation time step

The product of the transfer rate for sediment type J and the simulation time step is calculated ($AKJ = KJT*DELTA$), and the resulting value is substituted into Equations 38 and 39. Two forms of Equation 38 are written. Equation 40 expresses conservation of material at the beginning of the simulation interval and Equation 41 expresses conservation of material at the end of the interval:

$$- \text{SUM [1 to 6]} ((RSEDJ*SQALJO) - \text{VOL}*DQALO) = -\text{TOT} \quad (40)$$

$$- \text{SUM [1 to 6]} ((RSEDJ*SQALJ) - \text{VOL}*DQAL) = -\text{TOT} \quad (41)$$

Equation 39 is rewritten as:

$$RSEDJ((1.0 + AKJ)/(AKJ*KDJ))*SQALJ - RSEDJ*DQAL = (RSEDJ*SQALJO)/(AKJ*KDJ) \quad (42)$$

Equations 41 and 42 can be written in matrix form and solved for unknowns SQALJ and DQAL using standard procedures such as Gaussian elimination or the Crout reduction. The solutions are:

$$DQAL = (\text{TOT} - \text{SUM [1 to 6]} (RSEDJ*CJ)/AJJ) / (\text{VOL} + \text{SUM [1 to 6]} (RSEDJ/AJJ)) \quad (43)$$

$$SQALJ = (CJ/AJJ) + (DQAL/AJJ) \quad (44)$$

where:

DQAL = concentration of dissolved qual after adsorption/desorption
 SQALJ = concentration of qual on sediment type J after adsorption/desorption
 AJJ = $(1 + AKJ)/(AKJ*KDJ)$
 CJ = $(SQALJO/AKJ*KDJ)$

By combining Equations 40 and 43, TOT can be eliminated, and a final solution for DQAL can be obtained:

$$DQAL = (\text{VOL}*DQALO + \text{SUM [1 to 6]} (SQALJO - CJ/AJJ)*RSEDJ) / (\text{VOL} + \text{SUM [1 to 6]} (RSEDJ/AJJ)) \quad (45)$$

In subroutine ADSDES, the following variables are used to facilitate the evaluation of Equations 44 and 45:

$$\text{AINVJ} = 1.0/AJJ = (AKJ*KDJ)/(1.0 + AKJ) \quad (46)$$

$$\text{CAINVJ} = CJ/AJJ = (SQALJO/(1.0 + AKJ)) \quad (47)$$

4.2(3).7 Simulate Constituents Involved in Biochemical Transformations
(Section RQUAL of Module RCHRES)

RQUAL is the parent routine to the four subroutine groups which simulate constituents involved in biochemical transformations. Within module section RQUAL the following constituents may be simulated:

dissolved oxygen
 biochemical oxygen demand
 ammonia
 nitrite
 nitrate
 orthophosphorus
 phytoplankton
 benthic algae
 zooplankton
 dead refractory organic nitrogen
 dead refractory organic phosphorus
 dead refractory organic carbon
 total inorganic carbon
 pH
 carbon dioxide

Four additional quantities are estimated from simulation of these constituents. These quantities are total organic nitrogen, total organic phosphorus, total organic carbon, and potential biochemical oxygen demand. The definition of these quantities is determined by their method of calculation:

$$\begin{aligned} \text{TORN} &= \text{ORN} + \text{CVBN} * (\text{ZOO} + \text{PHYTO} + \text{BOD} / \text{CVBO}) & (1) \\ \text{TORP} &= \text{ORP} + \text{CVBP} * (\text{ZOO} + \text{PHYTO} + \text{BOD} / \text{CVBO}) & (2) \\ \text{TORC} &= \text{ORC} + \text{CVBC} * (\text{ZOO} + \text{PHYTO} + \text{BOD} / \text{CVBO}) & (3) \\ \text{POTBOD} &= \text{BOD} + \text{CVNRBO} * (\text{ZOO} + \text{PHYTO}) & (4) \end{aligned}$$

where:

TORN = total organic nitrogen (mg N/l)
 TORP = total organic phosphorus (mg P/l)
 TORC = total organic carbon (mg C/l)
 POTBOD = potential BOD (mg O/l)
 ORN = dead refractory organic nitrogen (mg N/l)
 ORP = dead refractory organic phosphorus (mg P/l)
 ORC = dead refractory organic carbon (mg C/l)
 BOD = biochemical oxygen demand from dead nonrefractory organic materials (mg O/l)
 CVBN = conversion from mg biomass to mg nitrogen
 CVBP = conversion from mg biomass to mg phosphorus
 CVBC = conversion from mg biomass to mg carbon
 CVNRBO = conversion from mg biomass to mg biochemical oxygen demand (with allowance for non-refractory fraction)
 CVBO = conversion from mg biomass to mg oxygen
 ZOO = zooplankton (mg biomass/l)
 PHYTO = phytoplankton (mg biomass/l)

Subroutine RQUAL performs two tasks. First, RQUAL is responsible for calling the four subroutine groups which simulate the constituents listed above. These four groups and their functions are:

1. OXRX: simulate primary dissolved oxygen and biochemical oxygen demand balances
2. NUTRX: determine inorganic nitrogen and phosphorus balances
3. PLANK: simulate plankton populations and associated reactions
4. PHCARB: simulate pH and inorganic carbon species

The four groups are listed in their order of execution, and the execution of a group is dependent upon the execution of the groups listed above it. For example, subroutine group PHCARB cannot be activated unless OXRX, NUTRX, and PLANK are active. On the other hand, the reactions in OXRX can be performed without the reactions contained in the other three subroutine groups.

The other function of RQUAL is to determine the values for variables which are used jointly by the four subroutine groups. The following variables are evaluated:

1. AVVELE: the average velocity of water in the RCHRES (ft/s)
2. AVDEPE: the average depth of water in the RCHRES (ft)
3. DEPCOR: conversion factor from square meters to liters (used for changing areal quantities from the benthal surface to equivalent volumetric values based on the depth of water in the RCHRES)
4. SCRFAC: scouring factor to be used for calculation of benthal release rates of inorganic nitrogen, orthophosphorus, carbon dioxide, and biochemical oxygen demand

SCRFAC has one of two values depending on the average velocity (AVVELE) of the water in the RCHRES. AVVELE is compared to the value of parameter SCRVEL, the user-specified velocity at and above which scouring occurs. If AVVELE is less than the value of parameter SCRVEL, then SCRFAC is set equal to 1.0, and there is no increase of benthal release rates due to scouring. If AVVELE is greater than SCRVEL, SCRFAC is set equal to the value of parameter SCRMUL, which is a constant multiplication factor applied directly to the release rates to account for scouring by rapidly moving water.

4.2(3).7.1 Simulate Primary DO and BOD Balances
(Subroutine Group OXRX of Module RCHRES)

Purpose

The purpose of this code is to simulate the primary processes which determine the dissolved oxygen concentration in a reach or mixed reservoir. Dissolved oxygen concentration is generally viewed as an indicator of the overall well-being of streams or lakes and their associated ecological systems. In relatively unpolluted waters, sources and sinks of oxygen are in approximate balance, and the concentration remains close to saturation. By contrast, in a stream receiving untreated waste waters, the natural balance is upset, bacteria predominate, and a significant depression of dissolved oxygen results (O'Connor and DiToro, 1970).

Schematic View of Fluxes and Storages

Figures 4.2(3).7.1-1 and 4.2(3).7.1-2 illustrate the fluxes and storages modeled in this subroutine group. In order to account for temporal variations in oxygen balance, state variables for both dissolved oxygen and biochemical oxygen demand must be maintained. The state variable DOX represents the oxygen dissolved in water and immediately available to satisfy the oxygen requirements of the system. The BOD state variable represents the total quantity of oxygen required to satisfy the first-stage (carbonaceous) biochemical oxygen demand of dead nonrefractory organic materials in the water.

Subroutine OXRX considers the following processes in determining oxygen balance:

1. longitudinal advection of DOX and BOD
2. sinking of BOD material
3. benthic oxygen demand
4. benthic release of BOD material
5. reaeration
6. oxygen depletion due to decay of BOD materials

Additional sources and sinks of DOX and BOD are simulated in other sections of the RCHRES module. If module section NUTRX (Section 4.2(3).7.2) is active, the effects of nitrification on dissolved oxygen and denitrification on BOD balance can be considered. If module section PLANK (Section 4.2(3).7.3) is active, the dissolved oxygen balance can be adjusted to account for photosynthetic and respiratory activity by phytoplankton and/or benthic algae and respiration by zooplankton. Adjustments to the BOD state variable in section PLANK include increments due to death of plankton and nonrefractory organic excretion by zooplankton.

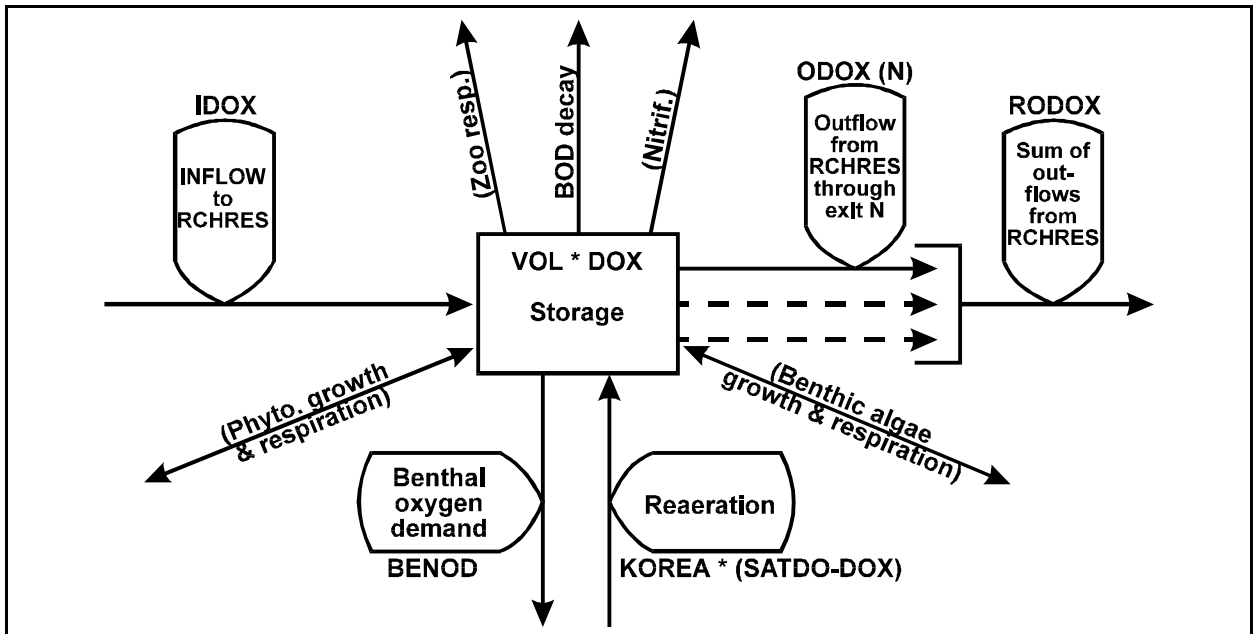


Figure 4.2(3).7.1-1 Flow diagram for dissolved oxygen in the OXRX subroutine group of the RCHRES Application Module

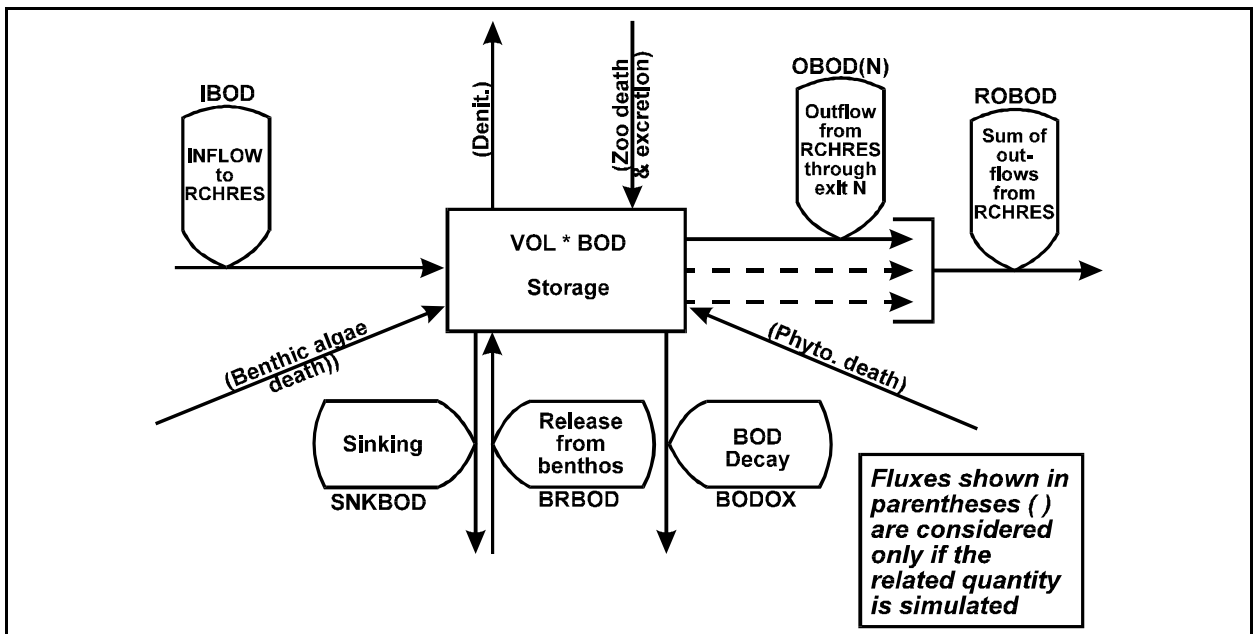


Figure 4.2(3).7.1-2 Flow diagram for biochemical oxygen demand in the OXRX subroutine group of the RCHRES Application Module

Subroutine Group OXR

Subroutine OXR uses five subroutines to simulate dissolved oxygen and biochemical oxygen demand. Advection of DOX and BOD is performed by ADVECT. Sinking of BOD material is carried out by SINK. OXBEN calculates benthic oxygen demand and benthic release of BOD materials. The oxygen reaeration coefficient is determined by utilizing OXREA, and BOD decay calculations are performed in BODDEC.

Since subroutine OXREA may also be called by module section GQUAL to obtain the oxygen reaeration coefficient (KOREA) for calculation of volatilization rates for generalized quality constituents, the change in dissolved oxygen concentration in water due to reaeration is calculated in OXR rather than OXREA. The equation for reaeration is:

$$\text{DOX} = \text{DOXS} + \text{KOREA} * (\text{SATDO} - \text{DOXS}) \quad (1)$$

where:

DOX = dissolved oxygen concentration after reaeration (mg/l)
DOXS = dissolved oxygen concentration at start of interval (mg/l)
KOREA = reaeration coefficient calculated in OXREA
SATDO = saturated concentration of dissolved oxygen (mg/l)

The saturation concentration of dissolved oxygen is computed at prevalent atmospheric conditions by the equation:

$$\text{SATDO} = (14.652 + \text{TW} * (-0.41022 + \text{TW} * (0.007991 - 0.7777\text{E-}4 * \text{TW}))) * \text{CFPRES} \quad (2)$$

where:

SATDO = saturated concentration of dissolved oxygen (mg/l)
TW = water temperature (deg C)
CFPRES = ratio of site pressure to sea level pressure
(CFPRES is calculated by the Run Interpreter dependent upon mean elevation of RCHRES)

4.2(3).7.1.1 Simulate Benthic Oxygen Demand and Benthic Release of BOD
(subroutine OXBEN)

Purpose

OXBEN accounts for two possible demands exerted on available oxygen by the benthos. These two demands are categorized as benthic oxygen demand and benthic release of BOD materials. Benthic oxygen demand results from materials in the bottom muds which require oxygen for stabilization. This process results in a direct loss of oxygen from the RCHRES. The second demand on oxygen caused by the release and suspension of BOD materials is a less direct form of oxygen demand. This process increases the pool of BOD present in the RCHRES and exerts a demand on the dissolved oxygen concentration at a rate determined by the BOD decomposition kinetics.

Benthic Oxygen Demand

The user approximates the oxygen demand of the bottom muds at 20 degrees Celsius by assigning a value to BENOD for each RCHRES. The effects of temperature and dissolved oxygen concentration on realized benthic demand are determined by the following equation:

$$\text{BENOX} = \text{BENOD} * (\text{TCBEN} ** \text{TW20}) * (1.0 - \text{Exp}(-\text{EXPOD} * \text{DOX})) \quad (3)$$

where:

BENOX = amount of oxygen demand exerted by benthic muds (mg/m²/interval)
 BENOD = reach dependent benthic oxygen demand at 20 degrees C
 (mg/m²/interval)
 TCBEN = temperature correction factor for benthic oxygen demand
 TW20 = water temperature - 20.0 (deg C)
 EXPOD = exponential factor to benthic oxygen demand function
 (default value = 1.22)
 DOX = dissolved oxygen concentration (mg/l)

The first portion of the above equation adjusts the demand at 20 degrees Celsius to a demand at any temperature. The second portion of the equation indicates that low concentrations of dissolved oxygen suppress realized oxygen demand. For example, 91 percent of BENOD may be realized at a dissolved oxygen concentration of 2 mg/l, 70 percent at 1 mg/l, and none if the waters are anoxic.

After the value of BENOX has been calculated, the dissolved oxygen state variable is updated:

$$\text{DOX} = \text{DOX} - \text{BENOX} * \text{DEPCOR} \quad (4)$$

where:

DEPCOR = factor which converts from mg/m² to mg/l, based on the average depth of water in the RCHRES during the simulation interval
 (DEPCOR is calculated in subroutine RQUAL)

Benthic Release of BOD

Bottom releases of BOD are a function of scouring potential and dissolved oxygen concentration. The equation used to calculate BOD release is:

$$\text{RELBOD} = (\text{BRBOD}(1) + \text{BRBOD}(2) * \text{Exp}(-\text{EXPREL} * \text{DOX})) * \text{SCRFAC} \quad (5)$$

where:

RELBOD = BOD released by bottom muds (mg/m² per interval)
 BRBOD(1) = base release rate of BOD materials (aerobic conditions)
 (mg/m²/interval)
 BRBOD(2) = increment to bottom release rate due to decreasing
 dissolved oxygen concentration
 EXPREL = exponential factor to BOD benthic release function
 (default value = 2.82)
 DOX = dissolved oxygen concentration (mg/l)
 SCRFAC = scouring factor dependent on average velocity of water
 (SCRFAC is calculated in subroutine RQUAL)

The above equation accounts for the fact that benthic releases are minimal during conditions of low velocity and ample dissolved oxygen. Under these conditions a thin layer of hardened, oxidized material typically retards further release of materials from the benthos. However, anaerobic conditions or increased velocity of overlying water disrupts this layer, and release rates of BOD and other materials are increased. Solution of Equation 3 indicates that 6 percent of the incremental release rate (BRBOD(2)) occurs when 1 mg/l of dissolved oxygen is present, 75 percent occurs when 0.1 mg/l is present, and the entire increment occurs under anoxic conditions.

4.2(3).7.1.2 Calculate Oxygen Reaeration Coefficient (subroutine OXREA)

Purpose

Various methods have been used to calculate atmospheric reaeration coefficients, and experience has shown that the most effective method of calculation in any given situation depends upon the prevalent hydraulic characteristics of the system (Covar, 1976). Based upon user instructions, subroutine OXREA calculates oxygen reaeration by using one of four built-in solution techniques.

Approach

The general equation for reaeration is:

$$\text{DOX} = \text{DOXS} + \text{KOREA} * (\text{SATDO} - \text{DOXS}) \quad (6)$$

where:

DOX = dissolved oxygen concentration after reaeration (mg/l)
 KOREA = reaeration coefficient (greater than zero and less than one)
 SATDO = oxygen saturation level for given water temperature (mg/l)
 DOXS = dissolved oxygen concentration at start of interval (mg/l)

Lake Reaeration

In a lake or reservoir, calculation of reaeration is dependent upon surface area, volume, and wind speed. The wind speed factor is determined using the following empirical relationship:

$$\text{WINDF} = \text{WINDSP} * (-0.46 + 0.136 * \text{WINDSP}) \quad (7)$$

where:

WINDF = wind speed factor in lake reaeration calculation
WINDSP = wind speed (m/sec)

For low wind speeds, less than 6.0 m/s, WINDF is set to 2.0. The reaeration coefficient for lakes is calculated as:

$$\text{KOREA} = (.032808 * \text{WINDF} * \text{CFOREA} / \text{AVDEPE}) * \text{DEL60} \quad (8)$$

where:

CFOREA = correction factor to reaeration coefficient for lakes; for lakes with poor circulation characteristics, CFOREA may be less than 1.0, and lakes with exceptional circulation characteristics may justify a value greater than 1.0
AVDEPE = average depth of water in RCHRES during interval (ft)
DEL60 = conversion from hourly time interval to simulation interval

Stream Reaeration

One of three approaches to calculating stream reaeration may be used:

1. Energy dissipation method (Tsivoglou-Wallace, 1972). Oxygen reaeration is calculated based upon energy dissipation principles:

$$\text{KOREA} = \text{REAKT} * (\text{DELTHE} / \text{FLOTIM}) * (\text{TCGINV} ** (\text{TW} - 20.)) * \text{DELTS} \quad (9)$$

where:

REAKT = escape coefficient with a typical value between 0.054/ft and 0.110/ft.
DELTHE = drop in energy line along length of RCHRES (ft)
FLOTIM = time of flow through RCHRES (seconds)
TCGINV = temperature correction coefficient for gas invasion rate with a default value of 1.047
DELTS = conversion factor from units of /second to units of /interval

DELTHE, the drop in elevation over the length of the RCHRES, is supplied by the user. REAKT, the escape coefficient, referred to in Tsivoglou's work, is also supplied by the user. The value for FLOTIM is calculated by dividing the length of the RCHRES by the average velocity for the simulation interval. Tsivoglou's method of calculation is activated by setting the reaeration method flag (REAMFG) to 1.

2. Covar's method of determining reaeration (Covar, 1976). Reaeration is calculated as a power function of hydraulic depth and velocity. The general equation is:

$$KOREA = REAK*(AVVELE**EXPREV)*(AVDEPE**EXPRED) \quad (10)$$

$$*(TCGINV**(TW - 20.))*DELT60$$

where:

KOREA = reaeration coefficient (per interval)
 REAK = empirical constant for reaeration equation (/hour)
 AVVELE = average velocity of water (ft/s)
 EXPREV = exponent to velocity function
 AVDEPE = average water depth (ft)
 EXPRED = exponent to depth function
 TCGINV = temperature correction coefficient for reaeration
 defaulted to 1.047
 DELT60 = conversion factor from units of per hour to units of per interval

Depending on current depth and velocity, one of three sets of values for REAK, EXPREV, and EXPRED is used. Each set corresponds to an empirical formula which has proven accurate for a particular set of hydraulic conditions. The three formulas and their associated hydraulic conditions and coefficients are:

1. Owen's formula (Owen et al., 1964). This formula is used for depths of less than 2 ft. For this formula, REAK = 0.906, EXPREV = 0.67, and EXPRED = -1.85.
2. Churchill's formula (1962). This formula is used for high velocity situations in depths of greater than 2 ft. For this formula, REAK = 0.484, EXPREV = 0.969, and EXPRED = -1.673.
3. O'Connor-Dobbins formula (1958). This formula is used for lower velocity situations in depths of greater than 2 ft. The coefficient values are: REAK = 0.538, EXPREV = 0.5, and EXPRED = -1.5.

This method of calculation of reaeration is activated by setting the reaeration method flag (REAMFG) to 2.

3. Users may select their own power function of hydraulic depth and velocity for use under all conditions of depth and velocity. In this case, the user supplies values for REAK, EXPREV, and EXPRED. This option is selected by setting the reaeration method flag (REAMFG) to 3.

Reaeration may be modeled as a constant process for any given temperature. In this case, the user must supply a value for REAK, and a value of zero for both EXPREV and EXPRED. Note that subroutine OXREA requires input values for REAK, EXPREV, and EXPRED only if REAMFG is 3.

4.2(3).7.1.3 Calculate BOD Decay (subroutine BODDEC)

Purpose

Subroutine BODDEC adjusts the dissolved oxygen concentration of the water to account for the oxygen consumed by microorganisms as they break down complex materials to simpler and more stable products. Only carbonaceous BOD is considered in this subroutine. The BOD decay process is assumed to follow first-order kinetics and is represented by:

$$\text{BODOX} = (\text{KBOD20} * (\text{TCBOD} ** (\text{TW} - 20.))) * \text{BOD} \quad (11)$$

where:

BODOX = quantity of oxygen required to satisfy BOD decay (mg/l per interval)
 KBOD20 = BOD decay rate at 20 degrees C (/interval)
 TCBOD = temperature correction coefficient, defaulted to 1.075
 TW = water temperature (degrees C)
 BOD = BOD concentration (mg/l)

If there is not sufficient dissolved oxygen available to satisfy the entire demand exerted by BOD decay, only the fraction which can be satisfied is subtracted from the BOD state variable, and the DOX variable is set to zero.

4.2(3).7.2 Simulate Primary Inorganic Nitrogen and Phosphorus Balances (Subroutine Group NUTRX of Module RCHRES)

Purpose

This code simulates the primary processes which determine the balance of inorganic nitrogen and phosphorus in natural waters. When modeling the water quality of an aquatic system, consideration of both nitrogen and phosphorus is essential. Nitrogen, in its various forms, can deplete dissolved oxygen levels in receiving waters, stimulate aquatic growth, exhibit toxicity toward aquatic life, or present a public health hazard (EPA, 1975). Phosphorus is vital in the operation of energy transfer systems in biota, and in many cases is the growth limiting factor for algal communities. Consequently, it is necessary to model phosphorus in any study concerned with eutrophication processes.

Schematic View of Fluxes and Storages

Figures 4.2(3).7.2-1 and 4.2(3).7.2-2 illustrate the fluxes and storages of four constituents which are introduced into the RCHRES modeling system in subroutine group NUTRX. In addition to these constituents, the state variables for dissolved oxygen and BOD are also updated. If subroutine group NUTRX is active (NUTFG = 1), nitrate will automatically be simulated; the user must specify whether or not nitrite, total ammonia, and/or orthophosphorus are to be simulated in addition to nitrate by assigning appropriate values to NO2FG, TAMFG, and PO4FG in the User's Control Input. In addition, if ammonia or orthophosphorus is simulated, the user may specify whether to simulate the adsorbed (particulate) forms of ammonia and orthophosphorus. If either adsorbed nutrient is simulated, Section SEDTRN must be active to provide the inorganic sediment (sand, silt, and clay) concentrations and fluxes. If all possible constituents are simulated, subroutine NUTRX considers the following processes:

1. longitudinal advection of dissolved NO₃, NO₂, NH₃, and PO₄
2. benthic release of inorganic nitrogen (NH₃) and PO₄ (if BENRFG = 1)
3. ammonia ionization (NH₃/NH₄⁺ equilibrium)
4. ammonia vaporization (if AMVFG = 1)
5. nitrification of NH₃ and NO₂
6. denitrification of NO₃ (if DENFG = 1)
7. ammonification due to degradation of BOD materials
8. adsorption/desorption of NH₃ and PO₄ to inorganic sediment in the water column (if ADNHFG = 1 or ADPOFG = 1)
9. deposition/scour and longitudinal advection of adsorbed NH₃ and PO₄ (if ADNHFG = 1 or ADPOFG = 1)

Additional sources and sinks of NO₃, NH₃, and PO₄ are simulated in the PLANK section (4.2(3).7.3) of this module. If section PLANK is active, the state variables for these three constituents can be adjusted to account for nutrient uptake by phytoplankton and/or benthic algae, and for respiration and inorganic excretion by zooplankton.

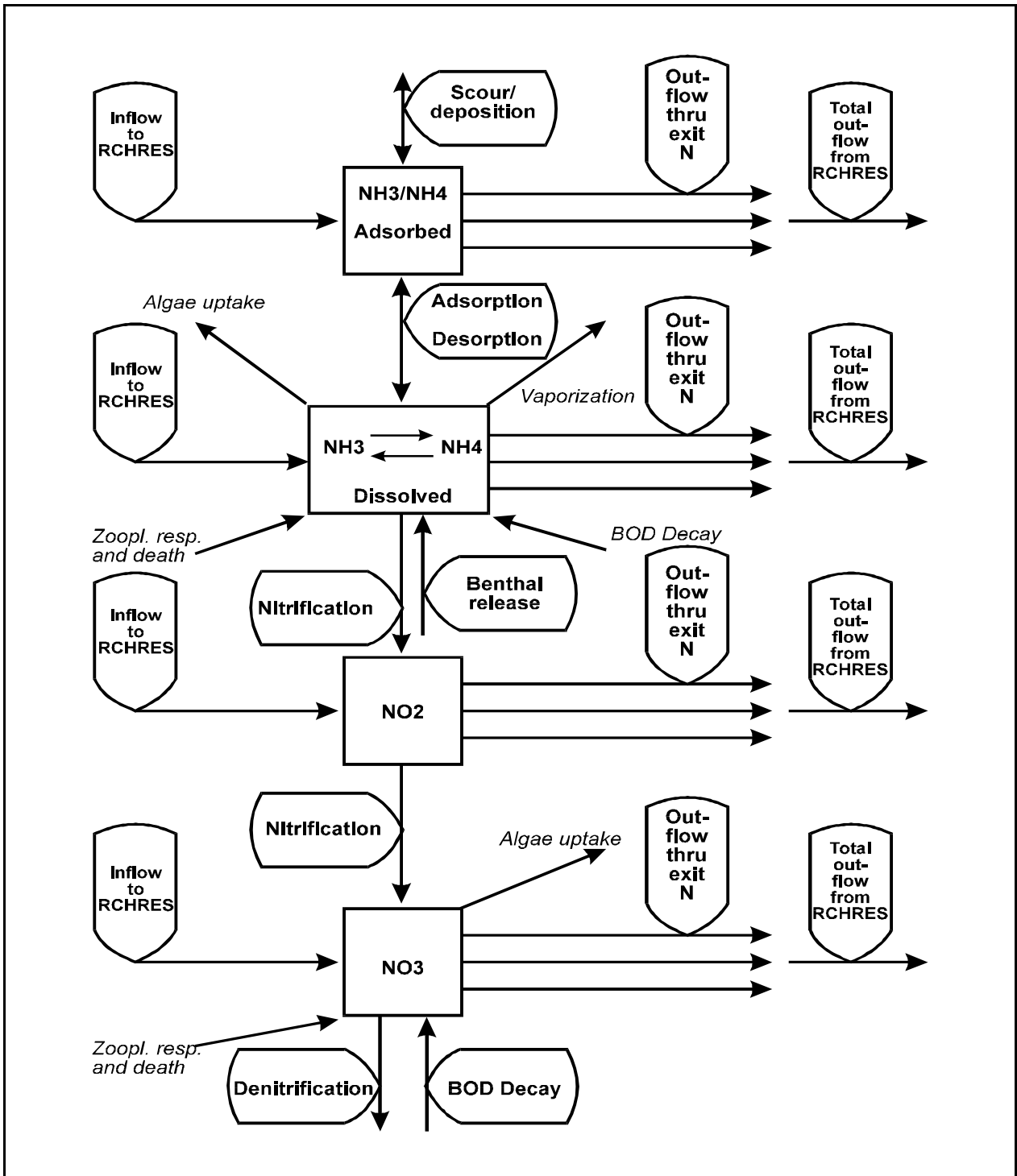


Figure 4.2(3).7.2-1 Flow diagram for inorganic nitrogen in the NUTRX subroutine group of the RCHRES Application Module

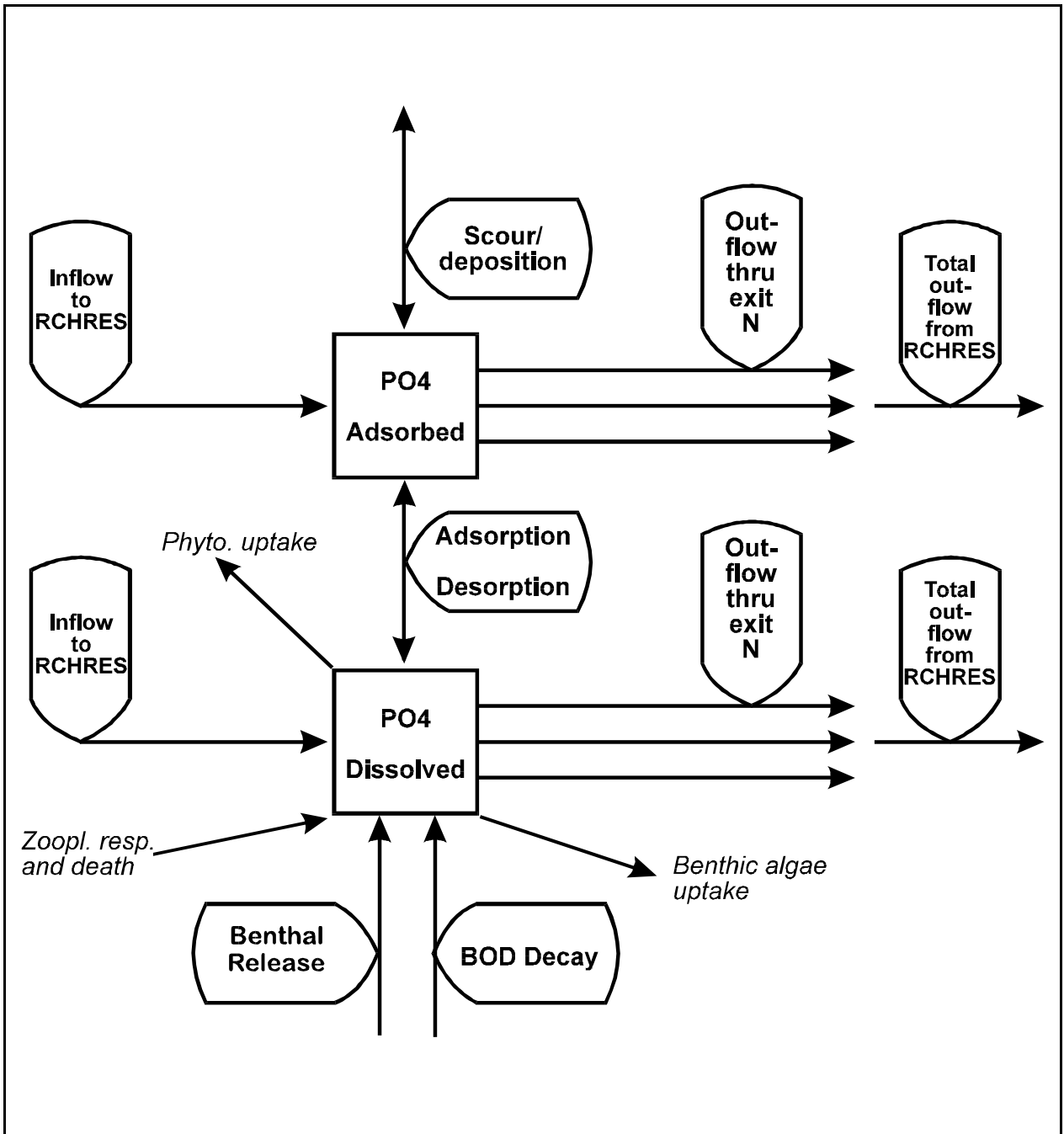


Figure 4.2(3).7.2-2 Flow diagram for ortho-phosphate in the NUTRX subroutine group of the RCHRES Application Module

Subroutine Group NUTRX

Subroutine NUTRX utilizes nine principal routines to simulate inorganic nitrogen and phosphorus. Advection of dissolved NO₃, NO₂, NH₃, and PO₄ is performed by ADVECT. BENTH determines the amount of inorganic nitrogen and phosphorus which is released to the overlying waters from the benthos. The nitrification and denitrification processes are simulated by NITRIF and DENIT, respectively. Adsorption/desorption of NH₃ and PO₄ is computed by ADDSNU, and the advection and deposition/scour of the adsorbed forms are simulated in ADVNUT. The ammonia ionization and volatilization calculations are performed in AMMION and NH3VOL, respectively. Finally, the production of inorganic nitrogen and phosphorus resulting from decay of BOD materials is simulated by DECBAL.

Before ADVECT is called, NUTRX sums the inputs of dissolved NO₃, NH₃, and PO₄ from upstream reaches, tributary land areas, and atmospheric deposition (deposition of NO₂ is not considered):

$$\text{INNUT} = \text{INUT} + \text{SAREA} * \text{ADFX} + \text{SAREA} * \text{PREC} * \text{ADCN} \quad (1)$$

where:

INNUT = total input of dissolved nutrient to reach
INUT = input of dissolved nutrient from upstream reaches and tributary land
SAREA = surface area of reach
ADFX = dry or total atmospheric deposition flux in mass/area per interval
PREC = precipitation depth
ADCN = concentration for wet atmospheric deposition in mass/volume

Atmospheric deposition inputs can be specified in two possible ways depending on the form of the available data. If the deposition is in the form of a flux (mass per area per time), then it is considered "dry deposition". If the deposition is in the form of a concentration in rainfall, then it is considered "wet deposition", and the program automatically combines it with the input rainfall time series to compute the resulting flux. Either type of deposition data can be input as a time series, which covers the entire simulation period, or as a set of monthly values that is used for each year of the simulation. The specific atmospheric deposition time series are documented in the EXTNL table of the Time Series Catalog for RCHRES, and are specified in the EXT SOURCES block of the UCI. Monthly values are input in the MONTH-DATA block in the UCI.

4.2(3).7.2.1 Simulate Benthic Release of Constituents (subroutine BENTH)

Purpose

This subroutine checks to see whether present water conditions are aerobic or anaerobic, calculates benthic release for a constituent based on this check, and updates the concentration of the constituent.

Approach

The equation used to calculate release is:

$$\text{RELEAS} = \text{BRCON}(I) * \text{SCRFAC} * \text{DEPCOR} \quad (1)$$

where:

RELEAS = amount of constituent released (mg/l per interval)
 BRCON(I) = benthic release rate (BRTAM or BRPO4) for constituent
 (mg/m² per interval)
 SCRFAC = scouring factor, dependent on average velocity of the water
 (SCRFAC is computed in RQUAL)
 DEPCOR = conversion factor from mg/m² to mg/l (computed in RQUAL)

The dissolved oxygen concentration below which anaerobic conditions are considered to exist is determined by the input parameter ANAER. Two release rates are required for each of the constituents: one for aerobic conditions and one for anaerobic conditions. Typically, the aerobic release rate is less than the anaerobic rate, because a layer of oxidized materials forms on the benthic surface during aerobic periods, and this layer retards the release rate of additional benthic materials. BRCON(1) is the aerobic release rate and BRCON(2) is the anaerobic rate. The choice of which release rate is used is determined by comparing the current value of DOX to ANAER.

If ammonia is simulated, the inorganic nitrogen release from the benthos is assumed to be in the form of ammonia, and the NH₃ (TAM) state variable is updated. If ammonia is not simulated, benthic release of inorganic nitrogen is assumed to not occur. If orthophosphate is simulated, an additional call is made to BENTH to account for release of PO₄.

Simulation of benthic release processes is activated by assigning a value of one to BENRFG in the User's Control Input for RQUAL.

4.2(3).7.2.2 Simulate Nitrification (subroutine NITRIF)

Purpose

NITRIF simulates the oxidation of ammonium and nitrite by chemoautotrophic bacteria. This oxidation provides energy for bacteria much the same way that sunlight provides energy for photosynthetic algae. The Nitrosomonas genera are responsible for conversion of ammonium to nitrite, and Nitrobacter perform oxidation of nitrite to nitrate. Oxidation of inorganic nitrogen is dependent upon a suitable supply of dissolved oxygen; subroutine NITRIF does not simulate nitrification if the DO concentration is below 2 mg/l.

Method

The rate of nitrification is represented by a first order equation in which nitrification is directly proportional to the quantity of reactant present, either ammonia or nitrite. The equation used to calculate the amount of NH₃ oxidized to NO₂ is:

$$TAMNIT = KTAM20 * (TCNIT ** (TW - 20.)) * TAM \quad (2)$$

where:

TAMNIT = amount of NH₃ oxidation (mg N/l per interval)
 KTAM20 = ammonia oxidation rate coefficient at 20 degrees C (/interval)
 TCNIT = temperature correction coefficient, defaulted to 1.07
 TW = water temperature (degrees C)
 TAM = total ammonia concentration (mg N/l)

Similarly, if nitrite is simulated, the amount of nitrite oxidized to nitrate is determined by the equation:

$$NO2NIT = KNO220 * (TCNIT ** (TW - 20.)) * NO2 \quad (3)$$

where:

NO2NIT = amount of NO₂ oxidation (mg N/l/interval)
 KNO220 = NO₂ oxidation rate coefficient at 20 degrees C (/interval)
 NO2 = nitrite concentration (mg N/l)

The amount of oxygen used during nitrification is 3.43 mg oxygen per mg NH₃-N oxidized to NO₂-N, and 1.14 mg oxygen per mg NO₂-N oxidized to NO₃-N. In the RCHRES module, these figures are adjusted to 3.22 mg and 1.11 mg, respectively, to account for the effects of carbon dioxide fixation by bacteria (Wezerak and Gannon, 1968). Thus, the oxygen demand due to nitrification is evaluated as:

$$DODEMD = 3.22 * TAMNIT + 1.11 * NO2NIT \quad (4)$$

where:

DODEMD = loss of dissolved oxygen from the RCHRES due to nitrification
 (mg O/l per interval)

If the value of DODEMD is greater than available dissolved oxygen, the amounts of oxidation from NH₃ to NO₂ and from NO₂ to NO₃ are proportionally reduced, so that the state variable DOX maintains a non-negative value. If nitrite is not simulated, the calculated amount of oxidized ammonia is assumed to be fully oxidized to nitrate.

4.2(3).7.2.3 Simulate Denitrification (subroutine DENIT)

Purpose

DENIT simulates the reduction of nitrate by facultative anaerobic bacteria such as Pseudomonas, Micrococcus, and Bacillus. These bacteria can use NO₃ for respiration in the same manner that oxygen is used under aerobic conditions. Facultative organisms use oxygen until the environment becomes nearly or totally anaerobic, and then switch over to NO₃ as their oxygen source. In HSPF, the end product of denitrification is assumed to be nitrogen gas.

Approach

Denitrification does not occur in the RCHRES module unless the dissolved oxygen concentration is below a user-specified threshold value (DENOXT). If that situation occurs, denitrification is assumed to be a first-order process based on the NO₃ concentration. The amount of denitrification for the interval is calculated by the following equation:

$$\text{DENNO3} = \text{KNO320} * (\text{TCDEN}^{*(\text{TW}-20)}) * \text{NO3} \quad (5)$$

where:

DENNO3 = amount of NO₃ denitrified (mg N/l per interval)
 KNO320 = NO₃ denitrification rate coefficient at 20 degrees C (/interval)
 TCDEN = temperature correction coefficient for denitrification
 NO3 = nitrate concentration (mg N/l)

4.2(3).7.2.4 Simulate Adsorption/Desorption of Ammonia and Orthophosphorus (subroutine ADDSNU)

Purpose

This subroutine simulates the exchange of nutrient (ammonium and orthophosphorus) between the dissolved state and adsorption on suspended sediment. The sorbents considered are suspended sand, silt, and clay, which are simulated in section SEDTRN. The adsorption/desorption process is not simulated in bed sediments.

Approach

The adsorption/desorption for each sediment fraction is represented with an equilibrium, linear isotherm, i.e., a standard K_d approach, which is described as follows:

$$\text{SNUT}(J) = \text{DNUT} * \text{ADPM}(J) \quad (6)$$

where:

SNUT(J) = equilibrium concentration of adsorbed nutrient on sediment fraction J (mg/kg)
 DNUT = the equilibrium concentration of dissolved nutrient (mg/l)
 ADPM(J) = adsorption parameter (or Kd) for sediment fraction J (l/kg)

This expression for SNUT(J) is substituted into the following mass balance expression for total nutrient in the reach:

$$\text{NUM} = \text{DNUT} * \text{VOL} + \sum_{J=1,3} 3 [\text{SNUT}(J) * \text{RSED}(J)] = \text{total nutrient in reach} \quad (7)$$

where:

NUM = variable used to represent total nutrient mass in the reach (mg)
 VOL = volume of reach (l)
 RSED(J) = mass of sediment fraction J in suspension (kg)

After substituting, rearranging, and solving for DNUT, the following expression is obtained:

$$\text{DNUT} = \frac{\text{NUM}}{\text{VOL} + \sum_{J=1,3} 3 [\text{RSED}(J) * \text{ADPM}(J)]} \quad (8)$$

In the above equation, the value of NUM is obtained from a "non-equilibrium" version of Equation (7) in which temporary DNUT and SNUT values include the effects of other processes such as advection, scour/deposition, nitrification, etc, that have occurred during the interval. Therefore, the overall procedure involves performing all processes that affect the nutrient concentrations, and then partitioning (equilibrating) the total mass of nutrient among the four phases, i.e., dissolved phase and three sediment fractions.

Note, the units listed for some variables in the preceding discussion are simplified from the internal (code) HSPF units.

4.2(3).7.2.5 Simulate Advection and Deposition/Scour of Adsorbed Ammonia and Orthophosphorus (subroutine ADVNUT)

Purpose

ADVNUT simulates the advective processes for a nutrient (NH₃ or PO₄) attached to one sediment size fraction. Processes handled in this routine include:

1. Inflow to the RCHRES of nutrient attached to suspended sediment.
2. Migration of nutrient from suspension in the water to the bed as a result of deposition of the sediment to which the nutrient is adsorbed.

3. Migration of nutrient from the bed into suspension in the water as a result of scour of the bed sediments to which the nutrient is adsorbed.
4. Outflow from the RCHRES of nutrient attached to suspended sediment.

Method

The movement of adsorbed nutrient is completely determined by the movement of the sediment to which it is attached. All fluxes of adsorbed nutrient are expressed as the product of the flux of a sediment fraction (sand, silt, or clay) and the concentration of nutrient associated with that fraction (expressed in mg per kg of sediment). Likewise, storages of adsorbed nutrient are expressed as the product of the sediment fraction storage and the associated concentration of nutrient. Note that the nutrient storage in the bed is essentially infinite. Nutrients that deposit to the bed are assumed to be lost from the RCHRES, and scoured sediment is assumed to have a constant (user-specified) adsorbed nutrient concentration; thus the scoured nutrient flux is limited only by the storage of sediment in the bed. A simplified flow diagram of sediment and associated nutrient fluxes and storages is provided in Figure 4.2(3).7.2-3 to facilitate the following discussion. ADVNUT is designed to operate on one sediment fraction and one nutrient each time it is called by subroutine NUTRX.

If the sediment simulation in module section SEDTRN indicates that scour of bed storage of a sediment fraction occurs, the following actions are taken in ADVNUT:

1. The flux of nutrient from bed to suspension is calculated as:

$$DSNUT = BNUT * DEPSCR \quad (9)$$

where:

DSNUT = amount of nutrient scoured from bed and added to suspension
(mg/l)*(ft³/ivl) or (mg/l)*(m³/ivl)
 BNUT = constant concentration of nutrient on bed sediment fraction
under consideration (mg/mg sediment)
 DEPSCR = amount of sediment fraction which is scoured from
the bed (mg.ft³/l.ivl or mg.m³/l.ivl)

2. The concentration of adsorbed nutrient in suspension is updated to account for scour:

$$SNUT = (ISNUT + RSNUTS - DSNUT) / (RSED + ROSED) \quad (10)$$

where:

SNUT = concentration of adsorbed nutrient in suspension
(mg/mg suspended sediment)

ISNUT = inflow of nutrient to the RCHRES as a result of inflowing
sediment fraction ((mg/l)*(ft³/ivl) or (mg/l)*(m³/ivl))

RSNUTS = storage of nutrient on suspended sediment fraction
((mg/l)*ft³ or (mg/l)*m³)

RSED = amount of sediment fraction in suspension
at end of interval (mg.ft³/l or mg.m³/l)

ROSED = amount of sediment fraction contained in outflow from the RCHRES
during the interval (mg.ft³/l.ivl or mg.m³/l.ivl)

3. The concentration of nutrient on bed sediment is set equal to zero if the storage of bed sediment at the end of the interval is zero.

5. Amount of nutrient leaving the RCHRES as outflow is determined as:

$$\text{ROSNUT} = \text{ROSED} * \text{SNUT} \quad (11)$$

If the sediment simulation in module section SEDTRN indicates that deposition of suspended sediment occurs, ADVNUT performs the following operations:

1. Concentration of nutrient on total suspended sediment fraction (inflow + suspended storage) for the RCHRES is calculated:

$$\text{SNUT} = (\text{ISNUT} + \text{RSNUTS}) / (\text{RSED} + \text{DEPSCR} + \text{ROSED}) \quad (12)$$

2. Amount of nutrient leaving the RCHRES due to outflow of sediment fraction is determined:

$$\text{ROSNUT} = \text{ROSED} * \text{SNUT} \quad (13)$$

3. Amount of nutrient leaving suspension due to deposition of the sediment to which it is adsorbed is found by:

$$\text{DSNUT} = \text{DEPSCR} * \text{SNUT} \quad (14)$$

4. The concentration of nutrient on sediment in suspension is set equal to zero if the suspended storage of sediment is zero.

The final operation which ADVNUT performs is the computation of outflow of adsorbed nutrient through individual exits (when more than one exit is specified). The algorithm is:

$$\text{OSNUT}(I) = \text{ROSNUT} * \text{OSED}(I) / \text{ROSED} \quad (15)$$

where:

OSNUT(I) = outflow of adsorbed nutrient through exit gate I

ROSNUT = total outflow of adsorbed nutrient from RCHRES

OSED(I) = outflow of sediment fraction through exit gate I

4.2(3).7.2.6 Simulate Ionization of Ammonia to Ammonium
(subroutine AMMION)

Approach

The total dissolved ammonia state variable (TAM) consists of two forms, NH_4^+ and NH_3 . The ionized form is dominant at typical pH's and temperatures found in nature; however, the un-ionized form is toxic to aquatic species at fairly low concentrations, and may be significant at some extreme environmental pH's. Therefore, while the process formulations in HSPF are based on the total ammonia, the un-ionized form is computed and output.

The fraction (FRAC) of total ammonia that is present as un-ionized ammonia is calculated as:

$$\text{FRAC} = \frac{10^{\text{pH}}}{10^{\text{pH}} + \text{RATIO}} \quad (16)$$

where:

RATIO = ratio of ionization products for water k_w and ammonia (k_b)

RATIO is computed using an empirical relationship based on pH and temperature as described by Loehr et al. (1973):

$$\text{RATIO} = -3.39753 \log_e(0.02409 \text{ TW}) 10^9 \quad (17)$$

The pH used in Equation 16 may be obtained from Section PHCARB (if it is active) or specified by the user in the form of a constant value, 12 monthly values, or an input time series.

4.2(3).7.2.7 Simulate Ammonia Volatilization
(subroutine NH3VOL)

Approach

The amount of total ammonia lost from the RCHRES due to ammonia volatilization is calculated by a standard two-layer model of mass transfer across the air-water interface; this is based on Henry's Law and the flux of mass through the water and air films. The inverse of the overall mass transfer coefficient is given by the following expression:

$$\frac{1}{\text{KR}} = \text{KRINV} = \frac{1}{\text{NH3KL}} + \frac{8.21 \times 10^{-5} * \text{TWKELV}}{\text{HCNH3} * \text{NH3KG}} \quad (18)$$

where:

KR = overall mass transfer coefficient (cm/hr)
 KRINV = inverse of coefficient (hr/cm)
 NH3KL = liquid film mass transfer coefficient (cm/hr)
 NH3KG = gas film mass transfer coefficient (cm/hr)
 HCNH3 = Henry's Law Constant for ammonia (atm-m³/mole)
 8.21E-5 = the ideal gas constant (atm-m³/K/mole)
 TWKELV = water temperature (degrees K)

Computation of the liquid-film coefficient is based on correlation with the reaeration rate (i.e., the rate of transfer of oxygen gas across the interface). The proportionality constant is a function of the ratio of the molecular weights. Therefore, the liquid-film coefficient is given by:

$$\text{NH3KL} = [\text{KOREA} * \text{AVDEPM} * 100/\text{DELT60}] * [1.878^{**}(\text{EXPNVL}/2.)] \quad (19)$$

where:

KOREA = the oxygen reaeration rate (per interval)
 AVDEPM = average depth of the reach (m)
 100 = conversion from meters to centimeters
 DELT60 = conversion from units of per interval to units of per hour
 1.878 = ratio of molecular weight of oxygen (32) to ammonia (17)
 EXPNVL = user-specified exponential factor

Note that in the first part of the above equation, KOREA is being converted to the same units as NH3KL, i.e., cm/hr.

In a similar manner to the liquid-film coefficient, the gas-film coefficient is computed from the water evaporation rate which is primarily driven by the wind. The gas film coefficient is computed as:

$$\text{NH3KG} = 700. * \text{WINDSP} * 1.057^{**}(\text{EXPNVG}/2.) \quad (20)$$

where:

700 = an empirical constant relating the wind speed in m/s and the evaporation rate in cm/hr
 WINDSP = wind speed (m/s)
 1.057 = ratio of water molecular weight to that of ammonia
 EXPNVG = user-specified exponential factor

The Henry's constant for ammonia (HCNH3) is interpolated from a table of values based on temperature and pH.

The reach-specific, first-order rate constant for volatilization is computed by:

$$\text{KNVOL} = \text{KR} * \text{DELT60}/(\text{AVDEPM} * 100) \quad (21)$$

where:

KNVOL = first-order rate constant for volatilization (/interval)
 100 = conversion from units of 1/cm to 1/m

Finally, the volatilization loss is computed as:

$$\text{NH3VLT} = \text{KNVOL} * \text{TAM} \quad (22)$$

where:

NH3VLT = volatilization loss during the interval (mg N/l)

TAM = concentration of total ammonia (mg N/l)

Simulation of ammonia volatilization is activated by setting AMVFG equal to one in the User's Control Input. Of course, total ammonia simulation must also be activated by setting TAMFG equal to 1.

4.2(3).7.2.8 Perform Materials Balance for Transformation from Organic to Inorganic Material (subroutine DECBAL)

Purpose

DECBAL adjusts the inorganic nitrogen and orthophosphorus state variables to account for decomposition of organic materials.

Method

In subroutine NUTRX the total BOD decay for the time interval is used to compute the corresponding amounts of inorganic nitrogen and orthophosphorus produced by the decay are determined as:

$$\text{DECNIT} = \text{BODOX} * \text{CVON} \quad (23)$$

$$\text{DECPO4} = \text{BODOX} * \text{CVOP} \quad (24)$$

where:

BODOX = total BOD decay (mg O/l per interval)

CVON = stoichiometric conversion factor from mg oxygen to mg nitrogen

CVOP = stoichiometric conversion factor from mg oxygen to mg phosphorus

The values for DECNIT and DECPO4 are passed to subroutine DECBAL. If ammonia is simulated, the value of DECNIT is added to the NH3 (TAM) state variable; if not, DECNIT is added to the NO3 state variable. If orthophosphorus is simulated, the value of DECPO4 is added to the PO4 state variable.

4.2(3).7.3 Simulate Plankton Populations and Associated Reactions (Subroutine Group PLANK of Module RCHRES)

Purpose

PLANK simulates phytoplankton, zooplankton, and/or benthic algae.

Schematic View of Fluxes and Storages

Figures 4.2(3).7.3-1 through 4.2(3).7.3-4 illustrate the fluxes and storages of the six constituents which are introduced into the RCHRES modeling system in subroutine PLANK. In addition to these constituents, the state variables for dissolved oxygen, biochemical oxygen demand, nitrate, total ammonia, and orthophosphorus are also updated. If subroutine group PLANK is active (PLKFG = 1), dead refractory organics will automatically be simulated. The state variables for these organics are ORN (dead refractory organic nitrogen), ORP (dead refractory organic phosphorus), and ORC (dead refractory organic carbon). The user must specify whether or not phytoplankton, zooplankton, and/or benthic algae are simulated by assigning appropriate values to PHYFG, ZOOFG, and BALFG in the User's Control Input. The state variable PHYTO represents the free floating photosynthetic algae, ZOO represents the zooplankton which feed on PHYTO, and BENAL is the state variable for algae attached to the benthic surface.

Subroutine group PLANK is a large and complex code segment. It uses twelve subroutines to perform simulation of the three types of plankton. Longitudinal advection of PHYTO and ZOO is performed by ADVPLK, a special advection routine for plankton. ORN, ORP, and ORC are advected by ADVECT. The sinking of PHYTO, ORN, ORP, and ORC is performed by subroutine SINK. The user controls the sinking rate of these constituents by assigning values to parameters PHYSET and REFSET in the User's Control Input. PHYSET is the rate of phytoplankton settling, and REFSET is the settling rate for all three of the dead refractory organic constituents. Advection and sinking are performed every interval.

Before ADVECT is called, PLANK sums the inputs of ORN, ORP, and ORC from upstream reaches, tributary land areas, and atmospheric deposition:

$$\text{INORG} = \text{IORG} + \text{SAREA} * \text{ADFX} + \text{SAREA} * \text{PREC} * \text{ADCN} \quad (1)$$

where:

INORG = total input of organic to reach
 IORG = input of organic from upstream reaches and tributary land
 SAREA = surface area of reach
 ADFX = dry or total atmospheric deposition flux in mass/area per interval
 PREC = precipitation depth
 ADCN = concentration for wet atmospheric deposition in mass/volume

Atmospheric deposition inputs can be specified in two possible ways depending on the form of the available data. If the deposition is in the form of a flux (mass per area per time), then it is considered "dry deposition". If the deposition is in the form of a concentration in rainfall, then it is considered "wet deposition", and the program automatically combines it with the input rainfall time series to

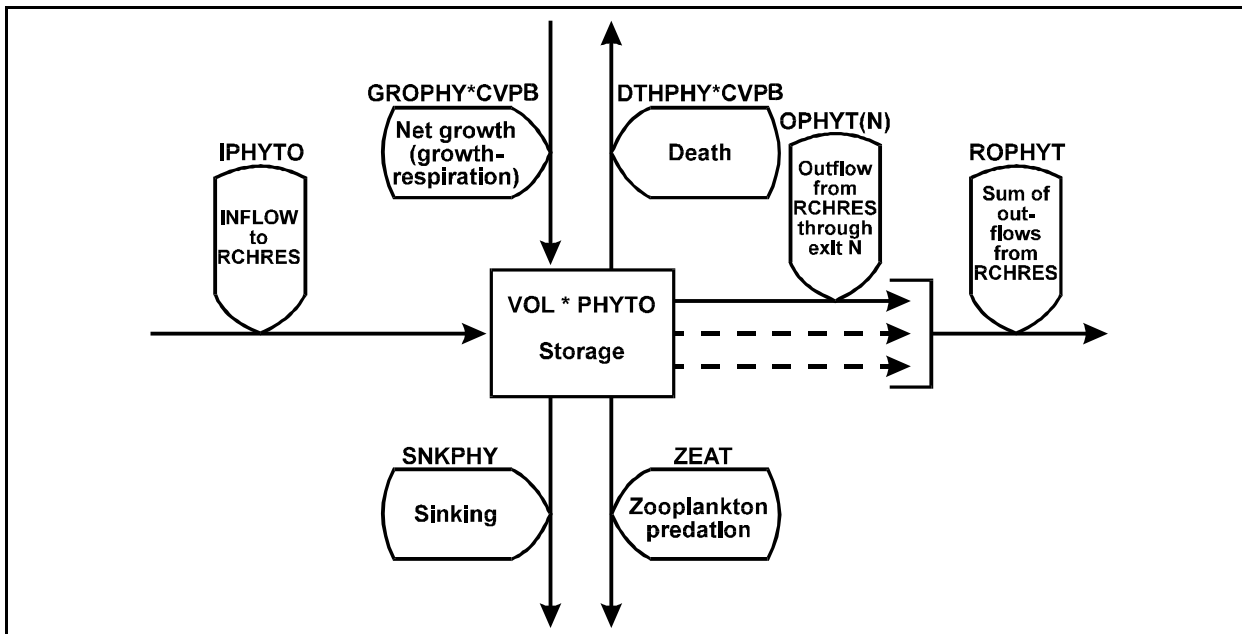


Figure 4.2(3).7.3-1 Flow diagram for phytoplankton in the PLANK section of the RCHRES Application Module

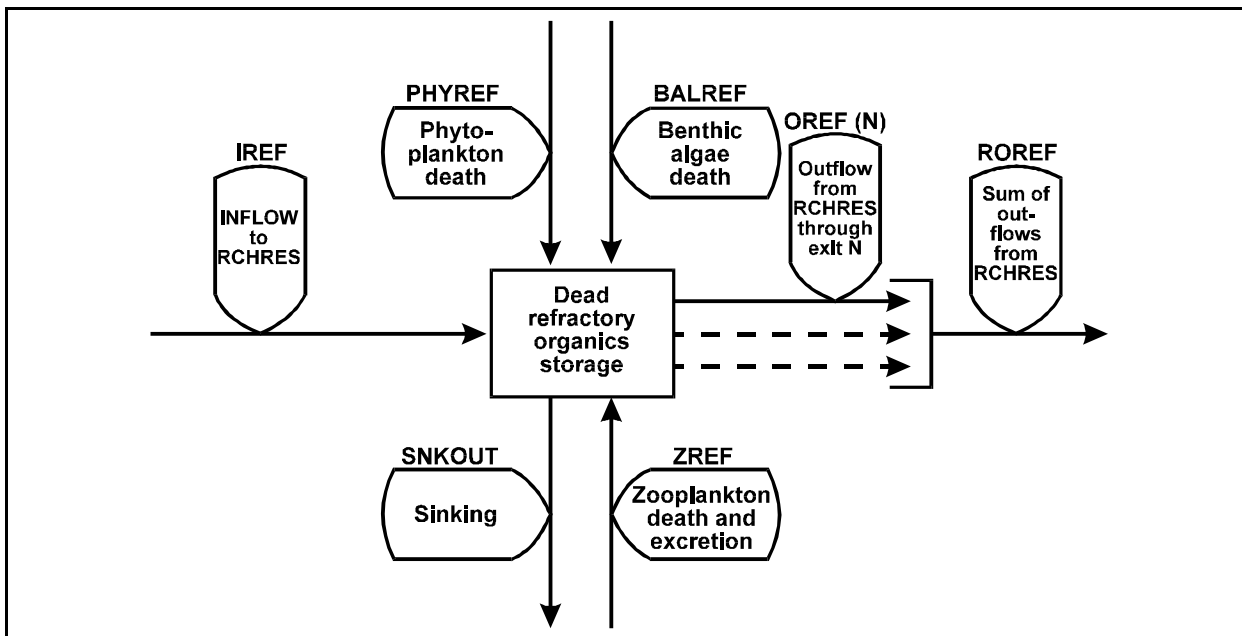


Figure 4.2(3).7.3-2 Flow diagram for dead refractory organics in the PLANK section of the RCHRES Application Module

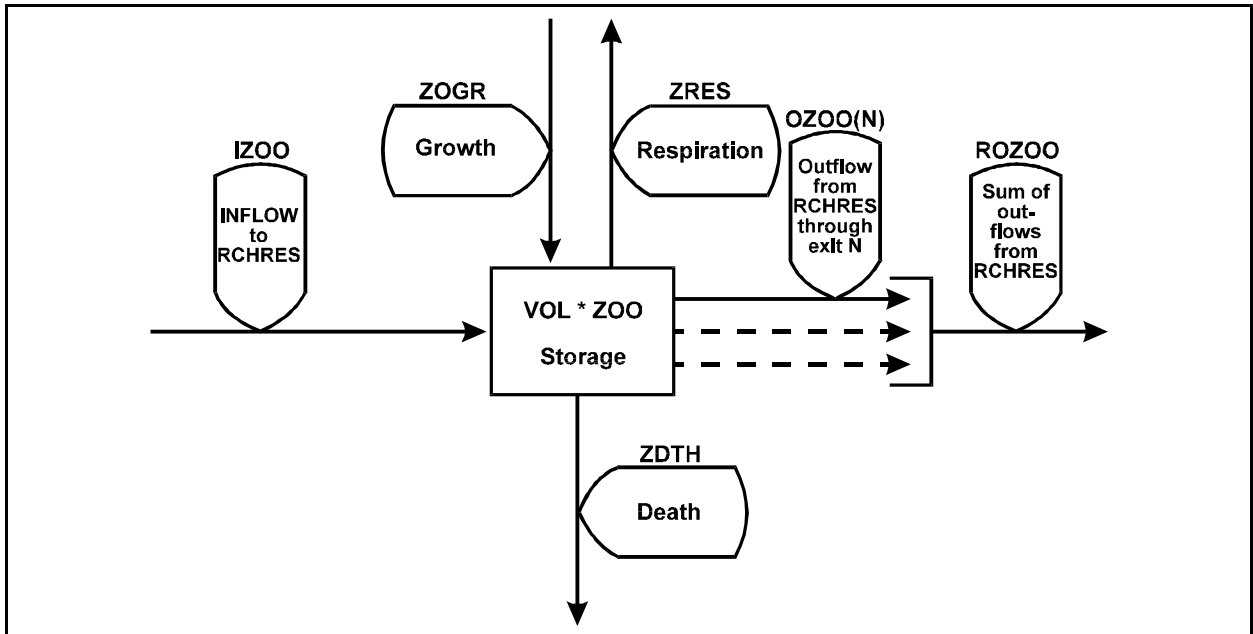


Figure 4.2(3).7.3-3 Flow diagram for zooplankton in the PLANK section of the RCHRES Application Module

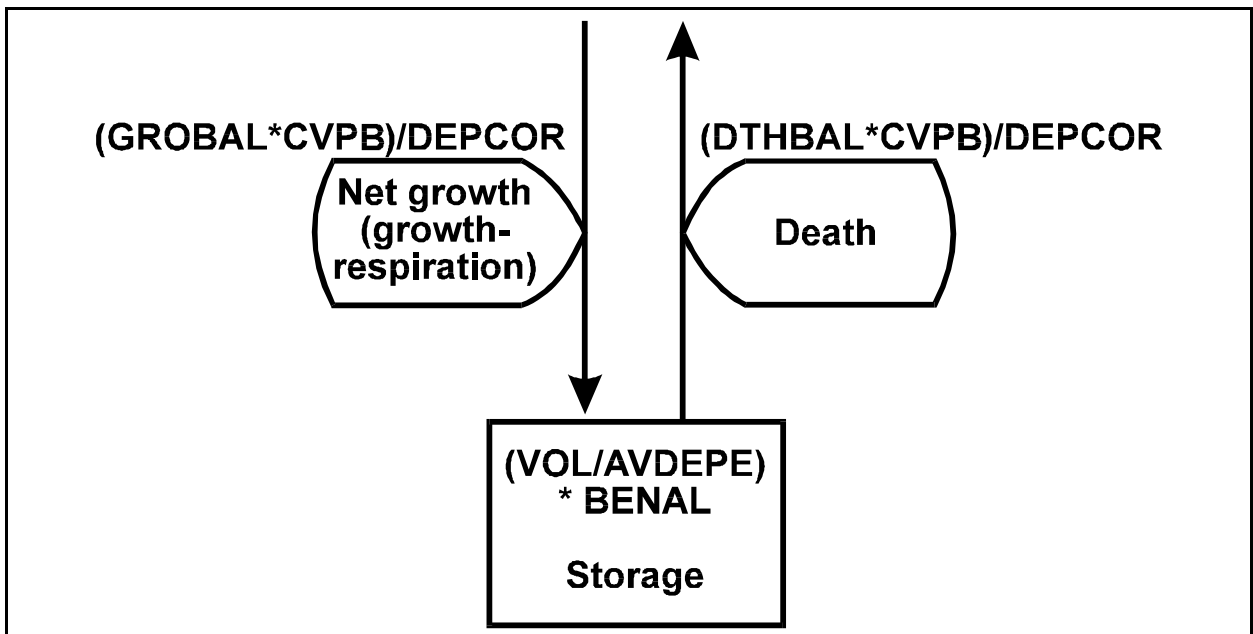


Figure 4.2(3).7.3-4 Flow diagram for benthic algae in the PLANK section of the RCHRES Application Module

Subroutine Group PLANK

compute the resulting flux. Either type of deposition data can be input as a time series, which covers the entire simulation period, or as a set of monthly values that is used for each year of the simulation. The specific atmospheric deposition time series for NUTRX are documented in the EXTNL table of the Time Series Catalog for RCHRES, and are specified in the EXT SOURCES block of the UCI. The monthly values are input in the MONTH-DATA block in the UCI.

The remainder of the processes modeled in PLANK are only performed when the average depth of water in the RCHRES is at least 2 inches. Experience has shown that the algorithms used to represent these processes are not accurate for excessively shallow waters. If 2 inches or more of water is present in the RCHRES, PLANK performs a series of operations which are necessary to determine the availability of light to support algal growth. First the light intensity at the RCHRES surface is calculated by the following equation:

$$\text{INLIT} = 0.97 * \text{CFSAEX} * \text{SOLRAD} / \text{DELT} \quad (1)$$

where:

INLIT = light intensity immediately below water surface (langleys/min)
0.97 = correction factor for surface reflection (assume 3 percent)
CFSAEX = input parameter that specifies the ratio of radiation at water surface to gage radiation values. This factor also accounts for shading of the water body, e.g. by trees and streambanks
SOLRAD = solar radiation (langleys/interval)
DELT = conversion from units of per interval to per minute

After the light intensity at the water surface has been calculated, PLANK determines the factors which diminish the intensity of light as it passes through the water. In addition to the natural extinction due to passage through water, extinction may result from interference caused by suspended sediment or phytoplankton. If SDLTFG is assigned a value of one, the contribution of total suspended sediment to light extinction is calculated as:

$$\text{EXTSED} = \text{LITSED} * \text{SSEDT} \quad (2)$$

where:

EXTSED = increment to base extinction coefficient due to total suspended sediment (/ft)
LITSED = multiplication factor to total suspended sediment conc. (supplied in User's Control Input)
SSEDT = total suspended sediment (sand + silt + clay) (mg/l)

The contribution of suspended phytoplankton to light extinction is determined by the empirical relationship:

$$\text{EXTCLA} = 0.00452 * \text{PHYCLA} \quad (3)$$

where:

EXTCLA = increment to base extinction coefficient due to phytoplankton (/ft)
0.00452 = multiplication factor to phytoplankton chlorophyll a concentration
PHYCLA = phytoplankton concentration (micromoles/l of chlorophyll a)

Subroutine Group PLANK

After values for INLIT, EXTSED, and EXTCLA have been calculated, PLANK calls subroutine LITRCH to determine the light correction factor to algal growth and the amount of light available to phytoplankton and benthic algae. Once these calculations have been completed, PLANK checks a series of flags to determine which types of plankton are to be simulated. If PHYFG is assigned a value of one, simulation of phytoplankton is performed. Zooplankton are simulated if ZOOFG is given a value of one. Zooplankton simulation can be performed only if the phytoplankton section is active. Finally, a value of one for BALFG activates benthic algae simulation.

4.2(3).7.3.1 Advect Plankton (subroutine ADVPLK)

Purpose

ADVPLK performs the advection of phytoplankton and zooplankton. The normal advection method (subroutine ADVECT) used in the RCHRES module assumes that each constituent concentration is uniform throughout the RCHRES. This assumption is not valid for plankton. Both phytoplankton and zooplankton locate their breeding grounds near the channel boundaries. Since the water near the boundaries moves downstream much more slowly than the mean water velocity, the plankton populations have a much longer residence time in the RCHRES than would be indicated by the mean flowtime. The geographical extent of the plankton breeding grounds is inversely related to the flow rate. At low flows, large areas of slow moving waters which are suitable for breeding exist along the channel boundaries. As flowrates increase, more and more of these areas are subject to flushing. The special advection routine is critical to plankton simulation, because the only source of plankton is within the reach network. Thus an upstream RCHRES with no plankton inflows can maintain a significant plankton population only if the growth rate of plankton exceeds the rate at which plankton are advected out of the RCHRES. Since biological growth rates are typically much slower than "normal" advection rates, few free-flowing RCHRES's could maintain a plankton population without the use of the special advection routine.

Method

Figure 4.2(3).7.3-5 illustrates the relationships used to perform plankton advection.

ADVPLK assumes that a certain concentration of plankton (STAY) is not subject to advection, but any excess of organisms will be advected in the normal way. A small population (SEED) of plankton are never subject to advection, even during the periods of greatest flow. The maximum concentration of plankton which is not subject to advection (MXSTAY) occurs during low flow conditions. Each simulation interval ADVPLK calculates STAY based on the values of these two parameters and OREF. OREF is the outflow rate at which STAY has a value midway between SEED and MXSTAY. First, the average flow rate through the RCHRES for the interval is calculated:

$$\text{OFLO} = (\text{SROVOL} + \text{EROVOL}) / \text{DELTS} \quad (4)$$

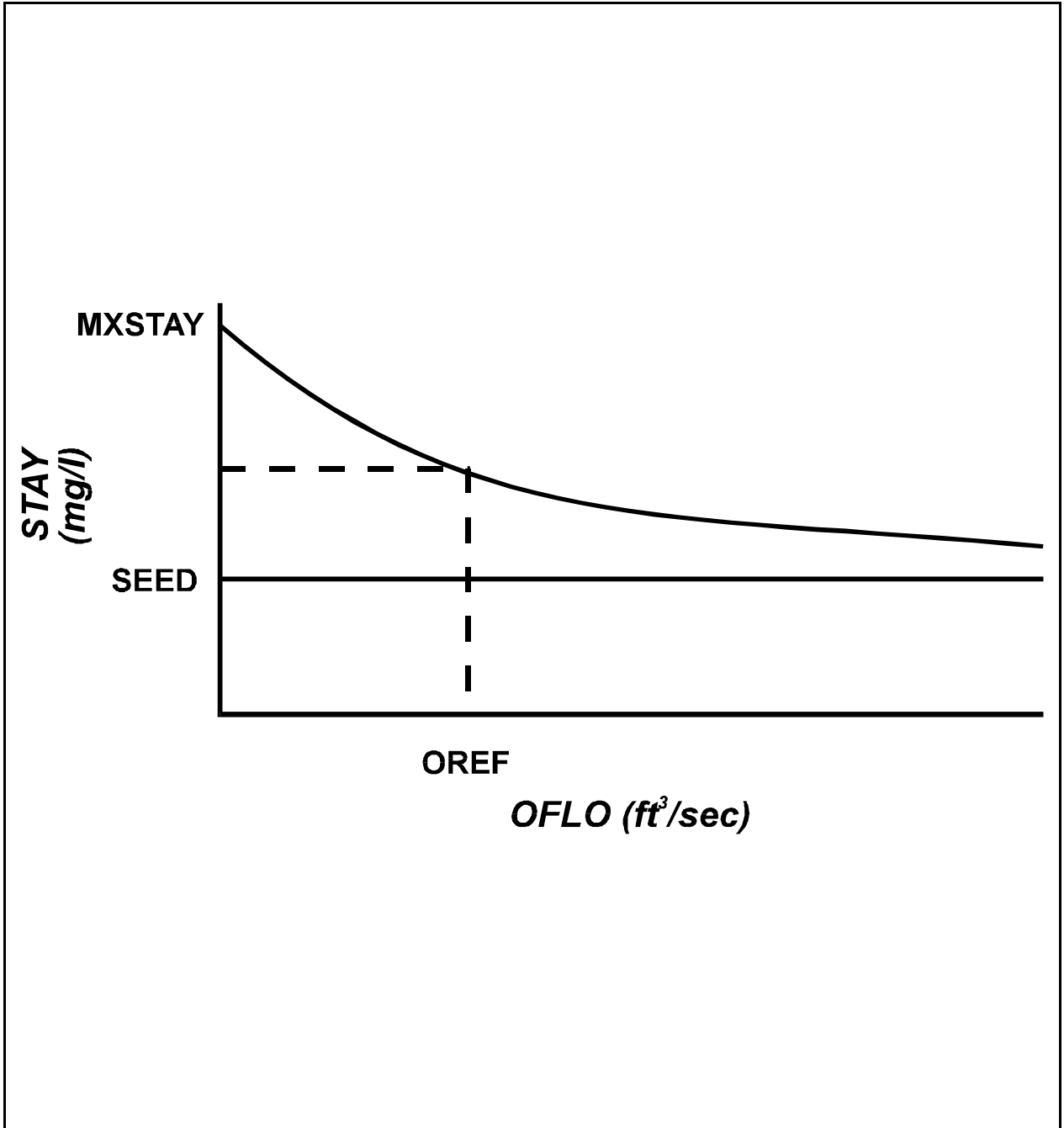


Figure 4.2(3).7.3-5 Relationship of parameters for special advection of plankton

where:

OFLO = average flow rate (ft³/s or m³/s)
 DELTS = number of seconds per interval
 SROVOL and EROVOL are as defined in Section 4.2(3).2

The concentration of plankton which is not subject to advection is then determined:

$$STAY = (MXSTAY - SEED) * (2.0 ** (-OFLO / OREF)) + SEED \quad (5)$$

where:

STAY = plankton concentration not advected (mg/l)
 MXSTAY = maximum concentration not subject to advection
 SEED = concentration of plankton never subject to advection
 OREF = outflow rate at which STAY has a value midway between SEED and MXSTAY (ft³/s or m³/s)

The amount of plankton not subject to advection is converted to units of mass (MSTAY) by multiplying STAY by the volume in the RCHRES at the start of the interval (VOL). The concentration of plankton which is advected is:

$$PLNKAD = PLANK - STAY \quad (6)$$

ADVPLK calls subroutine ADVECT to perform longitudinal advection of the quantity PLNKAD. The updated value of PLNKAD is then added to the amount of plankton which did not undergo advection to determine the concentration of plankton in the RCHRES at the end of the interval:

$$PLANK = PLNKAD + MSTAY / VOL \quad (7)$$

where:

PLANK = concentration of plankton at end of interval
 PLNKAD = concentration of advected plankton which remain in RCHRES
 MSTAY = mass of plankton not advected
 VOL = volume in RCHRES at end of interval

If the concentration of plankton in the RCHRES at the start of the interval is less than the value assigned to SEED, advection of plankton is not performed in the RCHRES, and the value of PLANK at the end of the interval is calculated as:

$$PLANK = (MSTAY + IPLANK) / VOL \quad (8)$$

where:

IPLANK = mass of plankton which enters RCHRES during interval

4.2(3).7.3.2 Calculate Light-related Information Needed for Algal Simulation
(subroutine LITRCH)

Purpose

Subroutine LITRCH determines the light correction factor to algal growth and the amount of light available to phytoplankton and benthic algae.

Method

The overall light extinction factor for the interval is obtained by adding EXTSED and EXTCLA to the base extinction coefficient (EXTB). The value of EXTB is assumed constant for a particular RCHRES and must be assigned in the User's Control Input. The resulting sum (EXTCO) is used to calculate the euphotic depth, which is the distance below the surface of the water body at which 1 percent of the light incident on the surface is still available:

$$EUDEP = 4.60517/EXTCO \quad (9)$$

where:

EUDEP = euphotic depth (ft)
EXTCO = total light extinction coefficient (/ft)

HSPF assumes that growth of algae occurs only in the euphotic zone (that is, the water above euphotic depth). When EUDEP has been calculated, it is possible to assign a value to CFLIT, the light correction factor to algal growth. A value of 1.0 is assigned to CFLIT if the calculated euphotic zone includes all the water of the RCHRES. $CFLIT = EUDEP/AVDEPE$, if the euphotic depth is less than the average depth of water (AVDEPE). CFLIT is used in subroutine ALGRO, to adjust the computed rate of algal growth.

Finally, the amount of light available to phytoplankton and benthic algae is calculated. The equation used to calculate the amount of light available to phytoplankton assumes that all phytoplankton are at mid-depth in the RCHRES or the middle of the euphotic zone, whichever is closer to the surface:

$$PHYLIT = INLIT * \text{Exp}(-EXTCO * (.5 * \text{Min}(EUDEP, AVDEPE))) \quad (10)$$

where:

PHYLIT = light available to phytoplankton (langleys/min)
INLIT = light available at water surface (langleys/min)
EXTCO = light extinction coefficient (/ft)
AVDEPE = average depth of water in the RCHRES (ft)
Exp = Fortran exponential function
Min = Fortran minimum function

The equation used to calculate the amount of light available to benthic algae assumes that all benthic algae are at AVDEPE below the surface of the RCHRES:

$$BALLIT = INLIT * \text{Exp}(-EXTCO * AVDEPE) \quad (11)$$

4.2(3).7.3.3 Simulate Phytoplankton (subroutine PHYRX)

Purpose

PHYRX simulates the algae which float in the water of a RCHRES. Because these organisms use energy from light to produce organic matter, they are called primary producers and are considered the first trophic level in the aquatic ecosystem. The biological activity of the ecosystem depends upon the rate of primary production by these photosynthetic organisms. The activities of the phytoplankton are in turn affected by the physical environment. Through the process of photosynthesis, phytoplankton consume carbon dioxide and release oxygen back into the water. At the same time, algal respiration consumes oxygen and releases carbon dioxide. Phytoplankton reduce the concentration of nutrients in the water by consuming phosphates, nitrate, and ammonia. Through assimilation these nutrients are transformed into organic materials which serve as a food source for higher trophic levels. A portion of the organic matter that is not used for food decomposes, which further affects the oxygen and nutrient levels in the water. Where the phytoplankton population has grown excessively, much of the available oxygen supply of the water may be depleted by decomposition of dead algae and respiration. In this situation, phytoplankton place a serious stress upon the system.

Approach

To describe quantitatively the dynamic behavior of phytoplankton populations, a number of assumptions must be made. PHYRX treats the entire phytoplankton population as if it were one species, and the mean behavior of the population is described through a series of generalized mathematical formulations. While such an approach obscures the behavior of individual species, the overall effect of the phytoplankton population on the water quality can be modeled with reasonable accuracy.

The HSPF system assumes that biomass of all types (phytoplankton, zooplankton, benthic algae, dead organic materials) has a consistent chemical composition. The user specifies the biomass composition by indicating the carbon:nitrogen:phosphorus ratio and the percent-by-weight carbon. This is done by assigning values to the following parameters:

1. CVBPC: number of moles of carbon per mole of phosphorus in biomass (default = 106)
2. CVBPN: number of moles of nitrogen per mole of phosphorus in biomass (default = 16)
3. BPCNTC: percentage of biomass weight which is carbon (default = 49)

The algorithms used in PHYRX and its subroutines require that the phytoplankton population be expressed in units of micromoles of phosphorus per liter. PHYRX converts the value for state variable PHYTO in milligrams biomass per liter into micromoles phosphorus per liter and assigns this value to the internal state variable STC (standing crop).

Subroutine Group PLANK

PHYRX uses five routines to simulate phytoplankton. ALGRO computes unit growth and respiration rates and determines the growth limiting factor for the phytoplankton. If the amount of growth exceeds the amount of respiration for the interval, GROCHK adjusts growth to account for nutrient limitations. PHYDTH calculates the amount of death occurring during the interval. State variables ORN, ORP, ORC, and BOD are updated by ORGBAL to account for materials resulting from phytoplankton death. Finally, NUTRUP adjusts the values for PO₄, NO₃, and TAM (total ammonia) to account for uptake of nutrients by phytoplankton. In addition to these updates, the dissolved oxygen state variable is adjusted in PHYRX to account for the net effect of phytoplankton photosynthesis and respiration:

$$\text{DOX} = \text{DOX} + (\text{CVPB} * \text{CVBO} * \text{GROPHY}) \quad (12)$$

where:

CVPB = conversion factor from micromoles phosphorus to mg biomass
CVBO = conversion factor from mg biomass to mg oxygen
GROPHY = net growth of phytoplankton (micromoles phosphorus/l per interval)

After all the operations in PHYRX and its subroutines have been performed, the value of STC is converted back into units of milligrams biomass per liter and becomes the updated value of PHYTO.

4.2(3).7.3.3.1 Calculate Unit Growth and Respiration Rates for Algae (subroutine ALGRO)

Purpose

ALGRO calculates the unit growth rate of algae based on light, temperature, and nutrients. Each time step, ALGRO determines the rate limiting factor for growth, and passes a label which identifies the limiting factor to the subroutines responsible for printed output. The labels and their meanings are as follows:

'LIT' Growth is light limited.
'NON' Insufficient nutrients are available to support growth.
'TEM' Water temperature does not allow algal growth.
'NIT' Growth is limited by availability of inorganic nitrogen.
'PO4' Growth is limited by availability of orthophosphorus.
'NONE' There is no limiting factor to cause less than maximal growth.
'WAT' Insufficient water is available to support growth.

ALGRO is also responsible for calculating the unit respiration rate for algae. This routine is used in the simulation of both phytoplankton and benthic algae.

Approach

ALGRO performs a series of initial checks to determine whether or not conditions are suitable for growth during the interval. If the light intensity for the interval is less than 0.001 langley/min, insufficient light is available for growth, and growth is not calculated. Likewise, if the concentration of either inorganic nitrogen or orthophosphorus is less than 0.001 mg/l, no growth occurs. If these checks indicate that conditions are suitable for growth, ALGRO next determines the effects of water temperature on the growth potential.

Temperature Control

The user specifies the temperature preferences of the algae by assigning values to three parameters: TALGRL, TALGRM, and TALGRH. If the water temperature is less than the value assigned to TALGRL or greater than the value assigned to TALGRH, no growth occurs. For water temperatures between TALGRL and TALGRH, a correction factor to maximum growth rate (MALGR) is calculated. This correction factor increases in value linearly from 0.0 at TALGRL to 1.0 at TALGRM. Thus, TALGRM specifies the minimum temperature at which growth can occur at a maximum rate. ALGRO assumes that there is no temperature retardation of maximum growth rate for temperatures between TALGRM and TALGRH. The temperature corrected maximum growth rate is:

$$\text{MALGRT} = \text{MALGR} * \text{TCMALG} \quad (13)$$

where:

MALGRT = temperature corrected maximum algal growth rate (/interval)

MALGR = maximum unit growth rate for algae

TCMALG = temperature correction to growth (TCMALG ranges between 0 and 1)

Once the temperature correction to potential growth rate has been made, ALGRO uses Monod growth kinetics with respect to orthophosphorus, inorganic nitrogen, and light intensity to determine the actual growth rate. The procedure taken in ALGRO is to consider each possible limiting factor separately to determine which one causes the smallest algal growth rate during each simulation interval. This method does not preclude that interactions between factors affect the actual growth rate; in cases where it has been established that there is such an interaction, as in the uptake of phosphate, the phenomena are included in the model. If none of the factors considered is limiting, growth will be maximal and temperature dependent.

Phosphorus Limited Growth

Algae are dependent upon uptake of orthophosphorus to provide the continual supply of phosphorus necessary for ordinary cellular metabolism and reproductive processes. In phosphorus-limited situations, the resultant growth rate has been shown to be dependent not only on the concentration of phosphate ions, but on nitrate concentration as well (DiToro, et al., 1970). The phosphorus limited growth rate is determined by:

$$\text{GROP} = \text{MALGRT} * \text{PO4} * \text{NO3} / ((\text{PO4} + \text{CMMP}) * (\text{NO3} + \text{CMMNP})) \quad (14)$$

where:

GROPP = unit growth rate based on phosphorus limitation (/interval)
 MALGRT = temperature corrected maximum algal growth rate
 PO4 = orthophosphorus concentration (mg P/l)
 NO3 = nitrate concentration (mg N/l)
 CMMP = orthophosphorus Michaelis-Menten constant for phosphorus
 limited growth (mg P/l) (CMMP is defaulted to 0.015 mg P/l)
 CMMNP = nitrate Michaelis-Menten constant for phosphorus limited
 growth (mg N/l) (CMMNP is defaulted to 0.0284 mg N/l)

Nitrogen Limited Growth

Nitrogen is essential to algae for assimilation of proteins and enzymes. In the form of nitrate, nitrogen serves as the essential hydrogen acceptor in the metabolic pathways which enable organisms to grow. ALGRO allows for two different sources of inorganic nitrogen. If ammonia is being simulated and a value of one is assigned to the nitrogen source flag (NSFG), both ammonia and nitrate are used by algae to satisfy their nitrogen requirements. Otherwise, only nitrate is considered in the kinetics formulations. High ratios of ammonia to nitrate have been found to retard algal growth. If a value of one is assigned to the ammonia retardation flag (AMRFG), this phenomenon is simulated by the equation:

$$\text{MALGN} = \text{MALGRT} - 0.757 \cdot \text{TAM} + 0.051 \cdot \text{NO3} \quad (15)$$

where:

MALGN = maximum unit growth rate corrected for ammonia retardation
 (/interval)
 MALGRT = temperature corrected maximum unit growth rate

Nitrogen limitation on growth is calculated by the equation:

$$\text{GRON} = \text{MALGN} \cdot \text{MMN} / (\text{MMN} + \text{CMMN}) \quad (16)$$

where:

GRON = unit growth rate based on nitrogen limitation (per interval)
 MALGN = maximum unit growth rate (MALGN has the same value
 as MALGRT if AMRFG is set to zero)
 MMN = total pool of inorganic nitrogen considered available for growth
 CMMN = Michaelis-Menten constant for nitrogen limited growth (mg N/l)
 (CMMN is defaulted to 0.045 mg N/l)

Light Limited Growth

The equation used to determine the limitation on growth rate imposed by light intensity was derived by Dugdale and Macisaac (1971) based on uptake rates of inorganic nitrogen under varying light intensities:

$$\text{GROL} = \text{MALGRT} \cdot \text{LIGHT} / (\text{CMMLT} + \text{LIGHT}) \quad (17)$$

where:

GROL = unit growth rate based on light limitation (/interval)
 MALGRT = temperature corrected maximum unit growth rate (/interval)
 LIGHT = light intensity available to algae in RCHRES (langleys/min)
 CMMLT = Michaelis-Menten constant for light limited growth (langleys/min)
 (CMMLT is defaulted to 0.033 langleys/min)

Algal Respiration

Algal respiration is dependent upon water temperature and is calculated by the equation:

$$RES = ALR20*(TW/20.) \quad (18)$$

where:

RES = unit algal respiration rate (/interval)
 ALR20 = unit respiration rate at 20 degrees C
 TW = water temperature (deg C)

4.2(3).7.3.3.2 Check Nutrients Required for Computed Growth (subroutine GROCHK)

GROCHK assures that a minimum concentration of 0.001 mg/l of each nutrient remains in the RCHRES waters after growth occurs. If this condition is not satisfied, the computed growth rate is adjusted accordingly. Orthophosphorus and inorganic nitrogen are always considered as nutrients. If pH is simulated (PHFG = 1), the user may specify that carbon dioxide concentration also be considered as a limiting nutrient by setting the value of DECFG equal to zero.

4.2(3).7.3.3.3 Calculate Phytoplankton Death (subroutine PHYDTH)

Purpose

PHYDTH calculates algal death each interval by using one of two unit death rates specified in the User's Control Input. ALDL, the low unit death rate, is used when environmental conditions encourage sustained life. In situations where nutrients are scarce or the phytoplankton population becomes excessive, ALDH, the high algal death rate, is used.

Method

The high algal death rate, which has a default value of 0.01/hr, is used if any one of three conditions exists:

1. the concentration of PO₄ is less than the value of parameter PALDH
2. the concentration of inorganic nitrogen is less than the value of parameter NALDH
3. the concentration of phytoplankton is greater than the value of parameter CLALDH

Regardless of whether these tests indicate that ALDH or ALDL should be used, an additional increment to death occurs if anaerobic conditions prevail during the interval. The increment to death rate due to anaerobic conditions is determined by the value of parameter OXALD. The amount of phytoplankton death which occurs during the interval is calculated as:

$$DTHPHY = ALD * STC \quad (19)$$

where:

DTHPHY = amount of phytoplankton death (micromoles P/l per interval)
 ALD = unit algal death rate determined by environmental conditions
 (/interval)
 STC = concentration of phytoplankton (micromoles P/l)

4.2(3).7.3.3.4 Perform Materials Balance for Transformation from Living to Dead Organic Material (subroutine ORGBAL)

Purpose

ORGBAL increments the concentrations of dead organics to account for plankton death. Plankton death may either be algal death, zooplankton death, or phytoplankton ingested by zooplankton but not assimilated. In each case in which ORGBAL is called, the increments to ORP, ORN, ORC, and BOD are calculated in the subroutine which makes the call and passed on to ORGBAL. ORGBAL is merely a service program which performs the additions to these state variables.

4.2(3).7.3.3.5 Perform Materials Balance for Transformation from Inorganic to Organic Materials (subroutine NUTRUP)

Purpose

NUTRUP adjusts the concentrations of inorganic chemicals to account for net growth of algae. Net growth may be either positive or negative depending on the relative magnitude of growth and respiration. The state variables which are updated by NUTRUP include PO4, NO3, TAM, and CO2.

Method

The adjustments to PO4 and CO2 are straightforward. The PO4 state variable is always updated; the CO2 state variable is only updated if pH is simulated (PHFG = 1) and carbon dioxide is considered as a limiting nutrient (DECFG = 0). Adjustment of the inorganic nitrogen state variables is more complex. If ammonia is not specified as a source of inorganic nitrogen for growth (NSFG = 0), only the NO3 state variable is updated to account for net growth. If ammonia is considered a nutrient (NSFG = 1), negative net growth is accounted for by adding the total flux of nitrogen to the TAM state variable. If net growth is positive, a portion of the nitrogen flux is subtracted from both the NO3 and TAM state variables. The relative proportions of NO3 and TAM are governed by the value of parameter ALNPR, which is the fraction of nitrogen requirements for growth which are preferably satisfied by nitrate.

4.2(3).7.3.4 Simulate Zooplankton (subroutine ZORX)

Purpose

ZORX simulates the growth and death of zooplankton, and the resultant changes in the biochemical balance of the RCHRES. Zooplankton play an important role in determining the water quality of rivers and lakes. By feeding on the algal, bacterial, and detrital mass, they are a natural regulator in the aquatic environment. At the same time zooplankton are a source of food material for higher trophic levels such as fish. Through excretion, zooplankton provide nutrients for phytoplankton growth. HSPF is only concerned with those zooplankton which feed on phytoplankton, although in reality zooplankton may be herbivores, omnivores, or carnivores.

Schematic View of Fluxes and Storages

Figure 4.2(3).7.3-3 illustrates the fluxes and storage of zooplankton modeled in ZORX. In addition to zooplankton, the state variables for dissolved oxygen, biochemical oxygen demand, total ammonia, nitrate, orthophosphate, and refractory organics are also updated. Subroutine ZORX considers the following processes:

1. filtering and ingestion of phytoplankton by zooplankton
2. assimilation of ingested materials to form new zooplankton biomass
3. zooplankton respiration
4. inorganic and organic zooplankton excretion
5. zooplankton death

Filtering and Ingestion

The amount of phytoplankton ingested per milligram zooplankton is calculated by the equation:

$$\text{ZOEAT} = \text{ZFIL20} * (\text{TCZFIL} ** (\text{TW} - 20.)) * \text{PHYTO} \quad (20)$$

where:

ZOEAT = unit ingestion rate (mg phyto/mg zoo per interval)
 ZFIL20 = zooplankton filtering rate at 20 degrees C
 (liters filtered/mg zoo per interval)
 TCZFIL = temperature correction coefficient for filtering
 TW = water temperature (deg C)
 PHYTO = phytoplankton concentration (mg phyto/l)

The filtering rate is dependent upon water temperature and phytoplankton concentration. Rates for most biological activities double for every 10 degrees Centigrade increase in temperature. The filtering rate meets this criterion if the default value of 1.17 is used for the temperature correction coefficient TCZFIL.

Subroutine Group PLANK

When the phytoplankton biomass is below a critical concentration, the unit filtering rate will be maximal and constant. As the phytoplankton biomass increases above the critical concentration, the limiting rate is dependent on ingestive and digestive capabilities, and not on the concentration of the food source. Under these conditions, the filtering rate decreases proportionally such that the algal biomass ingested remains constant at the value of the parameter MZOEAT, which is defaulted to 0.055 mg phytoplankton/mg zooplankton per hour. The code simulates this by reducing ZOEAT to MZOEAT, if Equation 20 gives a value greater than MZOEAT. HSPF assumes that the filtering activities of zooplankton are 100 percent efficient; that is, the zooplankton ingest all of the food which is contained in the water which they filter. The total amount of phytoplankton ingested by the zooplankton is calculated as:

$$ZEAT = ZOEAT * ZOO \quad (21)$$

where:

ZEAT = ingested phytoplankton (mg biomass/l per interval)

ZOEAT = unit ingestion rate

ZOO = zooplankton concentration (mg biomass/l)

ZORX checks that the calculated amount of ingestion does not reduce the phytoplankton population to less than 0.0025 micromoles of phosphorus per liter; if it does, the ingestion rate is adjusted to maintain a phytoplankton concentration at this level.

Assimilation

Assimilation is the process by which ingested phytoplankton are converted to new zooplankton mass. The process of assimilation is never 100 percent efficient in biological systems. Unassimilated food is excreted as organic and inorganic waste products. Zooplankton assimilation efficiency is dependent upon quality and concentration of food. High quality food is assimilated at high efficiency, whereas low quality food is mostly excreted as waste resulting in low assimilation efficiency. The relationship between food concentration and assimilation efficiency is more complex. If the concentration of available food and the filtering rate of an organism are such that the organism ingests more food than can be readily used for growth and metabolism, the organism's assimilation efficiency decreases. The model represents the effect of food quality and concentration on assimilation as shown in Figure 4.2(3).7.3-6.

The quality of the zooplankton food is assigned in the User's Control Input by the parameter ZFOOD. Three qualities of food are allowed. From these, one type must be chosen to represent the overall food source available to the zooplankton:

ZFOOD = 1 = high quality food
 2 = medium quality
 3 = low quality

Depending on the value assigned to ZFOOD, the assimilation efficiency ZEFF is calculated by one of the following equations:

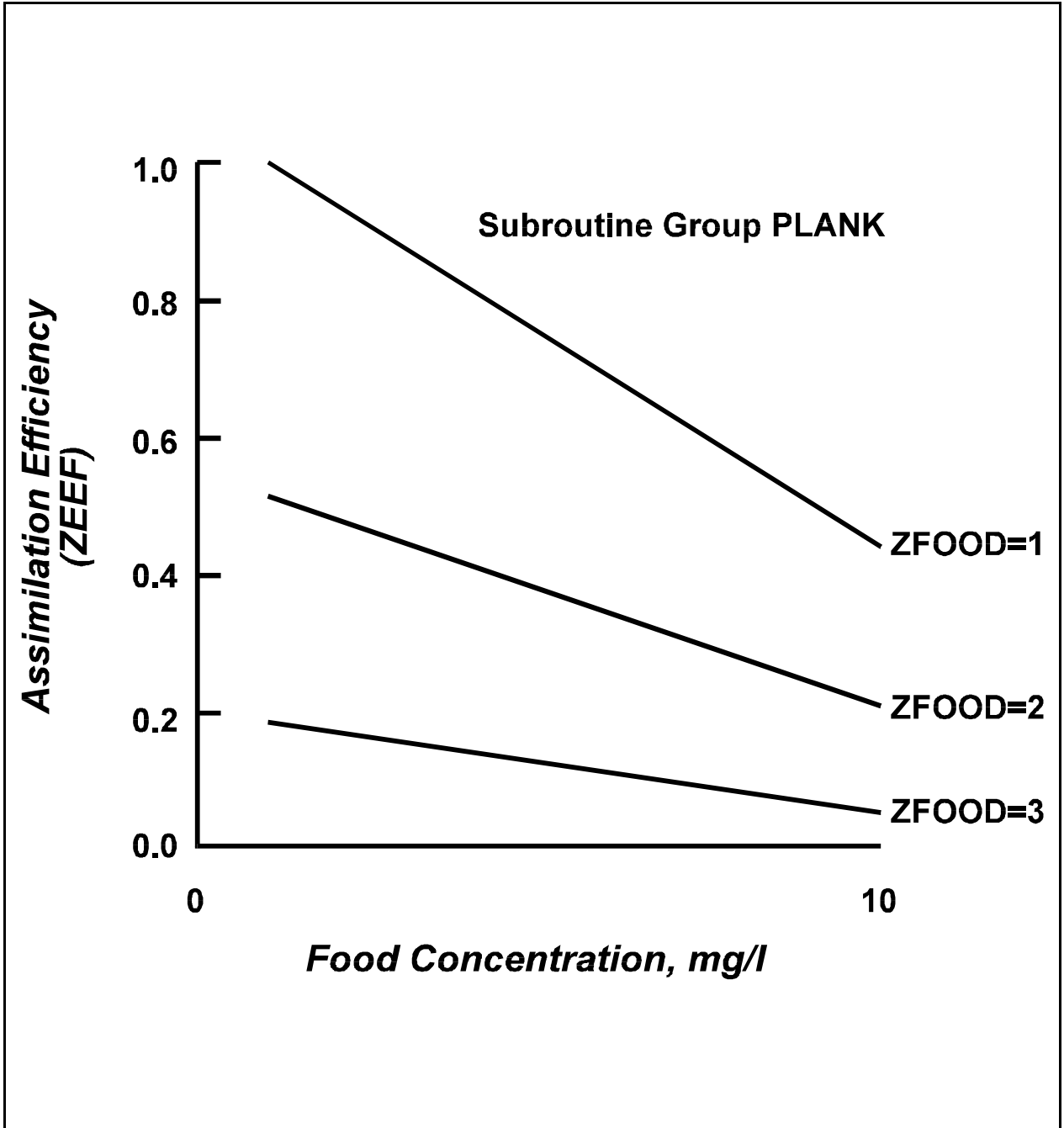


Figure 4.2(3).7.3-6 Zooplankton assimilation efficiency

Subroutine Group PLANK

```
IF ZFOOD = 1 THEN ZEFF = -0.06*PHYTO + 1.03           (22)
  IF ZEFF > 0.99 THEN ZEFF = 0.99
```

```
IF ZFOOD = 2 THEN ZEFF = -0.03*PHYTO + 0.47
  IF ZEFF < 0.20 THEN ZEFF = 0.20
```

```
IF ZFOOD = 3 THEN ZEFF = -0.013*PHYTO + 0.17
  IF ZEFF < 0.03 THEN ZEFF = 0.03
```

These equations are extrapolations from research on *Daphnia* (Schindler, 1968). The corrections to ZEFF set reasonable upper or lower limits on efficiency for assimilating each type of food. The mass of ingested phytoplankton assimilated by zooplankton is calculated as:

```
ZOGR = ZEFF*ZEAT                                     (23)
```

where:

```
ZOGR = zooplankton growth (mg biomass/l per interval)
ZEFF = assimilation efficiency (dimensionless)
ZEAT = ingested phytoplankton (mg biomass/l per interval)
```

Respiration

Respiration is the biochemical process by which organic molecules are broken down, resulting in a release of energy which is essential for cellular and organismal activities. The oxidized molecules may either be carbohydrates and fats stored within the organism or food passing through the organism's digestive system. In either case, the end result of respiration is a decrease in zooplankton mass and a subsequent release of inorganic nutrients. The equation governing zooplankton respiration is:

```
ZRES = ZRES20*(TCZRES**(TW - 20.))*ZOO             (24)
```

where:

```
ZRES   = zooplankton biomass respired (mg zoo/l per interval)
ZRES20 = respiration rate at 20 degrees C (default= 0.0015/hr)
TCZRES = temperature correction factor for respiration (default = 1.07)
ZOO     = zooplankton (mg biomass/l)
```

Excretion Products

Excretion is the ingested food which is not assimilated by the zooplankton. These waste products contain both refractory and nonrefractory materials. The amount of refractory organic excretion is calculated as:

```
ZREFEX = REFR*ZEXMAS                                (25)
```

where:

ZREFEX = refractory organic material excreted by zooplankton
(mg refractory biomass/l per interval)
ZEXMAS = total mass of zooplankton excretion
(ZEXMAS is the difference between ZEAT and ZOGR)
REFR = fraction of biomass which is refractory
(REFR is the complement of parameter NONREF)

The nonrefractory portion of the excretion is released to the water in the form of inorganic nutrients and undegraded BOD materials. The relative abundance of the materials is dependent upon the unit ingestion rate of the zooplankton (ZOEAT). At higher ingestion rates, a larger fraction of the nonrefractory excretion is not decomposed and is released as BOD materials. In the model, the parameter ZEXDEL is the fraction of nonrefractory excretion which is immediately decomposed and released to the water as inorganic nutrients when the unit ingestion rate of the zooplankton is maximal. If the unit ingestion rate is less than maximal, the model assumes that all the nonrefractory excretion is released to the water as inorganic nutrients. Thus, the amount of excretion released as inorganic materials is:

$$ZINGEX = ZEXDEC * (ZEXMAS - ZREFEX) \quad (26)$$

where:

ZINGEX = amount of biomass decomposed to inorganic excretion
(mg biomass/l per interval)
ZEXDEC = fraction of nonrefractory inorganic excretion
(ZEXDEC = 1 for ZOEAT <= MZOEAT and ZEXDEC = ZEXDEL for
ZOEAT > MZOEAT. Value of ZOEAT is that given by equation
20, i.e., prior to adjustment.)

The remaining portion of the excretion is considered to be BOD materials, and is calculated as:

$$ZNRFEX = ZEXMAS - ZREFEX - ZINGEX \quad (27)$$

where:

ZNRFEX = amount of biomass released as nonrefractory organic excretion
(mg biomass/l per interval)

Death

Zooplankton death is the termination of all ingestion, assimilation, respiration, and excretion activities. After death, zooplankton contribute both refractory and nonrefractory materials to the system. Under aerobic conditions, the mass rate of zooplankton death is determined by multiplying the natural zooplankton death rate, ZD, by the zooplankton concentration. If anaerobic conditions exist, an increase in zooplankton death rate is modeled by adding the value of the anaerobic death rate parameter, OXZD, to ZD. The default value of ZD is 0.0001/hr and that of OXZD is 0.03/hr.

Materials Balance for Related Constituents

Research has shown that 1.10 mg of oxygen are consumed for every gram of zooplankton mass which is respired (Richman, 1958). The DOX state variable is reduced accordingly in ZORX. If there is not sufficient oxygen available to satisfy respiration requirements, the deficit is added to the BOD state variable, and DOX is set equal to zero.

ZORX makes use of subroutine DECBAL to update the state variables TAM, NO3, and PO4 to account for additions from zooplankton respiration and inorganic excretion. The amount of inorganic constituents produced by these two processes is calculated by the following equations:

$$\begin{aligned} \text{ZNIT} &= (\text{ZINGEX} + \text{ZRES}) * \text{CVBN} \\ \text{ZPO4} &= (\text{ZINGEX} + \text{ZRES}) * \text{CVBP} \\ \text{ZCO2} &= (\text{ZINGEX} + \text{ZRES}) * \text{CVBC} \end{aligned} \quad (28)$$

where:

ZNIT = increment to TAM or NO3 state variable (mg N/l per interval)
 ZPO4 = increment to PO4 state variable (mg P/l per interval)
 ZCO2 = increment to CO2 state variable (mg C/l per interval)
 ZINGEX = biomass decomposed to inorganic excretion (mg biomass/l per interval)
 ZRES = biomass respired by zooplankton (mg biomass/l per interval)
 CVBN = conversion factor from biomass to equivalent nitrogen
 CVBP = conversion factor from biomass to equivalent phosphorus
 CVBC = conversion factor from biomass to equivalent carbon

If ammonia is simulated, the inorganic nitrogen released is added to the TAM variable; otherwise, it is added to the NO3 variable. The value of ZCO2 is computed for use in subroutine group PHCARB if pH simulation is performed. Finally, ZORX calls subroutine ORGBAL to update the state variables for ORN, ORP, ORC, and BOD to account for additions from zooplankton death and organic excretion. The amounts of organic constituents produced by these processes are calculated as:

$$\begin{aligned} \text{ZORN} &= ((\text{REFR} * \text{ZDTH}) + \text{ZREFEX}) * \text{CVBN} \\ \text{ZORP} &= ((\text{REFR} * \text{ZDTH}) + \text{ZREFEX}) * \text{CVBP} \\ \text{ZORC} &= ((\text{REFR} * \text{ZDTH}) + \text{ZREFEX}) * \text{CVBC} \\ \text{ZBOD} &= (\text{ZDTH} * \text{CVNRBO}) + (\text{ZNRFEFEX} * \text{CVBO}) \end{aligned} \quad (29)$$

where:

ZORN = increment to ORN state variable (mg N/l per interval)
 ZORP = increment to ORP state variable (mg P/l per interval)
 ZORC = increment to ORC state variable (mg C/l per interval)
 ZBOD = increment to BOD state variable (mg O/l per interval)
 REFR = refractory fraction of biomass
 ZDTH = zooplankton death (mg biomass/l per interval)
 ZREFEX = refractory organic excretion (mg biomass/l per interval)
 ZNRFEFEX = nonrefractory organic excretion (mg biomass/l per interval)
 CVBO = conversion from biomass to equivalent oxygen
 CVNRBO = conversion from nonrefractory biomass to equivalent oxygen,
 times NONREF

4.2(3).7.3.5 Simulate Benthic Algae (subroutine BALRX)

Purpose

BALRX simulates those algae in the RCHRES which are attached to rocks or other stable structures. In free flowing streams, large diurnal fluctuations of oxygen can be attributed to benthic algae. During the sunlight hours, if sufficient nutrients exist to support photosynthesis, oxygen is produced in such large quantities that supersaturation often occurs. However, at night, when photosynthesis cannot occur, the benthic algae can exert a significant demand on the oxygen supply of the RCHRES due to respiratory requirements. Benthic algae influence the nutrient balance of the RCHRES by their extraction of nutrients for growth.

Approach

The growth and death of benthic algae are modeled in much the same manner as their free floating relatives, the phytoplankton. In fact, four of the five subroutines that are used for phytoplankton simulation are also used in the benthic algae simulation. These routines are ALGRO, GROCHK, ORGBAL, and NUTRUP. There are two major differences in modeling the two types of algae. First, since the benthic algae are attached to materials in the RCHRES, they are not subject to longitudinal advection. Second, the manner in which death of benthic algae is modeled is sufficiently different from the method used for phytoplankton that a special routine, BALDTH, is used. Within BALRX benthic algae are in units of micromoles phosphorus per liter so that the benthic algae simulation can take advantage of the same subroutines used by PHYRX. In order to obtain these units, the following conversion is performed:

$$BAL = BENAL * DEPCOR / CVPB \quad (30)$$

where:

BAL = benthic algae (micromoles phosphorus/l)
 BENAL = benthic algae (mg biomass/m²)
 CVPB = conversion factor from micromoles phosphorus to mg biomass
 DEPCOR = conversion from square meters to liters based on average depth of water in RCHRES during the interval (DEPCOR is computed in RQUAL)

Net Growth

Unit growth and respiration rates for benthic algae are calculated by subroutine ALGRO. The user has the option of multiplying either of these rates by a constant factor if there is evidence that the benthic algae population does not exhibit the same growth and respiration rates as the phytoplankton population. Thus, net growth rate is calculated as:

$$GROBAL = (GRO * CFBALG - RES * CFBALR) * BAL \quad (31)$$

where:

GROBAL = net growth rate of benthic algae (micromoles P/l per interval)
 GRO = unit growth rate as calculated in subroutine ALGRO
 CFBALG = ratio of benthic algae to phytoplankton growth rates
 under identical growth conditions (default = 1.0)
 RES = unit respiration rate as calculated in subroutine ALGRO
 CFBALR = ratio of benthic algae to phytoplankton respiration rates
 (default = 1.0)
 BAL = benthic algae concentration (micromoles P/l)

After GROBAL has been calculated, subroutine GROCHK is called to assure that the calculated growth does not reduce any nutrient to a concentration less than 0.001 mg/l. If it does, GROBAL is adjusted to satisfy this requirement.

Death of Benthic Algae

Subroutine BALDTH calculates the amount of benthic algae death and passes this information back to BALRX (variable DTHBAL). BALRX updates the state variable BAL to account for net growth and death. The value of BAL is not allowed to fall below 0.0001 micromoles of phosphorus per square meter.

Materials Balance for Related Constituents

The DOX state variable is updated to account for the net effect of benthic algae photosynthesis and respiration according to the following equation:

$$\text{DOX} = \text{DOX} + (\text{CVPB} * \text{CVBO} * \text{GROBAL}) \quad (32)$$

where:

DOX = concentration of dissolved oxygen (mg/l)
 CVPB = conversion factor from micromoles phosphorus to mg biomass
 CVBO = conversion factor from mg biomass to mg oxygen
 GROBAL = net growth of benthic algae (micromoles phosphorus/l per interval)

The additions to ORN, ORP, ORC, and BOD resulting from benthic algae death are calculated as:

$$\begin{aligned} \text{BALORN} &= \text{REFR} * \text{DTHBAL} * \text{CVBPN} * .014 \\ \text{BALORP} &= \text{REFR} * \text{DTHBAL} * .031 \\ \text{BALORC} &= \text{REFR} * \text{DTHBAL} * \text{CVBPC} * .012 \\ \text{BALBOD} &= \text{CVNRBO} * \text{CVPB} * \text{DTHBAL} \end{aligned} \quad (33)$$

where:

BALORN = increment to ORN state variable (mg N/l per interval)
 BALORP = increment to ORP state variable (mg P/l per interval)
 BALORC = increment to ORC state variable (mg C/l per interval)
 BALBOD = increment to BOD state variable (mg O/l per interval)
 REFR = refractory fraction of biomass
 DTHBAL = benthic algae death (micromoles P/l per interval)
 CVNRBO = conversion from mg biomass to equivalent mg
 oxygen demand (allowing for refractory fraction)
 CVPB = conversion from micromoles phosphorus to mg biomass
 CVBPN = conversion from micromoles phosphorus to micromoles nitrogen
 CVBPC = conversion from micromoles phosphorus to micromoles carbon

When BALORN, BALORP, BALORC, and BALBOD have been evaluated, subroutine ORGBAL is called to perform the actual increments to the appropriate state variables. Finally, subroutine NUTRUP is called to update the inorganic state variables to account for net growth.

External Units

The output values for benthic algae are in units of milligrams biomass per square meter and micrograms chlorophyll a per square meter.

4.2(3).7.3.5.1 Calculate Benthic Algae Death (subroutine BALDTH)

Purpose

BALDTH calculates algal death each interval by using one of two unit death rates specified in the User's Control Input. ALDL, the low unit death rate, is used when environmental conditions encourage sustained life; in situations where nutrients are scarce or the benthic algae population becomes excessive, ALDH, the high algal death rate, is used.

Method

The high algal death rate, which has a default value of 0.01/hr, is used if any one of three conditions exists:

1. the concentration of PO₄ is less than the value of parameter PALDH
2. the concentration of inorganic nitrogen is less than the value of parameter NALDH
3. the areal density of benthic algae is greater than the value of parameter MBAL

Subroutine Group PLANK

Regardless of whether these tests indicate that ALDH or ALDL (default equals 0.001/hr) should be used, an additional increment to death occurs if anaerobic conditions are prevalent during the interval. The increment to death rate due to anaerobic conditions is determined by the value of parameter OXALD. When the benthic algae population grows to a size greater than that which may be supported on the bottom surface, algae begin to break away from the bottom, a phenomenon known as sloughing. Whenever the population calculated exceeds the maximum allowable bottom density (MBAL), the sloughing process removes the excess algae. The amount of benthic algae death which occurs during the interval is calculated as:

$$DTHBAL = (ALD * BAL) + SLOF \quad (34)$$

where:

DTHBAL = amount of benthic algae death (micromoles P/l per interval)
ALD = unit algal death rate determined by environmental conditions
(/interval)
BAL = concentration of benthic algae (micromoles P/l)
SLOF = amount of benthic algae sloughed (micromoles P/l per interval)

4.2(3).7.4 Simulate pH, Carbon Dioxide, Total Inorganic Carbon,
and Alkalinity (Subroutine Group PHCARB of Module RCHRES)

Purpose

PHCARB calculates the pH of the water within a RCHRES. The primary value of pH is as an indicator of the chemical environment of the system. Under normal circumstances, pH is near neutral, that is, near seven. Most life sustaining processes are impaired at extremes of pH.

Method

Figure 4.2(3).7.4-1 illustrates the fluxes and storages of constituents introduced in this section. Determination of pH requires simulation of alkalinity, carbon dioxide, and total inorganic carbon. Within PHCARB, state variables for alkalinity (ALK), carbon dioxide (CO₂), and total inorganic carbon (TIC) are expressed as molar concentrations to correspond to the equilibrium expressions necessary to determine pH. The conversion from mg/l to moles/l takes place after longitudinal advection has been considered. Externally, ALK, CO₂, and TIC are expressed in mg/l.

Alkalinity

Alkalinity is defined as the amount of acid required to attain a pH value equal to that of a total inorganic carbon molar solution of H₂CO₃. This pH value is near 4.5, which is approximately the lowest pH value tolerated by most forms of aquatic life. Alkalinity is interpreted as the acid neutralizing capacity of natural waters.

Alkalinity is simulated as a conservative constituent, in module section CONS. Parameter ALKCON, in the User's Control Input for PHCARB, specifies which conservative substance is alkalinity. For example, if ALKCON = 3 then subroutine PHCARB will assume that alkalinity is the 3rd conservative constituent.

Carbon Dioxide and Total Inorganic Carbon

HSPF assumes that changes in the TIC concentration occur only as changes in CO₂ concentration. Thus, the sources of TIC are:

1. carbon dioxide invasion (input) from the atmosphere
2. zooplankton respiration
3. carbon dioxide released by BOD decay
4. net growth of algae (if negative)
5. benthic release of carbon dioxide (if BENRFG = 1)

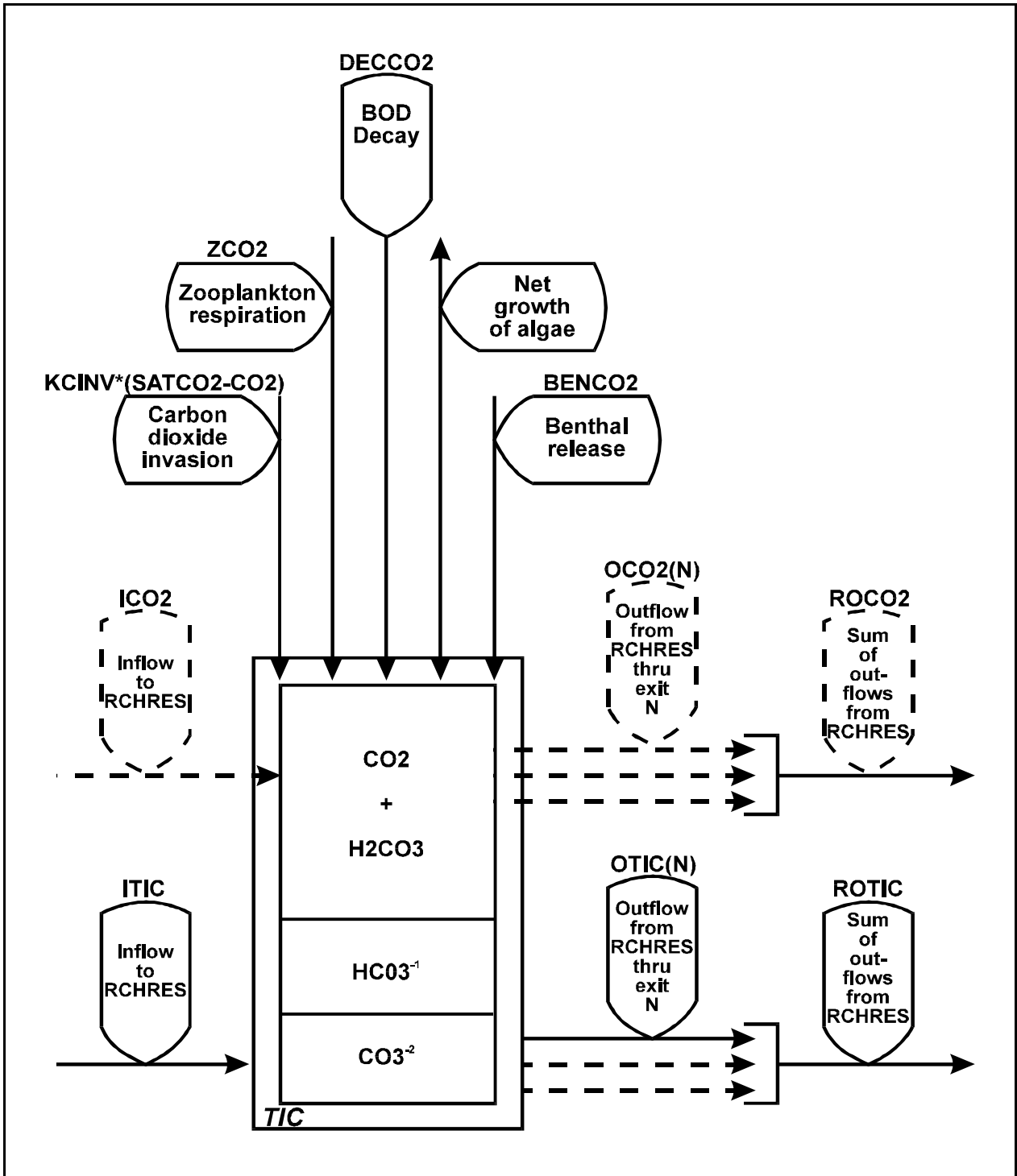


Figure 4.2(3).7.4-1 Flow diagram of inorganic carbon in the PHCARB group of the RCHRES Application Module

The sinks of TIC are:

1. carbon dioxide release to the atmosphere
2. net growth of algae (if positive)

All of these quantities except carbon dioxide invasion are calculated in other subroutines and passed into PHCARB.

Carbon Dioxide Invasion

In order to calculate carbon dioxide invasion, the saturation concentration of CO₂ must be determined. First, Henry's constant for CO₂, defined as the molar concentration of atmospheric CO₂ divided by the partial pressure of CO₂, is calculated by the equation:

$$S = 10.**(2385.73/TWKELV - 14.0184 + 0.0152642*TWKELV) \quad (1)$$

where:

S = Henry's constant for CO₂
 TWKELV = temperature of water (deg K)

Using Henry's constant, the saturation concentration of CO₂ is calculated as:

$$SATCO2 = 3.16E-04*CFPRES*S \quad (2)$$

where:

SATCO2 = saturation concentration of CO₂ (moles CO₂-C/l)
 CFPRES = correction to atmospheric pressure resulting from elevation difference (calculated in the Run Interpreter)
 S = Henry's constant for CO₂

The carbon dioxide invasion is then calculated by the following equation:

$$ATCO2 = KCINV*(SATCO2 - CO2) \quad (3)$$

where:

ATCO2 = carbon dioxide invasion expressed as moles CO₂-C/l per interval
 KCINV = carbon dioxide invasion coefficient (/interval)
 SATCO2 = saturation concentration of CO₂ (moles CO₂-C/l)
 CO2 = concentration of CO₂ after longitudinal advection (moles CO₂-C/l)

A positive value for ATCO₂ indicates addition of CO₂ to the water; a negative value indicates a release of CO₂ from water to the atmosphere. The value of KCINV is dependent upon the value calculated for KOREA, the oxygen reaeration coefficient, in subroutine group OXRX:

$$KCINV = CFCINV * KOREA \quad (4)$$

where:

KCINV = carbon dioxide invasion coefficient (/interval)
 CFCINV = parameter specifying ratio of CO₂ invasion rate to O₂ reaeration rate
 KOREA = oxygen reaeration coefficient (/interval)

Net Carbon Dioxide Flux

The net carbon dioxide flux is determined by the following equation:

$$DELTCO_2 = ATCO_2 + (ZCO_2 - ALGCO_2 + DECCO_2 + BENCO_2) / 12000. \quad (5)$$

where:

DELTCO₂ = net CO₂ flux (moles CO₂-C/l per interval)
 ATCO₂ = CO₂ invasion (moles CO₂-C/l per interval)
 ZCO₂ = CO₂ released by zooplankton excretion and respiration (mg CO₂-C/l per interval)
 ALGCO₂ = CO₂ flux due to net growth of algae (mg CO₂-C/l per interval)
 DECCO₂ = CO₂ released by BOD decay (mg CO₂-C/l per interval)
 BENCO₂ = benthic release of CO₂ (mg CO₂-C/l per interval)
 12000. = conversion from mg CO₂-C/l to moles CO₂-C/l

If DECFG, the flag which decouples CO₂ from the algal simulation, has a value of one, ALGCO₂ has a value of zero in this equation. Benthic release rates for both aerobic and anaerobic conditions must be included in the User's Control Input if benthic release of CO₂ is simulated. Since HSPF assumes that changes in total inorganic carbon concentration only occur as changes in carbon dioxide, the update to the TIC state variable for each simulation interval is:

$$TIC = TIC + DELTCO_2 \quad (6)$$

where:

TIC = total inorganic carbon (moles C/l)

The Carbonate System

The value of pH is controlled by the carbonate system. There are three species of importance to the system: [H₂CO₃*], [HCO₃], and [CO₃]. [H₂CO₃*] is defined as the sum of [H₂CO₃] and [CO₂]; for modeling purposes [H₂CO₃] is negligible relative to [CO₂]. The carbonate system can be described by the following equations:

$$\begin{aligned} [H] * [HCO_3] / [H_2CO_3^*] &= K1EQU \\ [H] * [CO_3] / [HCO_3] &= K2EQU \\ [H] * [OH] &= KWEQU \\ [H_2CO_3^*] + [HCO_3] + [CO_3] &= TIC \\ [HCO_3] + 2 * [CO_3] + [OH] - [H] &= ALK \end{aligned} \quad (7)$$

where:

[H] = hydrogen ion concentration (moles/l)
 [OH] = hydroxide ion concentration (moles/l)
 [CO3] = carbonate ion concentration (moles/l)
 [HCO3] = bicarbonate ion concentration (moles/l)
 [H2CO3*] = carbonic acid/carbon dioxide concentration (moles/l)
 K1EQU = first dissociation constant for carbonic acid
 K2EQU = second dissociation constant for carbonic acid
 KWEQU = ionization product of water

The five unknown values ([H2CO3*], [HCO3], [CO3], [H], [OH]) can be determined when K1EQU, K2EQU, KWEQU, TIC, and ALK are known. K1EQU, K2EQU, and KWEQU are all functions of water temperature and are evaluated by the following equations:

$$\begin{aligned} K1EQU &= 10.**(-3404.71/TWKELV + 14.8435 - 0.032786*TWKELV) \\ K2EQU &= 10.**(-2902.39/TWKELV + 6.4980 - 0.02379*TWKELV) \\ KWEQU &= 10.**(-4470.99/TWKELV + 6.0875 - 0.01706*TWKELV) \end{aligned} \quad (8)$$

where:

TWKELV = absolute temperature of water (deg K)

Calculation of pH and CO2

Once values have been determined for K1EQU, K2EQU, KWEQU, TIC, and ALK, an equilibrium equation can be developed for hydrogen ion concentration ([H]). The five equations representing the carbon system (Equation 7) can be reduced to a fourth order polynomial expression:

$$[H]**4 + COEFF1*([H]**3) + COEFF2*([H]**2) + COEFF3*[H] + COEFF4 = 0 \quad (9)$$

where:

COEFF1 = ALK + K1EQU
 COEFF2 = -KWEQU + ALK*K1EQU + K1EQU*K2EQU - TIC*K1EQU
 COEFF3 = -2.*K1EQU*K2EQU*TIC - K1EQU*KWEQU + ALK*K1EQU*K2EQU
 COEFF4 = -K1EQU*K2EQU*KWEQU
 [H] = hydrogen ion concentration (moles/l)

The solution of this equation is performed by subroutine PHCALC. Based on the hydrogen ion concentration calculated in PHCALC, the concentration of CO2 is recalculated as:

$$CO2 = TIC/(1. + K1EQU/HPLUS + K1EQU*K2EQU/(HPLUS**2)) \quad (10)$$

where:

CO2 = carbon dioxide concentration (moles C/l)
 TIC = total inorganic carbon concentration (moles C/l)

Subroutine Group PHCARB

K1EQU = first dissociation constant of carbonic acid
K2EQU = second dissociation constant of carbonic acid
HPLUS = hydrogen ion concentration (moles H/l)

Finally, the units of TIC, CO₂, and ALK are converted back to mg/l for use outside of PHCARB.

4.2(3).7.4.1 Calculate pH (subroutine PHCALC)

PHCALC uses the Newton-Raphson method to solve the fourth order polynomial expression for the hydrogen ion concentration (Equation 9). The user specifies the maximum number of iterations performed by assigning a value to parameter PHCNT. PHCALC continues the iteration process until the solutions for pH concentration of two consecutive iterations differ by no more than one tenth of a pH unit. If the solution technique does not converge within the maximum allowable number of iterations, PHCALC passes this information back to PHCARB by assigning a value of zero to CONVFG. An error message is printed and then PHCALC is called again, to repeat the unsuccessful iteration process. This time, the "debug flag" (PHDBG) is set ON so that, for each iteration, PHCALC will print information which will help the user track down the source of the problem.

4.2(11) Copy Time Series (Utility Module COPY)

This utility module is used to copy one or more time series from a source specified in the EXT SOURCES or NETWORK Block of the User's Control Input (UCI), to a target specified in the NETWORK or EXT TARGETS Block (Part F, Section 4.6).

To operate the COPY module, the user must specify the time interval used in the internal scratch pad (INDELT) and the number of point-valued and mean-valued time series to be copied (NPT and NMN in Part F, Section 4.4(11).1). Up to 20 point-valued and/or 20 mean-valued time series may be copied in a single operation.

Module TSGET transfers the time series from the source(s), which may be either external (e.g. WDM or DSS data set or sequential file) or the output(s) from one or more preceding operations, to the INPAD. DSS Data sets with time steps other than the internal scratch pad time interval (INDELT) will be automatically aggregated or disaggregated. Data from sequential files must be at the INDELT interval. It also automatically alters the "kind" of time series, if appropriate, and can multiply each value by a user-specified factor.

Module TSPUT then transfers the time series from the INPAD to the target which, again, can be either external or internal. The work performed is a mirror image of that done by TSGET; time series can be aggregated/disaggregated and/or transformed in the same way.

Module COPY is typically used to transfer time series, such as precipitation and potential evapotranspiration data, from a sequential file (e.g., ASCII data) to a data set in the WDM file or DSS. Thereafter, when these data are used as inputs to simulation operations, they are read directly from the WDM or DSS.

COPY can also be used to change the "kind" and/or interval of one or more time series. For example, a WDM data set containing hourly precipitation data could be input to COPY and the output stored in another WDM data set with a daily time step. The data would automatically be aggregated.

4.2(12) Prepare Time Series for Display on a Plotter (Utility Module PLTGEN)

This utility module prepares one or more time series for simultaneous display on a plotter. As with the COPY module (Section 4.2(11)), the user must specify the input(s) (sources), using entries in the EXT SOURCES or NETWORK Blocks in his control input (UCI). The internal time-step and the number of point- and/or mean-valued time series to be displayed must also be specified.

TSGET transfers the time series from the source(s) to the INPAD (as in COPY). PLTGEN then outputs these data to a plot file (PLOTFL). This is a sequential file; the first 25 records contain general information, such as the plot heading, number of curves to be plotted, scaling information, etc. Each subsequent record contains:

<u>Cols</u>	<u>Contents</u>
1 - 4	Identifier (first 4 characters of title)
6 - 10	Year
11 - 13	Month
14 - 16	Day
17 - 19	Hour
20 - 22	Minute
25 - 36	Value for curve 1, for this date/time
39 - 50	Value for curve 2, for this date/time
etc	(repeats until data for all curves are supplied)

Format: A4,1X,I5,4I3,10(2X,G12.5)

The time resolution of the PLOTFL is the INDELT of the run, an integer multiple of the INDELT which is also evenly divisible into one day, one month, or one year.

A PLOTFL may contain only records greater than a certain threshold value, THRESH, or during a certain span of time specified in the Special Actions Block.

The contents of a sample PLOTFL are listed in Figure 4.2(12)-1. To keep the listing short, only the first four values have been included

A plot file is intended to be read by a stand-alone plot program, which translates its contents into information used to drive a plotting device. Alternative uses of a PLOTFL are:

1. To display one or more time series in printed form. For example: To examine the contents of a data set in the WDM file, input it to PLTGEN and list the contents of the PLOTFL on a line printer or terminal.
2. To transfer time series to some other stand-alone program, such as a spreadsheet or graphical display program. For example, one could specify the contents of a PLOTFL as input to a program which performs statistical analysis or computes cross correlations between time series.

```

Plot HSPF FILE FOR DRIVING SEPARATE PLOT PROGRAM
Plot Time interval: 30 mins          Last month in printout year: 9
Plot No. of curves plotted: Point-valued: 2  Mean-valued: 0  Total: 2
Plot Label flag: 0          PIVL: 1          IDELT: 30
Plot Plot title: Plot of reservoir flowrates
Plot Y-axis label: Flow (ft3/sec)
Plot Scale info: Ymin: .00000E+00
Plot          Ymax: 1000.0
Plot          Time: 48.000          intervals/inch
Plot Data for each curve (Point-valued first, then mean-valued):
Plot Label          LINTYP          INTEQ          COLCOD          TRAN          TRANCOD
Plot Inflow          0          0          1          SUM          1
Plot Outflow         0          0          1          SUM          1
Plot
Plot
Plot
Plot
Plot
Plot
Plot
Plot
Plot
Plot
Plot Time series (pt-valued, then mean-valued):
Plot
Plot Date/time          Values
Plot
Plot 1974 5 31 24 0          .00000E+00          1.0000
Plot 1974 6 1 0 30          .82838          1.0000
Plot 1974 6 1 1 0          1.5071          1.0000
Plot 1974 6 1 1 30          2.0631          1.0000

```

Figure 4.2(12)-1 Sample PLOTFL (showing four time points)

4.2(13) Display Time Series in a Convenient Tabular Format (Utility Module DISPLY)

The purpose of this module is to permit any time series to be displayed (at a variety of time intervals) in a tabular format. Sample outputs are shown in Figures 4.2(13)-1 through -3. Salient features of this module are:

1. Any time series (input or computed) can be displayed. The user specifies the time series in the EXT SOURCES or NETWORK Block, as with any other module.
2. As with any other module, the data are first placed in the INPAD, by module TSGET. At this point they are at the time interval specified for this operation in the OPN SEQUENCE Block (INDELT). This might have involved aggregation or disaggregation if the data were brought in from the WDM file. In general, INDELT can be any of the 19 HSPF supported time steps, ranging from 1 minute to 1 day.
3. The user can elect to display the data in a "long-span table" or a "short-span table". The term "span" refers to the period covered by each table. A short-span table (Figures 4.2(13)-1 and -2) covers a day or a month at a time and a long-span table (Figure 4.2(13)-3) covers a year.
4. The user selects the time-step for the individual items in a short-span display (the display interval) by specifying it as a multiple (PIVL) of INDELT. For example, the data in Figure 4.2(13)-1 are displayed at an interval of 5 minutes. This could have been achieved with the following scenarios:

INDELT	PIVL
5 min	1
1 min	5

If the display interval is less than one hour, one hours worth of data are displayed on one printed "row" (Figure 4.2(13)-1). The number of items in a row depends on their interval (e.g., 60 for one minute, 12 for 5 minutes, 2 for 30 mins.). A "row" may actually occupy up to 5 physical lines of printout because a maximum of 12 items is placed on a line. The entire table spans one day.

If the display interval is greater than or equal to one hour, a day's worth of data are displayed on one "row" (Figure 4.2(13)-2). Again, the number of items in a row depends on the display interval. In this case the entire table spans a month.

5. A long-span table always covers one year; the display interval for the individual items in the table is one day (Figure 4.2(13)-3). The user can select the month which terminates the display (December in the example) so that the data can be presented on a calendar year, water year or some other basis.
6. For the purpose of aggregating the data from the interval time step (INDELT) to the display interval, day-value, month-value, or year-value, one of five "transformation codes" can be specified:

Code	Meaning
SUM	Sum of the data
AVER	Average of the data
MAX	Take the max of the values at the smaller time step
MIN	Take the minimum
LAST	Take the last of the values belonging to the shorter time step

SUM is appropriate for displaying data like precipitation; AVER is useful for displaying data such as temperatures.

7. The module incorporates a feature designed to permit reduction of the quantity of printout produced when doing short-span displays. If the "row-value" ("hour-sum" in Figure 4.2(13)-1; "day-average" in Figure 4.3(13)-2) is less than or equal to a threshold value, printout of the entire row is suppressed. The default threshold is 0.0. Thus, in Figure 4.2(13)-1; data for dry hours are not printed.
8. The user can also specify the following:
 - a. The number of decimal digits to use in a display.
 - b. A title for the display.
 - c. A linear transformation, to be performed on the data when they are at the INDELT time interval (i.e. before module DISPLAY performs any aggregation). By default, no transformation is performed.

WDM 39 Precip. (in/100)
 Summary for DAY 1976/10/4
 Date interval: 5 mins

HOUR	SUM	Interval Number													
		1	2	3	4	5	6	7	8	9	10	11	12		
3:	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	1.0
4:	3.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
5:	5.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2.0
6:	6.0	1.0	1.0	2.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7:	3.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
8:	3.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
9:	3.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0
10:	3.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
11:	3.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0
12:	4.0	1.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0
13:	3.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0
14:	2.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
15:	4.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0
16:	7.0	0.0	0.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0	1.0	0.0
17:	3.0	1.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
18:	6.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0
19:	5.0	1.0	1.0	1.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0

WDM 121 Temperature (Deg. F)
 Summary for MONTH 1976/8/
 Data interval: 120 mins

DAY	AVER	Interval Number											
		1	2	3	4	5	6	7	8	9	10	11	12
1	67.7	58.0	61.3	55.1	61.3	69.0	75.6	79.8	81.8	77.4	71.4	65.9	61.2
2	67.2	57.5	55.2	54.2	60.8	69.1	76.1	80.7	82.8	77.6	70.4	64.0	58.4
3	66.7	54.1	51.5	50.2	57.8	67.2	75.1	80.4	82.8	78.6	72.8	67.5	62.8
4	72.8	59.3	57.2	56.2	63.5	72.7	80.3	85.4	87.8	84.4	79.6	75.4	71.6
5	73.0	68.8	67.0	66.1	69.8	74.3	78.2	80.7	81.9	78.6	74.1	69.9	66.3
6	68.3	63.6	61.9	61.1	65.4	70.8	75.4	78.4	79.9	74.9	68.2	62.2	56.9
7	65.2	52.8	50.4	49.2	57.0	66.7	74.8	80.3	82.8	77.4	70.1	63.5	57.7
8	66.0	53.2	50.5	49.2	57.2	67.1	75.6	81.1	83.8	78.6	71.4	65.0	59.4
9	71.4	55.1	52.5	51.2	59.9	70.8	79.9	85.9	88.8	85.2	80.2	75.8	71.9
10	76.5	68.9	67.1	66.1	71.2	77.4	82.7	86.2	87.9	84.4	79.6	75.4	71.6
11	75.9	68.8	67.0	66.1	70.9	76.9	81.9	85.3	86.9	83.4	78.6	74.4	70.6
12	75.5	67.8	66.0	65.1	70.4	76.9	82.4	86.2	87.9	83.7	78.1	73.1	68.6
13	70.7	65.2	63.2	62.2	66.2	71.3	75.7	78.6	79.9	77.0	73.2	69.7	66.6
14	68.6	64.2	62.8	62.1	66.0	70.8	74.9	77.6	78.9	74.6	68.8	63.5	58.8
15	63.4	55.3	53.2	52.2	57.9	64.9	71.0	74.9	76.9	72.2	65.9	60.3	55.4
16	63.3	51.6	49.3	48.2	54.8	63.0	70.1	74.7	76.8	73.7	69.4	65.5	62.1
17	71.5	59.5	57.9	57.1	63.8	72.1	79.1	83.7	85.8	82.	76.9	72.2	68.2
18	73.0	65.0	63.1	62.1	67.4	73.9	79.4	83.2	84.9	81.2	76.2	71.8	67.9
19	72.8	64.9	63.1	62.1	67.6	74.5	80.2	84.1	85.9	81.4	75.4	69.9	65.1
20	72.6	61.5	59.2	58.2	65.1	73.6	80.8	85.6	87.8	83.4	77.4	71.9	67.1
21	75.9	63.5	61.2	60.2	67.5	76.7	84.3	89.4	91.8	87.4	81.4	75.9	71.1
22	76.2	67.5	65.2	64.2	69.9	76.9	83.0	86.9	88.9	85.1	79.9	75.2	71.2
23	74.9	68.0	66.1	65.1	70.2	76.4	81.7	85.2	86.9	82.7	77.1	72.1	67.6
24	73.0	64.2	62.2	61.2	66.6	73.5	79.2	83.1	84.9	81.6	77.1	72.9	69.3
25	75.6	66.6	64.9	64.1	69.9	76.9	83.0	86.9	88.9	84.6	78.8	73.5	68.9
26	78.5	65.3	63.2	62.2	69.5	78.7	86.3	91.4	93.8	90.1	84.9	80.2	76.2
27	73.4	73.0	71.1	70.1	72.8	76.2	79.1	81.1	81.9	77.4	71.4	65.9	61.2

WDM 121 Temperature (Deg. F)
Annual data display: Summary for period ending 1976/12

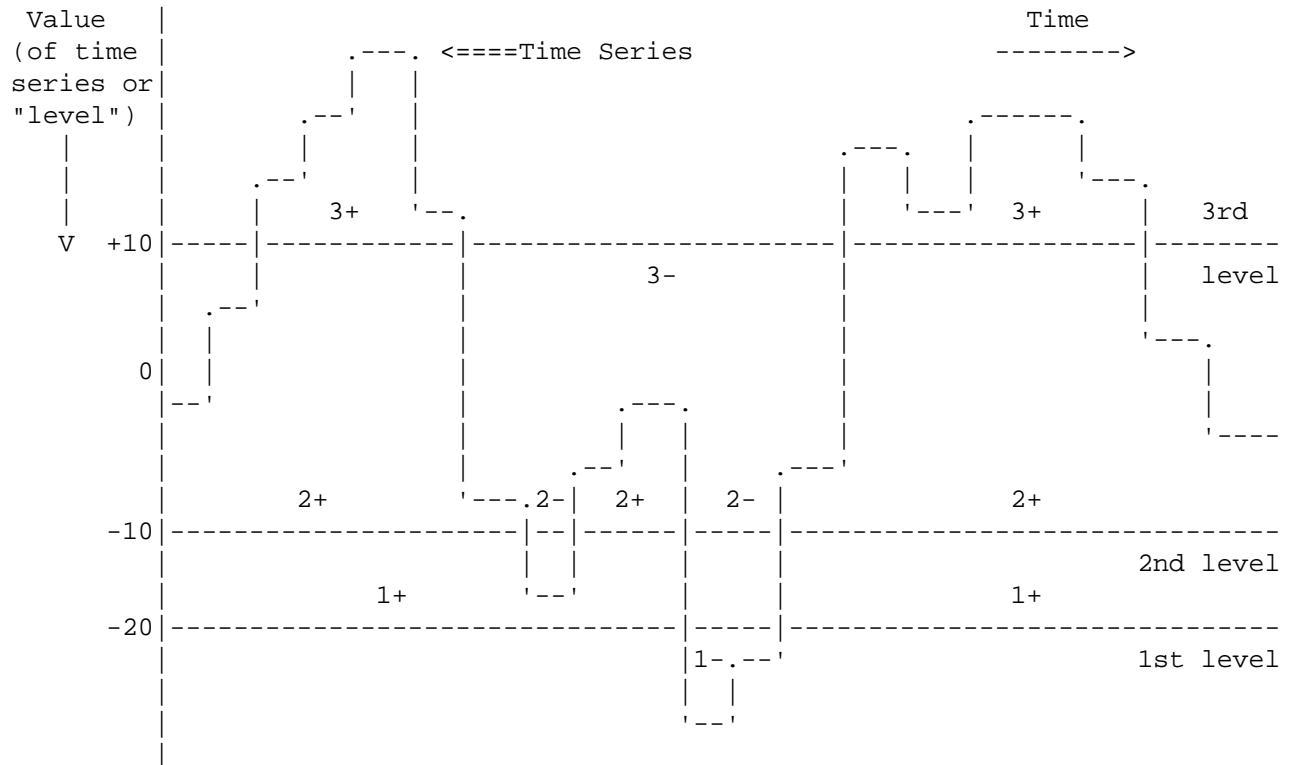
DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	27.6	9.4	33.1	49.2	49.4	67.5	67.0	67.7	68.3	68.2	45.7	11.8
2	18.4	17.7	33.3	48.5	45.3	66.3	67.3	67.2	68.9	66.8	42.7	9.1
3	7.0	21.9	29.8	49.3	49.7	65.1	70.5	66.7	72.7	65.9	35.3	13.4
4	13.8	12.6	28.6	48.9	59.7	68.7	73.0	72.8	67.8	58.5	33.0	16.5
5	20.3	15.9	25.0	52.0	57.3	71.0	72.7	73.0	66.1	46.5	36.7	18.0
6	18.0	24.8	25.7	50.8	49.0	71.4	72.8	68.2	71.8	42.4	32.9	4.2
7	0.5	32.5	31.1	47.8	50.6	73.1	76.1	65.2	71.8	43.4	29.1	2.5
8	5.5	36.7	32.7	46.1	55.2	74.0	77.4	66.0	65.4	45.5	34.1	17.7
9	9.9	39.0	35.1	53.6	64.2	72.6	82.0	71.4	63.2	51.5	35.5	23.1
10	16.6	36.5	38.8	54.1	60.9	75.2	84.9	76.5	62.3	56.0	25.2	9.3
11	30.4	44.2	36.4	43.6	58.8	77.2	81.9	75.9	66.3	62.6	20.3	11.3
12	26.7	46.0	32.2	48.7	57.0	78.8	77.7	75.5	68.6	59.9	20.7	11.7
13	27.5	37.1	34.0	54.8	58.5	72.2	80.9	70.7	69.0	59.5	23.9	20.4
14	30.1	41.2	33.2	64.7	63.0	72.2	81.3	68.6	68.0	57.2	27.5	29.7
15	28.5	44.0	27.5	67.6	60.1	69.6	73.8	63.4	59.1	43.5	32.8	28.4
16	13.5	34.6	30.7	71.1	58.2	68.2	68.1	63.3	60.4	39.4	36.7	35.2
17	11.6	33.6	44.1	65.7	56.2	69.8	69.9	71.5	66.9	34.8	46.0	38.9
18	21.5	39.6	55.7	59.2	58.3	65.5	72.7	73.0	62.2	32.9	40.8	36.5
19	20.7	39.6	55.8	48.4	68.3	65.8	78.9	72.8	62.5	40.1	35.5	27.7
20	18.8	34.2	48.1	48.0	71.5	66.7	76.0	72.6	58.9	37.4	29.7	9.7
21	25.5	27.7	35.7	54.9	65.3	67.1	71.8	75.9	61.9	37.8	27.6	17.1
22	25.7	29.0	43.8	50.8	58.8	69.6	78.9	76.2	58.2	35.5	23.1	17.1
23	28.6	36.3	55.2	50.6	59.2	66.5	79.8	74.9	54.4	38.8	28.8	22.3
24	27.2	40.8	55.8	47.0	58.1	71.1	74.3	73.0	51.0	42.1	41.0	23.8
25	22.6	47.5	49.3	43.4	60.1	72.5	71.9	75.6	54.3	36.9	41.7	25.1
26	10.1	44.8	45.5	43.8	62.0	73.9	75.4	78.5	56.1	37.1	28.7	30.5
27	18.1	41.2	47.3	46.3	65.9	74.1	73.8	73.4	53.7	37.3	10.3	22.3
28	22.2	39.2	45.3	48.5	62.5	72.2	73.9	65.8	57.6	40.2	6.3	3.8

4.2(14) Perform Duration Analysis on a Time Series (Utility Module DURANL)

This module examines the behavior of a time series, computing a variety of statistics relating to its excursions above and below certain specified levels (Figure 4.2(14)-1). Sample printout is shown in Figure 4.2(14)-2. The quantity of printout produced can be regulated by the user with a print-level-flag (PRFG), which has a valid range of values from 1 through 6.

The basic principles are:

1. The module works on the time series after it has been placed in the INPAD. The data are, thus, at the internal time step of the operation (INDELT). This module operates on a mean-valued input time series. Therefore, if a point-valued time series is routed to it, TSGET will, by default, generate mean values for each time step, and these will be analyzed.
2. When the value of the time series rises above the user-specified level, a positive excursion commences. When it next falls below the level, this excursion ends. A negative excursion is defined in the reverse way. (Figure 4.2(14)-1).
3. If the time series has a value less than $-10.0^{**}10$ this is considered to be an undefined event (e.g., the concentration of a constituent when there is no water). In this case the value is in a special category - it is in neither a positive nor a negative excursion.
4. The above is true if the specified duration is one time step. In this case, the results produced include a conventional frequency analysis (e.g., flow duration) of the data. However, the user may specify up to 10 durations; each is given as a multiple (N) of the basic time step (INDELT). Then, for an excursion or undefined event to be considered, it has to endure for at least N consecutive intervals; else it is ignored.
5. The user may specify an analysis season. This is a period (the same in each year) for which the data will be analyzed (e.g., Oct 1 through May 10). Data falling outside the analysis season will not be considered.



Legend: 2+ excursion above second level (duration >=1)
 2- excursion below second level (duration >=1)
 etc.

Figure 4.2(14)-1 Definition of terms used in duration analysis module

The analyses performed, and printout produced (Figure 4.2(14)-2), are:

1. Introductory information - Title, start and end date/time, analysis season.
2. The next seven sets of tables are all similar in format; each contains data on positive and negative excursions, for each level and duration, and information on undefined event conditions which persisted for each of the specified durations. The value of PRFG required to generate each of these, and the table heading and the data displayed in it are:
 - a) PRFG > 0. "Fraction of time spent in excursions at each level with duration greater than or equal the specified durations. The fraction is relative to the total time span." These are the fractions of total considered time that each of the above-defined conditions existed.
 - b) PRFG > 1. "Fraction of time spent in excursions at each level with duration greater than or equal the specified durations. The fraction is relative to the time spent in excursions at each level." In the "Positive Excursions" table, this gives, for each specified level, the total time that an excursion of duration N existed, divided by the total time that an excursion of duration 1 existed. A similar definition holds for the numbers in the "Negative Excursions" table.
 - c) PRFG > 2. "Time spent in excursions at each level with duration greater than or equal the specified durations." The tables give the total number of time steps for which the various conditions occurred.
 - d) PRFG > 3. "Number of excursions at each level with duration greater than or equal the specified durations". These give the total number of events that were found (number of positive and negative excursions for each level and duration, and number of "undefined occurrences" of each duration).
 - e) PRFG > 4. "Average duration of excursions at each level given that the duration is greater than or equal the specified durations". These values answer the question: "given that a specified excursion or undefined condition occurred, what was the mean number of time steps that it persisted?"
 - f) PRFG > 5. "Standard deviation of duration of excursions at each level given that the duration is greater than or equal the specified durations." These tables are similar to those discussed in (e) above, except that the standard deviation, instead of the mean, is considered.
 - g) PRFG > 6. "Fraction of excursions with duration N with respect to the total number of excursions (duration 1) for each level". These tables give the number of excursions at each duration divided by the number of excursions at duration 1 for each level.
3. Summary information: Total number of time intervals analyzed, total number of time intervals for which values were "undefined", total number of days analyzed, sample size, max, min, mean, standard deviation.

Duration analysis operation no. 1
 Analysis of Subb. 4 Outflow (cfs)
 Start date: 1972/12/31 24: 0 End date: 1974/12/31 24: 0
 Analysis season starts: 2/28 24: 0 Ends: 11/30 24: 0

PERCENT OF TIME TABLES (WITH RESPECT TO THE TOTAL SPAN OF TIME)

POSITIVE EXCURSIONS

LEVELS	DURATIONS		
	1	12	24
.0000E+00	1.000	1.000	1.000
10.00	.7308	.7259	.7235
20.00	.5128	.5062	.5034
50.00	.1790	.1674	.1633
500.0	.2273E-02	.0000E+00	.0000E+00

NEGATIVE EXCURSIONS

LEVELS	DURATIONS		
	1	12	24
.0000E+00	.0000E+00	.0000E+00	.0000E+00
10.00	.2692	.2655	.2645
20.00	.4872	.4813	.4762
50.00	.8210	.8121	.8030
500.0	.9977	.9977	.9977

UNDEFINED EVENTS (NO WATER)

DURATIONS			
	1	12	24
	.0000E+00	.0000E+00	.0000E+00

Figure 4.2(14)-2 Sample Duration Analysis Printout
 [Continued on next 2 pages]

PERCENT OF TIME TABLES (WITH RESPECT TO THE TIME SPENT IN EXCURSIONS)

POSITIVE EXCURSIONS

		DURATIONS		
		1	12	24
LEVELS				
	.0000E+00	1.000	1.000	1.000
	10.00	1.000	.9933	.9899
	20.00	1.000	.9871	.9817
	50.00	1.000	.9353	.9124
	500.0	1.000	.0000E+00	.0000E+00

NEGATIVE EXCURSIONS

		DURATIONS		
		1	12	24
LEVELS				
	.0000E+00	.0000E+00	.0000E+00	.0000E+00
	10.00	1.000	.9862	.9828
	20.00	1.000	.9879	.9775
	50.00	1.000	.9892	.9780
	500.0	1.000	1.000	1.000

UNDEFINED EVENTS (NO WATER)

		DURATIONS		
		1	12	24
		.0000E+00	.0000E+00	.0000E+00

TIME SPENT IN EXCURSIONS

POSITIVE EXCURSIONS

		DURATIONS		
		1	12	24
LEVELS				
	.0000E+00	.1320E+05	.1320E+05	.1320E+05
	10.00	9647.	9582.	9550.
	20.00	6769.	6682.	6645.
	50.00	2363.	2210.	2156.
	500.0	30.00	.0000E+00	.0000E+00

NEGATIVE EXCURSIONS

		DURATIONS		
		1	12	24
LEVELS				
	.0000E+00	.0000E+00	.0000E+00	.0000E+00
	10.00	3553.	3504.	3492.
	20.00	6431.	6353.	6286.
	50.00	.1084E+05	.1072E+05	.1060E+05
	500.0	.1317E+05	.1317E+05	.1317E+05

UNDEFINED EVENTS (NO WATER)

		DURATIONS		
		1	12	24
		.0000E+00	.0000E+00	.0000E+00

STANDARD DEVIATION OF TIME SPENT IN EXCURSIONS

POSITIVE EXCURSIONS

LEVELS	DURATIONS		
	1	12	24
.0000E+00	.0000E+00	.0000E+00	.0000E+00
10.00	922.9	2032.	2181.
20.00	321.6	581.1	602.0
50.00	71.65	132.1	128.7
500.0	.7423	.0000E+00	.0000E+00

NEGATIVE EXCURSIONS

LEVELS	DURATIONS		
	1	12	24
.0000E+00	.0000E+00	.0000E+00	.0000E+00
10.00	107.2	113.8	113.3
20.00	127.0	140.0	141.4
50.00	167.6	188.1	191.6
500.0	1202.	1202.	1202.

UNDEFINED EVENTS (NO WATER)

	DURATIONS		
	1	12	24
	.0000E+00	.0000E+00	.0000E+00

SUMMARY

TOTAL LENGTH OF DEFINED EVENTS: 13200. INTERVALS
 TOTAL LENGTH OF UNDEFINED EVENTS: 0. INTERVALS
 TOTAL LENGTH OF ANALYSIS: 550. DAYS
 SAMPLE SIZE: 13200
 SAMPLE MAXIMUM: .1307E+05
 SAMPLE MINIMUM: 2.290
 SAMPLE MEAN: 37.80
 SAMPLE STANDARD DEVIATION: 164.0

4. Lethality analysis:

The function of this section of the DURANL module is to assess the risk associated with any contaminant concentration time series generated by the HSPF application modules. The methodology links frequency data on instream contaminant levels to toxicity information resulting from both acute and chronic laboratory bioassays. The methodology is based on the Frequency Analysis of Concentration (FRANCO) program developed by Battelle, Pacific Northwest Laboratories as part of their Chemical Migration and Risk Assessment (CRMA) Methodology.

Laboratory toxicity experiments provide the main basis for developing a risk analysis for fish or other aquatic organisms. A common method of summarizing the results of these experiments is to use a lethal concentration where 50% of the fish die (LC50). Usually information for LC50 concentrations at 24, 48, and 96 hours can be derived from laboratory experiments in the form of pairs of lethal concentration and duration values. By connecting these pairs with straight line segments and extending the function in a reasonable manner at each end, a function is defined such that an event defined by a particular concentration level with a particular duration can be classified as exceeding or not exceeding the function, i.e., exceeding an LC50 value. (Figure 4.2(14)-3). An event exceeds the LC function when the concentration defining the event and the duration of the event results in the pair falling above and to the right of the combined LC50, or global exceedance, curve.

If LCNUM is greater than zero, a global exceedance summary table is printed which gives the fraction of time that a global exceedance curve is exceeded. Up to 5 LC curves can be analyzed at one time. It should be noted that the global exceedance summary eliminates double counting by reporting only those exceedance events with the lowest concentrations that occur in different contaminant peaks. (FRANCO documentation should be consulted for more detailed discussion).

If LCOUT=1 and LCNUM=0, a lethal event summary is printed to supplement the global exceedance information. The table gives a summary of all lethal events including ending time, lethal curve number, number of intervals in event, and concentration level. Printout is to unit PUNIT, which should be unique to the duration analysis; otherwise, the output from the lethal event summary will be mixed with the printout from application modules.

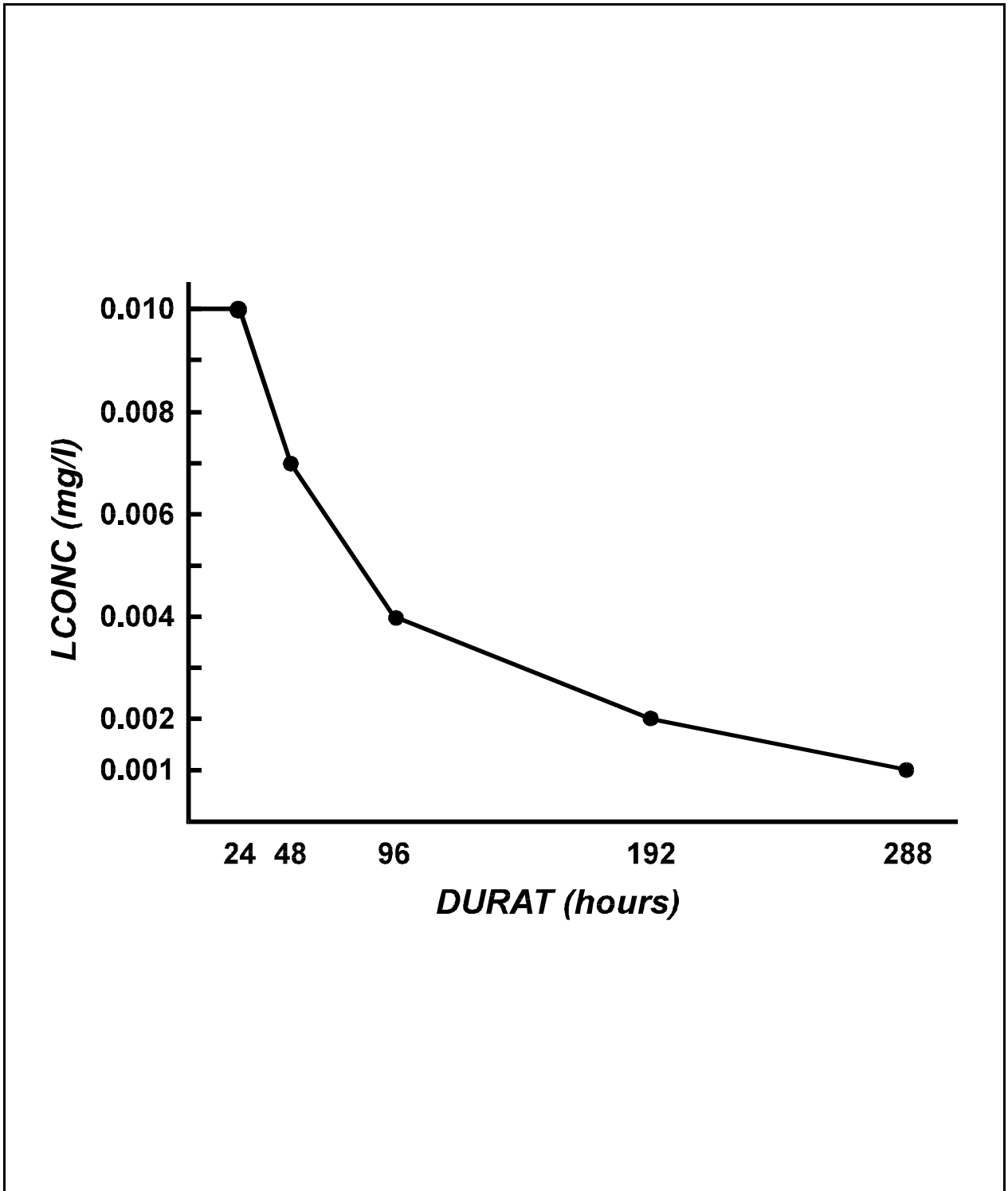


Figure 4.2(14)-3 Sample Lethal Concentration (LC) Function for Global Exceedance Calculation

4.2(15) Generate a Time Series from One or Two Other Time Series (Utility Module GENER)

This module is designed to perform any one of several possible transformations on input time series. The transformation is specified by supplying an "option code" (OPCODE). If A and B are the input time series and C is the computed time series, then the transformations performed for each possible value of OPCODE are:

OPCODE	Action
1	C= Abs value (A)
2	C= Square root (A)
3	C= Truncation (A) e.g. If A=4.2, C=4.0 A=-3.5, C=-3.0
4	C= Ceiling (A). The "ceiling" is the integer \geq given value. e.g. If A=3.5, C=4.0 A=-2.0, C=-2.0
5	C= Floor (A). The "floor" is the integer \leq given value. e.g. If A=3.0, C=3.0 A=-2.7, C=-3.0
6	C= loge (A)
7	C= log10 (A)
8	C= $K(1)+K(2)*A+K(3)*A**2$ (up to 7 terms) The user supplies the number of terms and the values of the coefficients (K).
9	C= $K**A$
10	C= $A**K$
11	C= A+K
12	C= Sin (A)
13	C= Cos (A)
14	C= Tan (A)
15	C= Sum (A)
16	C= A+B
17	C= A-B
18	C= A*B
19	C= A/B
20	C= MAX (A,B)
21	C= MIN (A,B)
22	C= A**B
23	C= cumulative departure of A below B
24	C= K
25	C= Max (A,K)
26	C= Min (A,K)

Note that if OPCODE is less than 15, or OPCODE equals 25 or 26, only one input time series is involved (unary operators); if OPCODE is 24, no inputs are required (constant); otherwise two inputs are required (binary operators). As with the other operating modules, the input time series are first placed in the INPAD by module TSGET (This may involve a change of time step and/or "kind"). Therefore, by the time module GENER works on them, they are mean valued time series with a time step equal to INDELT.

4.2(16) Multiple Sequential Input of Time Series from an HSPF Stand Alone Plotter File (Utility Module MUTSIN)

This utility module reads a sequential external file previously written on disk. This file has the same format as the PLOTFL produced with utility module PLTGEN (Section 4.2(12)). The user specifies the number of point and/or mean-valued time series to be read and the number of lines to skip at the beginning of the external file.

The missing data flag, MISSFG, is used to specify how MUTSIN reacts to missing data. A MISSFG value of 0 indicates that MUTSIN is to report an error and quit if any data are missing. Therefore, in this case, the internal time-step (DELTA) must equal the time-step of the external file, the starting time of the run must correspond with the first entry read from the external file, and no entries may be missing. A MISSFG value of 1 indicates that MUTSIN is to fill missing sequential file entries with 0.0. A MISSFG value of 2 indicates that MUTSIN is to fill missing entries with $-1.0E30$. A MISSFG value of 3 indicates that MUTSIN is to fill missing values with the value of the next available entry.

Note that the date and time appearing in each record of the file must be in the same format as that used by the PLTGEN module to write a PLOTFL. (Section 4.2(12)). That is, the full year/month/day/hour/minute string must be present and a time, e.g., midnight is coded as 74 01 02 24 00, not 75 01 03 00 00.

The EXT TARGETS and/or NETWORK blocks are used to specify where TSPUT places the time series data read in from the external file.

MUTSIN has four potential uses:

1. It may be used to form a simple interface with other continuous models. The other model can output its results in the form of an HSPF PLOTFL (or a format conversion program can be used), and MUTSIN can be used to input this data to HSPF. Conversely, data can be output from HSPF, using the PLTGEN module, for input to the other model.
2. MUTSIN may be used to transfer data in a WDM file to another WDM file. This transfer requires the use of PLTGEN to output the data from the source file and MUTSIN to input to the target file.
3. MUTSIN can be used to transfer data between different types of computer hardware where WDM or DSS files are incompatible (e.g., Unix to personal computer and vice versa).
4. MUTSIN may also be used to input point valued data or data with a time interval not included in the standard HSPF sequential input formats (Part F, Section 4.9).

4.3 Module TSPUT

Module TSPUT is complementary to, and may be viewed as a mirror image of, module TSGET (Section 4.1). TSGET obtains time series from a WDM file, DSS, sequential file, or the INPAD and places its output in the INPAD. Conversely, TSPUT obtains a time series from the INPAD and places its output in the WDM file, DSS, or back in the INPAD. It has similar capabilities to TSGET, to alter the time step, "kind" or to perform a linear transformation on the time series with which it deals.

Compared to TSGET, module TSPUT contains one major complicating factor. When a time series is to be written to a WDM or DSS data set, the action taken depends on how any pre-existing data are to be treated. The possible access modes, ADD and REPL, are discussed in Part F, Section 4.6.

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PART F

FORMAT FOR THE USER'S CONTROL INPUT

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1.0 GENERAL INFORMATION AND CONVENTIONS

1.1 The User's Control Input

The User's Control Input (UCI) consists of text lines limited to 80 characters. A general feature of the UCI is that the lines are collected into groups. Groups may contain subordinate groups; that is, they may be nested. In every case, a group commences with a heading (such as RUN) and ends with a delimiter (such as END RUN).

The HSPF system will ignore any line in the UCI which contains three or more consecutive asterisks (***) , just as a computer language compiler bypasses comments in a source program. Blank lines are also ignored. This feature can be used to insert headings and comments which make the text more intelligible to the reader, but are not required or read by the HSPF system itself.

The body of the User's Control Input consists of one or more major groups of text, called RUN input sets:

```
<RUN input set 1>
<RUN input set 2>
-----
-----
```

A RUN input set contains all the input needed to perform a single RUN. A RUN is a set of operations with a common START date-time and END date-time.

1.2 General Comments on Method of Documentation

The documentation of each portion of the UCI is divided into three sections: "layout", "details", and "explanation".

The "layout" section shows how the input is arranged. Text always appearing in the same form (e.g., RUN) is shown in upper case. Text which varies from job to job is shown by lower case symbols enclosed in angle brackets (<spa>). Lines containing illustrative text, not actually required by the system, have three consecutive asterisks, just as they might have in the UCI. Optional material, or that which is not always required, is enclosed in brackets []. The column numbers printed at the head of each layout show the starting location of each keyword and symbol.

The "details" section describes the input values required for each symbol appearing in the layout. The Fortran identifiers used to store the value(s) in the code are given, followed by the format. The field(s) specified in this format start in the column containing the < which immediately precedes the symbol in the layout. For example, < range >, which consists of the starting and ending operations that the current line applies to, starts in column 1 and ends in column 10. Where relevant, the Details section also indicates default values and minimum and maximum values for each item in the UCI.

The "explanation" section contains any necessary explanatory material which could not fit into the details section.

2.0 FORMAT OF A TSSMGR DATA SET (omitted)

Note: the TSSMGR module and all other TSS functionality is no longer documented or maintained; refer to Version 10 (or earlier) documentation for details.

3.0 SAMPLE TSSMGR INPUT SET (omitted)

4.0 FORMAT OF THE USERS CONTROL INPUT

Summary

The User's Control Input starts with a RUN heading and ends with an END RUN delimiter. The body of the text consists of several groups, called "blocks," which may appear in any sequence:

RUN

GLOBAL Block

Contains information of a global nature. It applies to every operation in the RUN.

FILES Block

Specifies disk files to be used by the run and their file unit numbers.

OPN SEQUENCE Block

Specifies the operations to be performed in the RUN, in the sequence they will be executed. It indicates any grouping (INGROUPS).

<Operation-type> Block

Deals with data pertaining to all the operations of the same <Operation-type>, for example, parameters and initial conditions for all Pervious Land-segments in a RUN. It is not concerned with relationships between operations, or with external sources or targets for time series. There is one <Operation-type> Block for each <operation-type> involved in the RUN.

[FTABLES Block]

A collection of function tables (FTABLES). A function table is used to document, in discrete numerical form, a functional relationship between two or more variables. FTABLES are used to specify the depth-volume-discharge relationship for RCHRES operations.

[EXT SOURCES Block]

Specifies time series which are input to the operations from external sources (WDM file, DSS file, or sequential (SEQ) files).

[NETWORK Block]

Specifies any time series which are passed between operations.

[EXT TARGETS Block]

Specifies those time series which are output from operations to external destinations (WDM or DSS file).

[SCHEMATIC Block]

Specifies structure of watershed, i.e., connections of land segments and stream reaches to each other. Operates in tandem with MASS-LINK block to simplify definition of complex watersheds.

[MASS-LINK Block]

Specifies groups of time series to combine with network connections defined in the SCHEMATIC block in order to specify mass flows in the watershed.

[MONTH-DATA Block]

Specifies monthly values of atmospheric deposition fluxes and concentrations (in rain) for water quality constituents.

[CATEGORIES Block]

Specifies the number of water categories to be simulated in the streams and reservoirs represented by RCHRES operations.

[PATHNAMES Block]

Associates DSS pathnames with data-set ID numbers for all DSS data sets in the EXT SOURCES and EXT TARGETS blocks.

[FORMATS Block]

Contains any user-supplied formats which may be required to read time series on external sequential (SEQ) files.

[SPEC-ACTIONS Block]

Specifies operation, variable location, type or name, date/time and action code in order to change a variable's value during a run.

END RUN

Usually, a User's Control Input will not include all of the above blocks. Their presence will be dictated by the operations performed in the RUN and the options which are selected.

4.1 GLOBAL Block

This block must always be present in a RUN input set.

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

GLOBAL

```
<----- run-info ----->
START <---s-date-time---> END<---e-date-time--->
RUN INTERP OUTPT LEVELS<lev><spa>
RESUME <res> RUN <run> UNITS <ufg>
END GLOBAL
```

Example

GLOBAL

```
Seven Mile River - Water quality run
START 1980/01/01 00:00 END 1987/12/31 12:00
RUN INTERP OUTPT LEVELS 4 3
RESUME 0 RUN 1 UNITS 1
END GLOBAL
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<run-info>	RUNINF(20)	A78	none	none	none
<s-date-time>	SYR,	I8,	none	1	32767
	SMO,	1X,I2,	1	1	12
	SDA,	1X,I2,	1	1	varies
	SHR,	1X,I2,	0	0	23
	SMI	1X,I2	0	0	59
<e-date-time>	EYR,	I8,	none	1	32767
	EMO,	1X,I2,	12	1	12
	EDA,	1X,I2,	varies	1	varies
	EHR,	1X,I2,	#24	0	24 #only if EMI is 0
	EMI	1X,I2	0	0	59
<lev>	OUTLEV	I5	0	0	10
<spa>	SPOUT	I5	2	0	10
<res>	RESMFG	I5	0	0	1
<run>	RUNFG	I5	0	0	1
<ufg>	EMFG	I5	1	1	2

Explanation

RUNINF stores the users title/comments regarding the RUN.

Users conventionally label the same point in time differently, depending whether they are looking forward or backward towards it. For example, if we say that a RUN starts on 1978/05 we mean that it commences at the start of May 1978. On the other hand, if we say it ends on 1978/05 we mean it terminates at the end of May 1978. Thus, HSPF has two separate conventions for the external labeling of time. When supplying values for a date/time field a user may omit any element in the field except the year, which must be supplied as a 4 digit figure. HSPF will substitute the defaults given above for any blank or zero values. The completed starting and ending date/time fields are translated into another format, which is the only one used to label intervals and time points internally. It has a resolution of 1 minute. Thus, time is recorded as a year/month/day/hour/minute set, to completely specify either a time interval or point. The date/time used by the internal clock uses the "contained within" principle. For example, the first minute in an hour is numbered 1 (not 0) and the last is numbered 60 (not 59). The same applies to the numbering of hours. Thus, the time conventionally labeled 11:15 is in the 12th hour of the day so is labeled 12:15 internally; the last minute of 1978 is labeled 1978/12/31 24:60. This convention is extended to the labeling of points by labeling it with the minute that immediately precedes it. Thus, midnight New Year's eve 1978/1979 is 1978/12/31 24:60, not 1979/01/01 00:00. This gives a system for uniquely labeling each point internally.

OUTLEV is a flag which governs the quantity of informative output produced by the Run Interpreter. A value of 0 results in minimal output; 10 results in very detailed output useful primarily for debugging the software. A value of 3 or 4 is appropriate for most runs. OUTLEV does not affect error or warning messages.

SPOUT is a flag that governs the quantity of output produced in the Run Interpreter Output file whenever a Special Action is performed during the simulation. A value of 1 results in minimal output, and a value of 10 results in maximum output.

RESMFG represents a feature that is not supported in this version of HSPF. It should be set to 0.

If RUNFG is 1, the system will both interpret the input and execute the RUN. If it is 0, only the interpretation will be done.

EMFG is the UCI units system flag for all simulation operations (i.e., PERLND, IMPLND and RCHRES operations). If EMFG is 1, all input values in the UCI file will be interpreted using the English units defined in the tables in this section (Part F) of this manual. If EMFG is 2, Metric units are assumed for UCI values.

4.2 FILES Block

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

FILES

```
<ftyp> <un#> <-----filename----->
```

```
.....
```

(repeats until all files are specified)

```
.....
```

END FILES

Example

FILES

```
<FTYP> UNIT# FILE NAME ***
```

```
WDM1      24 test.wdm
```

```
MESSU     21 test.mes
```

```
          61 test.dsp
```

```
          33 test.pls
```

END FILES

```
*****
```

Details

Symbol	Fortran Name(s)	Format	Comment
<ftyp>	FSTYPE	A6	File type; valid values are: MESSU, WDM, WDM1, WDM2, WDM3, WDM4, DSS1, DSS2, DSS3, DSS4, DSS5, PLTGEN (for VAX only), and blank (" ").
<un#>	FUNIT	I5	File unit number; valid values are 1-99 (21-99 recommended).
<filename>	FNAME	A64	File name; complete path name or local name if in default/current directory.

Explanation

The FILES Block contains the names of input and output files used by the program during the run; this block associates the unit numbers specified in various parts of the UCI file with actual disk file names. It is designed to eliminate the need for a separate command file, such as a DOS batch (BAT) file or VAX command (COM) file, where the correspondence between file name and unit number is often performed for batch programs such as HSPF. Since the FILES Block requires that the program be able to locate the UCI file, HSPF prompts the user for its name. Alternatively, on DOS-based PCs, the command line for invoking HSPF may include the name of the UCI file. The syntax is as follows:

```
hspf uci-file-name <RET>
```

FTYPE is a keyword that identifies the type of file. There are twelve FTYPE's that HSPF recognizes, and FTYPE must be specified for these types of files. Note, however, that the WDM and WDM1 keywords are synonymous, and should not appear together in the same FILES block. For all other files, this field should be left blank. The FTYPE keyword should be left-justified in columns one through six. The valid FTYPE values are shown below:

<u>DESCRIPTION</u>	<u>FTYPE</u>
Run interpreter output	MESSU
Watershed Data Management	WDM, WDM1, WDM2, WDM3, WDM4
HEC Data Storage System files	DSS1, DSS2, DSS3, DSS4, DSS5
VAX (only) PLTGEN output file	PLTGEN
Other input and output files	(blank)

FUNIT is the file unit number of the file. This corresponds to the unit number of those files specified in other parts of the UCI file. FUNIT is an integer value that should be right-justified in columns 9 through 13; valid values are 1-99. Each value of FUNIT in the FILES Block should be unique, and the values 7 and 9 are reserved for internal scratch files. Preferably, values of 21 and greater should be used to avoid any conflicts.

FNAME is the name of the file. If the file is not in the current (default) directory, the complete path name should be specified. FNAME should be left-justified in columns 17 through 80.

The FILES Block is usually required. In particular, if a WDM or DSS file is needed by the run, it must be specified in the FILES Block, since the program does not have a default name for these files.

FILES Block

Similarly, for the operating modules (PERLND, IMPLND, RCHRES, DISPLY, PLTGEN, DURANL, and MUTSIN), and sequential (SEQ) time series input, the user must specify file unit numbers as the destination for printout (or source for MUTSIN or sequential time series input). Also, it is recommended that these files be explicitly assigned names in the FILES Block. However, if the user does not include an entry in the FILES block for one of these operations, a file is automatically opened by HSPF with the default name "hspfxx.dat", where xx is the unit number (except for the MESSU file, which defaults to "hspfecho.out").

4.3 OPN SEQUENCE Block

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
OPN SEQUENCE
  [ INGRP                INDELT <idt>]
    <-opn-id----->
      . . . . .
    <-opn-id----->
  [ END INGRP ]
    <-opn-id-----> INDELT <idt>
      . . . . .
    <-opn-id-----> INDELT <idt>
  [ INGRP                INDELT <idt>]
    <-opn-id----->
      . . . . .
  [ END INGRP ]
    . . . . .
END OPN SEQUENCE
```

Example

```
OPN SEQUENCE
  INGRP                INDELT 02:00
    PERLND             20
    PERLND             21
    PERLND             22
  END INGRP
  RCHRES              1  INDELT 12:00
END OPN SEQUENCE
```

Details

Symbol	Fortran Name(s)	Format	Comment
<idt>	HRMIN(2)	I2,1X,I2	Time interval (hour:min) used in the INPAD e.g., 00:05
<-opn-id->	OPTYP,OPTNO	A6,5X,I3	Type and number of this operation. e.g., RCHRES 100

Explanation

This block specifies the various operations to be performed in the RUN and, optionally, their grouping into INGROUPTS. The operations will be performed in the sequence specified in the block, apart from repetition implied by grouping. **A maximum of 200 operations can be specified in one run.**

Every <-opn-id-> consists of OPTYP and OPTNO. The OPTYP field must contain an identifier of up to 6 characters which corresponds to one of the operating module identifiers in the HSPF system. The OPTNO field contains an integer which distinguishes operations of the same type from one another. Every <opn-id> (OPTYP plus OPTNO) must be unique.

The time intervals of the INGROUPTS (or the RUN) are specified in this block. These appear on the INGROUPT lines, except where the user has not placed an operation in an INGROUPT. In that case <idt> is specified alongside <-opn-id->.

4.3.1 Optimization of Operation Sequencing

The sequence of operations within the Operations Sequence block should be optimized to make most efficient use of the internal scratch pad (INPAD). Optimal use of the INPAD is accomplished by reducing the maximum number of time series (rows) on the INPAD. This increases the length of each row and the INSPAN, which reduces swapping between operations.

A time series occupies a row on the INPAD from the moment it is either read from an external source or is created by an operation until the moment it is used by the last operation requiring it. HSPF automatically optimizes the reading of data from external sources and writing of data to external targets.

Optimal sequencing of operations requires that an operation be executed as soon as all input timeseries produced by other operations have been created. For example, a DISPLY operation which displays outflow from a PERLND operation should immediately follow the PERLND operation. A RCHRES operation representing a section of stream should immediately follow any RCHRES operations representing reaches upstream and any PERLND operations which contribute local inflow.

For example, a watershed is represented by 4 PERLND operations, 5 RCHRES operations, 2 PLTGEN operations, 4 DISPLY operations, and 1 DURANL operation. These are defined as follows:

OPN SEQUENCE Block

PERLND 1 - rain gage 1, land use of pasture
PERLND 2 - rain gage 1, land use of corn
PERLND 3 - rain gage 2, land use of pasture
PERLND 4 - rain gage 2, land use of corn
RCHRES 1 - local inflow from PERLND 1 and 2
RCHRES 2 - upstream inflow from RCHRES 1, local inflow from PERLND 1 and 2
RCHRES 3 - local inflow from PERLND 3 and 4
RCHRES 4 - upstream inflow from RCHRES 2 and 3, local inflow from
PERLND 3 and 4
RCHRES 5 - upstream inflow from RCHRES 4, local inflow from PERLND 3 and 4
DISPLY 1 - outflow from RCHRES 5
DISPLY 2 - outflow from RCHRES 3
DISPLY 3 - unit flow from PERLND 2
DISPLY 4 - unit flow from PERLND 4
PLTGEN 1 - outflow from RCHRES 5, measured flow at bottom of RCHRES 5
PLTGEN 2 - outflow from RCHRES 1, area weighted sum of unit flow from
PERLND 1 and 2
DURANL 1 - outflow from RCHRES 5

The optimum order for these operations is:

PERLND 1
PERLND 2
DISPLY 3
RCHRES 1
PLTGEN 2
RCHRES 2
PERLND 3
PERLND 4
DISPLY 4
RCHRES 3
DISPLY 2
RCHRES 4
RCHRES 5
DISPLY 1
DURANL 1
PLTGEN 1

4.4 <Operation-type> Block

```
*****
      1      2      3      4      5      6      7      8
123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
<otyp>
  General input
  Section 1 input  --
  Section 2 input  | Only supplied if the operating module contains sections
                    | and the section is active
                    |
  .                 |
  .                 |
  Section N input  --
END <otyp>
```

```
*****
```

Details

Symbol	Fortran Name(s)	Format	Comment
<otyp>	OPTYP	A6	Type of operation covered in this block, e.g., RCHRES, PERLND

Explanation

This type of block deals with data which pertain to all operations of the same <Operation-type>, e.g., the parameters and initial conditions for all the Pervious Land segments in a RUN. It is not concerned with relationships between operations or with external sources or targets for time series.

This type of block provides for general input and for input which is specific to individual sections of the operating module. The latter only apply to modules which are sectioned (PERLND, IMPLND, and RCHRES). The general input contains all of the information which simple (non-sectioned) modules require; for sectioned modules it contains input which is not specific to any one section.

The general organization of the <Operation-type> blocks is as follows:

The user supplies his input in a set of tables (e.g., ACTIVITY, Sect 4.4(1).1.1 below). Each table has a name (eg. ACTIVITY), called the "Table-type". A table starts with the heading <Table-type> and ends with the delimiter END <Table-type>. The body of the table consists of:

```
<range><-----values----->
```

where <range> is the range of operation-type numbers to which the <values> apply. If the second field in <range> is blank, the range is assumed to consist of a single operation. Thus, in the example in Sect 4.4(1).1.1, Previous Land-segments (PERLNDs) 1 through 7 have the same set of active sections, while PERLND 9 has a different set.

Thus, a table lists the values given to a specified set of variables (occupying only 1 line) for all the operations of a given type. The input was designed this way to minimize the quantity of data supplied when many operations have the same values for certain sets of input.

HSPF will only look for a given Table-type if the options already specified by the user require data contained within it. Thus, Table-type MON-INTERCEP (Sect 4.4(1).4.6) is relevant only if VCSFG in Table-type PWAT-PARM1 (4.4(1).4.1) is set to 1 for one or more PERLNDs. The system has been designed to ignore redundant information. Thus, if VCSFG is 0 and Table-type MON-INTERCEP is supplied, the table will be ignored.

On the other hand, if an expected value is not supplied, the system will attempt to use a default value. This situation can arise in one of three ways:

1. The entire table may be missing from the UCI.
2. The table may be present but not contain an entry (line) for the operation in question. The example in Sect 4.4(1).1.1 has no entry for PLS No. 8. Thus, all values in its active sections vector will have the default of 0.
3. A field may be left blank. In the example in Section 4.4(1).4.2, KVARY will acquire the default value 0.0 for PLS's 1 through 7.

When appropriate, the HSPF system will also check that a value supplied by the user falls within an allowable range. If it does not, an error message is generated.

Note that a table contains either integers or real values, but generally not both. For example, Table-type ACTIVITY (Sect 4.4(1).1.1) contains only integer flags, while Table-type PWAT-PARM2 (4.4(1).4.2) contains only real numbers. For tables containing real-valued data, the documentation gives separate defaults, minima and maxima for the English and Metric unit systems. The user specifies the units system for the UCI in the GLOBAL block.

4.4(1) PERLND Block

```
*****  
          1          2          3          4          5          6          7          8  
1234567890123456789012345678901234567890123456789012345678901234567890  
*****
```

Layout

PERLND

General input

[section ATEMP input]

[section SNOW input]

[section PWATER input]

[section SEDMNT input]

[section PSTEMP input]

[section PWTGAS input]

[section PQUAL input]

[section MSTLAY input]

[section PEST input]

[section NITR input]

[section PHOS input]

[section TRACER input]

END PERLND

Explanation

This block contains the data which are domestic to all the Pervious Land Segments in the RUN. The general input is always relevant: other input is only required if the module section concerned is active.

4.4(1).1 PERLND BLOCK -- General input

```
*****  
          1          2          3          4          5          6          7          8  
1234567890123456789012345678901234567890123456789012345678901234567890  
*****  
Layout  
*****
```

```
Table-type ACTIVITY  
[Table-type PRINT-INFO]  
Table-type GEN-INFO
```

```
*****
```

Explanation

The exact format of each of the tables mentioned above is detailed in the documentation which follows.

Tables enclosed in brackets [] above are not always required; for example, because all the values can be defaulted.

4.4(1).1.1 Table-type ACTIVITY -- Active Sections Vector

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
ACTIVITY
<-range><-----a-s-vector----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END ACTIVITY
```

Example

```
ACTIVITY
  <PLS >           Active Sections           ***
  # - # ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC***
  1   7   1   1   1
  9       0   0   0   1
END ACTIVITY
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<a-s-vector>	ASVEC(12)	12I5	0	0	1

Explanation

The PERLND module is divided into 12 sections. The values supplied in this table specify which sections are active and which are not, for each operation involving the PERLND module. A value of 0 means inactive and 1 means active. Any meaningful subset of sections may be active.

4.4(1).1.2 Table-type PRINT-INFO -- Printout information for PERLND

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
PRINT-INFO
<-range><-----print-flags-----><piv><pyr>
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PRINT-INFO
```

```
*****
Example
*****
```

```
PRINT-INFO
<PLS > ***** Print-flags ***** PIVL  PYR
# - # ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC *****
1   7   2   4   6                4   3   2   10  12
END PRINT-INFO
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<print-flags>	PFLAG(12)	12I5	4	2	6
<piv>	PIVL	I5	1	1	1440
<pyr>	PYREND	I5	9	1	12

Explanation

HSPF permits the user to vary the printout level (maximum frequency) for the various active sections of an operation. The meaning of each permissible value for PFLAG() is:

- 2 means every PIVL intervals
- 3 means every day
- 4 means every month
- 5 means every year
- 6 means never

In the example above, output from Pervious Land-segments 1 thru 7 will occur as follows:

Section	Maximum frequency
ATEMP	10 intervals
SNOW	month
PWATER	never
SEDMNT	--
thru	month (defaulted)
PEST	--
NITR	month
PHOS	day
TRACER	10 intervals

A value need only be supplied for PIVL if one or more sections have a printout level of 2. For those sections, printout will occur every PIVL intervals (that is, every PIVL*DELT minutes, where DELT is the number of minutes in the time step or the RUN or INGROUP). PIVL must be chosen such that there are an integer number of printout periods in a day.

HSPF will automatically provide printed output at all standard intervals greater than the specified interval. In the above example, output for section PHOS will be printed at the end of each day, month, and year.

PYREND is the calendar month which will terminate the year for printout purposes. Thus, the annual summary can reflect the situation over the past water year or the past calendar year, etc.

4.4(1).1.3 Table-type GEN-INFO -- Other general information for PERLND

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
GEN-INFO
<-range><---PLS-id----->          <unit-sys><-printu->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END GEN-INFO
```

```
*****
Example
*****
```

```
GEN-INFO
  <PLS >   PLS Name                Units   Printout ***
  # - #                t-series Engr Metr ***
                in  out                ***
  1      Yosemite Valley           1    1    23    24
  2      Kings river                1    1    23    24
END GEN-INFO
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<PLS-id>	LSID(5)	5A4	none	none	none
<unit-sys>	IUNITS,OUNITS	2I5	1	1	2
<printu>	PUNIT(2)	2I5	0	0	99

Explanation

Any string of up to 20 characters may be supplied as the identifier (LSID) for a PERLND.

The values supplied for <unit-sys> indicate the system of units for data in the input time series and output time series, respectively: 1 means English units, 2 means Metric units.

Note: All operations in the run must use the same units system for data in the UCI file; therefore, this system of units is specified by EMFG in the GLOBAL block.

The values supplied for PUNIT(*) indicate the destinations (files) of printout in English and metric units, respectively. A value of 0 means no printout is required in that unit system. A non-zero value means printout is required in that system, and the value is the unit number of the file to which printout is to be written. The unit number is associated with a filename in the FILES BLOCK.

Note that printout for each Impervious Land Segment can be obtained in either the English or Metric systems, or both (irrespective of the system used to supply the inputs).

4.4(1).2 PERLND BLOCK -- Section ATEMP input

```
*****  
          1          2          3          4          5          6          7          8  
1234567890123456789012345678901234567890123456789012345678901234567890  
*****  
Layout  
*****
```

[Table-type ATEMP-DAT]

```
*****
```

Explanation

The exact format of the table mentioned above is detailed in the documentation which follows.

Tables enclosed in brackets [] above are not always required; for example, because all the values can be defaulted.

4.4(1).2.1 Table-type ATEMP-DAT -- Elevation difference between gage & PLS

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
ATEMP-DAT
<-range><el-diff-><-airtmp->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END ATEMP-DAT
```

```
*****
Example
*****
```

```
ATEMP-DAT
  <PLS >   El-diff   ***
  # - #     (ft)     ***
  1   7     150.
END ATEMP-DAT
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<el-diff>	ELDAT	F10.0	0.0	none	none	ft	Engl
			0.0	none	none	m	Metric
<airtmp>	AIRTMP	F10.0	60	-60	140	Deg F	Engl
			15	-50	60	Deg C	Metric

Explanation

ELDAT is the difference in elevation between the temperature gage and the PERLND; it is used to estimate the temperature over the segment by application of a lapse rate. ELDAT is positive if the segment is higher than the gage, and vice versa.

AIRTMP is the air temperature over the land segment at the start of the RUN.

4.4(1).3 PERLND BLOCK -- Section SNOW input

```
*****  
          1          2          3          4          5          6          7          8  
1234567890123456789012345678901234567890123456789012345678901234567890  
*****  
Layout  
*****
```

```
[Table-type ICE-FLAG]  
  Table-type SNOW-PARM1  
[Table-type SNOW-PARM2]  
[Table-type SNOW-INIT1]  
[Table-type SNOW-INIT2]
```

```
*****
```

Explanation

The exact format of each of the tables mentioned above is detailed in the documentation which follows.

Tables enclosed in brackets [] above are not always required; for example, because all the values can be defaulted.

4.4(1).3.1 Table-type ICE-FLAG -- governs simulation of ice formation in snow

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
ICE-FLAG
<-range><ice>
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END ICE-FLAG
```

```
*****
Example
*****
```

```
ICE-FLAG
  <PLS > Ice-   ***
  # - # flag    ***
  1   7   1
END ICE-FLAG
```

```
*****
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<ice>	ICEFG	I5	0	0	1

Explanation

A value of 0 means ice formation in the snow pack will not be simulated; 1 means it will.

4.4(1).3.2 Table-type SNOW-PARM1 -- First group of SNOW parameters

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
SNOW-PARM1
<-range><-----snowparm1----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END SNOW-PARM1
```

```
*****
Example
*****
```

```
SNOW-PARM1
  <PLS > Latitude      Mean-      SHADE      SNOWCF      COVIND ***
  # - #                elev
  1   7   39.5         3900.        0.3        1.2        10.
END SNOW-PARM1
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<snowparm1>	LAT	5F10.0	40.0	-90.0	90.0	degrees	Both
	MELEV		0.0	0.0	30000.0	ft	Engl
			0.0	0.0	10000.0	m	Metric
	SHADE		0.0	0.0	1.0	none	Both
	SNOWCF		none	1.0	100.0	none	Both
	COVIND		none	0.01	none	in	Engl
			none	0.25	none	mm	Metric

Explanation

LAT is the latitude of the pervious land segment (PLS). It is positive for the northern hemisphere, and negative for the southern hemisphere.

MELEV is the mean elevation of the PLS above sea level.

SHADE is the fraction of the PLS which is shaded from solar radiation, by trees for example.

SNOWCF is the factor by which the input precipitation data will be multiplied, if the simulation indicates it is snowfall, to account for poor catch efficiency of the gage under snow conditions.

COVIND is the maximum snowpack (water equivalent) at which the entire PLS will be covered with snow (see SNOW section in Functional Description).

4.4(1).3.3 Table-type SNOW-PARM2 -- Second group of SNOW parameters

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
SNOW-PARM2
<-range><-----snowparm2----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END SNOW-PARM2
```

Example

```
SNOW-PARM2
  <PLS >                                     ***
  # - #      RDCSN      TSNOW      SNOEVP      CCFACT      MWATER      MGMELT ***
  1   7      0.2       33.
END SNOW-PARM2
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<snowparm2>	RDCSN	F10.0	0.15	0.01	1.0	none	Both
	TSNOW	F10.0	32.0	30.0	40.0	degF	Engl
			0.0	-1.0	5.0	degC	Metric
	SNOEVP	F10.0	0.1	0.0	1.0	none	Both
	CCFACT	F10.0	1.0	0.0	2.0	none	Both
	MWATER	F10.0	0.03	0.0	1.0	none	Both
MGMELT	F10.0	0.01	0.0	1.0	in/day	Engl	
		0.25	0.0	25.	mm/day	Metric	

Explanation

RDCSN is the density of cold, new snow relative to water. This value applies to snow falling at air temperatures lower than or equal to 0 degrees F. At higher temperatures the density of snow is adjusted.

TSNOW is the air temperature below which precipitation will be snow, under saturated conditions. Under non-saturated conditions the temperature is adjusted slightly.

SNOEVP is a parameter which adapts the snow evaporation (sublimation) equation to field conditions.

CCFACT is a parameter which adapts the snow condensation/convection melt equation to field conditions.

MWATER is the maximum water content of the snow pack, in depth of water per depth of water.

MGMELT is the maximum rate of snowmelt by ground heat, in depth of water per day. This is the value which applies when the pack temperature is at the freezing point.

4.4(1).3.4 Table-type SNOW-INIT1 -- First group of initial values for SNOW

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
SNOW-INIT1
<-range><-----snowinit1----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END SNOW-INIT1
```

```
*****
Example
*****
```

```
SNOW-INIT1
  <PLS >
  # - # Pack-snow  Pack-ice Pack-watr   RDENPF      DULL      PAKTMP***
  1   7      2.1          .02      .40
END SNOW-INIT1
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<snowinit1>	Pack-snow	F10.0	0.0	0.0	none	in	Engl
			0.0	0.0	none	mm	Metric
	Pack-ice	F10.0	0.0	0.0	none	in	Engl
			0.0	0.0	none	mm	Metric
	Pack-watr	F10.0	0.0	0.0	none	in	Engl
			0.0	0.0	none	mm	Metric
	RDENPF	F10.0	0.2	.01	1.0	none	Both
	DULL	F10.0	400.	0.0	800.	none	Both
	PAKTMP	F10.0	32.	none	32.	degF	Engl
			0.0	none	0.0	degC	Metric

Explanation

Pack-snow is the quantity of snow in the pack (water equivalent).

Pack-ice is the quantity of ice in the pack (water equivalent).

Pack-watr is the quantity of liquid water in the pack.

RDENPF is the density of the frozen contents (snow and ice) of the pack, relative to water.

DULL is an index to the dullness of the snow pack surface, from which albedo is estimated.

PAKTMP is the mean temperature of the frozen contents of the snow pack.

4.4(1).3.5 Table-type SNOW-INIT2 -- Second group of initial values for SNOW

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
SNOW-INIT2
<-range><-----snowinit2----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END SNOW-INIT2
```

Example

```
SNOW-INIT2
  <PLS >          ***
  # - #   COVINX   XLNMLT   SKYCLR***
  1   7           0.50
END SNOW-INIT2
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<snowinit2>	COVINX	F10.0	0.01	0.01	none	in	Engl
			0.25	0.25	none	mm	Metric
	XLNMLT	F10.0	0.0	0.0	none	in	Engl
			0.0	0.0	none	mm	Metric
	SKYCLR	F10.0	1.0	.15	1.0	none	Both

Explanation

COVINX is the current snow pack depth (water equivalent) required to obtain complete areal coverage of the PLS. If the pack is less than this amount, areal cover is prorated (PACKF/COVINX).

XLNMLT is the current remaining possible increment to ice storage in the pack (see Functional Description). It is relevant if ice formation is simulated (ICEFG= 1).

SKYCLR is the fraction of sky which is assumed to be clear at the present time.

4.4(1).4 PERLND BLOCK -- Section PWATER input

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
[Table-type PWAT-PARM1]
  Table-type PWAT-PARM2
[Table-type PWAT-PARM3]
  Table-type PWAT-PARM4
[Table-type PWAT-PARM5]
[Table-type MON-INTERCEP]  --
[Table-type MON-UZSN]      |
[Table-type MON-MANNING]   | only required if the relevant quantity
[Table-type MON-INTERFLW]  | varies through the year
[Table-type MON-IRC]       |
[Table-type MON-LZETPARM]  --
[Table-type PWAT-STATE1 ]
```

```
*****
```

Explanation

The exact format of each of the tables mentioned above is detailed in the documentation which follows.

Tables enclosed in brackets [] above are not always required; for example, because all the values can be defaulted.

4.4(1).4.1 Table-type PWAT-PARM1 -- First group of PWATER parameters (flags)

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
PWAT-PARM1
<-range><-----pwatparm1----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PWAT-PARM1
```

```
*****
Example
*****
```

```
PWAT-PARM1
  <PLS >                Flags                ***
  # - # CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE IFFC ***
  1   7   1   1
END PWAT-PARM1
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<pwatparm1>	CSNOFG	I5	0	0	1
	RTOPFG	I5	0	0	1
	UZFG	I5	0	0	1
	VCSFG	I5	0	0	1
	VUZFG	I5	0	0	1
	VNNFG	I5	0	0	1
	VIFWFG	I5	0	0	1
	VIRCFG	I5	0	0	1
	VLEFG	I5	0	0	1
	IFFCFG	I5	1	1	2

Explanation

If CSNOFG is 1, section PWATER assumes that snow accumulation and melt is being considered. It will, therefore, expect that the time series produced by section SNOW are available, either internally (produced in this RUN) or from external sources (e.g., produced in a previous RUN). If CSNOFG is 0, no such time series are expected. See the Functional Description for further information.

RTOPFG is a flag that selects the algorithm for computing overland flow. Two optional methods are provided. If RTOPFG is 1, routing of overland flow is done in the same way as in the predecessor models HSPX, ARM and NPS. A value of 0 results in a different algorithm (see Functional Description for details).

UZFG selects the method for computing inflow to the upper zone. If UZFG is 1, upper zone inflow is computed in the same way as in the predecessor models HSPX, ARM and NPS. A value of 0 results in the use of a different algorithm, which is less sensitive to changes in DELT (see functional description).

The flags beginning with "V" indicate whether or not certain parameters will be assumed to vary through the year on a monthly basis: 1 means they do vary, 0 means they do not. The quantities which can vary on a monthly basis are:

VCSFG	interception storage capacity
VUZFG	upper zone nominal storage
VNNFG	Manning's n for the overland flow plane
VIFWFG	interflow inflow parameter
VIRCFG	interflow recession constant
VLEFG	lower zone evapotranspiration (E-T) parameter

If any of these flags are on (1), monthly values for the parameter concerned must be supplied (see Table-types MON-xxx, documented later in this section).

If IFFCFG is 1, then the effect of frozen ground on infiltration rate is computed from the amount of ice in the snow pack (PACKI). CSNOFG must be turned on, and if section SNOW does not compute PACKI (because ICEFG is off or the section is inactive) PACKI must be supplied as an input time series. If IFFCFG is 2, then the infiltration adjustment factor is determined from the soil temperature in the lower layer/groundwater layer, which is either computed in section PSTEMP or must be supplied as an input time series. (See Table-type PWAT-PARM5 for more details.)

4.4(1).4.2 Table-type PWAT-PARM2 -- Second group of PWATER parameters

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
PWAT-PARM2
<-range><-----pwatparm2----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PWAT-PARM2
```

```
*****
Example
*****
```

```
PWAT-PARM2
  <PLS > ***
  # - # ***FOREST      LZSN      INFILT      LSUR      SLSUR      KVARV      AGWRC
  1  7      0.2        8.0        0.7        400.      .001
END PWAT-PARM2
```

```
*****
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<pwatparm2>	FOREST	F10.0	0.0	0.0	1.0	none	Both
	LZSN	F10.0	none none	.01 .25	100. 2500.	in mm	Engl Metric
	INFILT	F10.0	none none	0.0001 0.0025	100. 2500.	in/hr mm/hr	Engl Metric
	LSUR	F10.0	none none	1.0 0.3	none none	ft m	Engl Metric
	SLSUR	F10.0	none	.000001	10.	none	Both
	KVARY	F10.0	0.0 0.0	0.0 0.0	none none	1/in 1/mm	Engl Metric
	AGWRC	F10.0	none	0.001	0.999	1/day	Both

Explanation

FOREST is the fraction of the PLS which is covered by forest, and which will therefore continue to transpire in winter. This is only relevant if snow is being considered (i.e., CSNOFG = 1).

LZSN is the lower zone nominal storage.

INFILT is an index to the infiltration capacity of the soil.

LSUR is the length of the assumed overland flow plane.

SLSUR is the slope of the overland flow plane.

KVARY is a parameter which affects the behavior of groundwater recession flow, enabling it to be non-exponential in its decay with time.

AGWRC is the basic groundwater recession rate if KVARY is zero and there is no inflow to groundwater; AGWRC is defined as the rate of flow today divided by the rate of flow yesterday.

4.4(1).4.3 Table-type PWAT-PARM3 -- Third group of PWATER parameters

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
PWAT-PARM3
<-range><-----pwatparm3----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PWAT-PARM3
```

```
*****
Example
*****
```

```
PWAT-PARM3
<PLS >***
# - #*** PETMAX      PETMIN      INFEXP      INFILD      DEEPFR      BASETP      AGWETP
1   7
9           39         33          3.0         1.5
END PWAT-PARM3
```

```
*****
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<pwatparm3>	PETMAX	F10.0	40.	none	none	degF	Engl
			4.4	none	none	degC	Metric
	PETMIN	F10.0	35. 1.7	none none	none none	degF degC	Engl Metric
	INFEXP	F10.0	2.0	0.0	10.0	none	Both
	INFILD	F10.0	2.0	1.0	2.0	none	Both
	DEEPFR	F10.0	0.0	0.0	1.0	none	Both
	BASETP	F10.0	0.0	0.0	1.0	none	Both
	AGWETP	F10.0	0.0	0.0	1.0	none	Both

Explanation

PETMAX is the air temperature below which E-T will arbitrarily be reduced below the value obtained from the input time series, and PETMIN is the temperature below which E-T will be zero regardless of the value in the input time series. These values are only used if snow is being considered (CSNOFG= 1).

INFEXP is the exponent in the infiltration equation, and INFILD is the ratio between the maximum and mean infiltration capacities over the PLS.

DEEPFR is the fraction of groundwater inflow which will enter deep (inactive) groundwater, and, thus, be lost from the system as it is defined in HSPF.

BASETP is the fraction of remaining potential E-T which can be satisfied from baseflow (groundwater outflow), if enough is available.

AGWETP is the fraction of remaining potential E-T which can be satisfied from active groundwater storage if enough is available.

4.4(1).4.4 Table-type PWAT-PARM4 -- Fourth group of PWATER parameters

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
PWAT-PARM4
<-range><-----pwatparm4----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PWAT-PARM4
```

Example

```
PWAT-PARM4
<PLS >                                     ***
# - #      CEPSC      UZSN      NSUR      INTFW      IRC      LZETP***
1   7      0.1       1.3       0.1       3.         0.5       0.7
END PWAT-PARM4
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<pwatparm4>	CEPSC	F10.0	0.0	0.0	10.0	in	Engl
			0.0	0.0	250.	mm	Metric
	UZSN	F10.0	none	0.01	10.0	in	Engl
			none	0.25	250.	mm	Metric
	NSUR	F10.0	0.1	0.001	1.0	complex	Both
	INTFW	F10.0	none	0.0	none	none	Both
	IRC	F10.0	none	1.0E-30	0.999	1/day	Both
	LZETP	F10.0	0.0	0.0	0.999	none	Both

Explanation

Values in this table need only be supplied for those parameters which do not vary through the year. If they do vary (as specified in Table-type PWAT-PARM1), monthly values are supplied in the tables documented below (MON-xxx).

CEPSC is the interception storage capacity.

UZSN is the upper zone nominal storage.

NSUR is Manning's n for the assumed overland flow plane.

INTFW is the interflow inflow parameter.

IRC is the interflow recession parameter. Under zero inflow, this is the ratio of today's interflow outflow rate to yesterday's rate.

LZETP is the lower zone E-T parameter. It is an index to the density of deep-rooted vegetation.

4.4(1).4.5 Table-type PWAT-PARM5 -- Fifth group of PWATER parameters

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
PWAT-PARM5
<-range><---pwatparm5----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PWAT-PARM5
```

```
*****
Example
*****
```

```
PWAT-PARM3
<PLS >***
# - #***      FZG      FZGL
1   7
9           0.9      0.1
END PWAT-PARM3
```

```
*****
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<pwatparm5>	FZG	F10.0	1.0	0.0001	none	/in	Engl
		F10.0	0.0394	0.0001	none	/mm	Metr
	FZGL	F10.0	0.1	0.0001	1.0	none	Both

Explanation

FZG is the parameter that adjusts for the effect of ice in the snow pack on infiltration when IFFCFG is 1. It is not used if IFFCFG is 2.

FZGL is the lower limit of INFFAC as adjusted by ice in the snow pack when IFFCFG is 1. If IFFCFG is 2, FZGL is the value of INFFAC when the lower layer temperature is at or below freezing.

4.4(1).4.6 Table-type MON-INTERCEP -- Monthly interception storage capacity

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MON-INTERCEP
<-range><-----mon-icep----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-INTERCEP
```

```
*****
Example
*****
```

```
MON-INTERCEP
  <PLS > Interception storage capacity at start of each month      ***
  # - #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC***
  1   7  .02  .03  .03  .04  .05  .08  .12  .15  .12  .05  .03  .01
END MON-INTERCEP
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-icep>	CEPSCM(12)	12F5.0	0.0	0.0	10.	in	Engl
			0.0	0.0	250.	mm	Metric

Explanation

Monthly values of interception storage. Only required if VCSFG is 1 in Table-type PWAT-PARM1.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(1).4.7 Table-type MON-UZSN -- Monthly upper zone nominal storage

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MON-UZSN
<-range><-----mon-uzsn----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-UZSN
```

```
*****
Example
*****
```

```
MON-UZSN
<PLS > Upper zone storage at start of each month          ***
# - #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
1   7   .30  .35  .30  .45  .56  .57  .45  .67  .64  .54  .56  .40
END MON-UZSN
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-uzsn>	UZSNM(12)	12F5.0	none	.01	10.	in	Engl
			none	.25	250.	mm	Metric

Explanation

Monthly values of upper zone nominal storage. This table is only required if VUZFG is 1 in Table-type PWAT-PARM1.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(1).4.8 Table-type MON-MANNING -- Monthly Manning's n values

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MON-MANNING
<-range><-----mon-Manning----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-MANNING
```

```
*****
Example
*****
```

```
MON-MANNING
<PLS > Manning's n at start of each month          ***
# - #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
1   7  .23  .34  .34  .35  .28  .35  .37  .35  .28  .29  .30  .30
END MON-MANNING
```

```
*****
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-Manning>	NSURM(12)	12F5.0	.10	.001	1.0	complex	Both

Explanation

Monthly values of Manning's constant for overland flow. This table is only required if VNNFG is 1 in Table-type PWAT-PARML.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(1).4.9 Table-type MON-INTERFLW -- monthly interflow inflow parameters

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MON-INTERFLW
<-range><-----mon-interflw----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-INTERFLW
```

```
*****
Example
*****
```

```
MON-INTERFLW
  <PLS > Interflow inflow parameter for start of each month      ***
  # - #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
  1   7  2.0  3.3  3.6  3.8  4.2  5.6  5.6  7.6  7.5  5.6  4.6  3.4
END MON-INTERFLW
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-interflw>	INTFWM(12)	12F5.0	none	0.0	none	none	Both

Explanation

Monthly values of the interflow inflow parameter. This table is only required if VIFWFG is 1 in Table-type PWAT-PARML.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(1).4.10 Table-type MON-IRC -- Monthly interflow recession constants

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MON-IRC
<-range><-----mon-irc----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-IRC
```

```
*****
Example
*****
```

```
MON-IRC
  <PLS > Interflow recession constant at start of each month      ***
  # - #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC***
  1   7  .35  .40  .40  .40  .40  .43  .45  .45  .50  .45  .45  .40
END MON-IRC
```

```
*****
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-irc>	IRCM(12)	12F5.0	none	1.0E-30	0.999	/day	Both

Explanation

Monthly values of the interflow recession parameter. This table is only required if VIRCFG is 1 in Table-type PWAT-PARML.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(1).4.11 Table-type MON-LZETPARM -- Monthly lower zone E-T parameter

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MON-LZETPARM
<-range><-----mon-lzetparm----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-LZETPARM
```

```
*****
Example
*****
```

```
MON-LZETPARM
  <PLS > Lower zone evapotranspiration parm at start of each month ***
  # - # JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC***
  1   7 .30 .30 .35 .35 .40 .40 .45 .45 .45 .45 .42 .38
END MON-LZETPARM
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-lzetparm>	LZETPM(12)	12F5.0	0.0	0.0	0.999	none	Both

Explanation

Monthly values of the lower zone ET parameter. This table is only required if VLEFG is 1 in Table-type PWAT-PARM1.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(1).4.12 Table-type PWAT-STATE1 -- PWATER initial state variables

```
*****
      1      2      3      4      5      6      7      8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
PWAT-STATE1
<-range><-----pwat-statel----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PWAT-STATE1
```

```
*****
Example
*****
```

```
PWAT-STATE1
<PLS > PWATER state variables***
# - #***  CEPS      SURS      UZS      IFWS      LZS      AGWS      GWVS
1   7      0.05     0.10     0.25     0.01     8.2     2.0     .025
END PWAT-STATE1
```

```
*****
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<pwat-statel>	CEPS	7F10.0	0.0	0.0	100	inches	Engl
			0.0	0.0	2500	mm	Metric
	SURS		0.0	0.0	100	inches	Engl
			0.0	0.0	2500	mm	Metric
	UZS		.001	.001	100	inches	Engl
			.025	.025	2500	mm	Metric
	IFWS		0.0	0.0	100	inches	Engl
			0.0	0.0	2500	mm	Metric
	LZS		.001	.001	100	inches	Engl
			.025	.025	2500	mm	Metric
	AGWS		0.0	0.0	100	inches	Engl
			0.0	0.0	2500	mm	Metric
	GWVS		0.0	0.0	100	inches	Engl
			0.0	0.0	2500	mm	Metric

Explanation

This table is used to specify the initial water storages in the soil.

CEPS is the initial interception storage.

SURS is the initial surface (overland flow) storage.

UZS is the initial upper zone storage.

IFWS is the initial interflow storage.

LZS is the initial lower zone storage.

AGWS is the initial active groundwater storage.

GWVS is the initial index to groundwater slope; it is a measure of antecedent active groundwater inflow.

4.4(1).5 PERLND BLOCK -- Section SEDMNT input

```
*****  
          1          2          3          4          5          6          7          8  
1234567890123456789012345678901234567890123456789012345678901234567890  
*****  
Layout  
*****
```

```
[Table-type SED-PARM1]           Tables in brackets [] are  
  Table-type SED-PARM2           not always required.  
  Table-type SED-PARM3  
[Table-type MON-COVER]  
[Table-type MON-NVSI]  
[Table-type SED-STOR]
```

```
*****
```

Explanation

The exact format of each of the tables mentioned above is detailed in the documentation which follows.

4.4(1).5.1 Table-type SED-PARM1 -- First group of SEDMNT parameters

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
SED-PARM1
<-range><--sed-parml-->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END SED-PARM1
```

Example

```
SED-PARM1
<PLS >***
# - # CRV VSIV SDOP***
1 7 0 1 0
END SED-PARM1
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<sed-parml>	CRVFG	3I5	0	0	1
	VSIVFG		0	0	2
	SDOPFG		0	0	1

Explanation

If CRVFG is 1, erosion-related cover may vary throughout the year. Values are supplied in Table-type MON-COVER.

If VSIVFG is 1, the rate of net vertical sediment input may vary throughout the year. If VSIVFG is 2, the vertical sediment input is added to the detached sediment storage only on days when no rainfall occurred during the previous day. Values are supplied in Table-type MON-NVSI.

SDOPFG is a flag that determines the algorithm used to simulate removal of sediment from the land surface. If SDOPFG is 1, sediment removal will be simulated with the algorithm used in the predecessor models ARM and NPS. If it is 0, a different algorithm will be used (see the Functional Description for details).

4.4(1).5.2 Table-type SED-PARM2 -- Second group of SEDMNT parameters

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
SED-PARM2
<-range><-----sed-parm2----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END SED-PARM2
```

```
*****
Example
*****
```

```
SED-PARM2
<PLS >***
# - #      SMPF      KRER      JRER      AFFIX      COVER      NVSI***
1   7      0.9      0.08     1.90     0.01      0.5       -0.100
END SED-PARM2
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system	
<sedparm2>	SMPF	6F10.0	1.0	0.001	1.0	none	Both	
	KRER		0.0	0.0	none	complex	Both	
	JRER		none	none	none	complex	Both	
	AFFIX		0.0	0.0	1.0	/day	Both	
	COVER		0.0	0.0	1.0	none	Both	
	NVSI			0.0	none	none	lb/ac/day	Engl
				0.0	none	none	kg/ha/day	Metric

Explanation

SMPF is a "supporting management practice factor." It is used to simulate the reduction in erosion achieved by use of erosion control practices.

KRER is the coefficient in the soil detachment equation.

JRER is the exponent in the soil detachment equation.

AFFIX is the fraction by which detached sediment storage decreases each day as a result of soil compaction.

COVER is the fraction of land surface which is shielded from rainfall erosion (not considering snow cover, which is handled by the program).

NVSI is the rate at which sediment enters detached storage from the atmosphere. A negative value can be supplied, for example, to simulate removal by human activity or wind.

If monthly values for COVER and NVSI are being supplied, values supplied for these variables in this table are not relevant.

4.4(1).5.3 Table-type SED-PARM3 -- Third group of SEDMNT parameters

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
SED-PARM3
<-range><-----sed-parm3----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END SED-PARM3
```

```
*****
Example
*****
```

```
SED-PARM3
<PLS >***
# - #      KSER      JSER      KGER      JGER***
1   7      0.08     1.7     0.06     1.4
END SED-PARM3
```

```
*****
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<sedparm3>	KSER	4F10.0	0.0	0.0	none	complex	Both
	JSER		none	none	none	complex	Both
	KGER		0.0	0.0	none	complex	Both
	JGER		none	none	none	complex	Both

Explanation

KSER and JSER are the coefficient and exponent in the detached sediment washoff equation.

KGER and JGER are the coefficient and exponent in the matrix soil scour equation, which simulates gully erosion.

4.4(1).5.4 Table-type MON-COVER -- Monthly erosion-related cover values

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MON-COVER
<-range><-----mon-cover----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-COVER
```

```
*****
Example
*****
```

```
MON-COVER
  <PLS > Monthly values for erosion related cover ***
  # - # JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC***
  1   7 0.0 .12 .12 .24 .24 .56 .67 .56 .34 .34 .23 .12
END MON-COVER
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-cover>	COVERM(12)	12F5.0	0.0	0.0	1.0	none	Both

Explanation

Monthly values of the COVER parameter. This table is only required if CRVFG is 1 in Table-type SED-PARM1.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(1).5.5 Table-type MON-NVSI -- Monthly net vertical sediment input

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MON-NVSI
<-range><-----mon-nvsi----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-NVSI
```

```
*****
Example
*****
```

```
MON-NSVI
<PLS > Monthly net vertical sediment input***
# - # JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC***
1 7 -.01 -.02 -.03 -.04 -.05 -.03 -.02 -.01 0.0 .01 .03 .01
END MON-NVSI
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-nvsi>	NVSIM(12)	12F5.0	0.0	none	none	lb/ac/day	Engl
			0.0	none	none	kg/ha/day	Metric

Explanation

Monthly values of the net vertical sediment input. This table is only required if VSIVFG is greater than 0 in Table-type SED-PARML.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(1).5.6 Table-type SED-STOR -- Initial storage of detached sediment

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
SED-STOR
<-range><----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END SED-STOR
```

Example

```
SED-STOR
  <PLS > Detached sediment storage (tons/acre)    ***
  # - #                                           ***
  1   7           0.2
END SED-STOR
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<sed-stor>	DETS	F10.0	0.0 0.0	0.0 0.0	none none	tons/ac tonnes/ha	Engl Metric

Explanation

DETS is the initial storage of detached sediment.

4.4(1).6 PERLND BLOCK -- Section PSTEMP input

```
*****  
          1          2          3          4          5          6          7          8  
1234567890123456789012345678901234567890123456789012345678901234567890  
*****  
Layout  
*****
```

```
[Table-type PSTEMP-PARM1]  
  Table-type PSTEMP-PARM2           Tables in brackets [] are  
[Table-type MON-ASLT]               not always required  
[Table-type MON-BSLT]  
[Table-type MON-ULTP1]  
[Table-type MON-ULTP2]  
[Table-type MON-LGTP1]  
[Table-type MON-LGTP2]  
[Table-type PSTEMP-TEMPS]
```

```
*****
```

Explanation

The exact format of each of the tables mentioned above is detailed in the documentation which follows.

4.4(1).6.1 Table-type PSTEMP-PARM1 -- Flags for section PSTEMP

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
PSTEMP-PARM1
<-range><---pstemp-parm1--->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PSTEMP-PARM1
```

```
*****
Example
*****
```

```
PSTEMP-PARM1
  <PLS >  Flags for section PSTEMP***
  # - # SLTV ULTV LGTV TSOP***
  1   7   0   0   0   1
END PSTEMP-PARM1
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<pstemp-parm1>	SLTVFG	4I5	0	0	1
	ULTVFG		0	0	1
	LGTVFG		0	0	1
	TSOPFG		0	0	2

Explanation

If SLTVFG is 1, parameters for estimating surface layer temperature can vary throughout the year. Thus, Table-types MON-ASLT and MON-BSLT will be expected.

ULTVFG serves the same purpose for upper layer temperature calculations. Tables MON-ULTP1 and MON-ULTP2 will be expected if ULTVFG is 1. LGTVFG serves the same purpose for the lower layer and active groundwater layer temperature calculations. Table-types MON-LGTP1 and MON-LGTP2 will be expected if LGTVFG is 1.

TSOPFG governs the methods used to estimate subsurface soil temperatures. If TSOPFG is 0, they are computed using a mean departure from air temperature, together with smoothing factors. If TSOPFG is 2, the method is identical, except that the lower layer/groundwater layer temperature is calculated from the upper layer soil temperature, instead of directly from the air temperature. If TSOPFG is 1, upper layer soil temperature is estimated by regression on air temperature (like surface temperature). The lower layer/ground-water layer temperature is supplied directly by the user (a different value may be specified for each month).

4.4(1).6.2 Table-type PSTEMP-PARM2 -- Second group of PSTEMP parameters

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
PSTEMP-PARM2
<-range><-----pstemp-param2----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PSTEMP-PARM2
```

Example

```
PSTEMP-PARM2
<PLS >***
# - #      ASLT      BSLT      ULTP1      ULTP2      LGTP1      LGTP2***
1   7      24.      .5        24.        .5         40.        0.0
END PSTEMP-PARM2
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<pstemp-parm2>	ASLT	6F10.0	32.	0.0	100.	deg F	Engl
			0.	-18.	38.	deg C	Metric
	BSLT		1.0	0.001	2.0	deg F/F	Engl
			1.0	0.001	2.0	deg C/C	Metric

Definition of remaining quantities depends on soil temperature option flag (TSOPFG in Table-type PSTEMP-PARM1)

TSOPFG = 0 or 2:

ULTP1	none	none	none	none	Both
ULTP2	none	none	none	F deg	Engl
	none	none	none	C deg	Metric
LGTP1	none	none	none	none	Both
LGTP2	none	none	none	F deg	Engl
	none	none	none	C deg	Metric

TSOPFG = 1:

ULTP1	none	none	none	Deg F	Engl
	none	none	none	Deg C	Metric
ULTP2	none	none	none	Deg F/F	Engl
	none	none	none	Deg C/C	Metric
LGTP1	none	none	none	Deg F	Engl
LGTP2	none	none	none	Deg C	Metric
		not used			

Explanation

ASLT is the surface layer temperature when the air temperature is 32 degrees F (0 degrees C). It is the intercept of the surface layer temperature regression equation.

BSLT is the slope of the surface layer temperature regression equation.

If TSOPFG = 0 then:

ULTP1 is the smoothing factor in the upper layer temperature calculation.

ULTP2 is the mean difference between upper layer soil temperature and air temperature.

LGTP1 and LGTP2 are the smoothing factor and mean departure from air temperature for calculating lower layer/groundwater soil temperature.

If TSOPFG = 1 then:

ULTP1 and ULTP2 are the intercept and slope in the upper layer soil temperature regression equation (like ASLT and BSLT for the surface layer). LGTP1 is the lower layer/groundwater layer soil temperature. LGTP2 is not used.

If TSOPFG = 2 then:

ULTP1 is the smoothing factor in the upper layer temperature calculation.

ULTP2 is the mean difference between upper layer soil temperature and air temperature.

LGTP1 and LGTP2 are the smoothing factor and mean departure from the upper layer soil temperature for calculating lower layer/groundwater soil temperature.

If monthly values are being supplied for any of these quantities (in Table-type MON-xxx), the value appearing in this table is not relevant.

4.4(1).6.3 Table-type MON-ASLT -- Monthly values for ASLT

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MON-ASLT
<-range><-----mon-aslt----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-ASLT
```

```
*****
Example
*****
```

```
MON-ASLT
<PLS > Value of ASLT at start of each month (deg F)***
# - # JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC***
1 7 37. 38. 39. 40. 41. 42. 43. 44. 45. 44. 41. 40.
END MON-ASLT
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-aslt>	ASLTM(12)	12F5.0	32. 0.	0. -18.	100. 38.	deg F deg C	Engl Metric

Explanation

This table is only required if SLTVFG is 1 in Table-type PSTEMP-PARM1.

The input monthly values apply to the first day of the month; values for intermediate days are obtained by interpolating between successive monthly values.

4.4(1).6.4 Table-type MON-BSLT -- Monthly values for BSLT

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MON-BSLT
<-range><-----mon-bslt----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-BSLT
```

```
*****
Example
*****
```

```
MON-BSLT
<PLS > Value of BSLT at start of each month (deg F/F)***
# - # JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC***
1 7 .3 .3 .3 .4 .4 .5 .5 .5 .4 .4 .4 .3
END MON-BSLT
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-bslt>	BSLTM(12)	12F5.0	1.0	0.001	2.0	deg F/F	Engl
			1.0	0.001	2.0	deg C/C	Metric

Explanation

This table is only required if SLTVFG is 1 in Table-type PSTEMP-PARM1.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(1).6.5 Table-type MON-ULTP1 -- Monthly values for ULTP1

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

MON-ULTP1

<-range><-----mon-ultp1----->

.

(repeats until all operations of this type are covered)

.

END MON-ULTP1

Example

MON-ULTP1

<PLS > Value of ULTP1 at start of each month (TSOPFG=1) ***

# - #	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC***
1 7	37.	38.	39.	40.	42.	44.	47.	44.	42.	39.	39.	39.

END MON-ULTP1

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<mon-ultp1>	ULTP1M(12)	12F5.0	see notes for Table-type		PSTEMP-PARM2

Explanation

This table is only required if ULTVFG is 1 in Table-type PSTEMP-PARM1.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(1).6.6 Table-type MON-ULTP2 -- Monthly values for ULTP2

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MON-ULTP2
<-range><-----mon-ultp2----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-ULTP2
```

```
*****
Example
*****
```

```
MON-ULTP2
  <PLS > Value of ULTP2 at start of each month (TSOPFG=1)          ***
  # - #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC***
  1   7   .3   .3   .4   .5   .5   .5   .6   .6   .5   .4   .4   .3
END MON-ULTP2
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<mon-ultp2>	ULTP2M(12)	12F5.0	see notes for Table-type		PSTEMP-PARM2

Explanation

This table is only required if ULTVFG is 1 in Table-type PSTEMP-PARM1.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(1).6.7 Table-type MON-LGTP1 -- Monthly values for LGTP1

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MON-LGTP1
<-range><-----mon-lgtp1----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-LGTP1
```

```
*****
Example
*****
```

```
MON-LGTP1
  <PLS > Value of LGTP1 at start of each month (TSOPFG=1)          ***
  # - #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC***
  1   7  35.  38.  41.  43.  51.  45.  46.  45.  39.  37.  35.  35.
END MON-LGTP1
```

```
*****
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<mon-lgtp1>	LGTP1M(12)	12F5.0	see notes for Table-type PSTEMP-PARM2		

Explanation

This table is only required if LGTVFG is 1 in Table-type PSTEMP-PARM1.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(1).6.8 Table-type MON-LGTP2 -- Monthly values for LGTP2

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

MON-LGTP2

<-range><-----mon-lgtp2----->

.

(repeats until all operations of this type are covered)

.

END MON-LGTP2

Example

MON-LGTP2

<PLS > Value for LGTP2 at start of each month (F deg) (TSOPFG=0) ***

```
# - # JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC***
1   7 2.0 2.0 2.0 2.0 1.0 1.0 1.0 0.0 0.0 0.0 1.0 2.0
```

END MON-LGTP2

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-lgtp2>	LGTP2M(12)	12F5.0	none none	none none	none none	F deg C deg	Engl Metric

Explanation

This table is only required if LGTVFG is 1 in Table-type PSTEMP-PARM1, and TSOPFG is 0 or 2.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(1).6.9 Table-type PSTEMP-TEMPS -- Initial temperatures

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
PSTEMP-TEMPS
<-range><-----pstemp-temps----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PSTEMP-TEMPS
```

Example

```
PSTEMP-TEMPS
<PLS > Initial temperatures***
# - #      AIRTC      SLTMP      ULTMP      LGTMP***
1   7      48.       48.       48.       48.
END PSTEMP-TEMPS
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<pstemp-temps>	AIRTC	4F10.0	60.	-20.	120.	deg F	Engl
			16.	-29.	49.	deg C	Metric
	SLTMP		60.	-20.	120.	deg F	Engl
			16.	-29.	49.	deg C	Metric
	ULTMP		60.	-20.	120.	deg F	Engl
			16.	-29.	49.	deg C	Metric
	LGTMP		60.	-20.	120.	deg F	Engl
			16.	-29.	49.	deg C	Metric

Explanation

These are the initial temperatures:
 AIRTC - air temperature
 SLTMP - surface layer soil temperature
 ULTMP - upper layer soil temperature
 LGTMP - lower layer/groundwater layer soil temperature

4.4(1).7 PERLND BLOCK -- Section PWTGAS input

```
*****  
          1          2          3          4          5          6          7          8  
1234567890123456789012345678901234567890123456789012345678901234567890  
*****
```

Layout

```
[Table-type PWT-PARM1]  
[Table-type PWT-PARM2]           Tables in brackets [] are not  
[Table-type MON-IFWDOX]         always required  
[Table-type MON-IFWCO2]  
[Table-type MON-GRNDDOX]  
[Table-type MON-GRNDCO2]  
[Table-type PWT-TEMPS]  
[Table-type PWT-GASES]
```

```
*****
```

Explanation

The exact format of each of the tables mentioned above is detailed in the documentation which follows.

4.4(1).7.1 Table-type PWT-PARM1 -- Flags for section PWTGAS

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
PWT-PARM1
<-range><----pwt-parm1----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PWT-PARM1
```

Example

```
PWT-PARM1
  <PLS >  Flags for section PWTGAS***
  # - #  IDV  ICV  GDV  GVC***
  1   7   0   0   1   0
END PWT-PARM1
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<pwt-parm1>	IDVFG	4I5	0	0	1
	ICVFG		0	0	1
	GDVFG		0	0	1
	GCVFG		0	0	1

Explanation

Each of these flags indicate whether or not a parameter is allowed to vary throughout the year, and thus, whether or not the corresponding table of monthly values will be expected:

FLAG	PARAMETER	TABLE FOR MONTHLY VALUES
IDVFG	Interflow dissolved oxygen concentration	MON-IFWDOX
ICVFG	Interflow CO2 concentration	MON-IFWCO2
GDVFG	Groundwater dissolved oxygen concentration	MON-GRNDDOX
GCVFG	Groundwater CO2 concentration	MON-GRNDCO2

4.4(1).7.2 Table-type PWT-PARM2 -- Second group of PWTGAS parameters

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
PWT-PARM2
<-range><-----pwt-parm2----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PWT-PARM2
```

Example

```
PWT-PARM2
<PLS > Second group of PWTGAS parameters ***
# - #      ELEV      IDOXP      ICO2P      ADOXP      ACO2P***
1   7      1281.      8.2       0.2       8.2       0.3
END PWT-PARM2
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<pwt-parm2>	ELEV	5F10.0	0.0	-1000.	30000.	ft	Engl
			0.0	-300.	9100.	m	Metric
	IDOXP		0.0	0.0	20.	mg/l	Both
	ICO2P		0.0	0.0	1.0	mg C/l	Both
	ADOXP		0.0	0.0	20.	mg/l	Both
	ACO2P		0.0	0.0	1.0	mg C/l	Both

Explanation

ELEV is the elevation of the PLS above sea level; it is used to adjust the saturation concentrations of dissolved gases in surface outflow.

IDOXP is the concentration of dissolved oxygen in interflow outflow.

ICO2P is the concentration of dissolved CO2 in interflow outflow.

ADOXP is the concentration of dissolved oxygen in active groundwater outflow.

ACO2P is the concentration of dissolved CO2 in active groundwater outflow.

4.4(1).7.3 Table-type MON-IFWDOX -- Monthly interflow dissolved oxygen concentration

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MON-IFWDOX
<-range><-----mon-ifwdox----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-IFWDOX
```

```
*****
Example
*****
```

```
MON-IFWDOX
  <PLS > Value at start of each month for interflow DO concentration***
  # - #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC***
  1   7  4.5  4.7  5.7  6.5  7.6  7.6  7.4  6.3  4.3  5.3  4.3  3.5
END MON-IFWDOX
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-ifwdox>	IDOXPM(12)	12F5.0	0.0	0.0	20.0	mg/l	Both

Explanation

This table is only required if IDVFG is 1 in Table-type PWT-PARML.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(1).7.4 Table-type MON-IFWCO2 -- Monthly interflow CO2 concentration

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

MON-IFWCO2

<-range><-----mon-ifwco2----->

.

(repeats until all operations of this type are covered)

.

END MON-IFWCO2

Example

MON-IFWCO2

<PLS > Value at start of each month for interflow CO2 concentration***

- # JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC***

1 7 .123 .171 .142 .145 .157 .178 .122 .123 .143 .145 .176 .145

END MON-IFWCO2

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-ifwco2>	ICO2PM(12)	12F5.0	0.0	0.0	1.0	mg C/l	Both

Explanation

This table is only required if ICVFG is 1 in Table-type PWT-PARM1.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(1).7.5 Table-type MON-GRNDDOX -- Monthly groundwater dissolved oxygen concentration

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MON-GRNDDOX
<-range><-----mon-grnddox----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-GRNDDOX
```

```
*****
Example
*****
```

```
MON-GRNDDOX
  <PLS > Value at start of each month for groundwater DO concentration***
  # - #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC***
  1   7  4.5  4.7  4.9  4.9  4.9  4.9  5.0  5.6  5.7  5.8  5.4  5.1
END MON-GRNDDOX
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-grnddox>	ADOXPM(12)	12F5.0	0.0	0.0	20.0	mg/l	Both

Explanation

This table is only required if GDVFG is 1 in Table-type PWT-PARML.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(1).7.6 Table-type MON-GRNDCO2 -- Monthly groundwater CO2 concentration

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MON-GRNDCO2
<-range><-----mon-grndco2----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-GRNDCO2
```

```
*****
Example
*****
```

```
MON-GRNDCO2
  <PLS > Value at start of each month for groundwater CO2 concentration***
  # - # JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC***
  1   7 .23 .22 .22 .23 .24 .25 .24 .23 .22 .22 .22 .22
END MON-GRNDCO2
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-grndco2>	ACO2PM(12)	12F5.0	0.0	0.0	1.0	mg C/l	Both

Explanation

This table is only required if GCVFG is 1 in Table-type PWT-PARM1.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(1).7.7 Table-type PWT-TEMPS -- Initial water temperatures

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
PWT-TEMPS
<-range><-----pwt-temps----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PWT-TEMPS
```

```
*****
Example
*****
```

```
PWT-TEMPS
  <PLS >   Initial water temperatures***
  # - #     SOTMP      IOTMP      AOTMP***
  1   7      47.       47.       53.
END PWT-TEMPS
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<pwt-temps>	SOTMP	3F10.0	60.	32.	100.	deg F	Engl
			16.	0.	38.	deg C	Metric
	IOTMP		60.	32.	100.	deg F	Engl
			16.	0.	38.	deg C	Metric
	AOTMP		60.	32.	100.	deg F	Engl
			16.	0.	38.	deg C	Metric

Explanation

These are the initial values of outflow water temperatures:
 SOTMP is surface outflow temperature.
 IOTMP is interflow outflow temperature.
 AOTMP is active groundwater outflow temperature.

4.4(1).7.8 Table-type PWT-GASES -- Initial dissolved oxygen and CO2 concentrations

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

PWT-GASES

<-range><-----pwt-gases----->

.

(repeats until all operations of this type are covered)

.

END PWT-GASES

Example

PWT-GASES

<PLS >

Initial DO and CO2 concentrations***

#	-	#	SODOX	SOCO2	IODOX	IOCO2	AODOX	AOCO2***
1		7	8.9	.122	7.8	.132	3.5	.132

END PWT-GASES

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<pwt-gases>	SODOX	6F10.0	0.0	0.0	20.	mg/l	Both
	SOCO2		0.0	0.0	1.0	mg C/l	Both
	IODOX		0.0	0.0	20.	mg/l	Both
	IOCO2		0.0	0.0	1.0	mg C/l	Both
	AODOX		0.0	0.0	20.	mg/l	Both
	AOCO2		0.0	0.0	1.0	mg C/l	Both

Explanation

These are the initial concentrations of dissolved gases in outflow:

- SODOX is DO concentration in surface outflow.
- SOCO2 is CO2 concentration in surface outflow.
- IODOX is DO concentration in interflow outflow.
- IOCO2 is CO2 concentration in interflow outflow.
- AODOX is DO concentration in active groundwater outflow.
- AOCO2 is CO2 concentration in active groundwater outflow.

4.4(1).8 PERLND BLOCK -- Section PQUAL input

```
*****
      1      2      3      4      5      6      7      8
123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
[Table-type NQUALS]
[Table-type PQL-AD-FLAGS]

Table-type QUAL-PROPS      ---
[Table-type QUAL-INPUT]   |
[Table-type MON-POTFW]    |
[Table-type MON-POTFS]    |   repeat for each
[Table-type MON-ACCUM]    |   quality constituent
[Table-type MON-SQOLIM]   |
[Table-type MON-IFLW-CONC]|
[Table-type MON-GRND-CONC] ---
```

Explanation

The exact format of each of the tables mentioned above is detailed in the documentation which follows.

Tables enclosed in brackets [] are not always required; for example, because all the values can be defaulted.

4.4(1).8.1 Table-type NQUALS -- Total number of quality constituents simulated

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
NQUALS
<-range><nql>
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END NQUALS
```

Example

```
NQUALS
  <PLS >      ***
  # - #NQUAL***
  1   7   8
END NQUALS
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<nql>	NQUAL	I5	1	1	10

Explanation

The total number of quality constituents simulated in Section PQUAL is indicated in this table. The set of tables below Table-type PQL-AD-FLAGS is repeated for each quality constituent.

4.4(1).8.2 Table-type PQL-AD-FLAGS -- Atmospheric deposition flags for PQUAL

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
PQL-AD-FLAGS
<-range> <f><c> <f><c> <f><c> <f><c> <f><c> <f><c> <f><c> <f><c> <f><c> <f><c>
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PQL-AD-FLAGS
```

```
*****
Example
*****
```

```
PQL-AD-FLAGS
<PLS > Atmospheric deposition flags ***
*** QUAL1 QUAL2 QUAL3 QUAL4 QUAL5 QUAL6 QUAL7 QUAL8 QUAL9 QAL10
#*** # <F><C> <F><C> <F><C> <F><C> <F><C> <F><C> <F><C> <F><C> <F><C> <F><C>
1 7 -1 10 -1 -1 11 12 13 -1 0 0 0 11 0 -1 0 0 -1 0
END PQL-AD-FLAGS
```

```
*****
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<f><c>	PQADFG(*)	(1X,2I3)	0	-1	none

Explanation

PQADFG is an array of flags indicating the source of atmospheric deposition data. The QUAL ID number is determined by the order in which the QUALS are input in the tables below. Each QUAL has two flags. The first is for dry or total deposition flux, and the second is for wet deposition concentration. The flag values indicate:

- 0 No deposition of this type is simulated
- 1 Deposition of this type is input as time series PQADFX or PQADCN
- >0 Deposition of this type is input in the MONTH-DATA table with the corresponding table ID number. refer to the MONTH-DATA Block (Section 4.11)

It is an error to specify a non-zero flag value for a non-QUALOF.

4.4(1).8.3 Table-type QUAL-PROPS -- Identifiers and flags for a quality constituent

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
QUAL-PROPS
<-range><-qualid--->    <qt><-----flags----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END QUAL-PROPS
```

Example

```
QUAL-PROPS
<PLS > Identifiers and Flags***
# - #*** qualid      QTID  QSD  VPFW  VPFS  QSO  VQO  QIFW  VIQC  QAGW  VAQC
1  7      BOD        kg    0    0    0    1    1    1    0    1    1
END QUAL-PROPS
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<qualid>	QUALID	3A4	none	none	none
<qt>	QTYID	A4	none	none	none
<flags>	QSDFG	9I5	0	0	1
	VPFWFG		0	0	2
	VPFSFG		0	0	1
	QSOFG		0	0	1
	VQOFG		0	0	1
	QIFWFG		0	0	1
	VIQCFG		0	0	4
	QAGWFG		0	0	1
	VAQCFG		0	0	4

Explanation

QUALID is a string of up to 10 characters which identifies the quality constituent.

QTYID is a string of up to 4 characters which identifies the units associated with this constituent (e.g., kg, or lb). These are the units referred to as "qty" in subsequent tables (e.g., Table-type QUAL-INPUT).

If QSDFG is 1 then:

1. This constituent is a QUALSD; it is assumed to be sediment-associated.
2. If VPFWFG is 1 or greater, the washoff potency factor may vary throughout the year. Table-type MON-POTFW is expected. If VPFWFG is 2, the daily factors are not computed by interpolation between the monthly values.
3. If VPFSFG is 1, the scour potency factor may vary throughout the year. Table-type MON-POTFS is expected.

If QSOFG is 1 then:

1. This constituent is a QUALOF; it is assumed to be directly associated with overland flow.
2. If VQOFG is 1 then the rate of accumulation and the limiting storage of the QUALOF may vary throughout the year. Table-types MON-ACCUM and MON-SQOLIM are expected for this QUAL.

If QIFWFG is 1 then:

1. This constituent is a QUALIF; it is assumed to be associated with interflow.
2. If VIQCFG 1 or greater, the concentration of this constituent in interflow outflow may vary throughout the year. Table-type MON-IFLW-CONC is expected. If VIQCFG is 2 or 4, the daily values are obtained directly from the monthly values; no interpolation between monthly values is performed. If VIQCFG is 3 or 4, the units of the input concentrations are mg/l; note: this option requires that the "qty" units be pounds (English system) or kilograms (Metric system).

If QAGWFG is 1 then:

1. This constituent is a QUALGW (groundwater associated).
2. If VAQCFG is 1 or greater, the concentration of this constituent in groundwater outflow may vary throughout the year. Table-type MON-GRND-CONC is expected. If VAQCFG is 2 or 4, the daily values are obtained directly from the monthly values; no interpolation between monthly values is performed. If VAQCFG is 3 or 4, the units of the input concentrations are mg/l; note: this option requires that the "qty" units be pounds (English system) or kilograms (Metric system).

4.4(1).8.4 Table-type QUAL-INPUT -- Nonseasonal PQUAL parameters

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
QUAL-INPUT
<-range><-----qual-input----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END QUAL-INPUT
```

```
*****
Example
*****
```

```
QUAL-INPUT
  <PLS > Storage on surface and nonseasonal parameters***
  # - #      SQO   POTFW   POTFS   ACQOP   SQOLIM   WSQOP   IOQC   AOQC***
  1   7      1.21   17.2    1.1    0.02    2.0    1.70   15.2   17.1
END QUAL-INPUT
```

```
*****
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system	
<qual-input>	SQO	8F8.0	0.0	0.0	none	qty/ac	Engl	
			0.0	0.0	none	qty/ha	Metric	
	POTFW		0.0	0.0	none	qty/ton	Engl	
			0.0	0.0	none	qty/tonne	Metric	
	POTFS		0.0	0.0	none	qty/ton	Engl	
			0.0	0.0	none	qty/tonne	Metric	
	ACQOP		0.0	0.0	none	qty/ac/day	Engl	
			0.0	0.0	none	qty/ha/day	Metric	
	SQOLIM			.000001	.000001	none	qty/ac	Engl
				.000002	.000002	none	qty/ha	Metric
	WSQOP			1.64	0.01	none	in/hr	Engl
				41.7	0.25	none	mm/hr	Metric
	IOQC			0.0	0.0	none	qty/ft3	Engl
				0.0	0.0	none	qty/l	Metric
	AOQC			0.0	0.0	none	qty/ft3	Engl
				0.0	0.0	none	qty/l	Metric

Explanation

The following variables are applicable only if the constituent is a QUALSD:

1. POTFW is the washoff potency factor.
2. POTFS is the scour potency factor.

A potency factor is the ratio of constituent yield to sediment (washoff or scour) outflow.

The following variables are applicable only if the constituent is a QUALOF:

1. SQO is the initial storage of QUALOF on the surface of the PLS.
2. ACQOP is the rate of accumulation of QUALOF.
3. SQOLIM is the maximum storage of QUALOF.
4. WSQOP is the rate of surface runoff which will remove 90 percent of stored QUALOF per hour.

IOQC is the concentration of the constituent in interflow outflow; it is meaningful only if this QUAL is a QUALIF. AOQC is the concentration of the constituent in active groundwater outflow; it is meaningful only if this QUAL is a QUALGW.

If monthly values are being supplied for any of these quantities, the value in this table is not relevant; instead, the system expects and uses values supplied in Table-type MON-xxx.

4.4(1).8.5 Table-type MON-POTFW -- Monthly washoff potency factor

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MON-POTFW
<-range><-----mon-potfw----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-POTFW
```

```
*****
Example
*****
```

```
MON-POTFW
  <PLS > Value at start of each month for washoff potency factor (lb/ton)***
  # - # JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC***
  1   7 1.2 2.4 3.6 5.8 10.2 20.2 25.2 30.8 40.2 10.1 2.5 1.7
END MON-POTFW
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-potfw>	POTFWM(12)	12F5.0	0.0 0.0	0.0 0.0	none none	qty/ton qty /tonne	Engl Metric

Explanation

This table is only required if VPFWFG is greater than 0 in Table-type QUAL-PROPS.

If VPFWFG is 1 or 3, the input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values. If VPFWFG is 2 or 4, the input monthly values apply directly to all days of the month.

4.4(1).8.6 Table-type MON-POTFS -- Monthly scour potency factor

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MON-POTFS
<-range><-----mon-potfs----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-POTFS
```

```
*****
Example
*****
```

```
MON-POTFS
<PLS > Value at start of each month for scour potency factor (lb/ton)***
# - # JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC***
1 7 0.9 0.9 0.9 0.8 0.8 1.1 1.1 1.3 1.3 1.0 0.9 0.9
END MON-POTFS
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-potfs>	POTFSM(12)	12F5.0	0.0 0.0	0.0 0.0	none none	qty/ton qty /tonne	Engl Metric

Explanation

This table is only required if VPFSFG is 1 in Table-type QUAL-PROPS.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(1).8.7 Table-type MON-ACCUM -- Monthly accumulation rates of QUALOF

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MON-ACCUM
<-range><-----mon-accum----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-ACCUM
```

```
*****
Example
*****
```

```
MON-ACCUM
  <PLS > Value at start of month for accum rate of QUALOF (lb/ac.day)***
  # - # JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC***
  1   7 0.0 0.0 0.01 0.02 0.02 0.04 0.05 0.04 0.02 0.01 0.0 0.0
END MON-ACCUM
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-accum>	ACQOPM(12)	12F5.0	0.0 0.0	0.0 0.0	none none	qty/ac/day qty/ha/day	Engl Metric

Explanation

This table is only required if VQOFG is 1 in Table-type QUAL-PROPS.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(1).8.8 Table-type MON-SQOLIM -- Monthly limiting storage of QUALOF

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MON-SQOLIM
<-range><-----mon-sqolim----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-SQOLIM
```

```
*****
Example
*****
```

```
MON-SQOLIM
  <PLS > Value at start of month for limiting storage of QUALOF (lb/acre)***
  # - #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC***
  1   7  10  12  14  18  20  25  30  26  20  13  10   7
END MON-SQOLIM
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-sqolim>	SQOLIM(12)	12F5.0	1.E-6	1.E-6	none	qty/ac	Engl
			2.E-6	2.E-6	none	qty/ha	Metric

Explanation

This table is only required if VQOFG is 1 in Table-type QUAL-PROPS.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(1).8.9 Table-type MON-IFLW-CONC -- Monthly concentration of QUAL in interflow

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
MON-IFLW-CONC
<-range><-----mon-iflw-conc----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-IFLW-CONC
```

Example

```
MON-IFLW-CONC
<PLS > Conc of QUAL in interflow outflow for each month (lb/ft3)***
# - # JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC***
1   7.0012.0010.0005 0.0 0.0.0002 .005 .002 .001.0016.0014.0012
END MON-IFLW-CONC
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-iflw-conc>	IOQCM(12)	12F5.0	0.0	0.0	none	qty/ft3	Engl
			0.0	0.0	none	qty/l	Metric
If VIQCFG = 3 or 4 in Table-type QUAL-PROPS:			0.0	0.0	none	mg/l	Both

Explanation

This table is only required if VIQCFG is greater than 0 in Table-type QUAL-PROPS.

If VIQCFG is 1 or 3, the input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values. If VIQCFG is 2 or 4, the input monthly values apply directly to all days of the month.

4.4(1).8.10 Table-type MON-GRND-CONC -- Monthly concentration of QUAL in active groundwater

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
MON-GRND-CONC
<-range><-----mon-grnd-conc----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-GRND-CONC
```

Example

```
MON-GRND-CONC
  <PLS > Value at start of month for conc of QUAL in groundwater (lb/ft3)**
  # - # JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC***
  1   7.0013.0014.0012.0012.0012.001 .001 .001 .0011.0012.0012.0013
END MON-GRND-CONC
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-grnd-conc>	AOQCM(12)	12F5.0	0.0	0.0	none	qty/ft3	Engl
			0.0	0.0	none	qty/l	Metric
If VAQCFG = 3 or 4 in Table-type QUAL-PROPS:			0.0	0.0	none	mg/l	Both

Explanation

This table is only required if VAQCFG is greater than 0 in Table-type QUAL-PROPS.

If VAQCFG is 1 or 3, the input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values. If VAQCFG is 2 or 4, the input monthly values apply directly to all days of the month.

4.4(1).9 PERLND BLOCK -- Section MSTLAY input

```
*****
      1      2      3      4      5      6      7      8
123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```

Table-type VUZFG          | only if Section
Table-type UZSN-LZSN     | PWATER is
Table-type MON-UZSN if VUZFG= 1 | inactive

```

Table-type MST-PARM

Table-type MST-TOPSTOR

Table-type MST-TOPFLX

Table-type MST-SUBSTOR

Table-type MST-SUBFLX

Explanation

The exact format of each of the tables mentioned above, except MON-UZSN, is detailed in the documentation which follows. MON-UZSN is documented under the input for Section PWATER (4.4(1).4).

Note that if all the fields in a table have default values, the table can be omitted from the User's Control Input. Then, the defaults will be used.

Table-types MST-TOPSTOR through MST-SUBFLX should usually not be supplied. See the documentation of those tables for further details.

4.4(1).9.1 Table-type VUZFG -- Variable upper zone flag

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
VUZFG
<-range><vuz>
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END VUZFG
```

Example

```
VUZFG
  <PLS >VUZFG***
  # - #      ***
  1   7   1
END VUZFG
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<vuz>	VUZFG	I5	0	0	1

Explanation

VUZFG is a flag which indicates whether or not the upper zone nominal storage varies throughout the year or not. A value of zero means it does not vary, a value of 1 means it does. If it does vary, the system will expect a table of type MON-UZSN in the User's Control Input.

Note that Table VUZFG is only required if Section PWATER is inactive. If that section is active VUZFG would have already been provided in the input for PWATER (Table-type PWAT-PARM1).

4.4(1).9.2 Table-type UZSN-LZSN -- Values of UZSN, LZSN and initial surface storage

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
UZSN-LZSN
<-range><-uzsn-><-lzsn-><-surs->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END UZSN-LZSN
```

Example

```
UZSN-LZSN
  <PLS >   UZSN   LZSN   SURS   ***
  # - #     in    in    in     ***
  1   7     1.0   6.0   .02
END UZSN-LZSN
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<uzsn>	UZSN	F8.0	none	0.01	10.0	in	Engl
			none	0.25	250.	mm	Metric
<lzsn>	LZSN	F8.0	none	0.01	100.	in	Engl
			none	0.25	2500.	mm	Metric
<surs>	SURS	F8.0	.001	.001	100.	in	Engl
			.025	.025	2500.	mm	Metric

Explanation

This table is only required if Section PWATER is inactive; otherwise, the data would have already been supplied in the input for Section PWATER.

UZSN is the nominal upper zone storage. The value supplied here is irrelevant if VUZFG has been set to 1; in that case monthly values for UZSN are supplied in Table-type MON-UZSN.

LZSN is the nominal lower zone storage.

SURS is the initial surface detention storage.

4.4(1).9.3 Table-type MST-PARM -- Factors used to adjust solute leaching rates

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MST-PARM
<-range><-----leach-parms----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MST-PARM
```

```
*****
Example
*****
```

```
MST-PARM
  <PLS >      SLMPF      ULPF      LLPF***
  # - #                ***
  1   7          0.5      2.0      2.0
END MST-PARM
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<leach-parms>	SLMPF	3F10.0	1.0	.001	1.0	none	Both
	ULPF		1.0	1.0	10.0	none	Both
	LLPF		1.0	1.0	10.0	none	Both

Explanation

These are the factors that are used to adjust solute percolation rates. SLMPF affects percolation from the surface layer storage to the upper layer principal storage. ULPF affects percolation from the upper layer principal storage to the lower layer storage. LLPF affects percolation from the lower layer storage to the active and inactive groundwater.

4.4(1).9.4 Table-type MST-TOPSTOR -- Initial moisture storage in each topsoil layer

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
MST-TOPSTOR
<-range><-----topstor----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MST-TOPSTOR
```

Example

```
MST-TOPSTOR
  <PLS >      Topsoil storages (lb/ac)***
  # - #      SMSTM      UMSTM      IMSTM***
  1   7      100000    400000    300000
END MST-TOPSTOR
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<topstor>	SMSTM	3F10.0	0.0	0.0	none	lb/ac	Engl
			0.0	0.0	none	kg/ha	Metric
	UMSTM		0.0	0.0	none	lb/ac	Engl
			0.0	0.0	none	kg/ha	Metric
	IMSTM		0.0	0.0	none	lb/ac	Engl
			0.0	0.0	none	kg/ha	Metric

Explanation

This table is used to specify the initial moisture content in the surface, upper principal and upper transitory (interflow) storages, respectively.

Note that the values given in this table only affect the water storages for the start of the first interval in the run; there is no carry-over of the values beyond the starting instant. Therefore, in most runs, this table need not be supplied; the default zero values will not cause any problems.

4.4(1).9.5 Table-type MST-TOPFLX -- Initial fractional fluxes in topsoil layers

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MST-TOPFLX
<-range><-----top-flux----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MST-TOPFLX
```

```
*****
Example
*****
```

```
MST-TOPFLX
  <PLS > Fractional fluxes in topsoil layers (/ivl)      ***
  # - #      FSO      FSP      FII      FUP      FIO***
  1   7      .07     .03
END MST-TOPFLX
```

```
*****
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<top-flux>	FSO,FSP,FII, FUP,FIO	5F10.0	0.0	0.0	1.0	/ivl	Both

Explanation

These are the initial values of the fractional fluxes of soluble chemicals through the topsoil layers of a PLS.

Note that the values supplied in this table apply at the instant that the run starts. The program computes new values each time step and there is no carry-over of values from one time step to the next. Therefore, in most runs, you can omit this table; the default zero values will not cause any problems.

4.4(1).9.6 Table-type MST-SUBSTOR -- Initial moisture storage in subsurface layers

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
MST-SUBSTOR
<-range><-----substor----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MST-SUBSTOR
```

Example

```
MST-SUBSTOR
<PLS >Subsoil moisture (kg/ha)***
# - #      LMSTM      AMSTM      ***
1   7      800000    1000000
END MST-SUBSTOR
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<substor>	LMSTM,AMSTM	2F10.0	0.0	0.0	none	lb/ac	Engl
			0.0	0.0	none	kg/ha	Metric

Explanation

These are the initial moisture storages in the lower layer and active groundwater layers, respectively.

Usually, this table should be omitted and the default values used. The comments made on this subject in the explanation for Table-type MST-TOPSTOR are also applicable here.

4.4(1).9.7 Table-type MST-SUBFLX -- Initial fractional fluxes in subsurface layers

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
MST-SUBFLX
<-range><-----subflux----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MST-SUBFLX
```

Example

```
MST-SUBFLX
  <PLS >Subsurface fractional fluxes (/ivl) ***
  # - #      FLP      FLDP      FAO      ***
  1   7      0.1     0.05
END MST-SUBFLX
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<subflux>	FLP,FLDP,FAO	3F10.0	0.0	0.0	1.0	/ivl	Both

Explanation

These are the initial fractional fluxes of soluble chemicals through the subsoil layers.

Usually, this table should be omitted and the default values taken. The comments on this subject in the explanation for Table-type MST-TOPFLX are applicable here.

4.4(1).10 PERLND BLOCK -- Section PEST input

```
*****
      1      2      3      4      5      6      7      8
123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

[Table-type PEST-FLAGS]
[Table-type PEST-AD-FLAGS]
Table-type SOIL-DATA

Table-type PEST-ID

```
Table-type PEST-THETA
Table-type PEST-FIRSTPM   for surface layer   |   if
Table-type PEST-FIRSTPM   for upper layer     |   ADOPFG
Table-type PEST-FIRSTPM   for lower layer     |   =1
Table-type PEST-FIRSTPM   for groundwater layer |
```

```
Table-type PEST-CMAX
Table-type PEST-SVALPM     for surface layer   |   if
Table-type PEST-SVALPM     for upper layer     |   ADOPFG
Table-type PEST-SVALPM     for lower layer     |   =2
Table-type PEST-SVALPM     for groundwater layer |
```

```
Table-type PEST-CMAX
Table-type PEST-NONSVPM    for surface layer   |   if
Table-type PEST-NONSVPM    for upper layer     |   ADOPFG
Table-type PEST-NONSVPM    for lower layer     |   =3
Table-type PEST NONSVPM    for groundwater layer |
```

Table-type PEST-DEGRAD

```
Table-type PEST-STOR1 for surface layer storage
Table-type PEST-STOR1 for upper layer principal storage
Table-type PEST-STOR2 for upper layer transitory storage
```

```
Table-type PEST-STOR1 for lower layer storage
Table-type PEST-STOR1 for groundwater layer storage
```

repeat for
each
pesticide

```
*****
```

Explanation

The exact format of each of the tables mentioned above is detailed in the documentation which follows.

The comments given alongside the table names above indicate under what circumstances a table is expected.

Note that if all the fields in a table have default values, the table can be omitted from the User's Control Input. Then, the defaults will be adopted. However, any tables that are repeated for multiple soil layers should generally not be omitted because the "nth" occurrence of one of these tables refers to the corresponding "nth" layer. If a table for layer i is omitted, the next occurrence of the table (intended for layer i+1) will be applied to layer i, and unintended results may occur.

ADOPFG is the adsorption/desorption option flag. It is described in the documentation for Table-type PEST-FLAGS (Sect. 4.4(1).10.1) below.

4.4(1).10.1 Table-type PEST-FLAGS -- Flags for pesticide simulation

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
PEST-FLAGS
<-range><nps><----itmax----><----adopt---->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PEST-FLAGS
```

Example

```
PEST-FLAGS
<PLS > NPST|Max iterations|Adsorp option ***
# - #      |Pst1 Pst2 Pst3|Pst1 Pst2 Pst3***
1   7   2   20   20         1   3
END PEST-FLAGS
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<nps>	NPST	I5	1	1	3
<itmax>	ITMXPS(*)	3I5	30	1	100
<adopt>	ADOPFG(*)	3I5	2	1	3

Explanation

NPST is the number of pesticides being simulated in the PERLND. NPST is limited to 3.

ITMXPS is the maximum number of iterations that will be made in trying to solve for adsorbed and dissolved equilibrium using the Freundlich isotherm. A separate value may be supplied for each pesticide being simulated. If the Freundlich method is not being used, these values have no effect.

ADOPFG(*) are flags which indicate which method will be used to simulate adsorption/desorption for each pesticide:

- 1 - first-order kinetics
- 2 - single-value Freundlich method
- 3 - non-single value Freundlich method

4.4(1).10.2 Table-type PEST-AD-FLAGS -- Atmospheric deposition flags for pesticides

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

PEST-AD-FLAGS

<-range> <f><c> <f><c> <f><c> <f><c> <f><c> <f><c> <f><c> <f><c> <f><c>

.

(repeats until all operations of this type are covered)

.

END PEST-AD-FLAGS

Example

PEST-AD-FLAGS

<PLS >

Atmospheric deposition flags ***

```
***          PESTICIDE #1          PESTICIDE #2          PESTICIDE #3
***    CRYC  ADSB  SOLN    CRYC  ADSB  SOLN    CRYC  ADSB  SOLN
#*** # <F><C> <F><C> <F><C> <F><C> <F><C> <F><C> <F><C> <F><C> <F><C>
1    7  -1 10  -1 -1  11 12   13 -1  10  0    11    -1  0  0  -1  0
```

END PEST-AD-FLAGS

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<f><c>	PEADFG(*)	(1X,2I3)	0	-1	none

Explanation

PEADFG is an array of flags indicating the source of pesticide atmospheric deposition data. Each pesticide has three forms: crystalline, adsorbed, and solution. Each form has two flags. The first is for dry or total deposition flux (<f>), and the second is for wet deposition concentration (<c>). The flag values indicate:

- 0 No deposition of this type is simulated
- 1 Deposition of this type is input as time series PEADFX or PEADCN
- >0 Deposition of this type is input in the MONTH-DATA table with the corresponding table ID number. (Refer to Section 4.11 for details)

4.4(1).10.3 Table-type SOIL-DATA -- Soil layer depths and bulk densities

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
SOIL-DATA
<-range><-----depths-----><-----bulkdens----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END SOIL-DATA
```

```
*****
Example
*****
```

```
SOIL-DATA
<PLS >|
# - #|Surface  Upper  Lower Groundw|Surface  Upper  Lower Groundw|***
1   7   .12   6.0   40.0   80.   80.   120.
END SOIL-DATA
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<depths>	none	4F8.0	none	.001	1000	in	Engl
			none	.0025	2500	cm	Metric
<bulkdens>	none	4F8.0	103	50	150	lb/ft3	Engl
			1.65	0.80	2.40	g/cm3	Metric

Explanation

The first four values are the depths (thicknesses) of the surface, upper, lower and groundwater layers, respectively; the second group of four values are the corresponding bulk densities of the soil in those layers.

The depth and bulk density are multiplied together by the program to obtain the mass of soil in each layer. This is used to compute the concentrations of adsorbed chemicals.

4.4(1).10.4 Table-type PEST-ID -- Name of pesticide

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
PEST-ID
<-range><-----pestid----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PEST-ID
```

```
*****
Example
*****
```

```
PEST-ID
  <PLS >          Pesticide***
  # - #           ***
  1   7           Atrazine
END PEST-ID
```

```
*****
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<pestid>	PESTID(*)	5A4	none	none	none

Explanation

This table specifies the name of the pesticide to which the data in the following tables apply.

4.4(1).10.5 Table-type PEST-THETA -- Pesticide first-order reaction temperature correction parameters

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
PEST-THETA
<-range><-----theta----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PEST-THETA
```

Example

```
PEST-THETA
  <PLS >  Temperature parms ***
  # - #    THDSPS    THADPS ***
  1   7                1.07
END PEST-THETA
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<theta>	THDSPS,THADPS	2F10.0	1.05	1.00	2.00	none	Both

Explanation

These parameters are used to adjust the desorption and adsorption rate parameters (respectively), using a modified Arrhenius equation:

$$\text{Rate at } T = (\text{Rate at } 35 \text{ deg C}) * (\text{theta})^{(T-35)}$$

This table is only required if first-order kinetics are used to simulate adsorption/desorption (ADOPFG=1 in Table-type PEST-FLAGS).

4.4(1).10.6 Table-type PEST-FIRSTPM -- Pesticide first-order parameters

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
PEST-FIRSTPM
<-range><----firstparm----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PEST-FIRSTPM
```

```
*****
Example
*****
```

```
PEST-FIRSTPM
<PLS >First-order parms (/day)***
# - #      KDSPS      KADPS      ***
1   7       .07       .04
END PEST-FIRSTPM
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<firstparm>	KDSPS,KADPS	2F10.0	0.0	0.0	none	/day	Both

Explanation

KDSPS and KADPS are the desorption and adsorption rates at 35 deg C.

This table is only required if ADOPFG=1 (first-order kinetics) for this pesticide.

4.4(1).10.7 Table-type PEST-CMAX -- Maximum solubility of pesticide

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
PEST-CMAX
<-range><--cmax-->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PEST-CMAX
```

```
*****
Example
*****
```

```
PEST-CMAX
  <PLS >      CMAX***
  # - #       (ppm)***
  1   7       25.0
END PEST-CMAX
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<cmax>	CMAX	F10.0	0.0	0.0	none	ppm	Both

Explanation

CMAX is the maximum solubility of the pesticide in water.

This table is only required if ADOPFG= 2 or 3 for this pesticide (Freundlich method of simulating adsorption/desorption).

4.4(1).10.8 Table-type PEST-SVALPM -- Pesticide parameters for single-value Freundlich method

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
PEST-SVALPM
<-range><-----svalpm----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PEST-SVALPM
```

Example

```
PEST-SVALPM
  <PLS >      XFIX      K1      N1***
  # - #      (ppm)      ***
  1   7      20.      4.0      1.5
END PEST-SVALPM
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<svalpm>	XFIX	3F10.0	0.0	0.0	none	ppm	Both
	K1		0.0	0.0	none	l/kg	Both
	N1		none	1.0	none	none	Both

Explanation

XFIX is the maximum concentration (on the soil) of pesticide which is permanently fixed to the soil. K1 and N1 are the coefficient and exponent parameters for the Freundlich adsorption/desorption equation:

$$X = K1 * C^{(1/N1)} + XFIX$$

This table is only used if ADOFG= 2 for this pesticide (single-value Freundlich method). Then, the system expects it to appear four times for this pesticide; first, for the surface layer, second for the upper layer, third for the lower layer, and fourth for the active groundwater layer.

4.4(1).10.9 Table-type PEST-NONSVPM -- Pesticide parameters for non-single value Freundlich method

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
PEST-NONSVPM
<-range><-----nonsvpm----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PEST-NONSVPM
```

Example

```
PEST-NONSVPM
  <PLS >      XFIX          K1          N1          N2***
  # - #      (ppm)
  1   7      15.          5.0          1.5          1.7
END PEST-NONSVPM
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<nonsvpm>	XFIX	4F10.0	0.0	0.0	none	ppm	Both
	K1		0.0	0.0	none	l/kg	Both
	N1		none	1.0	none	none	Both
	N2		none	1.0	none	none	Both

Explanation

XFIX is the maximum concentration (on the soil) of pesticide which is permanently fixed in the soil. K1 and N1 are the coefficient and exponent parameters for the Freundlich curve used for adsorption. N2 is the exponent parameter for the auxiliary ("desorption") curve.

This table is only used if ADOPFG= 3 for this pesticide (non-single value Freundlich method).

4.4(1).10.10 Table-type PEST-DEGRAD -- Pesticide degradation rates

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
PEST-DEGRAD
<-range><-----degrad----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PEST-DEGRAD
```

```
*****
Example
*****
```

```
PEST-DEGRAD
  <PLS >   Pesticide degradation rates (/day)   ***
  # - #   Surface   Upper   Lower   Groundw***
  1   7     .05     .02     .01
END PEST-DEGRAD
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<degrad>	SDGCON,UDGCON, LDGCON,ADGCON	4F10.0	0.0	0.0	1.0	/day	Both

Explanation

These are the degradation rates of the pesticide in the surface, upper, lower and groundwater layers, respectively. These rates are not adjusted for temperature.

4.4(1).10.11 Table-type PEST-STOR1 -- Initial pesticide storage in surface, upper, lower or groundwater layer

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
PEST-STOR1
<-range><-cryst--><---ads--><--soln-->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PEST-STOR1
```

Example

```
PEST-STOR1
<PLS >Initial pesticide in surface layer (lb/ac)***
# - #      Cryst      Ads      Soln      ***
1   7      10.0      25.0      50.0
END PEST-STOR1
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<cryst>, <ads>	PSCY, PSAD,	3F10.0	0.0	0.0	none	lb/ac	Engl
<soln>	PSSU		0.0	0.0	none	kg/ha	Metric

Explanation

PSCY is the pesticide in crystalline form, PSAD is the pesticide in adsorbed form and PSSU is the pesticide in solution.

The values given in this table apply to one of the following four soil storages: surface, upper principal, lower or groundwater. The table should appear four times, once for each layer.

4.4(1).10.12 Table-type PEST-STOR2 -- Initial pesticide stored in upper layer transitory (interflow) storage

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
PEST-STOR2
<-range><--ips--->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PEST-STOR2
```

Example

```
PEST-STOR2
  <PLS > Interflow      ***
  # - #   storage(kg/ha)***
  1   7     20.0
END PEST-STOR2
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<ips>	IPS	F10.0	0.0	0.0	none	lb/ac	Engl
			0.0	0.0	none	kg/ha	Metric

Explanation

IPS is the initial storage of pesticide in the upper layer transitory (interflow) storage. Since only dissolved pesticide is modeled in that storage, only one value is needed (no crystalline or adsorbed material).

4.4(1).11 PERLND BLOCK -- Section NITR input

```
*****
      1      2      3      4      5      6      7      8
123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
Table-type SOIL-DATA  if section PEST is inactive
Table-type NIT-FLAGS
Table-type NIT-AD-FLAGS
Table-type NIT-FSTGEN
Table-type NIT-FSTPM  for surface layer
Table-type NIT-FSTPM  for upper layer
Table-type NIT-FSTPM  for lower layer
Table-type NIT-FSTPM  for groundwater layer
Table-type NIT-ORGPM  for surface layer
Table-type NIT-ORGPM  for upper layer
Table-type NIT-ORGPM  for lower layer
Table-type NIT-ORGPM  for groundwater layer
Table-type NIT-AMVOLAT  ---- if AMVOFG= 1

Table-type NIT-CMAX
Table-type NIT-SVALPM  for surface layer
Table-type NIT-SVALPM  for upper layer
Table-type NIT-SVALPM  for lower layer
Table-type NIT-SVALPM  for groundwater layer
----- if FORAFG= 1

Table-type NIT-UPTAKE  ----- if VNUTFG= 0
Table-type MON-NITUPT  for surface layer
Table-type MON-NITUPT  for upper layer
Table-type MON-NITUPT  for lower layer
Table-type MON-NITUPT  for groundwater layer
----- if VNUTFG= 1
----- if NUPTFG=0

Table-type SOIL-DATA2
Table-type CROP-DATES

Table-type NIT-YIELD
Table-type MON-NUPT-FR1
Table-type MON-NUPT-FR2  for surface layer
Table-type MON-NUPT-FR2  for upper layer
Table-type MON-NUPT-FR2  for lower layer
Table-type MON-NUPT-FR2  for groundwater layer
----- if NUPTFG= 1
```

```

Table-type NIT-UPIMCSAT
Table-type NIT-UPIMKMAX ---- if VNUTFG= 0
Table-type MON-NITUPNI
Table-type MON-NITUPAM | if VNUTFG= 1 | if NUPTFG= 2 or -2
Table-type MON-NITIMNI
Table-type MON-NITIMAM

```

Note: The preceding group of tables each repeat four times, once for each soil layer, if NUPTFG= 2, but appear only once for all soil layers if NUPTFG= -2

```

Table-type NIT-BGPLRET | if VPRNFG= 0
Table-type MON-NPRETBG for surface layer
Table-type MON-NPRETBG for upper layer
Table-type MON-NPRETBG for lower layer | if VPRNFG=1
Table-type MON-NPRETBG for groundwater layer
Table-type MON-NPRETFBG

```

```

Table-type NIT-AGUTF ----- if VNUTFG= 0
Table-type MON-NITAGUTF for surface layer
Table-type MON-NITAGUTF for upper layer
Table-type MON-NITAGUTF for lower layer | if VNUTFG= 1
Table-type MON-NITAGUTF for groundwater layer | if ALPNFG=1

```

```

Table-type NIT-AGPLRET ----- if VPRNFG= 0
Table-type MON-NPRETAG
Table-type MON-NPRETLI for surface layer
Table-type MON-NPRETLI for upper layer | if VPRNFG= 1
Table-type MON-NPRETFLI

```

```

Table-type NIT-STOR1 for surface layer storage
Table-type NIT-STOR1 for upper layer principal storage
Table-type NIT-STOR2 for upper layer transitory storage, above ground plant
and litter storage
Table-type NIT-STOR1 for lower layer storage
Table-type NIT-STOR1 for groundwater layer storage

```

Explanation

The exact format of each of the tables mentioned above, except SOIL-DATA, is detailed in the documentation which follows. SOIL-DATA is documented under the input for Section PEST (4.4(1).10).

This section is complex, and has many possible tables. Users are cautioned to carefully observe the options selected and the tables that are required. The comments given alongside the table names in the above list indicate under what circumstances a table is expected. The flags that determine the expected/required tables are described below as well as under the table where they are input (Table-type NIT-FLAGS in Sect. 4.4(1).11.1, below).

AMVOFG is the ammonia volatilization flag.

FORAFG is the ammonium adsorption/desorption method flag.

VNUTFG is the variable nitrogen plant uptake flag.

NUPTFG is the plant uptake method flag.

ALPNFG is the "above-ground plant N and litter compartment" flag.

VPRNFG is the variable plant return flag.

Note that if all the fields in a table have default values, the table can be omitted from the User's Control Input. Then, the defaults will be adopted. However, any tables that are repeated for multiple soil layers should generally not be omitted because the "nth" occurrence of one of these tables refers to the corresponding "nth" layer. If a table for layer *i* is omitted, the next occurrence of the table (intended for layer *i*+1) will be applied to layer *i*, and unintended results may occur.

4.4(1).11.1 Table-type NIT-FLAGS -- Flags for nitrogen simulation

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
NIT-FLAGS
<-range><-----nitflags----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END NIT-FLAGS
```

```
*****
Example
*****
```

```
NIT-FLAGS
  <PLS > Nitrogen flags                               ***
  x - x VNUT FORA ITMX BNUM CNUM NUPT FIXN AMVO ALPN VNPR ***
  1   7   1           3   1   2           1   1
END NIT-FLAGS
```

```
*****
Details
```

Symbol	Fortran name(s)	Format	Def	Min	Max
<nitflags>	VNUTFG	10I5	0	0	1
	FORAFG		0	0	1
	ITMAXA		30	1	100
	BNUMN		none	1	1000
	CNUMN		none	1	1000
	NUPTFG		0	-2	2
	FIXNFG		0	0	1
	AMVOFG		0	0	1
	ALPNFG		0	0	1
	VNPRFG		0	0	1

Explanation

If VNUTFG = 1, the first-order plant uptake parameters for nitrogen are allowed to vary throughout the year and four tables of type MON-NITUPT (or MON-NITUPNI and MON-NITUPAM if saturation kinetics are being simulated) are expected in the User's Control Input. The first appearance is for the surface layer, 2nd for upper layer, 3rd for the lower layer, and 4th for the groundwater layer. If VNUTFG = 0, the uptake rates do not vary through the year and a value for each layer is specified in a single table (Table-type NIT-UPTAKE if first-order kinetics are being simulated or NIT-UPIMKMAX if saturation kinetics are being simulated).

FORAFG indicates which method is to be used to simulate adsorption and desorption of ammonium:

- 0 first-order kinetics
- 1 single-value Freundlich method

ITMAXA is the maximum number of iterations that will be attempted in solving the Freundlich equation; applicable only if FORAFG= 1.

BNUMN is the number of time steps that will elapse between recalculation of biochemical reaction fluxes. For example, if BNUMN = 10 and the simulation time step is 5 minutes, then these fluxes will be recalculated every 50 minutes. All reactions except adsorption/desorption fall into this category. CNUMN is the corresponding number for the chemical (adsorption/desorption) reactions.

NUPTFG indicated which method is to be used to simulate plant uptake of nitrogen:

- 0 first-order kinetics
- 1 yield-based algorithm
- 2 saturation (Michaelis-Menton) kinetics
- 2 same as for 2, but with parameters constant over all soil layers

If FIXNFG is 1, nitrogen fixation is simulated. For this option, NUPTFG must also be 1. If FIXNFG is zero, or if NUPTFG is not 1, then N fixation is turned off.

If AMVOFG is 1, ammonia volatilization is simulated.

If ALPNFG is 1, above-ground and litter compartments for plant nitrogen are simulated.

If VNPRFG is 1, then the parameters for describing the return of plant nitrogen to the soil are allowed to vary monthly.

4.4(1).11.2 Table-type NIT-AD-FLAGS -- Atmospheric Deposition Flags for Nitrogen Species

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

NIT-AD-FLAGS

<-range> <f><c> <f><c> <f><c> <f><c> <f><c> <f><c> <f><c>

.

(repeats until all operations of this type are covered)

.

END NIT-AD-FLAGS

Example

NIT-AD-FLAGS

```
<PLS >      Atmospheric deposition flags ***
***          NITRATE          AMMONIA          ORGANIC N
***          SURF  UPPR      SURF  UPPR      SURF  UPPR
#*** # <F><C> <F><C> <F><C> <F><C> <F><C> <F><C>
1      7  -1 10  -1 -1   11 12  13 -1   10  0    11
```

END NIT-AD-FLAGS

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<f><c>	NIADFG(*)	(1X,2I3)	0	-1	none

Explanation

NIADFG is an array of flags indicating the source of atmospheric deposition data. Each species can be deposited into either the surface or upper soil layers. Each species/layer combination has two flags. The first is for dry or total deposition flux, and the second is for wet deposition concentration. The flag values indicate:

- 0 No deposition of this type is simulated
- 1 Deposition of this type is input as time series NIADFX or NIADCN
- >0 Deposition of this type is input in the MONTH-DATA table with the corresponding table ID number. (Refer to Section 4.11 for details)

4.4(1).11.3 Table-type NIT-FSTGEN -- Nitrogen first-order general parameters

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
NIT-FSTGEN
<-range><upt-fact><-----temp-parms----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END NIT-FSTGEN
```

```
*****
Example
*****
```

```
NIT-FSTGEN
  <PLS > Upt-facts<----- Temp-parms (theta) -----> ***
  # - #  NO3  NH4  PLN KDSA  KADA  KIMN  KAM  KDNI  KNI  KIMA  ***
  1   7   .5   .5 1.07 1.08
END NIT-FSTGEN
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<upt-fact>	NO3UTF	2F5.0	1.0	0.001	1.0	none	Both
	NH4UTF		0.0	0.0	1.0	none	Both
<temp-parms>	THPLN	8F5.0	1.07	1.0	2.0	none	Both
	THKDSA		1.05	1.0	2.0	none	Both
	THKADA		1.05	1.0	2.0	none	Both
	THKIMN		1.07	1.0	2.0	none	Both
	THKAM		1.07	1.0	2.0	none	Both
	THKDNI		1.07	1.0	2.0	none	Both
	THKNI		1.05	1.0	2.0	none	Both
	THKIMA		1.07	1.0	2.0	none	Both

Explanation

These general parameters apply to nitrogen reactions in all the layers; thus, this table only appears once (or not at all, if defaults are used).

NO3UTF and NH4UTF designate which fraction of nitrogen uptake comes from nitrate and ammonium, respectively. Their sum must be unity; otherwise an error message is generated. They are used only if first-order or yield-based plant uptake is being used (NUPTFG = 0 or 1 in Table-type NIT-FLAGS).

The remaining fields specify the temperature coefficients (theta) for the various reactions:

- THPLN Plant uptake (not relevant if NUPTFG = 1)
- THKDSA Ammonium desorption (only relevant if FORAFG = 0)
- THKADA Ammonium adsorption (only relevant if FORAFG = 0)
- THKIMN Nitrate immobilization
- THKAM Organic N ammonification
- THKDNI NO3 denitrification
- THKNI Nitrification
- THKIMA Ammonium immobilization

4.4(1).11.4 Table-type NIT-FSTPM -- Nitrogen first-order reaction parameters for the surface, upper, lower or active groundwater layer

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789 0123456789012345678901234567890
*****
```

Layout

NIT-FSTPM

<-range><-----fstparms----->

.

(repeats until all operations of this type are covered)

.

END NIT-FSTPM

Example

NIT-FSTPM

<PLS >*** Nitrogen first-order parameters for lower layer (/day)

#	-	***	KDSAM	KADAM	KIMNI	KAM	KDNI	KNI	KIMAM
1	7		.05	.03		.02		.05	

END NIT-FSTPM

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<fstparms>	KDSAM,KADAM, KIMNI,KAM,KDNI, KNI,KIMAM	7F10.0	0.0	0.0	none	/day	Both

Explanation

These are the first-order reaction rate parameters for a layer of soil:

- KDSAM Ammonium desorption (only relevant if FORAFG = 0)
- KADAM Ammonium adsorption (only relevant if FORAFG = 0)
- KIMNI Nitrate immobilization (only relevant if NUPTFG = 0 or 1)
- KAM Organic N ammonification
- KDNI Denitrification of NO₃
- KNI Nitrification
- KIMAM Ammonium immobilization (only relevant if NUPTFG = 0 or 1)

HSPF expects this table to appear four times in the User's Control Input; first for the surface layer, second for the upper layer, third for the lower layer, and fourth for the active groundwater layer. If one or more occurrences of the table are missing, all reaction parameters for the affected layer(s) will be defaulted to zero.

4.4(1).11.5 Table-type NIT-ORGPM -- Organic nitrogen transformation parameters for the surface, upper, lower, or groundwater layer

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
NIT-ORGPM
<-range><-----orgpm----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END NIT-ORGPM
```

```
*****
Example
*****
```

```
NIT-ORGPM
  <PLS >      KLON      KRON      KONLR      THNLR ***
  # - #                /day                ***
  1   3      250.      200.      .02      1.07
END NIT-ORGPM
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<orgpm>	KLON	4F10.0	1.0E20	0.0	1.0E20	none	Both
	KRON		1.0E20	0.0	1.0E20	none	Both
	KONLR		0.0	0.0	none	/day	Both
	THNLR		1.07	1.0	2.0	none	Both

Explanation

This table is only required in order to simulate detailed organic nitrogen transformations and transport (designed primarily for forests). The table is supplied four times - once for each soil layer. If one or more occurrences of the table are missing, all parameters for the affected layer(s) will be defaulted.

KLON is the particulate/soluble partitioning coefficient for labile organic N. KRON is the particulate/soluble partitioning coefficient for refractory organic N. KONLR is the first-order conversion rate of labile to refractory particulate organic N and THNLR is the associated temperature correction coefficient.

4.4(1).11.6 Table-type NIT-AMVOLAT -- Ammonia volatilization parameters

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
NIT-AMVOLAT
<-range><-----amvopm----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END NIT-AMVOLAT
```

```
*****
Example
*****
```

```
NIT-AMVOLAT
  <PLS >      SKVOL      UKVOL      LKVOL      AKVOL      THVOL      TRFVOL ***
  x - x      (/day)      (/day)      (/day)      (/day)      (-)      (deg C) ***
  1  3        0.4        0.2        0.1        0.0        1.07      20.0
END NIT-AMVOLAT
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<amvopm>	SKVOL, UKVOL, LKVOL, AKVOL	6F10.0	0.0	0.0	none	/day	Both
	THVOL		1.07	1.0	2.0	none	Both
	TRFVOL		20.0	0.0	35.0	deg C	Both

Explanation

SKVOL, UKVOL, LKVOL, and AKVOL are the ammonia volatilization rates in the surface, upper, lower, and groundwater layers, respectively. THVOL is the temperature correction coefficient. TRFVOL is the reference temperature for the correction.

This table is only used if volatilization of ammonia is simulated (AMVOFG = 1 in Table-type NIT-FLAGS).

4.4(1).11.7 Table-type NIT-CMAX -- Maximum solubility of ammonium

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
NIT-CMAX
<-range><--cmax-->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END NIT-CMAX
```

Example

```
NIT-CMAX
  <PLS >      CMAX***
  # - #       (ppm)***
  1   5       15.0
END NIT-CMAX
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<cmax>	CMAX	F10.0	0.0	0.0	none	ppm	Both

Explanation

CMAX is the maximum solubility of ammonium in water. This table only appears once, and is only required if FORAFG = 1 (adsorption/desorption is simulated using single-value Freundlich method).

4.4(1).11.8 Table-type NIT-SVALPM -- Nitrogen single value Freundlich adsorption/desorption parameters

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

NIT-SVALPM

<-range><-----svalpm----->

.
(repeats until all operations of this type are covered)

.
END NIT-SVALPM

Example

NIT-SVALPM

```
<PLS >      XFIX      K1      N1***
# - #      (ppm)      ***
1   3      10.0      5.0      1.2
```

END NIT-SVALPM

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<svalpm>	XFIX	3F10.0	0.0	0.0	none	ppm	Both
	K1		0.0	0.0	none	l/kg	Both
	N1		none	1.0	none	none	Both

Explanation

This table is only required if FORAFG = 1; that is, adsorption and desorption of ammonium is simulated using the single-value Freundlich method.

This table is exactly analogous to Table-type PEST-SVALPM.

4.4(1).11.9 Table-type NIT-UPTAKE -- Nitrogen plant uptake rate parameters

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
NIT-UPTAKE
<-range><-----uptake----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END NIT-UPTAKE
```

Example

```
NIT-UPTAKE
  <PLS >Nitrogen plant uptake rates (/day)      ***
  # - #   Surface   Upper    Lower   Groundw***
  1   2     0.01    0.02    0.01
END NIT-UPTAKE
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<uptake>	SKPLN,UKPLN, LKPLN,AKPLN	4F10.0	0.0	0.0	none	/day	Both

Explanation

SKPLN, UKPLN, LKPLN and AKPLN are the plant nitrogen uptake reaction rate parameters for the surface, upper, lower, and active groundwater layers, respectively. This table is required when first-order plant uptake is being used, and uptake parameters do not vary monthly (NUPTFG = 0 and VNUTFG = 0 in Table-type NIT-FLAGS).

4.4(1).11.10 Table-type MON-NITUPT -- Monthly plant uptake parameters for nitrogen, for the surface, upper, lower or groundwater layer

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

MON-NITUPT

<-range><-----mon-uptake----->

.

(repeats until all operations of this type are covered)

.

END MON-NITUPT

Example

MON-NITUPT

<PLS > Plant uptake parms for nitrogen in upper layer (/day) ***

- # JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC***

1 4 .01 .03 .05 .05 .03 .01

END MON-NITUPT

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-uptake>	KPLNM(*)	12F5.0	0.0	0.0	none	/day	Both

Explanation

This table is required if first-order plant uptake is being used and the plant uptake parameters vary throughout the year (NUPTFG = 0 and VNUTFG = 1 in Table-type NIT-FLAGS). The entire table is supplied four times; first for the surface layer, second for the upper layer, third for the lower layer, and fourth for the active groundwater layer. If omitted, default values will be supplied. For example, if the third and fourth occurrences of the table are omitted, the parameters for the lower and groundwater layers will default to zero.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(1).11.11 Table-type SOIL-DATA2 -- Wilting points for yield-based plant uptake

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
SOIL-DATA2
<-range><----wiltpt----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END SOIL-DATA2
```

```
*****
Example
*****
```

```
SOIL-DATA2
  <PLS > Wilting points for each soil layer      ***
  # - #   SURFACE   UPPER   LOWER   ACT GW   ***
  1   7     .02     .01     .01     .015
END SOIL-DATA2
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<wiltpt>	SWILTP,UWILTP LWILTP,AWILTP	4F10.0	0.0	0.0	none	none	Both

Explanation

The wilting point, which is input as a fraction (volume-basis) is used to determine when the soil is too dry for plant uptake to occur when the yield-based method of plant uptake is being used (NUPTFG = 1 in Table-type NIT-FLAGS and/or PUPTFG = 1 in Table-type PHOS-FLAGS). This table should only be entered once for the NITR and PHOS sections.

4.4(1).11.12 Table-type CROP-DATES -- Planting and harvesting dates for yield-based plant uptake

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
CROP-DATES
<-range><ncr>      <m><d>  <m><d>      <m><d>  <m><d>      <m><d>  <m><d>
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END CROP-DATES
```

```
*****
Example
*****
```

```
CROP-DATES
  <PLS >
    # - # NCRP      PM PD   HM HD      PM PD   HM HD      PM PD   HM HD ***
    1      2      4 15   8 20      9 5    9 29
END CROP-DATES
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<ncr>	NCRP	I5	1	1	3
<m>	CRPDAT(*)	2I3	1	1	12
<d>			1	1	31

Explanation

NCRP is the number of crops per year.

CRPDAT is the month and day of planting and harvesting for each crop. Crop seasons cannot overlap, but a season may wrap around the end of the calendar year.

Cropping dates are required only when the yield-based method of plant uptake is being used (NUPTFG = 1 in Table-type NIT-FLAGS and/or PUPTFG = 1 in Table-type PHOS-FLAGS). This table should only be entered once for the NITR and PHOS sections.

4.4(1).11.13 Table-type NIT-YIELD -- Yield-based nitrogen plant uptake parameters

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
NIT-YIELD
<-range><-target-><-maxrat->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END NIT-YIELD
```

```
*****
Example
*****
```

```
NIT-YIELD
  <PLS >   NUPTGT   NMXRAT ***
  # - #   (LB/AC)   ***
  1       100.00   1.5
END NIT-YIELD
```

```
*****
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<-target->	NUPTGT	F10.0	0.0	0.0	none	lb/ac	Engl
			0.0	0.0	none	kg/ha	Metric
<-maxrat->	NMXRAT	F10.0	1.0	1.0	none	none	Both

Explanation

NUPTGT is the total annual target for plant uptake of nitrogen for all soil layers and all crops during the calendar year.

NMXRAT is the ratio of the maximum uptake rate to the optimum (target) rate when the crop is making up a deficit in nitrogen uptake.

This table is required only when yield-based plant uptake is being used (i.e., NUPTFG = 1 in Table-type NIT-FLAGS).

4.4(1).11.14 Table-type MON-NUPT-FR1 -- Monthly fractions for yield-based plant uptake of nitrogen

```
*****
      1      2      3      4      5      6      7      8
123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MON-NUPT-FR1
<-range><-----mon-nuptfr----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-NUPT-FR1
```

```
*****
Example
*****
```

```
MON-NUPT-FR1
<PLS > Monthly fractions for plant uptake target      ***
# - #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
1      .1  .2  .2  .2  .1  .2
2      .1  .1  .05 .05 .1  .1  .1  .05 .05 .1  .1  .1
END MON-NUPT-FR1
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-nuptfr>	NUPTFM(*)	12F5.0	0.0	0.0	1.0	none	Both

Explanation

These are the fractions of the total annual nitrogen plant uptake target (NUPTGT in Table-type NIT-YIELD) applied to each month. The fractions across the year must sum to unity; otherwise, an error message is generated. This table is only required when yield-based plant uptake of nitrogen is being used (NUPTFG = 1 in Table-type NIT-FLAGS).

4.4(1).11.15 Table-type MON-NUPT-FR2 -- Monthly fractions for yield-based plant uptake of nitrogen from a soil layer

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

MON-NUPT-FR2

<-range><-----mon-layfr----->

.

(repeats until all operations of this type are covered)

.

END MON-NUPT-FR2

Example

MON-NUPT-FR2

<PLS > Monthly fractions for plant uptake target from surface ***

```
# - # JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC ***
2   .15 .15 .15 .1 .1 .1 .1 .1 .15 .12 .12 .1
```

END MON-NUPT-FR2

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-layfr>	SNUPTM(*),UNUPTM(*), LNUPTM(*),ANUPTM(*)	12F5.0	0.0	0.0	1.0	none	Both

Explanation

These are the fractions of the monthly nitrogen plant uptake target (NUPTGT in Table-type NIT-YIELD times NUPTFM in Table-type MON-NUPT-FR1) applied to each soil layer: surface, upper, lower, and active groundwater. The fractions across the four layers (NOT across the 12 months, as for MON-NUPT-FR1) must sum to unity; otherwise an error message is generated. This table is only required when yield-based plant uptake of nitrogen is being used (NUPTFG = 1 in Table-type NIT-FLAGS). Then, the system expects it to appear four times: first, for the surface layer, second for the upper layer, etc. If one or more occurrences of the table are missing, all parameters for the affected layer(s) will be defaulted to zero.

4.4(1).11.16 Table-type NIT-UPIMCSAT -- Half saturation constants for nitrogen uptake and immobilization when using saturation kinetics method (for surface, upper, lower, or groundwater layer)

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
NIT-UPIMCSAT
<-range><-----csatpm----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END NIT-UPIMCSAT
```

Example

```
NIT-UPIMCSAT
  <PLS >      CSUNI      CSUAM      CSINI      CSIAM ***
  x - x      (ug/l)      (ug/l)      (ug/l)      (ug/l) ***
  1   3       40.        15.         4.0         1.5
END NIT-UPIMCSAT
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<csatpm>	CSUNI,CSUAM CSINI,CSIAM	4F10.0	0.0	0.0	none	ug/l	Both

Explanation

CSUNI and CSUAM are the nitrate and ammonia half saturation constants for uptake. CSINI and CSIAM are the nitrate and ammonia half saturation constants for immobilization.

This table is only required if nitrogen uptake and immobilization are being simulated using the saturation kinetics method (NUPTFG = 2 or -2 in Table-type NIT-FLAGS). If NUPTFG = 2, HSPF expects this table to appear four times in the User's Control Input, once for each soil layer. If one or more occurrences of the table are missing, all parameters for the affected layer(s) will be defaulted to zero. If NUPTFG = -2, HSPF expects one occurrence of this table, and uses the same parameters for all four soil layers.

4.4(1).11.17 Table-type NIT-UPIMKMAX -- Maximum rate constants for nitrogen uptake and immobilization when using saturation kinetics method (for surface, upper, lower, or groundwater layer)

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
NIT-UPIMKMAX
<-range><-----kmaxpm----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END NIT-UPIMKMAX
```

Example

```
NIT-UPIMKMAX
<PLS > Maximum plant uptake and immobilization rates (mg/l/day) ***
x - x      KUPNI      KUPAM      KIMNI      KIMAM      ***
1   3        1.0        0.6        .05        .02
END NIT-UPIMKMAX
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<kmaxpm>	KUPNI,KUPAM KIMNI,KIMAM	4F10.0	0.0	0.0	none	mg/l/day	Both

Explanation

KUPNI and KUPAM are the nitrate and ammonia maximum uptake rates. KIMNI and KIMAM are the nitrate and ammonia maximum immobilization rates.

This table is only required if nitrogen uptake and immobilization are being simulated using the saturation kinetics method (NUPTFG = 2 or -2 in Table-type NIT-FLAGS). If NUPTFG = 2, HSPF expects this table to appear four times in the User's Control Input, once for each soil layer. If one or more occurrences of the table are missing, all parameters for the affected layer(s) will be defaulted to zero. If NUPTFG = -2, HSPF expects one occurrence of this table, and uses the same parameters for all four soil layers.

4.4(1).11.18 Table-type MON-NITUPNI -- Monthly nitrate uptake maximum rates when using saturation kinetics method (for the surface, upper, lower or groundwater layer)

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
MON-NITUPNI
<-range><-----mon-upnimp----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-NITUPNI
```

Example

```
MON-NITUPNI
<PLS > Maximum plant uptake rate for nitrate (mg/l/day)          ***
x - x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
1   4   .05 .25  .75  1.2  2.0  2.5  2.5  2.5  2.0  1.2  .75  .25
END MON-NITUPNI
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-upnimp>	KUNIM(*)	12F5.0	0.0	0.0	none	mg/l/day	Both

Explanation

This table contains the maximum nitrate uptake rates when using the saturation kinetics method. The table is required if saturation kinetics are being simulated for uptake and the rates vary monthly (NUPTFG = 2 or -2 and VNUTFG = 1 in Table-type NIT-FLAGS). If NUPTFG = 2, HSPF expects this table to appear four times in the User's Control Input, once for each soil layer. If one or more occurrences of the table are missing, all parameters for the affected layer(s) will be defaulted to zero. If NUPTFG = -2, HSPF expects one occurrence of this table, and uses the same parameters for all four soil layers.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(1).11.19 Table-type MON-NITUPAM -- Monthly ammonia uptake maximum rates when using saturation kinetics method (for the surface, upper, lower or groundwater layer)

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
MON-NITUPAM
<-range><-----mon-upampm----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-NITUPAM
```

Example

```
MON-NITUPAM
<PLS > Max ammonia uptake rate in upper layer (mg/l/day)      ***
# - #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
1   4  .03  .06  .12  .30  .45  .60  .60  .60  .45  .30  .15  .08
END MON-NITUPAM
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-upampm>	KUAMM(*)	12F5.0	0.0	0.0	none	mg/l/day	Both

Explanation

This table contains the maximum ammonia uptake rates when using the saturation kinetics method. The table is required if saturation kinetics are being simulated for uptake and the rates vary monthly (NUPTFG = 2 or -2 and VNUTFG = 1 in Table-type NIT-FLAGS). If NUPTFG = 2, HSPF expects this table to appear four times in the User's Control Input, once for each soil layer. If one or more occurrences of the table are missing, all parameters for the affected layer(s) will be defaulted to zero. If NUPTFG = -2, HSPF expects one occurrence of this table, and uses the same parameters for all four soil layers.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(1).11.20 Table-type MON-NITIMNI -- Monthly nitrate immobilization rates when using saturation kinetics method (for the surface, upper, lower or groundwater layer)

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
MON-NITIMNI
<-range><-----mon-immipm----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-NITIMNI
```

Example

```
MON-NITIMNI
<PLS > Nitrate immobilization rate in upper layer (mg/l/day)      ***
# - #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
1   4  .01  .01  .02  .02  .03  .04  .04  .04  .03  .03  .02  .01
END MON-NITIMNI
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-immipm>	KINIM(*)	12F5.0	0.0	0.0	none	mg/l/day	Both

Explanation

This table contains the maximum nitrate immobilization rates when using the saturation kinetics method. The table is required if saturation kinetics are being simulated for immobilization, and the rates vary monthly (NUPTFG = 2 or -2 and VNUTFG = 1 in Table-type NIT-FLAGS). If NUPTFG = 2, HSPF expects this table to appear four times in the User's Control Input, once for each soil layer. If one or more occurrences of the table are missing, all parameters for the affected layer(s) will be defaulted to zero. If NUPTFG = -2, HSPF expects one occurrence of this table, and uses the same parameters for all four soil layers.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(1).11.21 Table-type MON-NITIMAM -- Monthly ammonia immobilization rates when using saturation kinetics method (for the surface, upper, lower or groundwater layer)

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
MON-NITIMAM
<-range><-----mon-imampm----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-NITIMAM
```

Example

```
MON-NITIMAM
<PLS >  Ammonia immobilization rate in upper layer (mg/l/day)      ***
# - #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
1   4  .01  .01  .01  .02  .02  .02  .03  .03  .02  .02  .02  .01
END MON-NITIMAM
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-imampm>	KIAMM(*)	12F5.0	0.0	0.0	none	mg/l/day	Both

Explanation

This table contains the maximum ammonia immobilization rates when using the saturation kinetics method. The table is required if saturation kinetics are being simulated for immobilization, and the rates vary monthly (NUPTFG = 2 or -2 and VNUTFG = 1 in Table-type NIT-FLAGS). If NUPTFG = 2, HSPF expects this table to appear four times in the User's Control Input, once for each soil layer. If one or more occurrences of the table are missing, all parameters for the affected layer(s) will be defaulted to zero. If NUPTFG = -2, HSPF expects one occurrence of this table, and uses the same parameters for all four soil layers.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(1).11.22 Table-type NIT-BGPLRET -- Below-ground plant nitrogen return rates.

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
NIT-BGPLRET
<-range><-----plrepm----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END NIT-BGPLRET
```

```
*****
Example
*****
```

```
NIT-BGPLRET
  Below-ground plant return rates and refractory fraction ***
  <PLS>   SKPRBN   UKPRBN   LKPRBN   AKPRBN   BGNPRF ***
  x - x   (/day)  (/day)  (/day)  (/day)  ***
  1   3     .02    .01     .01     0.0    0.1
END NIT-BGPLRET
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<plrepm>	SKPRBN	F10.0	0.0	0.0	none	/day	Both
	UKPRBN	F10.0	0.0	0.0	none	/day	Both
	LKPRBN	F10.0	0.0	0.0	none	/day	Both
	AKPRBN	F10.0	0.0	0.0	none	/day	Both
	BGNPRF	F10.0	0.0	0.0	none	none	Both

Explanation

SKPRBN, UKPRBN, LKPRBN, and AKPRBN are the first-order return rates of below-ground plant N to organic N storage in the four layers. BGNPRF is the fraction of plant N return that becomes particulate refractory organic N. (The rest becomes particulate labile organic N.)

This table is only used when plant return rates are constant (VPRNFG = 0 in Table-type NIT-FLAGS).

4.4(1).11.23 Table-type MON-NPRETBG -- Monthly below-ground plant N return rates for the surface, upper, lower or groundwater layer

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MON-NPRETBG
<-range><-----mon-plrepm----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-NPRETBG
```

```
*****
Example
*****
```

```
MON-NPRETBG
  <PLS > Return rates for below-ground plant N in upper layer (/day) ***
  # - #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
  1   4                .01  .03  .05  .05  .03  .01
END MON-NPRETBG
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-plrepm>	KRBNM(*)	12F5.0	0.0	0.0	none	/day	Both

Explanation

This table contains the first-order return rates of below-ground plant N to organic N. The table is used if the plant N return parameters vary throughout the year (VPLRFG = 1 in Table-type NIT-FLAGS). The entire table is supplied four times; first for the surface layer, second for the upper layer, third for the lower layer, and fourth for the active groundwater layer. If omitted, default values will be supplied. For example, if the third and fourth occurrences of the table are omitted, the parameters for the lower and groundwater layers will default to zero.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(1).11.24 Table-type MON-NPRETFBG -- Monthly refractory fractions for below-ground plant N return

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

MON-NPRETFBG

<-range><-----mon-plrefr----->

.

(repeats until all operations of this type are covered)

.

END MON-NPRETFBG

Example

MON-NPRETFBG

<PLS > Monthly refractory fractions for below-ground plant N return ***

x - x JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC ***

1 4 .02 .02 .03 .04 .04 .05 .05 .05 .04 .04 .03 .03

END MON-NPRETFBG

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-plrefr>	BNPRFM(*)	12F5.0	0.0	0.0	1.0	none	Both

Explanation

This table contains the fractions of below-ground plant N return which become particulate refractory organic N. (The rest becomes particulate labile organic N.) The table is used only if the plant N return parameters vary throughout the year (VPLRFG = 1 in Table-type NIT-FLAGS).

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(1).11.25 Table-type NIT-AGUTF -- Above-ground plant uptake fractions

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
NIT-AGUTF
<-range><-----agutf----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END NIT-AGUTF
```

Example

```
NIT-AGUTF
  <PLS > Above-ground plant uptake fractions    ***
  x - x   SANUTF   UANUTF   LANUTF   AANUTF ***
  1   3     0.8     0.8     0.7     0.7
END NIT-AGUTF
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<agutf>	SANUTF,UANUTF, LANUTF,AANUTF	4F10.0	0.0	0.0	1.0	none	Both

Explanation

SANUTF, UANUTF, LANUTF and AANUTF are the above-ground plant uptake fractions for the surface, upper, lower, and active groundwater layers, respectively. This table is used only when the above-ground compartment is being simulated and uptake parameters do not vary monthly (ALPNFG = 1 and VNUTFG = 0 in Table-type NIT-FLAGS).

4.4(1).11.26 Table-type MON-NITAGUTF -- Monthly above-ground plant uptake fractions for nitrogen, for the surface, upper, lower or groundwater layer

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
MON-NITAGUTF
<-range><-----mon-agutf----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-NITAGUTF
```

Example

```
MON-NITAGUTF
  <PLS > Monthly above-ground fractions for plant uptake          ***
  x - x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
  1   4  .70  .70  .70  .75  .75  .80  .80  .80  .75  .75  .70  .70
END MON-NITAGUTF
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-agutf>	ANUFM(*)	12F5.0	0.0	0.0	1.0	none	Both

Explanation

This table contains the fractions of plant uptake which go to above-ground plant N storage. The table is used only if the above-ground compartment is being simulated and the plant uptake parameters vary throughout the year (ALPNFG = 1 and VNUTFG = 1 in Table-type NIT-FLAGS). The table is supplied four times; first for the surface layer, second for the upper layer, third for the lower layer, and fourth for the active groundwater layer. If omitted, default values will be supplied. For example, if the third and fourth occurrences of the table are omitted, the parameters for the lower and groundwater layers will default to zero.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(1).11.27 Table-type NIT-AGPLRET -- Above-ground plant nitrogen return rates.

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
NIT-AGPLRET
<-range><-----plrepm----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END NIT-AGPLRET
```

```
*****
Example
*****
```

```
NIT-AGPLRET
  Above-ground plant return rates and refractory fraction
  <PLS>   AGKPRN   SKPRLN   UKPRLN   LINPRF
  x - x   (/day)  (/day)   (/day)
  1   3     .01    .02     .01     0.1
END NIT-AGPLRET
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<plrepm>	AGKPRN	F10.0	0.0	0.0	none	/day	Both
	SKPRLN	F10.0	0.0	0.0	none	/day	Both
	UKPRLN	F10.0	0.0	0.0	none	/day	Both
	LINPRF	F10.0	0.0	0.0	none	none	Both

Explanation

AGKPRN is the first-order return rate of above-ground plant N to litter N. SKPRLN and UKPRLN are the first-order return rates of litter N to organic N storage in the surface and upper soil layers, respectively. LINPRF is the fraction of litter N return that becomes particulate refractory organic N. (The rest becomes particulate labile organic N.)

This table is only used when the above-ground and litter compartments are being simulated for nitrogen, and plant return rates are constant (i.e., ALPNFG = 1 and VPRNFG = 0 in Table-type NIT-FLAGS).

4.4(1).11.28 Table-type MON-NPRETAG -- Monthly above-ground plant N return rates to litter N

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MON-NPRETAG
<-range><-----mon-plrepm----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-NPRETAG
```

```
*****
Example
*****
```

```
MON-NPRETAG
  <PLS > Return rates for above-ground plant N to litter N (/day)   ***
  # - #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
  1   4                .01  .03  .05  .05  .03  .01
END MON-NPRETAG
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-plrepm>	KRANM(*)	12F5.0	0.0	0.0	none	/day	Both

Explanation

This table contains the first-order return rate of above-ground plant N to litter N. The table is used only when the above-ground compartment is being simulated and the plant N return parameters vary throughout the year (i.e., ALPNFG = 1 and VPLRFG = 1 in Table-type NIT-FLAGS).

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(1).11.29 Table-type MON-NPRETLI -- Monthly litter plant N return rates for the surface or upper layer

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MON-NPRETLI
<-range><-----mon-plrepm----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-NPRETLI
```

```
*****
Example
*****
```

```
MON-NPRETLI
  <PLS > Return rates for litter plant N to upper layer (/day)      ***
  # - #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC***
  1   4                .01  .03  .05  .05  .03  .01
END MON-NPRETLI
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-plrepm>	KRLNM(*)	12F5.0	0.0	0.0	none	/day	Both

Explanation

This table contains the return rates of litter plant N to particulate labile organic N in the surface or upper layer. The table is required if the plant N return parameters vary throughout the year (VPLRFG = 1 in Table-type NIT-FLAGS). The entire table is supplied two times; first for the surface layer and second for the upper layer. If omitted, default values will be supplied. For example, if the second occurrence of the table is omitted, the parameters for the upper layer will default to zero.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(1).11.30 Table-type MON-NPRETFLI -- Monthly refractory fractions for
litter N return

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MON-NPRETFLI
<-range><-----mon-plrefr----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-NPRETFLI
```

```
*****
Example
*****
```

```
MON-NPRETFLI
  <PLS > Monthly refractory fractions for litter N return          ***
  x - x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
  1   4   .02 .02  .03  .04  .04  .05  .05  .05  .04  .04  .03  .03
END MON-NPRETFLI
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-plrefr>	LNPRFM(*)	12F5.0	0.0	0.0	1.0	none	Both

Explanation

This table contains the fractions of litter N return which become particulate refractory organic N. (The rest becomes particulate labile organic N.) The table is used only if the litter compartment is being simulated and the plant N return parameters vary throughout the year (ALPNFG = 1 and VPLRFG = 1 in Table-type NIT-FLAGS).

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(1).11.31 Table-type NIT-STOR1 -- Initial storage of nitrogen in the surface, upper, lower, or groundwater layer

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
NIT-STOR1
<-range><-----nit-stor1----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END NIT-STOR1
```

```
*****
Example
*****
```

```
NIT-STOR1
  <PLS > Initial storage of N (lb/ac) ***
  x - x   LORGN   AMAD   AMSU   NO3   PLTN   RORGN ***
  1   4
END NIT-STOR1
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<nit-stor1>	LORGN,AMAD,AMSU,	6F10.0	0.0	0.0	none	lb/ac	Engl
	NO3,PLTN,RORGN		0.0	0.0	none	kg/ha	Metric

Explanation

This table is similar in organization to Table-type PEST-STOR1. It specifies the initial storage of N in one of the four major soil layers. The values in the table are:

- LORGN Labile organic nitrogen
- AMAD Adsorbed ammonium
- AMSU Solution ammonium
- NO3 Nitrate
- PLTN Nitrogen stored in plants
- RORGN Refractory organic nitrogen

4.4(1).11.32 Table-type NIT-STOR2 -- Initial storage of nitrogen in upper layer transitory (interflow) storage

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
NIT-STOR2
<-range><-----nit-stor2----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END NIT-STOR2
```

```
*****
Example
*****
```

```
NIT-STOR2
  <PLS > Initial N in interflow, above-ground, and litter storage (lb/ac) ***
  x - x   IAMSU   INO3   ISLON   ISRON   AGPLTN   LITTRN   ***
  1   2
  100.   10.
END NIT-STOR2
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<nit-stor2>	IAMSU,INO3,ISLON,ISRON,AGPLTN,LITTRN	6F10.0	0.0 0.0	0.0 0.0	none none	lb/ac kg/ha	Engl Metric

Explanation

This table specifies the initial storage of N in the upper layer transitory (interflow) storage. If the above-ground and litter compartments are being simulated (ALPNFG = 1 in Table-type NIT-FLAGS), then the initial storage for these compartments is also specified.

- IAMSU Solution ammonium
- INO3 Nitrate
- ISLON Solution labile organic nitrogen
- ISRON Solution refractory organic nitrogen
- AGPLTN Above-ground plant nitrogen (only relevant if ALPNFG = 1)
- LITTRN Litter nitrogen (only relevant if ALPNFG = 1)

4.4(1).12 PERLND BLOCK -- Section PHOS input

```
*****
      1      2      3      4      5      6      7      8
1234567890123456789012345678901234567890123456789 0123456789012345678901234567890
*****
```

Layout

```
Table-type SOIL-DATA  if sections PEST and NITR are inactive
Table-type PHOS-FLAGS
Table-type PHOS-AD-FLAGS
Table-type PHOS-FSTGEN
Table-type PHOS-FSTPM  for surface layer
Table-type PHOS-FSTPM  for upper layer
Table-type PHOS-FSTPM  for lower layer
Table-type PHOS-FSTPM  for groundwater layer
```

```

-----
Table-type PHOS-CMAX
Table-type PHOS-SVALPM for surface layer  | if          (single value
Table-type PHOS-SVALPM for upper layer   | FORPFG=     Freundlich
Table-type PHOS-SVALPM for lower layer   | 1           method)
Table-type PHOS-SVALPM for groundwater layer |
-----
```

```

-----
Table-type PHOS-UPTAKE  ----- if VPUTFG= 0
Table-type MON-PHOSUPT for surface layer  | if VPUTFG= 1 | if PUPTFG= 0
Table-type MON-PHOSUPT for upper layer   |
Table-type MON-PHOSUPT for lower layer   |
Table-type MON-PHOSUPT for groundwater layer |
-----
```

```

-----
Table-type SOIL-DATA2  | if NITR is inactive
Table-type CROP-DATES  | or NUPTFG= 0
-----
Table-type PHOS-YIELD
Table-type MON-PUPT-FR1
Table-type MON-PUPT-FR2 for surface layer
Table-type MON-PUPT-FR2 for upper layer
Table-type MON-PUPT-FR2 for lower layer
Table-type MON-PUPT-FR2 for groundwater layer
-----
if PUPTFG= 1
```

```
Table-type PHOS-STOR1  for surface layer storage
Table-type PHOS-STOR1  for upper layer principal storage
Table-type PHOS-STOR2  for upper layer transitory storage
Table-type PHOS-STOR1  for lower layer storage
Table-type PHOS-STOR1  for groundwater layer storage
```

Explanation:

The exact format of each of the tables mentioned above, except for SOIL-DATA, SOIL-DATA2 and CROP-DATES, is detailed in the documentation which follows. SOIL-DATA is documented under the input for Section PEST (4.4(1).10). SOIL-DATA2 and CROP-DATES are documented under the input for Section NITR (4.4(1).11).

The comments given alongside the table names above indicate under what circumstances a table is expected. Note that if all the fields in a table have default values, the table can be omitted from the User's Control Input. Then, the defaults will be adopted. However, any tables that are repeated for multiple soil layers should generally not be omitted because the "nth" occurrence of one of these tables refers to the corresponding "nth" layer. If a table for layer i is omitted, the next occurrence of the table (intended for layer i+1) will be applied to layer i, and unintended results may occur.

NUPTFG and PUPTFG are the plant uptake method flag for nitrogen and phosphorus, respectively. VPUTFG and FORPFG are the phosphorus plant uptake flag and the phosphate adsorption/desorption method flag, respectively. NUPTFG is described under Table-type NIT-FLAGS (Sect. 4.4(1).11.1) above. The others are described under Table-type PHOS-FLAGS (Sect. 4.4(1).12.1) below.

4.4(1).12.1 Table-type PHOS-FLAGS -- Flags governing simulation of phosphorus

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
PHOS-FLAGS
<-range><-----phosflags----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PHOS-FLAGS
```

```
*****
Example
*****
```

```
PHOS-FLAGS
  <PLS > VPUT FORP ITMX BNUM CNUM PUPT ***
  # - #
  1   4   1           10   10   1
END PHOS-FLAGS
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<phosflags>	VPUTFG	5I5	0	0	1
	FORPFG		0	0	1
	ITMAXP		30	1	100
	BNUMP		none	1	1000
	CNUMP		none	1	1000
	PUPTFG		0	0	1

Explanation

If VPUTFG = 1, the first-order plant uptake parameters for phosphorus are allowed to vary throughout the year and four tables of type MON-PHOSUPT are expected in the User's Control Input. The first appearance is for the surface layer, 2nd for upper layer, 3rd for the lower layer, and 4th for the groundwater layer. If VPUTFG = 0, the uptake rates do not vary through the year and a value for each layer is specified in a single table (Table-type PHOS-UPTAKE).

FORPFG indicates which method is to be used to simulate adsorption and desorption of phosphate:

- 0 first-order kinetics
- 1 single-value Freundlich method

ITMAXP is the maximum number of iterations that will be attempted in solving the Freundlich equation; applicable only if FORPFG= 1.

BNUMP is the number of time steps that will elapse between recalculation of biochemical reaction fluxes. For example, if BNUMP = 10 and the simulation time step is 5 minutes, then these fluxes will be recalculated every 50 minutes. All reactions except adsorption/desorption fall into this category. CNUMP is the corresponding number for the chemical (adsorption/desorption) reactions.

PUPTFG indicated which method is to be used to simulate plant uptake of phosphorus:

- 0 first-order kinetics
- 1 yield-based algorithm

4.4(1).12.2 Table-type PHOS-AD-FLAGS -- Atmospheric deposition flags for PHOS

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

PHOS-AD-FLAGS

<-range> <f><c> <f><c> <f><c> <f><c> <f><c>

.

(repeats until all operations of this type are covered)

.

END PHOS-AD-FLAGS

Example

PHOS-AD-FLAGS

<PLS > Atmospheric deposition flags ***

*** PHOSPHATE ORGANIC P

*** SURF UPPR SURF UPPR

<F><C> <F><C> <F><C> <F><C>

1 7 -1 10 -1 -1 11 12 13 -1

END PHOS-AD-FLAGS

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<f><c>	PHADFG(*)	(1X,2I3)	0	-1	none

Explanation

PHADFG is an array of flags indicating the source of atmospheric deposition data. Each species can be deposited into either the surface or upper soil layers. Each species/layer combination has two flags. The first is for dry or total deposition flux, and the second is for wet deposition concentration. The flag values indicate:

- 0 No deposition of this type is simulated
- 1 Deposition of this type is input as time series PHADFX or PHADCN
- >0 Deposition of this type is input in the MONTH-DATA table with the corresponding table ID number. (Refer to Section 4.11 for details)

4.4(1).12.3 Table-type PHOS-FSTGEN -- Temperature correction parameters for phosphorus reactions

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

PHOS-FSTGEN

<-range><-----theta----->

.

(repeats until all operations of this type are covered)

.

END PHOS-FSTGEN

Example

PHOS-FSTGEN

<PLS > Temperature correction parameters (theta) ***

- # THPLP THKDSP THKADP THKIMP THKMP***

1 1.07 1.05 1.05 1.07 1.07 1.05

END PHOS-FSTGEN

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<theta>	THPLP	5F10.0	1.07	1.0	2.0	none	Both
	THKDSP		1.05	1.0	2.0	none	Both
	THKADP		1.05	1.0	2.0	none	Both
	THKIMP		1.07	1.0	2.0	none	Both
	THKMP		1.07	1.0	2.0	none	Both

Explanation

This table is analogous to Table-type NIT-FSTGEN, except for the first two values in that table. The temperature correction parameters supplied in this table (and the reactions they affect) are:

- THPLP Plant uptake (only relevant if PUPTFG=0 in Table PHOS-FLAGS)
- THKDSP Phosphate desorption (only relevant if FORPFG=0 in Table PHOS-FLAGS)
- THKADP Phosphate adsorption (only relevant if FORPFG=0 in Table PHOS-FLAGS)
- THKIMP Phosphate immobilization
- THKMP Organic P mineralization

4.4(1).12.4 Table-type PHOS-FSTPM -- Phosphorus first-order reaction parameters

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

PHOS-FSTPM

<-range><-----phos-fstpm----->

.
(repeats until all operations of this type are covered)

.
END PHOS-FSTPM

Example

PHOS-FSTPM

<PLS > Phosphorus first-order parameters for surface layer (/day) ***

#	-	#	KDSP	KADP	KIMP	KMP	***
1		5				.04	

END PHOS-FSTPM

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<phos-fstpm>	KDSP,KADP, KIMP,KMP	4F10.0	0.0	0.0	none	/day	Both

Explanation

This table is analogous to Table-type NIT-FSTPM. The reaction rate parameters supplied in this table are:

- KDSP Phosphate desorption (only used if FORPFG=0 in Table-type PHOS-FLAGS)
- KADP Phosphate adsorption (only used if FORPFG=0 in Table-type PHOS-FLAGS)
- KIMP Phosphate immobilization
- KMP Organic P mineralization

4.4(1).12.5 Table-type PHOS-CMAX -- Maximum solubility of phosphate

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
PHOS-CMAX
<-range><--cmax-->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PHOS-CMAX
```

Example

```
PHOS-CMAX
  <PLS >      CMAX***
  # - #      (ppm)***
  1   2      5.0
END PHOS-CMAX
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<cmax>	CMAX	F10.0	0.0	0.0	none	ppm	Both

Explanation

This table is exactly analogous to Table-type NIT-CMAX.

CMAX is the maximum solubility of phosphate in water. This table only appears once, and is only required if FORPFG = 1 in Table-type PHOS-FLAGS (adsorption/desorption is simulated using single-value Freundlich method).

4.4(1).12.6 Table-type PHOS-SVALPM -- Phosphorus single value Freundlich adsorption/desorption parameters

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
PHOS-SVALPM
<-range><-----svalpm----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PHOS-SVALPM
```

Example

```
PHOS-SVALPM
<PLS > Parameters for Freundlich method (lower layer) ***
# - #      XFIX      K1      N1      ***
1         30.      5.0      1.5
END PHOS-SVALPM
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<svalpm>	XFIX	3F10.0	0.0	0.0	none	ppm	Both
	K1		0.0	0.0	none		Both
	N1		none	1.0	none		Both

Explanation

This table is exactly analogous to Table-type NIT-SVALPM. It is only used if FORPFG= 1 in Table-type PHOS-FLAGS.

4.4(1).12.7 Table-type PHOS-UPTAKE -- Phosphorus plant uptake parameters

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
PHOS-UPTAKE
<-range><-----phos-uptake----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PHOS-UPTAKE
```

Example

```
PHOS-UPTAKE
<PLS > Phosphorus plant uptake parms (/day) ***
# - #      SKPLP      UKPLP      LKPLP      AKPLP***
1      .005      .03      .05      .01
END PHOS-UPTAKE
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<phos-uptake>	SKPLP,UKPLP, LKPLP,AKPLP	4F10.0	0.0	0.0	none	/day	Both

Explanation

This table is exactly analogous to Table-type NIT-UPTAKE.

SKPLP, UKPLP, LKPLP and AKPLP are the plant phosphorus uptake reaction rate parameters for the surface, upper, lower, and active groundwater layers, respectively. This table is required when first-order plant uptake is being used, and uptake parameters do not vary monthly (PUPTFG = 0 and VPUTFG = 0 in Table-type PHOS-FLAGS).

4.4(1).12.8 Table-type MON-PHOSUPT -- Monthly plant uptake parameters for phosphorus, for the surface, upper, lower or groundwater layer

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

MON-PHOSUPT

<-range><-----mon-phosupt----->

.

(repeats until all operations of this type are covered)

.

END MON-PHOSUPT

Example

MON-PHOSUPT

<PLS > Monthly phosphorus uptake parameters for surface layer (/day)***

- # JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

1 2 .01 .03 .07 .07 .04 .01

END MON-PHOSUPT

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-phosupt>	KPLPM(*)	12F5.0	0.0	0.0	none	/day	Both

Explanation

This table is exactly analogous to Table-type MON-NITUPT.

This table is required if first-order plant uptake is being used and the plant uptake parameters vary throughout the year (PUPTFG = 0 and VPUTFG = 1 in Table-type PHOS-FLAGS). The entire table is supplied four times; first for the surface layer, second for the upper layer, third for the lower layer, and fourth for the active groundwater layer. If omitted, default values will be supplied. For example, if the third and fourth occurrences of the table are omitted, the parameters for the lower and groundwater layers will default to zero.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(1).12.9 Table-type PHOS-YIELD -- Yield-based phosphorus plant uptake parameters

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
PHOS-YIELD
<-range><-target-><-maxrat->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PHOS-YIELD
```

Example

```
PHOS-YIELD
  <PLS >   PUPTGT   PMXRAT ***
  # - #   (LB/AC)      ***
  1       100.00     1.5
END PHOS-YIELD
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<-target->	PUPTGT	F10.0	0.0	0.0	none	lb/ac	Engl
			0.0	0.0	none	kg/ha	Metric
<-maxrat->	PMXRAT	F10.0	1.0	1.0	2.0	none	Both

Explanation

This table is exactly analogous to Table-type NIT-YIELD.

PUPTGT is the total annual target for plant uptake of phosphorus for all soil layers and all crops during the calendar year.

PMXRAT is the ratio of the maximum uptake rate to the optimum (target) rate when the crop is making up a deficit in phosphorus uptake.

This table is required only when yield-based plant uptake is being used (i.e., PUPTFG = 1 in Table-type PHOS-FLAGS).

4.4(1).12.10 Table-type MON-PUPT-FR1 -- Monthly fractions for yield-based plant uptake of phosphorus

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
MON-PUPT-FR1
<-range><-----mon-puptfr----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-PUPT-FR1
```

Example

```
MON-PUPT-FR1
<PLS > Monthly fractions for plant uptake target      ***
# - #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
1      .1  .1  .05  .05  .1  .1  .1  .05  .05  .1  .1  .1
2      .1  .1  .05  .05  .1  .1  .1  .05  .05  .1  .1  .1
END MON-PUPT-FR1
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-puptfr>	PUPTFM(*)	12F5.0	0.0	0.0	1.0	none	Both

Explanation

This table is exactly analogous to Table-type MON-NUPT-FR1.

These are the fractions of the total annual phosphorus plant uptake target (PUPTGT in Table-type PHOS-YIELD) applied to each month. The fractions across the year must sum to unity; otherwise, an error message is generated. This table is only required when yield-based plant uptake of phosphorus is being used (PUPTFG = 1 in Table-type PHOS-FLAGS).

4.4(1).12.11 Table-type MON-PUPT-FR2 -- Monthly fractions for yield-based plant uptake of phosphorus from a soil layer

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
MON-PUPT-FR2
<-range><-----mon-layfr----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-PUPT-FR2
```

Example

```
MON-PUPT-FR2
<PLS > Monthly fractions for plant uptake target from surface ***
# - # JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC ***
2   .15 .15 .15 .1 .1 .1 .1 .1 .15 .12 .12 .1
END MON-PUPT-FR2
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-layfr>	SPUPTM(*),UPUPTM(*), LPUPTM(*),APUPTM(*)	12F5.0	0.0	0.0	1.0	none	Both

Explanation

This table is exactly analogous to Table-type MON-NUPT-FR2. Refer to that table for details.

4.4(1).12.12 Table-type PHOS-STOR1 -- Initial phosphorus storage in the surface, upper, lower or groundwater layer

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
PHOS-STOR1
<-range><-----phos-stor1----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PHOS-STOR1
```

Example

```
PHOS-STOR1
  <PLS >Initial phosphorus in upper layer (lb/ac)      ***
  # - #      ORGP      P4AD      P4SU      PLTP      ***
  1   3      50.      2000.     200.
END PHOS-STOR1
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<phos-stor1>	ORGP,P4AD,	4F10.0	0.0	0.0	none	lb/ac	Engl
	P4SU,PLTP		0.0	0.0	none	kg/ha	Metric

Explanation

This table is analogous to Table-type NIT-STOR1. It specifies the initial storage of P in one of the four major soil layers. The values in the table are:

- ORGP Organic phosphorus
- P4AD Adsorbed phosphate
- P4SU Solution phosphate
- PLTP Phosphorus stored in plants

4.4(1).12.13 Table-type PHOS-STOR2 -- Initial storage of phosphate in upper layer transitory (interflow) storage

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
PHOS-STOR2
<-range><--phos-->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PHOS-STOR2
```

Example

```
PHOS-STOR2
  <PLS >Phosphate in interflow (kg/ha)  ***
  # - #      IP4SU                      ***
  1   6      100.
END PHOS-STOR2
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<phos>	IP4SU	F10.0	0.0	0.0	none	lb/ac	Engl
			0.0	0.0	none	kg/ha	Metric

Explanation

This table is analogous to Table-type NIT-STOR2. It specifies the initial storage of solution phosphate in the upper layer transitory (interflow) storage.

4.4(1).13 PERLND BLOCK -- Section TRACER input

```
*****
      1      2      3      4      5      6      7      8
123456789012345678901234567890123456789 0123456789012345678901234567890
*****
```

Layout

```
Table-type TRAC-ID
[Table-type TRAC-AD-FLAGS]
[Table-type TRAC-TOPSTOR]
[Table-type TRAC-SUBSTOR]
```

Explanation

The exact format of each of the tables mentioned above is detailed in the documentation which follows.

Note: if all the fields in a table have default values, the table can be omitted from the User's Control Input. Then, the defaults will be adopted.

4.4(1).13.1 Table-type TRAC-ID -- Name of conservative substance (tracer)

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
TRAC-ID
<-range><-----trac-id----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END TRAC-ID
```

Example

```
TRAC-ID
  <PLS >Name of tracer      ***
  # - #                      ***
  1  10 Chloride
END TRAC-ID
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<trac-id>	TRACID(*)	5A4	none	none	none

Explanation

Any 20 character string can be supplied as the name of the tracer substance.

4.4(1).13.2 Table-type TRAC-AD-FLAGS -- Atmospheric deposition flags for TRACER

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
TRAC-AD-FLAGS
<-range> <f><c> <f><c>
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END TRAC-AD-FLAGS
```

Example

```
TRAC-AD-FLAGS
  <PLS > Atmospheric deposition flags ***
    ***   SURF   UPPR
  #*** # <F><C> <F><C>
    1    7  -1 10  -1 -1
END TRAC-AD-FLAGS
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<f><c>	TRADFG(*)	(1X,2I3)	0	-1	none

Explanation

TRADFG is an array of flags indicating the source of atmospheric deposition data. The tracer substance can be deposited into either the surface or upper soil layers. Each layer has two flags. The first is for dry or total deposition flux, and the second is for wet deposition concentration. The flag values indicate:

- 0 No deposition of this type is simulated
- 1 Deposition of this type is input as time series TRADFX or TRADCN
- >0 Deposition of this type is input in the MONTH-DATA table with the corresponding table ID number. (Refer to Section 4.11 for details)

4.4(1).13.3 Table-type TRAC-TOPSTOR -- Initial quantity of tracer in topsoil storages

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
TRAC-TOPSTOR
<-range><-----trac-topstor----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END TRAC-TOPSTOR
```

Example

```
TRAC-TOPSTOR
  <PLS >Initial storage of chloride in topsoil (kg/ha)  ***
  # - #      STRSU      UTRSU      ITRSU      ***
  1              200.
END TRAC-TOPSTOR
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<trac-topstor>	STRSU,UTRSU,	3F10.0	0.0	0.0	none	lb/ac	Engl
	ITRSU		0.0	0.0	none	kg/ha	Metric

Explanation

This table specifies the initial storage of tracer (conservative) in the surface, upper principal, and upper transitory (interflow) storages.

4.4(1).13.4 Table-type TRAC-SUBSTOR -- Initial quantity of tracer in lower and active groundwater storages

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
TRAC-SUBSTOR
<-range><---trac-substor--->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END TRAC-SUBSTOR
```

Example

```
TRAC-SUBSTOR
  <PLS >Initial storage of chloride in subsoil layers (lb/ac) ***
  # - #      LTRSU      ATRSU                               ***
  1          300.      500.
END TRAC-SUBSTOR
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<trac-substor>	LTRSU,ATRSU	2F10.0	0.0	0.0	none	lb/ac	Engl
			0.0	0.0	none	kg/ha	Metric

Explanation

This table specifies the initial storage of conservative (tracer) material in the lower and active groundwater layers.

4.4(2) IMPLND Block

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

IMPLND

```
  General input
[section ATEMP input]
[section SNOW input]
[section IWATER input]
[section SOLIDS input]
[section IWTGAS input]
[section IQUAL input]
```

END IMPLND

Explanation

This block contains the data which are domestic to all the Impervious Land-segments in the RUN. The General input is always relevant: other input is only required if the module section concerned is active.

4.4(2).1 IMPLND BLOCK -- General input

```
*****
      1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789 012345678901234567890
*****
```

Layout

```
  Table-type ACTIVITY
[Table-type PRINT-INFO]
  Table-type GEN-INFO
```

Explanation

The exact format of each of the tables mentioned above is detailed in the documentation which follows.

Tables enclosed in brackets [] above are not always required; for example, because all the values can be defaulted.

4.4(2).1.1 Table-type ACTIVITY -- Active Sections Vector

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
ACTIVITY
<-range><-----a-s-vector----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END ACTIVITY
```

```
*****
Example
*****
```

```
ACTIVITY
  <ILS >           Active Sections  ***
  # - # ATMP SNOW IWAT  SLD  IWG IQAL  ***
  1   7   1   1   1
  9       0   0   0   1
END ACTIVITY
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<a-s-vector>	AIRTFG, SNOWFG, IWATFG, SLDFG, IWGFG, IQALFG	6I5	0	0	1

Explanation

The IMPLND module is divided into 6 sections. The values supplied in this table specify which sections are active and which are not, for each operation involving the IMPLND module. A value of 0 means inactive and 1 means active. Any meaningful subset of sections may be active.

4.4(2).1.2 Table-type PRINT-INFO -- Printout information for IMPLND

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
PRINT-INFO
<-range><-----print-flags-----><piv><pyr>
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PRINT-INFO
```

```
*****
Example
*****
```

```
PRINT-INFO
<ILS > ***** Print-flags ***** PIVL  PYR
# - # ATMP SNOW IWAT  SLD  IWG IQAL *****
1   7   2   4   6                10  12
END PRINT-INFO
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<print-flags>	PFLAG(6)	6I5	4	2	6
<piv>	PIVL	I5	1	1	1440
<pyr>	PYREND	I5	9	1	12

Explanation

HSPF permits the user to vary the printout level (maximum frequency) for the various active sections of an operation. The meaning of each permissible value for PFLAG() is:

- 2 means every PIVL intervals
- 3 means every day
- 4 means every month
- 5 means every year
- 6 means never

In the example above, output from Impervious Land-segments 1 thru 7 will occur as follows:

Section	Maximum frequency
ATEMP	10 intervals
SNOW	month
IWATER	never
SOLIDS	--
thru	month (defaulted)
IQUAL	--

A value need only be supplied for PIVL if one or more sections have a printout level of 2. For those sections, printout will occur every PIVL intervals (that is, every $PDEL T = PIVL * DEL T$ minutes). PIVL must be chosen such that there are an integer number of PDEL T periods in a day.

HSPF will automatically provide printed output at all standard intervals greater than the specified minimum interval. In the above example, output for section ATEMP will be printed at the end of each 10 intervals, day, month and year.

PYREND is the calendar month which will terminate the year for printout purposes. Thus, the annual summary can reflect the situation over the past water year or the past calendar year, etc.

4.4(2).1.3 Table-type GEN-INFO -- Other general information for IMPLND

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
GEN-INFO
<-range><---ILS-id----->      <unitsyst><-printu->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END GEN-INFO
```

Example

```
GEN-INFO
  <ILS >      Name                UnitSysts  Printout  ***
  # - #                t-series  Engl Metr  ***
                        in  out          ***
  1      Chicago loop
  2      Astrodome                1          23
END GEN-INFO
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<ILS-id>	LSID(5)	5A4	none	none	none
<unit-syst>	IUNITS,OUNITS	2I5	1	1	2
<printu>	PUNIT(2)	2I5	0	0	99

Explanation

Any string of up to 20 characters may be supplied as the identifier for an IMPLND.

The values supplied for IUNITS and OUNITS indicate the system of units for input and output time series, respectively. 1 means English units, 2 means Metric units.

IMPLND -- General Input

Note: All operations in the run must use the same units system for data in the UCI file; therefore, this system of units is specified by EMFG in the GLOBAL block.

The values supplied for PUNIT(*) indicate the destinations (files) of printout in English and metric units, respectively. A value of 0 means no printout is required in that unit system. A non-zero value means printout is required in that system and is the unit number of the file to which printout is to be written. The unit number is associated with a filename in the FILES BLOCK.

Note that printout for each Impervious Land Segment can be obtained in either the English or Metric systems, or both (irrespective of the system used to supply the inputs).

4.4(2).2 IMPLND BLOCK -- SECTION ATEMP INPUT

Section ATEMP is common to the PERLND and IMPLND modules. See Section 4.4(1).2 for documentation.

4.4(2).3 IMPLND BLOCK -- SECTION SNOW INPUT

Section SNOW is common to the PERLND and IMPLND modules. See Section 4.4(1).3 for documentation.

4.4(2).4 IMPLND BLOCK -- Section IWATER input

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789 0123456789012345678901234567890
*****
```

Layout

```
[Table-type IWAT-PARM1 ]
  Table-type IWAT-PARM2
[Table-type IWAT-PARM3 ]
```

```
[Table-type MON-RETN  ] | only required if the relevant quantity
[Table-type MON-MANNING] | varies through the year
```

```
[Table-type IWAT-STATE1]
```

Explanation

The exact format of each of the tables mentioned above is detailed in the documentation which follows.

Tables enclosed in brackets [] above are not always required; for example, because all the values can be defaulted.

4.4(2).4.1 Table-type IWAT-PARM1 -- First group of IWATER parameters (flags)

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
      IWAT-PARM1
      <-range><-----iwatparm1----->
      . . . . .
      (repeats until all operations of this type are covered)
      . . . . .
      END IWAT-PARM1
```

```
*****
Example
*****
```

```
      IWAT-PARM1
      <ILS >           Flags           ***
      # - # CSNO RTOP  VRS  VNN RTLI    ***
      1   7   1   1
      END IWAT-PARM1
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<iwatparm1>	CSNOFG,RTOPFG, VRSFG,VNNFG, RTLIFG	5I5	0	0	1

Explanation

If CSNOFG is 1, section IWATER assumes that snow accumulation and melt is being considered. It will, therefore, expect that the time series produced by section SNOW are available, either internally (produced in this RUN) or from external sources (produced in a previous RUN). If CSNOFG is 0, no such time series are expected. See the functional description for further information.

RTOPFG is a flag that selects the algorithm for computing overland flow. Two optional methods are provided. If RTOPFG is 1, routing of overland flow is done in the same way as in the NPS Model. A value of 0 results in a different algorithm. (See the functional description for details).

The flags beginning with "V" indicate whether or not certain parameters will be assumed to vary through the year: 1 means they do vary, 0 means they do not. The quantities concerned are:

VRSFG	retention storage capacity
VNNFG	Manning's n for the overland flow plane

If either of these flags are on, monthly values for the parameter concerned must be supplied (see Table-types MON-RETN and MON-MANNING).

If RTLIFG is 1, any lateral surface inflow to the ILS will be subject to retention storage; if it is 0, lateral inflow is not subject to retention storage.

4.4(2).4.2 Table-type IWAT-PARM2 -- Second group of IWATER parameters

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
IWAT-PARM2
<-range><-----iwatparm2----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END IWAT-PARM2
```

Example

```
IWAT-PARM2
  <ILS >          ***
  # - #          LSUR      SLSUR      NSUR      RETSC      ***
  1   7          400.      .001
END IWAT-PARM2
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<iwatparm2>	LSUR	F10.0	none	1.0	none	ft	Engl
			none	0.3	none	m	Metric
	SLSUR	F10.0	none	.000001	10.	none	Both
	NSUR	F10.0	0.1	0.001	1.0		Both
	RETSC	F10.0	0.0	0.0	10.0	in	Engl
0.0			0.0	250.	mm	Metric	

Explanation

LSUR is the length of the assumed overland flow plane, and SLSUR is the slope.

NSUR is Manning's n for the overland flow plane.

RETSC is the retention (interception) storage capacity of the surface.

4.4(2).4.3 Table-type IWAT-PARM3 -- Third group of IWATER parameters

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
IWAT-PARM3
<-range><----iwatparm3----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END IWAT-PARM3
```

Example

```
IWAT-PARM3
<ILS >***
# - #*** PETMAX      PETMIN
1   7
9           39        33
END IWAT-PARM3
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<iwatparm3>	PETMAX	F10.0	40.	none	none	degF	Engl
			4.4	none	none	degC	Metric
	PETMIN	F10.0	35.	none	none	degF	Engl
			1.7	none	none	degC	Metric

Explanation

PETMAX is the air temperature below which E-T will arbitrarily be reduced below the value obtained from the input time series.

PETMIN is the temperature below which E-T will be zero regardless of the value in the input time series. These values are only used if snow is being considered (i.e., CSNOFG= 1 in Table-type IWAT-PARM1).

4.4(2).4.4 Table-type MON-RETN -- Monthly retention storage capacity

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MON-RETN
<-range><-----mon-retn----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-RETN
```

```
*****
Example
*****
```

```
MON-RETN
  <ILS > Retention storage capacity at start of each month      ***
  # - #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC***
  1   7  .02  .03  .03  .04  .05  .08  .12  .15  .12  .05  .03  .01
END MON-RETN
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-retn>	RETSCM(12)	12F5.0	0.0	0.0	10.	in	Engl
			0.0	0.0	250.	mm	Metric

Explanation

This table is only required if VRSFG = 1 in Table-type IWAT-PARML.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(2).4.5 Table-type MON-MANNING -- Monthly Manning's n values

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

MON-MANNING

<-range><-----mon-Manning----->

.

(repeats until all operations of this type are covered)

.

END MON-MANNING

Example

MON-MANNING

<ILS > Manning's n at start of each month ***

# - #	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	***
1 7	.23	.34	.34	.35	.28	.35	.37	.35	.28	.29	.30	.30	

END MON-MANNING

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-Manning>	NSURM(12)	12F5.0	0.1	.001	1.0	complex	Both

Explanation

This table is only required if VNNFG = 1 in Table-type IWAT-PARM1.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(2).4.6 Table-type IWAT-STATE1 -- IWATER initial state variables

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
IWAT-STATE1
<-range><----iwat-statel--->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END IWAT-STATE1
```

Example

```
IWAT-STATE1
<ILS > IWATER state variables***
# - #***   RETS   SURS
1   7     0.05   0.10
END IWAT-STATE1
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<iwat-statel>	RETS	2F10.0	.001	.001	100	inches	Engl
			.025	.025	2500	mm	Metric
	SURS		.001	.001	100	inches	Engl
			.025	.025	2500	mm	Metric

Explanation

This table is used to specify the initial water storages.

RETS is the initial retention storage.

SURS is the initial surface (overland flow) storage.

4.4(2).5 IMPLND BLOCK -- Section SOLIDS input

```

*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****

```

- [Table-type SLD-PARM1]
- Table-type SLD-PARM2
- [Table-type MON-SACCUM]
- [Table-type MON-REMOV]
- [Table-type SLD-STOR]

```

*****

```

Explanation

The exact format of each of the tables mentioned above is detailed in the documentation which follows.

Tables enclosed in brackets [] above are not always required; for example, because all the values can be defaulted.

4.4(2).5.1 Table-type SLD-PARM1 -- First group of SOLIDS parameters

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
SLD-PARM1
<-range><--sld-parm1-->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END SLD-PARM1
```

Example

```
SLD-PARM1
  <ILS >          ***
  # - # VASD VRSD SDOP***
  1   7   0   1   0
END SLD-PARM1
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<sld-parm1>	VASDFG	3I5	0	0	1
	VRSDFG		0	0	1
	SDOPFG		0	0	1

Explanation

If VASDFG is 1, the accumulation rate of solids is allowed to vary throughout the year and Table-type MON-SACCUM is expected. If the flag is zero, the accumulation rate is constant, and is specified in Table-type SLD-PARM2. The corresponding flag for the unit removal rate is VRSDFG.

SDOPFG is a flag that determines the algorithm used to simulate removal of sediment from the land surface. If SDOPFG is 1, sediment removal will be simulated with the algorithm used in the NPS model. If it is 0, a different algorithm will be used. (See the functional description for details).

4.4(2).5.2 Table-type SLD-PARM2 -- Second group of SOLIDS parameters

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
SLD-PARM2
<-range><-----sld-parm2----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END SLD-PARM2
```

Example

```
SLD-PARM2
<ILS >***
# - #      KEIM      JEIM      ACCSDP      REMSDP***
1   7      0.08     1.90     0.01     0.5
END SLD-PARM2
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<sld-parm2>	KEIM	4F10.0	0.0	0.0	none	complex	Both
	JEIM		none	none	none	complex	Both
	ACCSDP		0.0	0.0	none	tons/ac/day	Engl
	REMSDP		0.0	0.0	1.0	tonnes/ha/day	Metric

Explanation

KEIM is the coefficient in the solids washoff equation.

JEIM is the exponent in the solids washoff equation.

ACCSDP is the rate at which solids accumulate on the land surface.

REMSDP is the fraction of solids storage which is removed each day when there is no runoff, for example, because of street sweeping.

If monthly values for the accumulation and unit removal rates are being supplied, values supplied for these variables in this table are not used by the program.

4.4(2).5.3 Table-type MON-SACCUM -- Monthly solids accumulation rates

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

MON-SACCUM

<-range><-----mon-accum----->

.

(repeats until all operations of this type are covered)

.

END MON-SACCUM

Example

MON-SACCUM

<ILS > Monthly values for solids accumulation (tonnes/ha.day) ***

#	-	#	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1		7	0.0	.12	.12	.24	.24	.56	.67	.56	.34	.34	.23	.12

END MON-SACCUM

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-accum>	ACCSDM(12)	12F5.0	0.0	0.0	none	tons/ac/day	Engl
			0.0	0.0	none	tonnes/ha/day	Metr

Explanation

This table is only required if VASDFG = 1 in Table-type SLD-PARM1.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(2).5.4 Table-type MON-REMOV -- Monthly solids unit removal rates

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MON-REMOV
<-range><-----mon-remov----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-REMOV
```

```
*****
Example
*****
```

```
MON-REMOV
  <ILS > Monthly solids unit removal rate          ***
  # - #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC***
  1   7  .05  .05  .07  .15  .15  .20  .20  .20  .20  .10  .05  .05
END MON-REMOV
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-remov>	REMSDM(12)	12F5.0	0.0	0.0	1.0	/day	Both

Explanation

This table is only required if VRSDFG = 1 in Table-type SLD-PARM1.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(2).5.5 Table-type SLD-STOR -- Initial solids storage

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
SLD-STOR
<-range><sld-stor>
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END SLD-STOR
```

```
*****
Example
*****
```

```
SLD-STOR
  <ILS > Solids storage (tons/acre) ***
  # - #           ***
  1   7           0.2
END SLD-STOR
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<sld-stor>	SLDS	F10.0	0.0 0.0	0.0 0.0	none none	tons/ac tonnes/ha	Engl Metric

Explanation

SLDS is the initial storage of solids on the impervious surface.

4.4(2).6 IMPLND BLOCK -- Section IWTGAS input

```

*****
      1      2      3      4      5      6      7      8
123456789012345678901234567890123456789012345678901234567890
*****

```

Layout

```

[Table-type IWT-PARM1]
[Table-type IWT-PARM2]           Tables in brackets [] are not
[Table-type MON-AWTF]           always required
[Table-type MON-BWTF]
[Table-type IWT-INIT]

```

Explanation

The exact format of each of the tables mentioned above is detailed in the documentation which follows.

4.4(2).6.1 Table-type IWT-PARM1 -- Flags for section IWTGAS

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
IWT-PARM1
<-range><iwtparml>
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END IWT-PARM1
```

Example

```
IWT-PARM1
  <ILS >  Flags for section IWTGAS***
  # - # WTFV CSNO          ***
  1   7   0   0
END IWT-PARM1
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<iwtparml>	WTFVFG	2I5	0	0	1
	CSNOFG		0	0	1

Explanation

WTFVFG indicates whether or not the water temperature regression parameters (AWTF and BWTF) are allowed to vary throughout the year, and thus, whether or not Table-types MON-AWTF and MON-BWTF are expected.

If CSNOFG=1, the effects of snow accumulation and melt are being considered; if it is zero, they are not. If section IWATER is active, the value of CSNOFG supplied here is ignored because it was first supplied in the input for that section (Table-type IWAT-PARM1).

4.4(2).6.2 Table-type IWT-PARM2 -- Second group of IWTGAS parameters

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
IWT-PARM2
<-range><-----iwt-parm2----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END IWT-PARM2
```

Example

```
IWT-PARM2
<ILS > Second group of IWTGAS parms***
# - #      ELEV      AWTF      BWTF***
1   7      1281.     40.0     0.8
END IWT-PARM2
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<iwt-parm2>	ELEV	3F10.0	0.0	-1000.	30000.	ft	Engl
			0.0	-300.	9100.	m	Metric
	AWTF		32.	0.0	100.	DegF	Engl
			0.0	-18.	38.	DegC	Metr
	BWTF		1.0	0.001	2.0	DegF/F	Engl
			1.0	0.001	2.0	DegC/C	Metr

Explanation

ELEV is the elevation of the ILS above sea level; it is used to adjust saturation concentrations of dissolved gases in surface outflow.

AWTF is the surface water temperature when the air temperature is 32 deg F (0 deg C). It is the intercept of the surface water temperature regression equation.

BWTF is the slope of the surface water temperature regression equation.

4.4(2).6.3 Table-type MON-AWTF -- Monthly values for AWTF

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MON-AWTF
<-range><-----mon-awtf----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-AWTF
```

```
*****
Example
*****
```

```
MON-AWTF
  <ILS > Value of AWTF at start of each month (deg F)          ***
  # - #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC***
  1   7  37.  38.  39.  40.  41.  42.  43.  44.  45.  44.  41.  40.
END MON-AWTF
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-awtf>	AWTFM(12)	12F5.0	32. 0.	0. -18.	100. 38.	deg F deg C	Engl Metric

Explanation

This table is only required if WTFVFG = 1 in Table-type IWT-PARML.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(2).6.4 Table-type MON-BWTF -- Monthly values for BWTF

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MON-BWTF
<-range><-----mon-bwtf----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-BWTF
```

```
*****
Example
*****
```

```
MON-BWTF
<ILS > Value of BWTF at start of each month (deg F/F)          ***
# - #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC***
1   7   .3   .3   .3   .4   .4   .5   .5   .5   .4   .4   .4   .3
END MON-BWTF
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mon-bwtf>	BWTFM(12)	12F5.0	1.0	0.001	2.0	deg F/F	Engl
			1.0	0.001	2.0	deg C/C	Metric

Explanation

This table is only required if WTFVFG = 1 in Table-type IWT-PARML.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(2).6.5 Table-type IWT-INIT -- Initial conditions for section IWTGAS

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
IWT-INIT
<-range><-----iwt-init----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END IWT-INIT
```

Example

```
IWT-INIT
  <ILS >      SOTMP      SODOX      SOCO2***
  # - #       DegC      mg/l      mg C/l***
  1   7       16.
END IWT-INIT
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<iwt-init>	SOTMP	3F10.0	60.0	32.	100.	Deg F	Engl
			16.0	.01	38.0	Deg C	Metric
	SODOX		0.0	0.0	20.0	mg/l	Both
	SOCO2		0.0	0.0	1.0	mg C/l	Both

Explanation

These are the initial values for the temperature, dissolved oxygen concentration, and CO2 concentration of the surface runoff. The values given in this table do not affect anything in the simulation beyond the start of the first interval of the run. Therefore, in most simulations, this table can be omitted.

4.4(2).7 IMPLND BLOCK -- Section IQUAL input

```

*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****

```

```

[Table-type NQUALS]
[Table-type IQL-AD-FLAGS]

Table-type QUAL-PROPS      |
[Table-type QUAL-INPUT]   |
[Table-type MON-POTFW]    | repeat this group of tables for each
[Table-type MON-ACCUM]    | quality constituent
[Table-type MON-SQOLIM]   |

```

Explanation

The exact format of each of the tables mentioned above is detailed in the documentation which follows or in the documentation for the PERLND module.

Tables enclosed in brackets [] are not always required; for example, because all the values can be defaulted.

4.4(2).7.1 Table-type NQUALS -- Total number of quality constituents simulated

This table is identical to the corresponding table for the PERLND module. See Section 4.4(1).8.1 (Module Section PQUAL) for documentation.

4.4(2).7.2 Table-type IQL-AD-FLAGS -- Atmospheric deposition flags for IQUAL

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

IQL-AD-FLAGS

```
<-range> <f><c> <f><c> <f><c> <f><c> <f><c> <f><c> <f><c> <f><c> <f><c> <f><c>
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END IQL-AD-FLAGS
```

Example

IQL-AD-FLAGS

```
<ILS > Atmospheric deposition flags ***
*** QUAL1 QUAL2 QUAL3 QUAL4 QUAL5 QUAL6 QUAL7 QUAL8 QUAL9 QAL10
#*** # <F><C> <F><C> <F><C> <F><C> <F><C> <F><C> <F><C> <F><C> <F><C> <F><C>
1 7 -1 10 -1 -1 11 12 13 -1 0 0 0 11 0 -1 0 0 -1 0
END IQL-AD-FLAGS
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<f><c>	IQADFG(*)	(1X,2I3)	0	-1	none

Explanation

IQADFG is an array of flags indicating the source of atmospheric deposition data for QUALs. Each QUAL has two flags. The first is for dry or total deposition flux, and the second is for wet deposition concentration. The flag values indicate:

- 0 No deposition of this type is simulated
- 1 Deposition of this type is input as time series IQADFX or IQADCN
- >0 Deposition of this type is input in the MONTH-DATA table with the corresponding table ID number. (Refer to Section 4.11 for details)

Note: atmospheric deposition can only be specified for QUALOF's; it is an error to specify a non-zero flag value for a non-QUALOF.

4.4(2).7.3 Table-type QUAL-PROPS -- Identifiers and flags for a quality constituent

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
QUAL-PROPS
<-range><-qualid--->      <qt><-----flags----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END QUAL-PROPS
```

Example

```
QUAL-PROPS
  <ILS >   Identifiers and Flags          ***
  # - #    QUALID      QTID  QSD VPFW  QSO  VQO***
  1   7     BOD        kg    0   0    1   1
END QUAL-PROPS
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<qualid>	QUALID	3A4	none	none	none
<qt>	QTYID	A4	none	none	none
<flags>	QSDFG	4I5	0	0	1
	VPFWFG		0	0	1
	QSOFG		0	0	1
	VQOFG		0	0	1

Explanation

QUALID is a string of up to 10 characters which identifies the quality constituent.

QTYID is a string of up to 4 characters which identifies the units associated with this constituent (e.g., kg, # (for coliforms)). These are the units referred to as "qty" in subsequent tables (e.g., Table-type QUAL-INPUT).

If QSDFG is 1 then:

1. This constituent is a QUALSD (sediment associated).
2. If VPFWFG is 1, the washoff potency factor may vary throughout the year. Table-type MON-POTFW is expected.

If QSDFG is 1 then:

1. This constituent is a QUALOF (directly associated with overland flow).
2. If VQOFG is 1, the rate of accumulation and the limiting storage of QUALOF may vary throughout the year. Table-types MON-ACCUM and MON-SQOLIM are expected.

4.4(2).7.4 Table-type QUAL-INPUT -- Surface storage of qual and nonseasonal parameters

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
QUAL-INPUT
<-range><-----qual-input----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END QUAL-INPUT
```

Example

```
QUAL-INPUT
<ILS > Storage on surface and nonseasonal parameters***
# - #      SQO   POTFW   ACQOP   SQOLIM   WSQOP      ***
1   7      1.21   .172    0.02     2.0       1.70
END QUAL-INPUT
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<qual-input>	SQO	5F8.0	0.0	0.0	none	qty/ac	Engl
			0.0	0.0	none	qty/ha	Metric
	POTFW		0.0	0.0	none	qty/ton	Engl
			0.0	0.0	none	qty/tonne	Metric
	ACQOP		0.0	0.0	none	qty/ac/day	Engl
			0.0	0.0	none	qty/ha/day	Metric
	SQOLIM		0.000001	0.000001	none	qty/ac	Engl
			0.000002	0.000002	none	qty/ha	Metric
	WSQOP		1.64	0.01	none	in/hr	Engl
			41.7	0.25	none	mm/hr	Metric

Explanation

The following variable is relevant only if the constituent is a QUALSD:

1. POTFW, the washoff potency factor.

POTFW (washoff potency factor) is the ratio of constituent yield to sediment outflow.

The following variables are applicable only if the constituent is a QUALOF:

1. SQO, the initial storage of QUALOF on the surface of the ILS.
2. ACQOP, the rate of accumulation of QUALOF on the surface.
3. SQOLIM, the maximum storage of QUALOF on the surface.
4. WSQOP, the rate of surface runoff that will remove 90 percent of stored QUALOF per hour.

If monthly values are being supplied for any of these quantities, the value in this table is not relevant; instead, the system expects and uses values supplied in the corresponding monthly table (Table-types MON-POTFW, MON-ACCUM, MON-SQOLIM).

4.4(2).7.5 Table-type MON-POTFW -- Monthly washoff potency factor

This table is identical to the corresponding table in the PERLND module. See Section 4.4(1).8 for documentation.

4.4(2).7.6 Table-type MON-ACCUM -- Monthly accumulation rates of QUALOF

This table is identical to the corresponding table in the PERLND module. See Section 4.4(1).8 for documentation.

4.4(2).7.7 Table-type MON-SQOLIM -- Monthly limiting storage of QUALOF

This table is identical to the corresponding table in the PERLND module. See Section 4.4(1).8 for documentation.

4.4(3) RCHRES Block

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
RCHRES
  General input
  [section HYDR input]
  [section ADCALC input]
  [section CONS input]
  [section HTRCH input]
  [section SEDTRN input]
  [section GQUAL input]
  [input for RQUAL sections]
  [section OXRX input]
  [section NUTRX input]
  [section PLANK input]
  [section PHCARB input]
END RCHRES
*****
```

Explanation

This block contains the data that are domestic to all RCHRES processing units in the RUN. The general input is always relevant; other input is only required if the module section concerned is active.

4.4(3).1 RCHRES BLOCK -- General input

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
  Table-type ACTIVITY
  [Table-type PRINT-INFO]
  Table-type GEN-INFO
*****
```

Explanation

The exact format of each of the tables mentioned above is detailed in the documentation which follows. Tables enclosed in brackets [], above, are not always required; for example, because all values can be defaulted.

4.4(3).1.1 Table-type ACTIVITY -- Active Sections Vector

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout:

```
ACTIVITY
<-range><-----a-s-vector----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END ACTIVITY
```

Example:

```
ACTIVITY
RCHRES Active sections***
# - # HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG ***
1 7 1 1 1 1 1 1 1 0 0 0
END ACTIVITY
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<a-s-vector>	HYDRFG,ADFG,CONSGF,HTFG,SEDFG GQALFG,OXFG,NUTFG,PLKFG,PHFG	10I5	0	0	1

Explanation

The RCHRES module is divided into eleven sections. The values supplied in this table specify which sections are active and which are not, for each operation involving the RCHRES module. A value of 0 means inactive and 1 means active (see below). Any meaningful subset of sections may be active, with the following provisos: 1) Section ADCALC must be active if any "quality" sections (CONS through PHCARB) are active. 2) If any section in the RQUAL group (Section OXRX through PHCARB) is active, all preceding RQUAL sections must also be active.

4.4(3).1.2 Table-type PRINT-INFO -- Printout information for RCHRES

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
PRINT-INFO
<-range><-----print-flags-----><piv><pyr>
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PRINT-INFO
```

Example

```
PRINT-INFO
RCHRES Printout level flags***
# - # HYDR ADCA CONS HEAT SED GQL OXRX NUTR PLNK PHCB PIVL PYR***
1 7 2 2 2 5 5 2 3 3 10 12
END PRINT-INFO
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<print-flags>	PFLAG(10)	10I5	4	2	6
<pivl>	PIVL	I5	1	1	1440
<pyr>	PYREND	I5	9	1	12

Explanation

HSPF permits the user to vary the printout level (maximum frequency) for the various active sections of an operation. The meaning of each permissible value for PFLAG(*) is:

- 2 means every PIVL intervals
- 3 means every day
- 4 means every month
- 5 means every year
- 6 means never

In the example above, output from RCHRESs 1 through 7 will occur as follows:

Section Maximum frequency

HYDR	10 intervals
ADCALC	10 intervals
CONS	10 intervals
HTRCH	year
SEDTRN	year
GQUAL	10 intervals
OXRX	day
NUTRX	day
PLANK	month (defaulted)
PHCARB	month (defaulted)

A value need only be supplied for PIVL if one or more sections have a printout level of 2. For those sections, printout will occur every PIVL intervals (that is, every $PDEL T = PIVL * DEL T$ minutes. PIVL must be chosen such that there are an integer number of PDEL T periods in a day.

HSPF will automatically provide printed output at all standard intervals greater than the specified minimum interval. In the above example, output for section NUTRX will be printed at the end of each day, month, and year.

PYREND is the calendar month which will terminate the year for printout purposes. Thus, the annual summary can reflect the situation over the past water year or the past calendar year, etc.

4.4(3).1.3 Table-type GEN-INFO -- Other general information for RCHRES

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
GEN-INFO
<-range><-----rchid-----><nex>      <unitsyst><-printu-><lak>
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END GEN-INFO
```

Example

```
GEN-INFO
RCHRES      Name      Nexits      UnitSysts  Printout      ***
# - #              t-series  Engl Metr  LKFG          ***
              in  out
4      East River-mile 4      2      1    1    23      0
END GEN-INFO
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<rchid>	RCHID(5)	5A4	none	none	none
<nex>	NEXITS	I5	1	1	5
<unit-syst>	IUNITS	5X,I5	1	1	2
	OUNITS	I5	1	1	2
<printu>	PUNIT(2)	2I5	0	0	99
<lak>	LKFG	I5	0	0	1

Explanation

Any string of up to 20 characters may be supplied as the identifier for a RCHRES.

NEXITS is the number of exits from the RCHRES. A maximum of 5 exits can be handled.

The values supplied for IUNITS and OUNITS indicate the system of units for input and output time series, respectively. 1 means English units, 2 means Metric units.

Note: All operations in the run must use the same units system for data in the UCI file; therefore, this system of units is specified by EMFG in the GLOBAL block.

The values supplied for PUNIT(*) indicate the destinations (files) of printout in English and metric units, respectively. A value of 0 means no printout is required in that unit system. A non-zero value means printout is required in that system and is the unit number of the file to which printout is to be written. The unit number is associated with a filename in the FILES BLOCK.

LKFG indicates whether the RCHRES is a lake (1) or a stream/river (0). This flag affects the method of calculating bed shear stress (in Section HYDR) and the reaeration coefficient (Section OXR).

4.4(3).2 RCHRES BLOCK -- Section HYDR input

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
[Table-type HYDR-PARM1]
  Table-type HYDR-PARM2
[Table-type MON-CONVF]      ---  if VCONFIG = 1 (in Table-type HYDR-PARM1)
[Table-type HYDR-INIT]
                                ---
[Table-type HYDR-CATEGORY]  |
[Table-type HYDR-CINIT]     |
[Table-type HYDR-CPREC]     |   if "categories" are being simulated
[Table-type HYDR-CEVAP]     |
[Table-type HYDR-CFVOL]     |
[Table-type HYDR-CDEMAND]   |
                                ---
```

Explanation

The exact format of each of the tables mentioned above is detailed in the documentation which follows.

Tables enclosed in brackets [], above, are not always required.

4.4(3).2.1 Table-type HYDR-PARM1 -- Flags for HYDR section

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
HYDR-PARM1
<-range> <v><1><2><3> <---odfvfg----> <---odgtfg----> <----funct---->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END HYDR-PARM1
```

```
*****
Example
*****
```

```
HYDR-PARM1
RCHRES  Flags for HYDR section***
# - #  VC A1 A2 A3  ODFVFG for each *** ODGTFG for each  FUNCT for each
      FG FG FG FG  possible  exit *** possible  exit  possible  exit
  1   7  0  1  1  1   0  0  0  0  1       1  1  1  1  1       3  3  3  3  3
END HYDR-PARM1
```

```
*****
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<v>	VCONFIG	I3	0	0	1
<1>	AUX1FG	I3	0	0	1
<2>	AUX2FG	I3	0	0	1
<3>	AUX3FG	I3	0	0	1
<odfvfg>	ODFVFG(5)	5I3	0	-5	8
<odgtfg>	ODGTFG(5)	5I3	0	0	5
<funct>	FUNCT(5)	5I3	1	1	3

Explanation

A value of 1 for VCONFIG means that F(vol) (volume-dependent) outflow demand components are multiplied by a factor which is allowed to vary through the year. These monthly adjustment factors are input in Table-type MON-CONVF in this section.

A value of 1 for AUX1FG means a routine will be called to compute depth, stage, surface area, average depth, and top width, and values for these parameters will be reported in the printout. These are used in the calculation of precipitation and evaporation fluxes, and simulation of most water quality sections. A value of 0 suppresses the calculation and printout of this information.

A value of 1 for AUX2FG means average velocity and average cross sectional area will be calculated, and values for these parameters will be reported in the printout. These are used in the simulation of oxygen. A value of 0 suppresses the calculation/printout of this information. If AUX2FG is 1, AUX1FG must also be 1.

A value of 1 for AUX3FG means the shear velocity and bed shear stress will be calculated. These are used in the calculation of deposition and scour of sediment (inorganic and organic). AUX3FG may only be turned ON (=1) if AUX1FG and AUX2FG are also 1.

The value specified for ODFVFG(I) determines the F(vol) component of the outflow demand for exit I. A value of 0 means that the outflow demand does not have a volume dependent component. A value greater than 0 indicates the column number in the FTABLE which contains the F(vol) component. If the value specified for ODFVFG is less than 0, the absolute value indicates the element of array COLIND() which defines a pair of columns in the FTABLE which are used to evaluate the F(vol) component. Further explanation of this latter option is provided in the functional description of the HYDR section in Part E. A value of ODFVFG can be specified for each exit from a RCHRES. (Note: COLIND is specified as a time series.)

The value specified for ODGTFG(I) determines the G(t) (time-dependent) component of the outflow demand for exit I. A value of 0 means that the outflow demand does not have such a component. A value greater than 0 indicates the element (index) number of the array OUTDGT() (or array COTDGT() if Categories are being simulated) which contains the G(t) component. A value of ODGTFG can be specified for each exit from a RCHRES. (Note: OUTDGT and COTDGT are specified in the form of time series.)

FUNCT determines the function used to combine the components of an outflow demand. The possible values and their meanings are:

- 1 means use the smaller of F(vol) and G(t)
- 2 means use the larger of F(vol) and G(t)
- 3 means use the sum of F(vol) and G(t)

4.4(3).2.2 Table-type HYDR-PARM2 -- Parameters for HYDR section

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
HYDR-PARM2
<-range><-----hydr-parm2----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END HYDR-PARM2
```

```
*****
Example
*****
```

```
HYDR-PARM2
RCHRES ***
# - # DSN FTBN      LEN      DELTH      STCOR      KS***  DB50
1          17      2.7      120.      3.2      .5      0.2
2          100     2        1.5      60.      1.      .5      0.2
END HYDR-PARM2
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<hydr-parm2>	FTBDSN	F5.0	0	0	999	none	Both
	FTABNO	F5.0	none	1	999	none	Both
	LEN	F10.0	none	0.01	none	miles	Engl
			none	0.016	none	km	Metric
	DELTH	F10.0	0.0	0.0	none	ft	Engl
			0.0	0.0	none	m	Metric
	STCOR	F10.0	0.0	none	none	ft	Engl
			0.0	none	none	m	Metric
	KS	F10.0	0.0	0.0	.99	none	Both
			DB50	F10.0	.01	.0001	100.
		.25			.0025	2500.	mm

Explanation

FTBDSN is the WDM table data-set number containing the F-Table. If FTBDSN is greater than zero, the system searches the WDM file for the F-Table.

If FTBDSN = 0, FTABNO is the ID number for the F-Table (located in the FTABLES Block) which contains the geometric and hydraulic properties of the RCHRES. If FTBDSN > 0, FTABNO is the WDM table indicator specifying which table (within the WDM table data set given by FTBDSN) contains the F-Table.

LEN is the length of the RCHRES.

DELTH is the drop in water elevation from the upstream to the downstream extremities of the RCHRES. (It is used if section OXRX is active and reaeration is being computed using the Tsivoglou-Wallace equation; or if section SEDTRN is active and sandload transport capacity is being computed using either the Toffaleti or Colby method).

STCOR is the correction to the RCHRES depth to calculate stage.
(Depth + STCOR = Stage)

KS is the weighting factor for hydraulic routing. Choice of a realistic KS value is discussed in the functional description of the HYDR section in Part E.

DB50 is the median diameter of the bed sediment (assumed constant throughout the run). This value is used to:

1. Calculate the bed shear stress if the RCHRES is a lake.
2. Calculate the rate of sand transport if the Colby or Toffaleti methods are used.

Note: The value input for DB50 is also used in section SEDTRN as the sand particle diameter required for sandload computations.

4.4(3).2.3 Table-type MON-CONVF -- Monthly F(vol) adjustment factors

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MON-CONVF
<-range><-----mon-convf----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-CONVF
```

```
*****
Example
*****
```

```
MON-CONVF
RCHRES Monthly F(vol) adjustment factors***
# - # JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC***
1 7 .97 .89 .89 .91 .93 .93 .94 .95 .95 .98 .98 .97
END MON-CONVF
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<mon-convf>	CONVFM(12)	12F5.0	0.0	0.0	none

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(3).2.4 Table-type HYDR-INIT -- Initial conditions for HYDR section

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
HYDR-INIT
<-range><--vol--->  ct<-----colind----->  <-----outdgt----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END HYDR-INIT
```

```
*****
Example
*****
```

```
HYDR-INIT
      Initial conditions for HYDR section      ***
RCHRES      VOL  Cat  Initial value of COLIND ***  Initial value of OUTDGT
# - #      ac-ft      for each possible exit ***  for each possible exit
      <----->  <><---><---><---><---><---> *** <---><---><---><---><--->
1          12.050  UN          4.0          1.2          1.8
END HYDR-INIT
```

```
*****
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<vol>	VOL	F10.0	0.0	0.0	none	acre-ft	Engl
			0.0	0.0	none	Mm3	Metric
ct	CAT	A2	blank	none	none	none	Both
<colind>	COLIND(5)	5F5.0	4.0	4.0	8.0	none	Both
<outdgt>	OUTDGT(5)	5F5.0	0.0	0.0	none	ft3/s	Engl
			0.0	0.0	none	m3/s	Metric

Explanation

VOL is the initial volume of water in the RCHRES.

CAT may be either an integer or a category identifier (ID tag - defined in the CATEGORY block). If it is a tag, all initial volume belongs to that category. If CAT is an integer, the initial volume is divided according to Table-type HYDR-CINIT, where CAT entries are expected. If CAT is zero or blank, the initial volume is divided equally among all active categories. CAT is ignored if no CATEGORY block is present in the UCI file.

The value of COLIND(I) for exit I indicates the pair of columns in the FTABLE that are used to evaluate the initial value of the F(vol) (volume-dependent) component of outflow demand for the exit.

The array OUTDGT(I) specifies the initial value of the outflow demand for exit I, i.e., the G(t) (time-dependent) component. It is ignored if a Category block is present in the UCI file. Initial values for COTDGT are found in Table-type HYDR-CDEMAND.

A non-zero value of COLIND(I) is only meaningful if the outflow from exit I has an F(vol) component. Similarly, a non-zero value for OUTDGT(I) is only meaningful if the outflow from exit I has a G(t) component.

4.4(3).2.5 Table-type HYDR-CATEGORY -- Categories associated with outflows and other fluxes

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
HYDR-CATEGORY
      cpr  cev  cf1  cf2  cf3  cf4  cf5  ncgt
<range>  <>  <>  <>  <>  <>  <>  <>  <>
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END HYDR-CATEGORY
```

Example

```
HYDR-CATEGORY
  Categories specified for Outflows, Precipitation and Evaporation ***
RCHRES Prec Evap<-----FVOL----->NCOGT ***
# - #          1      2      3      4      5      ***
      <----><----><----><----><----><----><----><----> ***
1          UN      4          TX      2          3
END HYDR-CATEGORY
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
cpr	CPREC	A2	none	none	none	none	Both
cev	CEVAP	A2	none	none	none	none	Both
cf1-cf5	CFVOL(*)	A2	none	none	none	none	Both
ncgt	NCOGT	I5	0	0	20	none	Both

Explanation

CPREC, CEVAP, CFVOL(*)

This table may be used to specify the categories that are impacted by outflows and other fluxes. For the physical quantities precipitation, evaporation, and exit-specific F(vol) outflow, categories may be specified in one of two ways: 1) A single category is specified by its two-character tag, right-justified in the field. 2) If more than one category must be specified, then the number of categories is placed in the field. Then the multiple categories are fully specified in Table-types HYDR-CPREC, HYDR-CEVAP, and HYDR-CFVOL. If the field is blank or zero, or the table is omitted, then water is added to or subtracted from all categories in proportion to their current storage fraction.

NCOGT is the number of COTDGT time series specifying category-associated demands from the reach. These time series are assigned priorities and initial values in Table-type HYDR-CDEMAND. The time series are input in the time series blocks (e.g., EXT SOURCES). (See the Time Series Catalog for RCHRES).

4.4(3).2.6 Table-type HYDR-CINIT -- Allocation of initial volumes to categories

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
HYDR-CINIT
      ct cfrac  ct cfrac  ct cfrac  ct cfrac  ct cfrac  ct cfrac  ct cfrac
<-range> <><-----> <><-----> <><-----> <><-----> <><-----> <><-----> <><----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END HYDR-CINIT
```

Example

```
HYDR-CINIT
*** Initial Category Storage Fractions
*** RCHRES   c cfrac   c cfrac   c cfrac   c cfrac   c cfrac   c cfrac   c cfrac
*** # - # <><-----> <><-----> <><-----> <><-----> <><-----> <><-----> <><----->
      1      UN   0.2  TX   0.1  CU   0.1  FG   0.1  Z1   0.1  MI   0.05  A0   0.1
      1      BB   0.1  AA   0.05  BB   0.1
END HYDR-CINIT
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
ct	CINIT(*)	A2	none	none	none	none	Both
cfrac	CFRAC(*)	F6.0	0.0	0.0	1.0	none	Both

Explanation

This table is required when CAT in Table-type HYDR-INIT is a positive integer. CAT defines the number of pairs to be specified in this table; up to seven pairs can be specified on a line.

CINIT is a two-character category tag.

CFRAC is the fraction of the initial volume belonging to the corresponding category. The sum of all fractions must be 1.0; alternatively, if all CFRACS are blank or zero, the initial volume will be equally divided among all categories.

4.4(3).2.7 Table-type HYDR-CPREC -- Allocation of precipitation to categories

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
HYDR-CPREC
      ct cfrac  ct cfrac  ct cfrac  ct cfrac  ct cfrac  ct cfrac  ct cfrac
<-range> <><-----> <><-----> <><-----> <><-----> <><-----> <><-----> <><----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END HYDR-CPREC
```

```
*****
Example
*****
```

```
HYDR-CPREC
*** Category Fractions for precipitation
*** RCHRES  ct cfrac  ct cfrac  ct cfrac  ct cfrac  ct cfrac  ct cfrac  ct cfrac
*** # - #  <><-----> <><-----> <><-----> <><-----> <><-----> <><-----> <><----->
      1      UN   0.2  TX   0.1  CU   0.1  FG   0.1  Z1   0.1  MI   0.05  A0   0.1
      1      BB   0.1  AA   0.05  BB   0.1
END HYDR-CPREC
```

```
*****
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
ct	CPRECC(*)	A2	none	none	none	none	Both
cfrac	CPRECF(*)	F6.0	0.0	0.0	1.0	none	Both

Explanation

This table is required when CPREC in Table-type HYDR-CATEGORY is a positive integer. CPREC defines the number of pairs to be specified in this table; up to seven pairs can be specified on a line.

CPRECC is a two-character category tag.

CPRECF is the fraction of the precipitation which will be assigned to the corresponding category. The sum of all fractions must be 1.0; alternatively if all fractions are blank or zero, the precipitation will be equally divided among all the categories listed.

4.4(3).2.8 Table-type HYDR-CEVAP -- Allocation of evaporation to categories

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
HYDR-CEVAP
      ct pr frac  ct pr frac  ct pr frac  ct pr frac  ct pr frac
<-range> <><-><-----> <><-><-----> <><-><-----> <><-><-----> <><-><----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END HYDR-CEVAP
```

```
*****
Example
*****
```

```
HYDR-CEVAP
  Category Fractions and Priorities for Evaporation ***
RCHRES  ct pr frac  ct pr frac  ct pr frac  ct pr frac  ct pr frac ***
# - #  <><-><-----> <><-><-----> <><-><-----> <><-><-----> <><-><-----> ***
1      UN  1      CU  2  0.5  MI  2  0.5  TX  3  1.0  BB  4
1      AA  4
END HYDR-CEVAP
```

```
*****
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
ct	CEVAPC(*)	A2	none	none	none	none	Both
pr	CEVAPP(*)	I3	0	0	none	none	Both
cfrac	CEVAPF(*)	F6.0	0.0	0.0	1.0	none	Both

Explanation

This table is required when CEVAP in Table-type HYDR-CATEGORY is a positive integer. CEVAP defines the number of categories to be specified in this table; up to five categories can be specified on a line.

CEVAPC is a two-character category tag.

CEVAPP is an integer signifying the priority of the corresponding category when subtracting evaporation. Water is taken from the lowest priority categories first, then from the next-lowest priority categories, and so on. Categories with zero or undefined priority are taken last.

CEVAPF is the fraction of the evaporation which will be assigned to the corresponding category at a given priority level. The sum of all fractions at a priority level must be 1.0; alternatively, if they are all blank or zero, the evaporative loss will be equally divided among all the categories listed.

4.4(3).2.9 Table-type HYDR-CFVOL -- Allocation of volume-dependent outflow to categories

```
*****
      1      2      3      4      5      6      7      8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
HYDR-CFVOL
      ct x pr frac  ct x pr frac  ct x pr frac  ct x pr frac
<-range> <><><-><-----> <><><-><-----> <><><-><-----> <><><-><----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END HYDR-CFVOL
```

Example

```
HYDR-CFVOL
Category Fractions and Priorities for F(VOL) Outflow ***
RCHRES  ct x pr frac  ct x pr frac  ct x pr frac  ct x pr frac  ***
# - #  <><><-><-----> <><><-><-----> <><><-><-----> <><><-><-----> ***
1      UN 1 1      CU 1 2 0.5  MI 1 2 0.5  UN 2 1 0.5
1      BB 2 1 0.5  AA 2 2
END HYDR-CFVOL
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
ct	CFVOLC(*)	A2	none	none	none	none	Both
x	CFVOLE(*)	I2	0	0	5	none	Both
pr	CFVOLP(*)	I3	0	0	none	none	Both
cfrac	CFVOLF(*)	F6.0	0.0	0.0	1.0	none	Both

Explanation

This table is required when any member of CFVOL in Table-type HYDR-CATEGORY is a positive integer. The number of categories given in this table is the sum of the integer CFVOLs in HYDR-CATEGORY; up to four can be specified on a line.

CFVOLC is a two-character category tag.

CFVOLE is the number of the exit for which the category is being specified.

CFVOLP is an integer signifying the priority of the corresponding category when subtracting F(vol) (volume-dependent) outflow. Water is taken from the lowest priority categories first, then from the next-lowest priority categories, and so on. Categories with zero or undefined priority are taken last.

CFVOLF is the fraction of the F(vol) outflow which will be assigned to the corresponding category at a given priority level. The sum of all fractions at a priority level must sum to 1.0; alternatively, if all fractions for a priority level are blank or zero, the outflow demand will be equally divided among all of those categories.

4.4(3).2.10 Table-type HYDR-CDEMAND -- Allocation of time-dependent outflow to categories

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
HYDR-CDEMAND
      ct x  py  pm pd cotdgt  ct x  py  pm pd cotdgt
<-range> <><> <--> <> <> <----> <><> <--> <> <> <---->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END HYDR-CDEMAND
```

Example

```
HYDR-CDEMAND
Category Priorities and Initial Values for G(T) Demands ***
      ct x  Priority COTDGT  ct x  Priority COTDGT ***
RCHRES      (yyyy/mm/dd) (cfs)      (yyyy/mm/dd) (cfs) ***
# - #  <><> <--> <> <> <----> <><> <--> <> <> <---->
1      UN 1 1865      50.0  MI 1 1900/01      30.0
1      CU 2 1900/05/01  25.0
END HYDR-CDEMAND
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
ct	COGTC(*)	A2	none	none	none	none	Both
x	COGTE(*)	I2	0	0	5	none	Both
py	COGTPY(*)	I4	0	0	none	none	Both
pm	COGTPM(*)	I2	1	1	12	none	Both
pd	COGTPD(*)	I2	1	1	31	none	Both
cotdgt	COTDGT(*)	F6.0	0.0	0.0	none	none	Both

Explanation

This table is used in conjunction with the time-series COTDGT to specify outflow demands which are a function of time, and to allocate these outflow demands among categories. The table may be omitted when NCOGT in Table-type HYDR-CATEGORY is zero.

COGTC is a two-character category tag.

COGTE is the exit number for the demand being specified.

COGTPY (year), COGTPM (month), and COGTPD (day) signify the priority date of the corresponding demand timeseries. Multiple demands on the same category are satisfied from earliest to latest priority date. Unspecified (blank) priorities are satisfied last.

4.4(3).3 RCHRES BLOCK -- Section ADCALC input

```
*****
      1      2      3      4      5      6      7      8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

[Table-type ADCALC-DATA]

```
*****
```

Explanation

The exact format of this input is detailed below. Table ADCALC-DATA is not always required because its contents can be defaulted.

4.4(3).3.1 Table-type ADCALC-DATA -- Data for section ADCALC

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
ADCALC-DATA
<-range><---adcalc-data---->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END ADCALC-DATA
```

```
*****
Example
*****
```

```
ADCALC-DATA
RCHRES Data for section ADCALC ***
# - #      CRRAT      VOL      ***
5          1.7      324.
END ADCALC-DATA
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<adcalc-data>	CRRAT	2F10.0	1.5	1.0	none	none	Both
	VOL		0.0	0.0	none	acre-ft	Engl
			0.0	0.0	none	Mm3	Metric

Explanation

Section ADCALC must be active if any of the following sections are active.

CRRAT is the ratio of maximum velocity to mean velocity in the RCHRES cross-section under typical flow conditions.

VOL is the volume of water in the RCHRES at the start of the simulation. Input of this value is not necessary if section HYDR is active. (Note: Metric units are 10**6 m3).

4.4(3).4 RCHRES BLOCK -- Section CONS input

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
[Table-type NCONS]
[Table-type CONS-AD-FLAGS]
          ---
Table-type CONS-DATA  |   repeat for each conservative constituent
          ---
```

```
*****
```

Explanation

The exact formats of these tables are detailed below. Table-type NCONS is not required if only one conservative constituent is being simulated (default value).

4.4(3).4.1 Table-type NCONS -- Number of conservative constituents simulated

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
NCONS
<-range><ncn>
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END NCONS
```

Example

```
NCONS
  RCHRES      ***
  # - #NCONS  ***
  1   7   4
END NCONS
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<ncn>	NCONS	I5	1	1	10

Explanation

NCONS is the number of conservative constituents being simulated.

4.4(3).4.2 Table-type CONS-AD-FLAGS -- Atmospheric deposition flags for CONS

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

CONS-AD-FLAGS

```
<-range> <f><c> <f><c> <f><c> <f><c> <f><c> <f><c> <f><c> <f><c> <f><c> <f><c>
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END CONS-AD-FLAGS
```

Example

CONS-AD-FLAGS

```
RCHRES                      Atmospheric deposition flags ***
***   CONS1  CONS2  CONS3  CONS4  CONS5  CONS6  CONS7  CONS8  CONS9  QAL10
#*** # <F><C> <F><C> <F><C> <F><C> <F><C> <F><C> <F><C> <F><C> <F><C> <F><C>
1    7  -1 10  -1 -1  11 12  13 -1  10  0   0 11   0 -1   0  0          -1  0
END CONS-AD-FLAGS
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<f><c>	COADFG(*)	(1X,2I3)	0	-1	none

Explanation

COADFG is an array of flags indicating the source of atmospheric deposition data for the CONS section. Each CONS has two flags. The first is for dry or total deposition flux, and the second is for wet deposition concentration. The flag values indicate:

- 0 No deposition of this type is simulated
- 1 Deposition of this type is input as time series COADFX or COADCN
- >0 Deposition of this type is input in the MONTH-DATA table with the corresponding table ID number.

4.4(3).4.3 Table-type CONS-DATA -- Information about one conservative substance

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

CONS-DATA

<-range><----conid-----><---con--> <concid><--conv--> <qtyid->

.

(repeats until all operations of this type are covered)

.

END CONS-DATA

Example

CONS-DATA

RCHRES Data for conservative constituent No. 3 ***

# - #	Substance-id	Conc	ID	CONV	QTYID ***
1 7	Total Diss Solids	251.3	mg/l	1000.	kg

END CONS-DATA

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<conid>	CONID(5)	5A4	blank	none	none	none	Both
<con>	CON	F10.0	0.0	0.0	none	concid	Both
<concid>	CONCID	2A4	blank	none	none	none	Both
<conv>	CONV	F10.0	none	1.0E-30	none	see below	
<qtyid>	QTYID	2A4	blank	none	none	none	Both

Explanation

Any string of up to 20 characters may be supplied as the name of the conservative constituent (CONID).

CON is the initial concentration of the conservative constituent.

CONCID is a string of up to 8 characters which specifies the concentration units for the conservative constituent. If the constituent provides the alkalinity time series for section PHCARB, CONCID must be mg/l as CaCO₃.

QTYID is a string of up to 8 characters which specifies the units in which the total flow of constituent into, or out of, the RCHRES will be expressed, e.g., "kg".

CONV is the conversion factor from QTYID/VOL to the desired concentration units (CONCID): $CONC = CONV * (QTYID / VOL)$. If English units are being used (EMFG = 1 in the GLOBAL Block), VOL is in ft³; if Metric units are in effect (EMFG = 2), VOL is in m³. For example, if:

CONCID is mg/l

QTYID is kg

VOL is in m³,

then CONV=1000.

4.4(3).5 RCHRES BLOCK -- Section HTRCH input

```

*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
[Table-type HT-BED-FLAGS]
[Table-type HEAT-PARM]

[Table-type HT-BED-PARM]
[Table-type MON-HT-TGRND] if TGFLG = 3
                               ---
                               | if BEDFLG = 1 or 2
                               |
                               ---
                               ---
[Table-type HT-BED-DELH]
[Table-type HT-BED-DELTT]
                               | if BEDFLG = 3
                               |
                               ---

[Table-type HEAT-INIT]
*****

```

Explanation

The exact format of each of the tables above is detailed in the documentation which follows. Tables in brackets [] need not always be supplied; for example, because all of the inputs have default values.

4.4(3).5.1 Table-type HT-BED-FLAGS -- Flags for bed conduction in section HTRCH

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
HT-BED-FLAGS
<-range><bfg><gfg><tst>
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END HT-BED-FLAGS
```

```
*****
Example
*****
```

```
HT-BED-FLAGS
RCHRES                ***
# - # BDFG TGFG TSTP ***
1      3      55
2      2      2
END HT-BED-FLAGS
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<bfg>	BEDFLG	I5	0	0	3
<gfg>	TGFLG	I5	2	1	3
<tst>	TSTOP	I5	55	1	100

Explanation

BEDFLG is the bed conduction flag, with the following meanings:

- 0 - bed conduction is not simulated
- 1 - single interface (water-mud) heat transfer method
- 2 - two-interface (water-mud and mud-ground) heat transfer method
- 3 - Jobson method

TGFLG specifies the source of the ground temperature for the bed conduction; used when BEDFLG is 1 or 2 (TGFLG: 1=time series; 2=single value; 3=monthly values).

TSTOP is the number of time steps (prior to the current time step) that impact the heat flux at the current time step; used only when the Jobson method is in effect.

4.4(3).5.2 Table-type HEAT-PARM -- Parameters for section HTRCH

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
HEAT-PARM
<-range><--elev--><--eldat-><--cfsx--><--ktrd--><--kcnd--><--kevp-->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END HEAT-PARM
```

```
*****
Example
*****
```

```
HEAT-PARM
  RCHRES      ELEV      ELDAT      CFSAX      KATRAD      KCOND      KEVAP ***
  # - #       ft       ft
  1   7      2000.    1500.         .5         6.5         11.         4.
END HEAT-PARM
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<elev>	ELEV	F10.0	0.0	0.0	30000.	ft	Engl
			0.0	0.0	10000.	m	Metric
<eldat>	ELDAT	F10.0	0.0	none	none	ft	Engl
			0.0	none	none	m	Metric
<cfsx>	CFSAX	F10.0	1.0	0.001	2.0	none	Both
<ktrd>	KATRAD	F10.0	9.37	1.00	20.	none	Both
<kcnd>	KCOND	F10.0	6.12	1.00	20.	none	Both
<kevp>	KEVAP	F10.0	2.24	1.00	10.	none	Both

Explanation

ELEV is the mean RCHRES elevation.
 ELDAT is the difference in elevation between the RCHRES and the air temperature gage (positive if RCHRES is higher than the gage).
 CFSAX is the correction factor for solar radiation; it is the fraction of the RCHRES surface exposed to radiation.
 KATRAD is the longwave radiation coefficient.
 KCOND is the conduction-convection heat transport coefficient.
 KEVAP is the evaporation coefficient.

4.4(3).5.3 Table-type HT-BED-PARM -- Bed conduction parameters for section HTRCH

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
HT-BED-PARM
<-range><-muddep-><--tgrnd-><--kmud--><-kgrnd-->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END HT-BED-PARM
```

Example

```
HT-BED-PARM
  RCHRES      MUDDEP      TGRND      KMUD      KGRND      ***
  # - #          m        deg C      (kcal/m2/C/hr)  ***
  1   7         0.1       20.       50.4       1.42
END HT-BED-PARM
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<-muddep->	MUDDEP	F10.0	0.33	0.01	none	ft	Engl
			0.1	0.01	none	m	Metric
<--tgrnd->	TGRND	F10.0	59.	14.	113.	deg F	Engl
			15.	-10.	45.	deg C	Metric
<--kmud-->	KMUD	F10.0	50.	0.0	none	kcal/m2/C/hr	Both
<--kgrnd-->	KGRND	F10.0	1.4	0.0	none	kcal/m2/C/hr	Both

Explanation

MUDDEP is the depth of the mud layer in the two-interface model (BEDFLG = 2).

TGRND is the constant (TGFLG = 2) ground temperature; it is used in the one and two-interface models (BEDFLG = 1 or 2). Optionally, the ground temperature can be input in the form of twelve monthly values or a time series.

KMUD is the heat conduction coefficient between water and the mud/ground; it is used if BEDFLG = 1 or 2. Typical values range from 3 to 100 kcal/m2/C/hr.

KGRND is the heat conduction coefficient between ground and mud in the two-interface model (BEDFLG = 2).

4.4(3).5.4 Table-type MON-HT-TGRND -- Monthly ground temperatures for bed heat conduction algorithms

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
MON-HT-TGRND
<-range><-----12-values----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-HT-TGRND
```

Example

```
MON-HT-TGRND
  RCHRES  TG1  TG2  TG3  TG4  TG5  TG6  TG7  TG8  TG9  TG10  TG11  TG12***
  # - #
  1   7  15.  16.  17.  18.  19.  20.  20.  20.  20.  18.  17.  16.
END MON-HT-TGRND
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<12-values>	TGRNDM(1-12)	F5.0	none	14.	113.	deg F	English
			none	-10.	45	deg C	Metric

Explanation

TGRNDM(1) through TGRNDM(12) are monthly ground temperatures for use in the bed heat conduction models. This table must be included in the UCI only if TGFLG is assigned a value of 3 and BEDFLG = 1 or 2 in Table-type HT-BED-FLAGS.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(3).5.5 Table-type HT-BED-DELH -- Heat fluxes for Jobson bed heat conduction method

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
HT-BED-DELH
<-range><--delh1-><--delh2-><--delh3-><--delh4-><--delh5-><--delh6-><--delh7->
.
.
<-range><-delh99-><-delh100>
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END HT-BED-DELH
```

Example

```
HT-BED-DELH
RCHRES *** DELH      DELH      DELH      DELH      DELH      DELH      DELH
# - # ***      1          2          3          4          5          6          7
1          -14.2     -9.44     -7.80     -6.66     -5.77     -5.34     -4.99
1          -4.71     -4.47     -4.27     -3.81     -3.93     -3.53     -3.66
etc
END HT-BED-DELH
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<--delhi->	DELH(100)	F10.0	0.0	none	none	btu/ft2/F/iv1	English
			0.0	none	none	kcal/m2/C/iv1	Metric

Explanation

DELH are bed sediment-to-water heat fluxes (per one degree increase in water temperature) for the past TSTOP time intervals; used in the Jobson bed-conduction method. A maximum of 100 values of DELH are possible.

Caution: DELH values are dependent on the time step (INDELT in GLOBAL Block).

4.4(3).5.6 Table-type HT-BED-DELTT -- Initial temperature changes for Jobson bed conduction method

```
*****
      1      2      3      4      5      6      7      8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
HT-BED-DELTT
<-range><-deltt1-><-deltt2-><-deltt3-><-deltt4-><-deltt5-><-deltt6-><-deltt7->
.
.
<-range><deltt99-><deltt100>
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END HT-BED-DELTT
```

```
*****
Example
*****
```

```
HT-BED-DELTT
RCHRES *** DELTT      DELTT      DELTT      DELTT      DELTT      DELTT      DELTT
# - # ***      1      2      3      4      5      6      7
      ***      8      9     10     11     12     13     14
1      14.2     9.44     7.80     6.66     5.77     5.34     4.99
1      4.71     4.47     4.27     3.81     3.93     3.53     3.66
etc
END HT-BED-DELTT
```

```
*****
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<-deltti->	DELTT(100)	F10.0	0.0	none	none	deg F	English
			0.0	none	none	deg C	Metric

Explanation

DELTT are initial water temperature changes for the TSTOP time intervals immediately preceding the starting time of the simulation; used in the Jobson bed-conduction method. A maximum of 100 values of DELTT are possible. DELTT values are positive if the water temperature increases.

4.4(3).5.7 Table-type HEAT-INIT -- Initial conditions for HTRCH

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
HEAT-INIT
<-range><----init-temp----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END HEAT-INIT
```

```
*****
Example
*****
```

```
HEAT-INIT
  RCHRES      TW      AIRTMP ***
  # - #      degF    degF ***
  1   7      62.     70.
END HEAT-INIT
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<init-temp>	TW	F10.0	60.	32.	200.	degF	Engl
			15.5	0.0	95.	degC	Metric
	AIRTMP	F10.0	60.	-90.	150.	degF	Engl
			15.5	-70.0	65.	degC	Metric

Explanation

TW is the initial water temperature and AIRTMP indicates the initial air temperature at the RCHRES.

4.4(3).6 RCHRES-BLOCK -- Section SEDTRN input

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
[Table-type SANDFG]
Table-type SED-GENPARM
Table-type SED-HYDPARM -- only if Section HYDR is inactive
Table-type SAND-PM
Table-type SILT-CLAY-PM -- include twice, 1st for silt, 2nd for clay
[Table-type SSED-INIT]
[Table-type BED-INIT]
```

Explanation

The exact format of each of the tables above is detailed in the documentation which follows. Tables in brackets [] need not always be supplied; for example, because all of the inputs have default values.

4.4(3).6.1 Table-type SANDFG -- Sandload method flag

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
SANDFG
<-range><sfg>
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END SANDFG
```

Example

```
SANDFG
  RCHRES      ***
  # - # SDFG ***
  2          2
END SANDFG
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<sfg>	SANDFG	I5	3	1	3

Explanation

SANDFG indicates the method that will be used for sandload simulation:

- 1 = Toffaleti method
- 2 = Colby method
- 3 = user-specified power function method.

4.4(3).6.2 Table-type SED-GENPARM -- General sediment related parameters

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
SED-GENPARM
<-range><-----gen-parm----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END SED-GENPARM
```

```
*****
Example
*****
```

```
SED-GENPARM
  RCHRES   BEDWID   BEDWRN   POR***
  # - #     (m)      (m)      ***
  3  10     30.     2.       0.4
END SED-GENPARM
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<gen-parm>	BEDWID	F10.0	none	1.0	none	ft	Engl
			none	0.3	none	m	Metric
	BEDWRN	F10.0	100. 30.5	.001 .0003	none	ft m	Engl Metric
	POR	F10.0	0.5	0.1	0.9	none	Both

Explanation

BEDWID is the width of the cross-section over which HSPF will assume bed sediment is deposited (regardless of stage, top-width, etc); BEDWID is constant. It is used to estimate the depth of bed sediment.

BEDWRN is the bed depth which, if exceeded (e.g., through deposition) will cause a warning message to be printed in the echo file (MESSU).

POR is the porosity of the bed (volume voids/total volume). It is used to estimate bed depth.

4.4(3).6.3 Table-type SED-HYDPARM -- Parameters normally read in Section HYDR

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
SED-HYDPARM
<-range><-----sed-hydparm----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END SED-HYDPARM
```

```
*****
Example
*****
```

```
SED-HYDPARM
  RCHRES      LEN      DELTH      DB50***
  # - #      (km)      (m)      (mm)***
  2          5.0      4.0      0.5
  5          20.0     5.0      0.3
END SED-HYDPARM
```

```
*****
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<sed-hydparm>	LEN	F10.0	none	0.01	none	miles	Engl
			none	0.016	none	km	Metric
	DELTH	F10.0	0.0	0.0	none	ft	Engl
			0.0	0.0	none	m	Metric
	DB50	F10.0	.01	.0001	100.	in	Engl
			.25	.0025	2500.	mm	Metric

Explanation

This table is only required and read if Section HYDR is not active. Normally these parameters are supplied in Table-type HYDR-PARM2; see section HYDR for definitions.

4.4(3).6.4 Table-type SAND-PM -- Parameters related to sand transport

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

SAND-PM

<-range><-----sand-parms----->

.

(repeats until all operations of this type are covered)

.

END SAND-PM

Example

SAND-PM

```
RCHRES          D          W ***
# - #          (in)  (in/sec) ***
3              .01        1.2
```

END SAND-PM

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<sand-parms>	D	F10.0	none	.001	100.	in	Engl
			none	.025	2500.	mm	Metric
	W	F10.0	none	.02	500.	in/sec	Engl
			none	.5	12500.	mm/sec	Metric
	RHO	F10.0	2.65	1.0	4.0	gm/cm3	Both
	KSAND	F10.0	0.0	0.0	none	complex	Both
	EXPSND	F10.0	0.0	0.0	none	complex	Both

Explanation

D is the effective diameter of the transported sand particles, and W is the corresponding fall velocity in still water. Note: the sand transport algorithms do not actually use D; they use DB50, supplied in Table-type HYDR-PARM2. D is included here for consistency with the input data supplied for cohesive sediment.

RHO is the density of the sand particles.

KSAND and EXPSND are the coefficient and exponent in the sandload power function formula. These values should be input if SANDFG=3.

4.4(3).6.5 Table-type SILT-CLAY-PM -- Parameters for silt or clay

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
SILT-CLAY-PM
<-range><-----silt-clay-pm----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END SILT-CLAY-PM
```

```
*****
Example
*****
```

```
SILT-CLAY-PM
RCHRES      D          W          RHO      TAUCD      TAUCS      M      ***
# - #      (mm)    (mm/sec)  (gm/cm3)  (kg/m2)   (kg/m2)  (kg/m2.d)  ***
6          .03      .80      2.7      2.0      2.5      0.1
9          .04      1.5      2.6      2.0      3.0      .08
END SILT-CLAY-PM
```

```
*****
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<silt-clay-pm> D		F10.0	0.0	0.0	.003	in	Engl
			0.0	0.0	.07	mm	Metric
W		F10.0	0.0	0.0	.2	in/sec	Engl
			0.0	0.0	5.0	mm/sec	Metric
			RHO	F10.0	2.65	2.0	4.0
TAUCD		F10.0	1.0E10	1.0E-10	none	lb/ft2	Engl
			1.0E10	1.0E-10	none	kg/m2	Metric
TAUCS		F10.0	1.0E10	1.0E-10	none	lb/ft2	Engl
			1.0E10	1.0E-10	none	kg/m2	Metric
M		F10.0	0.0	0.0	none	lb/ft2.d	Engl
			0.0	0.0	none	kg/m2.d	Metric

Explanation

This table must be supplied twice; first for silt, then for clay.

D is the effective diameter of the particles and W is the corresponding fall velocity in still water.

RHO is the density of the particles.

TAUCD is the critical bed shear stress for deposition. Above this stress, there will be no deposition; as the stress drops below this value to zero, deposition will gradually increase to the value implied by the fall velocity in still water.

TAUCS is the critical bed shear stress for scour. Below this value, there will be no scour; above it, scour will steadily increase.

In general TAUCD should be less than or equal to TAUCS.

M is the erodibility coefficient of the sediment.

Note that the default values for W, TAUCD, TAUCS, and M have been set so that silt and clay will behave as "washload"; that is, material will settle at the rate implied by W (defaulted to zero) and there will be no scour; the material will behave like a conservative substance.

4.4(3).6.6 Table-type SSED-INIT -- Initial concentrations of suspended sediment

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
SSED-INIT
<-range><-----ssed-init----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END SSED-INIT
```

Example

```
SSED-INIT
RCHRES      Suspended sed concs (mg/l) ***
# - #       Sand      Silt      Clay ***
1   5       100.     50.     20.
END SSED-INIT
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<ssed-init>	SSED(3)	3F10.0	0.0	0.0	none	mg/l	Both

Explanation

The three values supplied are the initial concentrations of suspended sand, silt, and clay, respectively.

4.4(3).6.7 Table-type BED-INIT -- Initial content of bed sediment

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
BED-INIT
<-range><-bed-dep><fracsand><fracsilt><fracclay>
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END BED-INIT
```

```
*****
Example
*****
```

```
BED-INIT
  RCHRES      BEDDEP      Initial bed composition   ***
  # - #       (m)         Sand      Silt      Clay ***
  3           1.5         0.6      0.2      0.2
END BED-INIT
```

```
*****
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<bed-dep>	BEDDEP	F10.0	0.0	0.0	none	ft	Engl
			0.0	0.0	none	m	Metric
<fracsand>	temporary	F10.0	1.0	.0001	1.0	none	Both
<fracsilt>	array	F10.0	0.0	0.0	.9999	none	Both
<fracclay>		F10.0	0.0	0.0	.9999	none	Both

Explanation

BEDDEP is the initial total depth (thickness) of the bed.

The three values supplied under <fracsand>, <fracsilt>, and <fracclay> are the initial fractions (by weight) of sand, silt, and clay in the bed material. The default values are arranged to simulate an all-sand bed. The sum of the fractions must be 1.00.

4.4(3).7 RCHRES-BLOCK -- Section GQUAL input

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
[Table-type GQ-GENDATA]
[Table-type GQ-AD-FLAGS]
```

next 15 tables -- repeat for each qual

```
Table-type GQ-QALDATA
[Table-type GQ-QALFG]
[Table-type GQ-FLG2]
Table-type GQ-HYDPM -- only if qual undergoes hydrolysis (QALFG(1,I)=1)
Table-type GQ-ROXPM -- only if qual undergoes oxidation (QALFG(2,I)=1)
[Table-type GQ-PHOTPM] -- only if qual undergoes photolysis (QALFG(3,I)=1)
Table-type GQ-CFGAS -- only if qual undergoes volatilization (QALFG(4,I)=1)
```

next 2 tables -- only if qual undergoes biodegradation (QALFG(5,I)=1)

```
Table-type GQ-BIOPM
Table-type MON-BIO -- only if biomass is input monthly (GQPM2(7,I)=3)
Table-type GQ-GENDECAY -- only if qual has "general" decay (QALFG(6,I)=1)
```

next 5 tables -- only if qual is sediment associated (QALFG(7,I)=1)

```
[Table-type GQ-SEDDECAY]
Table-type GQ-KD
Table-type GQ-ADRATE
[Table-type GQ-ADTHETA]
[Table-type GQ-SEDCONC]
```

```
[Table-type GQ-VALUES]
```

next 3 tables -- only if the data are to be read as monthly values
(Source flag in Table-type GQ-GENDATA is ON)

```
[Table-type MON-WATEMP]
[Table-type MON-PHVAL] -- only if there is hydrolysis (any QALFG(1)=1)
[Table-type MON-ROXYGEN] -- only if there is oxidation (any QALFG(2)=1)
```

next 8 tables -- only if there is photolysis (any QALFG(3) = 1)

```
Table-type GQ-ALPHA
[Table-type GQ-GAMMA]
[Table-type GQ-DELTA]
[Table-type GQ-CLDFACT]
```

next 3 tables -- only if the data are to be read as monthly values
(Source flag in Table-type GQ-GENDATA is ON)

[Table-type MON-CLOUD]

[Table-type MON-SEDCONC]

[Table-type MON-PHYTO]

[Table-type SURF-EXPOSED] -- only if Section HTRCH is inactive
(see Section PLANK for documentation)

next 7 tables -- only if there is volatilization (any QALFG(4) = 1)

[Table-type OX-FLAGS]

[Table-type ELEV]

[Table-type OX-CFOREA]

[Table-type OX-TSIVOGLOU]

Table-type OX-LEN-DELTH

[Table-type OX-TCGINV]

Table-type OX-REAPARM

[Table-type GQ-DAUGHTER] -- repeat for each decay process that produces
daughter quals from parents

Explanation

A "qual" is a generalized quality constituent simulated using this module section.

The exact format of each of the tables above, except those "borrowed" from Sections OXRX and PLANK, is detailed in the documentation which follows. Tables in brackets [] need not always be supplied; for example, because all of the inputs have default values.

4.4(3).7.1 Table-type GQ-GENDATA -- General input for Section GQUAL

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
GQ-GENDATA
<-range><ngq><-----source-fgs-----><lat>
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END GQ-GENDATA
```

```
*****
Example
*****
```

```
GQ-GENDATA
  RCHRES NGQL TPGF PHFG ROFG CDFG SDFG PYFG  LAT***
  # - #
  1   7   3   2   2   1   2   2   3   48
END GQ-GENDATA
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<ngq>	NGQUAL	I5	1	1	3	none	Both
<source-fgs>	TEMPFG	I5	2	1	3	none	Both
	PHFLAG	I5	2	1	3	none	Both
	ROXFG	I5	2	1	3	none	Both
	CLDFG	I5	2	1	3	none	Both
	SDFG	I5	2	1	3	none	Both
	PHYTFG	I5	2	1	3	none	Both
	<lat>	LAT	I5	0	-54	54	degrees

Explanation

NGQUAL - number of generalized constituents (quals) being simulated.

TEMPFG - source of water temperature data. 1 means a time series - either input or computed; 2 means a single user-supplied value; 3 means 12 user-supplied values (one for each month).

PHFLAG - source of pH data. Input only if any QALFG(1)=1. Source designation scheme is the same as for TEMPG.

ROXFG - source of free radical oxygen data. Input only if any QALFG(2)=1. Source designation scheme is the same as for TEMPG.

CLDFG - source of cloud cover data. Input only if any QALFG(3)=1. Source designation scheme is the same as for TEMPG.

SDFG - source of total sediment concentration data. Input only if any QALFG(3)=1. Source designation scheme is the same as for TEMPG.

PHYTFG - source of phytoplankton data. Input only if any QALFG(3)=1. Source designation scheme is the same as for TEMPG.

LAT - latitude of the RCHRES. Input only if any QALFG(3)=1. Positive for northern hemisphere.

4.4(3).7.2 Table-type GQ-AD-FLAGS -- Atmospheric deposition flags for GQUAL

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

GQ-AD-FLAGS

<-range> <f><c> <f><c> <f><c>

.

(repeats until all operations of this type are covered)

.

END GQ-AD-FLAGS

Example

GQ-AD-FLAGS

RCHRES Atmospheric deposition flags ***

*** GQUAL1 GQUAL2 GQUAL3

<F><C> <F><C> <F><C>

1 7 -1 10 -1 -1 11 12

END GQ-AD-FLAGS

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<f><c>	GQADFG(*)	(1X,2I3)	0	-1	none

Explanation

GQADFG is an array of flags indicating the source of atmospheric deposition data. Each GQUAL has two flags. The first is for dry or total deposition flux, and the second is for wet deposition concentration. The flag values indicate:

- 0 No deposition of this type is simulated
- 1 Deposition of this type is input as time series GQADFX or GQADCN
- >0 Deposition of this type is input in the MONTH-DATA table with the corresponding table ID number.

4.4(3).7.3 Table-type GQ-QALDATA -- Data for a generalized quality constituent

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
GQ-QALDATA
<-range><-----gqid-----><--dqal-->      <cu><--conv--> <qtyid->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END GQ-QALDATA
```

```
*****
Example
*****
```

```
GQ-QALDATA
RCHRES   ***           GQID      DQAL      CONCID      CONV      QTYID
# - #   ***
1   7           Coliforms      2.0          #          .001          #
END GQ-QALDATA
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<gqid>	GQID	5A4	none	none	none	none	Both
<dqal>	DQAL	F10.0	0.0	0.0	none	concid	Both
<cu>	CONCID	A4	none	none	none	none	Both
<conv>	CONV	F10.0	none	1.0E-30	none	see below	
<qtyid>	QTYID	2A4	none	none	none	none	Both

Explanation

- GQID - Name of constituent (qual).
- DQAL - Initial dissolved concentration of qual.
- CONCID - Concentration units (implied that it is "per liter") eg."mg"/(l).
- QTYID - Name of mass quantity unit for qual.
- CONV - Factor to convert from QTYID/VOL to concentration (CONCID) units:
 Conc= CONV* QTYID/VOL (in the English system, VOL is in ft³)
 (in the Metric system, VOL is in m³).

4.4(3).7.4 Table-type GQ-QALFG -- First set of flags for a qual

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
GQ-QALFG
<-range><-----degrad-fgs-----><sfg>
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END GQ-QALFG
```

Example

```
GQ-QALFG
RCHRES HDRL OXID PHOT VOLT BIOD GEN SDAS***
# - #
1 7 1 1 0 0 1 0 1
END GQ-QALFG
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<degrad-fgs>	QALFG(1)	I5	0	0	1	none	Both
	QALFG(2)	I5	0	0	1	none	Both
	QALFG(3)	I5	0	0	1	none	Both
	QALFG(4)	I5	0	0	1	none	Both
	QALFG(5)	I5	0	0	1	none	Both
	QALFG(6)	I5	0	0	1	none	Both
	<sfg>	QALFG(7)	I5	0	0	1	none

Explanation

- QALFG(1) - indicates whether hydrolysis is considered for dissolved qual.
- QALFG(2) - indicates whether oxidation by free radical oxygen is considered for dissolved qual.
- QALFG(3) - indicates whether photolysis is considered for dissolved qual.
- QALFG(4) - indicates whether volatilization is considered for dissolved qual.
- QALFG(5) - indicates whether biodegradation is considered for dissolved qual.
- QALFG(6) - indicates whether general first order decay is considered for dissolved qual.
- QALFG(7) - indicates whether or not qual is associated with sediment. If so, adsorption/desorption of qual is simulated.

4.4(3).7.5 Table-type GQ-FLG2 -- Second set of flags for a qual

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
GQ-FLG2
<-range><-----daughter proc-----><sbm>
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END GQ-FLG2
```

Example

```
GQ-FLG2
  RCHRES HDRL OXID PHOT VOLT BIOD  GEN SBMS***
  # - #
  1   7   0   0   1   0   1   0   2
END GQ-FLG2
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<daughter proc>	GQPM2(1)	I5	0	0	1	none	Both
	GQPM2(2)	I5	0	0	1	none	Both
	GQPM2(3)	I5	0	0	1	none	Both
	GQPM2(4)	I5	0	0	1	none	Both
	GQPM2(5)	I5	0	0	1	none	Both
	GQPM2(6)	I5	0	0	1	none	Both
<sbm>	GQPM2(7)	I5	2	1	3	none	Both

Explanation

GQPM2(1) through GQPM2(6) indicate whether or not this qual is a daughter product through each of the six decay processes (1-hydrolysis, 2-oxidation, 3-photolysis, 4-reserved for future use, 5-biodegradation, 6-general first order decay). GQPM2(7) indicates the source of biomass data for qual. Input only if QALFG(5)=1. (1=time series, 2=single value, 3=twelve monthly values)

4.4(3).7.6 Table-type GQ-HYDPM -- Hydrolysis parameters

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
GQ-HYDPM
<-range><-----hydroly-parms----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END GQ-HYDPM
```

Example

```
GQ-HYDPM
RCHRES      KA      KB      KN      THHYD***
# - #
1 7 5000.    50.    .00004    1.03
END GQ-HYDPM
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<hydroly-parms>	KA	F10.0	none	1.0E-30	none	/M-sec	Both
	KB	F10.0	none	1.0E-30	none	/M-sec	Both
	KN	F10.0	none	1.0E-30	none	/sec	Both
	THHYD	F10.0	1.0	1.0	2.0	none	Both

Explanation

- KA - second-order acid rate constant for hydrolysis
- KB - second-order base rate constant for hydrolysis
- KN - first-order rate constant of neutral reaction with water
- THHYD - temperature correction coefficient for hydrolysis

4.4(3).7.7 Table-type GQ-ROXPM -- Parameters for free radical oxidation of qual

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
GQ-ROXPM
<-range><-----rox-pm----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END GQ-ROXPM
```

Example

```
GQ-ROXPM
  RCHRES      KOX      THOX***
  # - #              ***
  1   7   .000014    1.01
END GQ-ROXPM
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<rox-pm>	KOX	F10.0	none	1.0E-30	none	/M.sec	Both
	THOX	F10.0	1.0	1.0	2.0	none	Both

Explanation

KOX - second-order rate constant for oxidation by free radical oxygen
 THOX - temperature correction coefficient for oxidation by free radical oxygen

4.4(3).7.8 Table-type GQ-PHOTPM -- Parameters for photolysis

```
*****
      1      2      3      4      5      6      7      8
123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

GQ-PHOTPM

<-range><-----first-7----->

<-range><-----second-7----->

<-range><-----last-4-----><--phi--><-theta-->

.

(repeats until all operations of this type are covered)

.

END GQ-PHOTPM

Example

GQ-PHOTPM

```
  # - #***      K1      K2      K3      K4      K5      K6      K7
  # - #***      K8      K9      K10     K11     K12     K13     K14
  # - #***      K15     K16     K17     K18     PHI     THETA
  1  7          .5      .5      .5      .5      .5      .5      .5
  1  7          .5      .5      .5      .5      .5      .5      .5
  1  7          .5      .5      .5      .5      .47     1.02
```

END GQ-PHOTPM

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<first-7>	PHOTPM(1-7)	F10.0	0.0	0.0	none	l/M.cm	Both
<second-7>	PHOTPM(8-14)	F10.0	0.0	0.0	none	l/M.cm	Both
<last-4>	PHOTPM(15-18)	F10.0	0.0	0.0	none	l/M.cm	Both
<phi>	PHOTPM(19)	F10.0	1.0	.0001	10.0	M/E	Both
<theta>	PHOTPM(20)	F10.0	1.0	1.0	2.0	none	Both

Explanation

PHOTPM(1) through PHOTPM(18) are molar absorption coefficients for qual for 18 wavelength ranges of light (see functional description for subroutine DDECAY in Part E).

PHOTPM(19) is the quantum yield for the qual in air-saturated pure water.

PHOTPM(20) is the temperature correction coefficient for photolysis.

When an entry has to be continued onto more than 1 line:

1. No blank or comment lines may be put between any of the lines for a continued entry. Put all comments ahead of the entry. (See above example).
2. The <range> specification must be repeated for each line onto which the entry is continued.

4.4(3).7.9 Table-type GQ-CFGAS -- Ratio of volatilization rate to oxygen reaeration rate

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
GQ-CFGAS
<-range><--cfgas->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END GQ-CFGAS
```

Example

```
GQ-CFGAS
  RCHRES      CFGAS***
  # - #      ***
  1   7      .70
END GQ-CFGAS
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<cfgas>	CFGAS	F10.0	none	1.0E-30	none	none	Both

Explanation

CFGAS is the ratio of the volatilization rate to the oxygen reaeration rate.

4.4(3).7.10 Table-type GQ-BIOPM -- Biodegradation parameters

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
GQ-BIOPM
<-range><-----bioparm----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END GQ-BIOPM
```

```
*****
Example
*****
```

```
GQ-BIOPM
  RCHRES      BIOCON      THBIO      BIO***
  # - #
  1   7        .31        1.07        .04
END GQ-BIOPM
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<bioparm>	BIOCON	F10.0	none	1.0E-30	none	1/mg/day	Both
	THBIO	F10.0	1.07	1.0	2.0	none	Both
	BIO	F10.0	none	0.00001	none	mg/l	Both

Explanation

BIOCON - second order rate constant for biodegradation of qual by biomass
 THBIO - temperature correction coefficient for biodegradation of qual
 BIO - concentration of the biomass which causes biodegradation of qual

4.4(3).7.11 Table-type MON-BIO -- Monthly values of biomass

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MON-BIO
<-range><-----12-values----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-BIO
```

```
*****
Example
*****
```

```
MON-BIO
  RCHRES  BM1  BM2  BM3  BM4  BM5  BM6  BM7  BM8  BM9  BM10  BM11  BM12***
  # - #
  1   7  .03 .035  .03  .02  .02  .03  .03  .035 .040 .060 .050 .035
END MON-BIO
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<12-values>	BIOM(1-12)	F5.0	none	0.00001	none	mg/l	Both

Explanation

BIOM(1) through BIOM(12) are monthly concentrations of biomass that cause biodegradation of qual. This table must be included in the UCI only if GQPM2(7) is assigned a value of 3 in Table-type GQ-FLG2.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(3).7.12 Table-type GQ-GENDECAY -- Parameters for "general" decay of qual

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
GQ-GENDECAY
<-range><----decay-pms----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END GQ-GENDECAY
```

```
*****
Example
*****
```

```
GQ-GENDECAY
  RCHRES    FSTDEC    THFST***
  # - #
  1   7      0.2     1.05
END GQ-GENDECAY
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<decay-pms>	FSTDEC	F10.0	none	.00001	none	/day	Both
	THFST	F10.0	1.07	1.0	2.0	none	Both

Explanation

FSTDEC - first-order decay rate for qual
 THFST - temperature correction coefficient for first-order decay of qual

4.4(3).7.13 Table-type GQ-SEDDECAY -- Parameters for decay of contaminant adsorbed to sediment

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
GQ-SEDDECAY
<-range><-----ads-decay----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END GQ-SEDDECAY
```

Example

```
GQ-SEDDECAY
  RCHRES      KSUSP      THSUSP      KBED      THBED***
  # - #
  1   7      .01      1.06      .005      1.03
END GQ-SEDDECAY
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<ads-decay>	ADDCPM(1)	F10.0	0.0	0.0	none	/day	Both
	ADDCPM(2)	F10.0	1.07	1.0	2.0	none	Both
	ADDCPM(3)	F10.0	0.0	0.0	none	/day	Both
	ADDCPM(4)	F10.0	1.07	1.0	2.0	none	Both

Explanation

- ADDCPM(1) - decay rate for qual adsorbed to suspended sediment
- ADDCPM(2) - temperature correction coefficient for decay of qual on suspended sediment
- ADDCPM(3) - decay rate for qual adsorbed to bed sediment
- ADDCPM(4) - temperature correction coefficient for decay of qual on bed sediment

4.4(3).7.14 Table-type GQ-KD -- Adsorption coefficients of qual

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
GQ-KD
<-range><-----k-part----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END GQ-KD
```

Example

```
GQ-KD
  RCHRES      ADPM1      ADPM2      ADPM3      ADPM4      ADPM5      ADPM6***
  # - #
  1   7        1.0       5000      15000        .3        1000       4000
END GQ-KD
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<k-part>	ADPM(1,1)	F10.0	none	1.0E-10	none	l/mg	Both
	ADPM(2,1)	F10.0	none	1.0E-10	none	l/mg	Both
	ADPM(3,1)	F10.0	none	1.0E-10	none	l/mg	Both
	ADPM(4,1)	F10.0	none	1.0E-10	none	l/mg	Both
	ADPM(5,1)	F10.0	none	1.0E-10	none	l/mg	Both
	ADPM(6,1)	F10.0	none	1.0E-10	none	l/mg	Both

Explanation

ADPM(1,1) through ADPM(6,1) are distribution coefficients for qual with: 1-suspended sand, 2-suspended silt, 3-suspended clay, 4-bed sand, 5-bed silt, and 6-bed clay.

4.4(3).7.15 Table-type GQ-ADRATE -- Adsorption/desorption rate parameters

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
GQ-ADRATE
<-range><-----k-adsdes----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END GQ-ADRATE
```

```
*****
Example
*****
```

```
GQ-ADRATE
RCHRES      ADPM1      ADPM2      ADPM3      ADPM4      ADPM5      ADPM6***
# - #
1   7      400.      400.      400.      .0028      .0028      .0028
END GQ-ADRATE
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<k-adsdes>	ADPM(1,2)	F10.0	none	.00001	none	/day	Both
	ADPM(2,2)	F10.0	none	.00001	none	/day	Both
	ADPM(3,2)	F10.0	none	.00001	none	/day	Both
	ADPM(4,2)	F10.0	none	.00001	none	/day	Both
	ADPM(5,2)	F10.0	none	.00001	none	/day	Both
	ADPM(6,2)	F10.0	none	.00001	none	/day	Both

Explanation

ADPM(1,2) through ADPM(6,2) are transfer rates between adsorbed and desorbed states of qual with: 1-suspended sand, 2-suspended silt, 3-suspended clay, 4-bed sand, 5-bed silt, and 6-bed clay.

4.4(3).7.16 Table-type GQ-ADTHETA-- Adsorption/desorption temperature correction parameters

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
GQ-ADTHETA
<-range><-----thet-adsdes----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END GQ-ADTHETA
```

Example

```
GQ-ADTHETA
  RCHRES      ADPM1      ADPM2      ADPM3      ADPM4      ADPM5      ADPM6***
  # - #
  1   7      1.07      1.07      1.07      1.04      1.04      1.04
END GQ-ADTHETA
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<thet-adsdes>	ADPM(1,3)	F10.0	1.07	1.0	2.0	none	Both
	ADPM(2,3)	F10.0	1.07	1.0	2.0	none	Both
	ADPM(3,3)	F10.0	1.07	1.0	2.0	none	Both
	ADPM(4,3)	F10.0	1.07	1.0	2.0	none	Both
	ADPM(5,3)	F10.0	1.07	1.0	2.0	none	Both
	ADPM(6,3)	F10.0	1.07	1.0	2.0	none	Both

Explanation

ADPM(1,3) through ADPM(6,3) are temperature correction coefficients for adsorption/desorption on: 1-suspended sand, 2-suspended silt, 3-suspended clay, 4-bed sand, 5-bed silt, 6-bed clay.

4.4(3).7.17 Table-type GQ-SEDCONC -- Initial concentrations on sediment

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
GQ-SEDCONC
<-range><-----sedconc----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END GQ-SEDCONC
```

```
*****
Example
*****
```

```
GQ-SEDCONC
  RCHRES      SQAL1      SQAL2      SQAL3      SQAL4      SQAL5      SQAL6***
  # - #
  1   7        1.3        8.4        8.9        1.9        8.4        9.2
END GQ-SEDCONC
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<sedconc>	SQAL(1-6)	F10.0	0.0	0.0	none	concu/mg	Both

Explanation

SQAL(1) through SQAL(6) are initial concentrations of qual on: 1-suspended sand, 2-suspended silt, 3-suspended clay, 4-bed sand, 5-bed silt, 6-bed clay.

4.4(3).7.18 Table-type GQ-VALUES -- Initial values for inputs which are constant

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
GQ-VALUES
<-range><--twat--><-phval--><---roc--><---cld--><---sdcnc-><---phy--->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END GQ-VALUES
```

Example

```
GQ-VALUES
  RCHRES      TWAT      PHVAL      ROC      CLD      SDCNC      PHY***
  # - #
  1   7      22.       7.       .07      1.       11.       .007
END GQ-VALUES
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<twat>	TWAT	F10.0	60. 15.5	32. 0.1	212. 100.	deg F deg C	Engl Metric
<phval>	PHVAL	F10.0	7.0	1.0	14.	none	Both
<roc>	ROC	F10.0	0.0	0.0	none	mole/l	Both
<cld>	CLD	F10.0	0.0	0.0	10.	tenths	Both
<sdcnc>	SDCNC	F10.0	0.0	0.0	none	mg/l	Both
<phy>	PHY	F10.0	0.0	0.0	none	mg/l	Both

Explanation

In Table-type GQ-GENDATA, values for data source flags are specified. If any of the flags are assigned a value of 2, a single constant value for that data type must be provided in this table. For example, if ROXFG=2 a value for free radical oxygen concentration (ROC) must be supplied in columns 31-40 of this table.

TWAT - water temperature
PHVAL - pH
ROC - free radical oxygen concentration
CLD - cloud cover
SDCNC - total suspended sediment concentration
PHY - phytoplankton concentration (as biomass)

4.4(3).7.19 Table-type MON-WATEMP -- Monthly values of water temperature

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MON-WATEMP
<-range><-----12-values----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-WATEMP
```

```
*****
Example
*****
```

```
MON-WATEMP
  RCHRES   T1    T2    T3    T4    T5    T6    T7    T8    T9    T10   T11   T12***
  # - #
  1   7   34   37   39   42   55   59   64   62   58   54   46   38
END MON-WATEMP
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<12-values>	TEMPM(1-12)	F5.0	60.	32.	212.	degF	Engl
			15.5	0.1	100.	degC	Metric

Explanation

In Table-type GQ-GENDATA, values for data source flags are specified. If TEMPFQ is assigned a value of 3, 12 monthly values for water temperature must be supplied in this table.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(3).7.20 Table-type MON-PHVAL -- Monthly values of pH

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MON-PHVAL
<-range><-----12-values----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-PHVAL
```

```
*****
Example
*****
```

```
MON-PHVAL
  RCHRES  PH1  PH2  PH3  PH4  PH5  PH6  PH7  PH8  PH9  PH10  PH11  PH12***
  # - #
  1   7  6.8  6.8  6.4  6.1  5.9  5.6  5.6  5.9  6.1  6.4  6.8  6.8
END MON-PHVAL
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<12-values>	PHVALM(1-12)	F5.0	7.0	1.0	14.0	none	Both

Explanation

In Table-type GQ-GENDATA, values for data source flags are specified. If PHFLAG is assigned a value of 3, 12 monthly values for pH must be supplied in this table.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(3).7.21 Table-type MON-ROXYGEN -- Monthly values of free radical oxygen

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MON-ROXYGEN
<-range><-----12-values----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-ROXYGEN
```

```
*****
Example
*****
```

```
MON-ROXYGEN
  RCHRES  OX1  OX2  OX3  OX4  OX5  OX6  OX7  OX8  OX9  OX10  OX11  OX12***
  # - #
  1   7  .09  .09  .10  .11  .12  .12  .12  .12  .12  .10  .09  .09
END MON-ROXYGEN
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<12-values>	ROCM(1-12)	F5.0	0.0	0.0	none	mole/l	Both

Explanation

In Table-type GQ-GENDATA, values for data source flags are specified. If ROXFG is assigned a value of 3, 12 monthly values for free radical oxygen concentration must be supplied in this table.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(3).7.22 Table-type GQ-ALPHA -- Values of base absorbance coefficient

```
*****
      1      2      3      4      5      6      7      8
123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
GQ-ALPHA
<-range><-----first-7----->
<-range><-----second-7----->
<-range><-----last-4----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END GQ-ALPHA
```

```
*****
Example
*****
```

```
GQ-ALPHA
RCHRES***
# - #***      K1      K2      K3      K4      K5      K6      K7
# - #***      K8      K9      K10     K11     K12     K13     K14
# - #***      K15     K16     K17     K18
1  7      .008     .009     .010     .011     .011     .011     .012
1  7      .013     .015     .016     .017     .018     .019     .020
1  7      .021     .022     .024     .024
END GQ-ALPHA
```

```
*****
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<first-7>	ALPH(1-7)	F10.0	none	.00001	none	/cm	Both
<second-7>	ALPH(8-14)	F10.0	none	.00001	none	/cm	Both
<last-4>	ALPH(15-18)	F10.0	none	.00001	none	/cm	Both

Explanation

ALPH(1) through ALPH(18) are base absorption coefficients for 18 wavelengths of light passing through clear water.

This table is necessary only when a qual undergoes photolysis; i.e., when any QALFG(3)=1 in Table-type GQ-QALFG.

When an entry has to be continued onto more than 1 line:

1. No blank or comment lines may be put between any of the lines for a continued entry. Put all comments ahead of the entry. (See above example).
2. The <range> specification must be repeated for each line onto which the entry is continued.

4.4(3).7.23 Table-type GQ-GAMMA -- Values of sediment absorbance coefficient

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
GQ-GAMMA
<-range><-----first-7----->
<-range><-----second-7----->
<-range><-----last-4----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END GQ-GAMMA
```

Example

```
GQ-GAMMA
RCHRES***
# - #***      K1         K2         K3         K4         K5         K6         K7
# - #***      K8         K9         K10        K11        K12        K13        K14
# - #***      K15        K16        K17        K18
1  4          .001      .001      .001      .001      .001      .001      .001
1  4          .001      .002      .002      .002      .002      .002      .002
1  4          .002      .002      .002      .002
END GQ-GAMMA
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<first-7>	GAMM(1-7)	F10.0	0.0	0.0	none	l/mg.cm	Both
<second-7>	GAMM(8-14)	F10.0	0.0	0.0	none	l/mg.cm	Both
<last-4>	GAMM(15-18)	F10.0	0.0	0.0	none	l/mg.cm	Both

Explanation

GAMM(1) through GAMM(18) are increments to the base absorbance coefficient (Table-type GQ-ALPHA) for light passing through sediment-laden water.

This is table necessary only when a qual undergoes photolysis; i.e., when any QALFG(3)=1 in Table-type GQ-QALFG.

See rules for continuing an entry onto more than 1 line in Explanation for Table-type GQ-ALPHA.

4.4(3).7.24 Table-type GQ-DELTA -- Values of phytoplankton absorbance coefficient

```
*****
      1      2      3      4      5      6      7      8
123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
GQ-DELTA
<-range><-----first-7----->
<-range><-----second-7----->
<-range><-----last-4----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END GQ-DELTA
```

```
*****
Example
*****
```

```
GQ-DELTA
RCHRES***
# - #***      K1      K2      K3      K4      K5      K6      K7
# - #***      K8      K9      K10     K11     K12     K13     K14
# - #***      K15     K16     K17     K18
1  4      .0007     .0007     .0007     .0007     .0007     .0007     .0007
1  4      .0007     .0007     .0007     .0007     .0007     .0007     .0007
1  4      .0007     .0007     .0007     .0007
END GQ-DELTA
```

```
*****
Details
```

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<first-7>	DEL(1-7)	F10.0	0.0	0.0	none	l/mg.cm	Both
<second-7>	DEL(8-14)	F10.0	0.0	0.0	none	l/mg.cm	Both
<last-4>	DEL(15-18)	F10.0	0.0	0.0	none	l/mg.cm	Both

Explanation

DEL(1) through DEL(18) are increments to the base absorption coefficient (Table-type GQ-ALPHA) for light passing through plankton-laden water.

This table is necessary only when a qual undergoes photolysis; i.e., when any QALFG(3)=1 in Table-type GQ-QALFG.

See rules for continuing an entry onto more than 1 line in Explanation for Table-type GQ-ALPHA.

4.4(3).7.25 Table-type GQ-CLDFACT -- Light extinction efficiency of cloud cover

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
GQ-CLDFACT
<-range><-----first-7----->
<-range><-----second-7----->
<-range><-----last-4----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END GQ-CLDFACT
```

```
*****
Example
*****
```

```
GQ-CLDFACT
RCHRES***
# - #***      F1         F2         F3         F4         F5         F6         F7
# - #***      F8         F9         F10        F11        F12        F13        F14
# - #***      F15        F16        F17        F18
1   4         .10        .10        .10        .15        .15        .15        .15
1   4         .17        .17        .17        .17        .18        .19        .20
1   4         .21        .21        .21        .21
END GQ-CLDFACT
```

```
*****
Details
```

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<first-7>	KCLD(1-7)	F10.0	0.0	0.0	1.0	none	Both
<second-7>	KCLD(8-14)	F10.0	0.0	0.0	1.0	none	Both
<last-4>	KCLD(15-18)	F10.0	0.0	0.0	1.0	none	Both

Explanation

KCLD(1) through KCLD(18) are values of light extinction efficiency of cloud cover for each of 18 wavelengths.

This table is necessary only when a qual undergoes photolysis; i.e., when any QALFG(3)=1 in Table-type GQ-QALFG.

See rules for continuing an entry onto more than 1 line in Explanation for Table-type GQ-ALPHA.

4.4(3).7.26 Table-type MON-CLOUD -- Monthly values of cloud cover

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MON-CLOUD
<-range><-----12-values----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-CLOUD
```

```
*****
Example
*****
```

```
MON-CLOUD
  RCHRES   C1   C2   C3   C4   C5   C6   C7   C8   C9   C10  C11  C12***
  # - #
  1   7   3   3   4   3   2   1   1   1   0   1   1   2
END MON-CLOUD
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<12-values>	CLDM(1-12)	F5.0	0.0	0.0	10.0	tenths	Both

Explanation

CLDM(1) through CLDM(12) are monthly values of average cloud cover. This table must be included in the UCI only if CLDFG=3 in Table-type GQ-GENDATA.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(3).7.27 Table-type MON-SEDCONC -- Monthly values of sediment concentration

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
MON-SEDCONC
<-range><-----12-values----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-SEDCONC
```

```
*****
Example
*****
```

```
MON-SEDCONC
  RCHRES  SC1  SC2  SC3  SC4  SC5  SC6  SC7  SC8  SC9  SC10  SC11  SC12***
  # - #
  1   7   2.   4.  10. 120.  75.  10.   8.   8.   6.   6.   4.   4.
END MON-SEDCONC
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<12-values>	SDCNCM(1-12)	F5.0	0.0	0.0	none	mg/l	Both

Explanation

SDCNCM(1) through SDCNCM(12) are monthly average suspended sediment concentration values. This table must be included in the UCI only if SDFG=3 in Table-type GQ-GENDATA.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(3).7.28 Table-type MON-PHYTO -- Monthly values of phytoplankton concentration

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
MON-PHYTO
<-range><-----12-values----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MON-PHYTO
```

Example

```
MON-PHYTO
  RCHRES  P1   P2   P3   P4   P5   P6   P7   P8   P9  P10  P11  P12***
  # - #
  1   7  .01  .03  .03  .03  .04  .11  .33  .47  .31  .17  .15  .06
END MON-PHYTO
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<12-values>	PHYM(1-12)	F5.0	0.0	0.0	none	mg/l	Both

Explanation

PHYM(1) through PHYM(12) are monthly values of phytoplankton concentration. This table must be included in the UCI only if PHYTFG=3 in Table-type GQ-GENDATA.

Note: The input monthly values apply to the first day of the month, and values for intermediate days are obtained by interpolating between successive monthly values.

4.4(3).7.29 Table-type GQ-DAUGHTER -- Relationship between parent and daughter quals

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

GQ-DAUGHTER

<-range><--zero--><2-from-1><3-from-1>

<-range><--zero--><--zero--><3-from-2>

<-range><--zero--><--zero--><--zero-->

.

(repeats until all operations of this type are covered)

.

END GQ-DAUGHTER

Example

GQ-DAUGHTER

RCHRES

- # ZERO 2F1 3F1***

- # ZERO ZERO 3F2***

- # ZERO ZERO ZERO***

1 7 0.0 .36 .02

1 7 0.0 0.0 1.24

1 7 0.0 0.0 0.0

END GQ-DAUGHTER

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<zero>	0.0						
<2-from-1>	C(2,1)	F10.0	0.0	0.0	none	none	Both
<3-from-1>	C(3,1)	F10.0	0.0	0.0	none	none	Both
<3-from-2>	C(3,2)	F10.0	0.0	0.0	none	none	Both

Explanation

This table-type specifies the relationship between parent and daughter compounds. For example, variable C(2,1) indicates the amount of qual #2 which is produced by decay of qual #1 through one of the decay processes. The table must be repeated in sequence for each decay process that produces daughter quals from decay of parent quals. The proper sequence is: 1-hydrolysis, 2-oxidation by free radical oxygen, 3-photolysis, 4-(reserved for future use), 5-biodegradation, 6-general first order decay. For example, if biodegradation is the only process of interest, five of these tables must be included in the UCI file, and the fifth one should contain nonzero values.

4.4(3).8 RCHRES-BLOCK -- Input for RQUAL sections

```
*****  
          1          2          3          4          5          6          7          8  
1234567890123456789012345678901234567890123456789012345678901234567890  
*****  
Layout  
*****
```

```
[Table-type BENTH-FLAG]  
[Table-type SCOUR-PARMS]  
Section OXRX input  
[Section NUTRX input] if NUTRX is active  
[Section PLANK input] if PLANK is active  
[Section PHCARB input] if PHCARB is active
```

```
*****
```

Explanation

The exact format of each of the tables above is detailed in the documentation which follows. Tables in brackets [] need not always be supplied; for example, because all of the inputs have default values.

4.4(3).8.01 Table-type BENTH-FLAG -- Benthic release flag

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
BENTH-FLAG
<-range><ben>
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END BENTH-FLAG
```

Example

```
BENTH-FLAG
  RCHRES BENF***
  # - #      ***
  1   7
END BENTH-FLAG
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<ben>	BENRFG	I5	0	0	1	none	Both

Explanation

If BENRFG is 1, benthic influences are considered in the following sections.

4.4(3).8.02 Table-type SCOUR-PARMS -- Benthic scour parameters

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
SCOUR-PARMS
<-range><----scour-params---->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END SCOUR-PARMS
```

Example

```
SCOUR-PARMS
  RCHRES   SCRVEL   SCRML***
  # - #    ft/sec   ***
  1   7     15.     3.
END SCOUR-PARMS
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<scour-params>	SCRVEL	F10.0	10. 3.05	.01 .01	none none	ft/sec m/sec	Engl Metric
	SCRML	F10.0	2.0	1.0	none	none	Both

Explanation

SCRVEL is the threshold velocity above which the effect of scouring on benthic release rates is considered.

SCRML is the multiplier by which benthic releases are increased during scouring.

4.4(3).8.1 RCHRES-BLOCK -- Section OXRX input

```
*****
      1      2      3      4      5      6      7      8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
+ [Table-type OX-FLAGS]
  Table-type OX-GENPARM
+ [Table-type ELEV]      if section HTRCH is not active
  [Table-type OX-BENPARM] if BENRFG=1 (Table-type BENTH-FLAG)
+ [Table-type OX-CFOREA] if LKFG=1 (Table-type GEN-INFO)

                                     --- if
+ [Table-type OX-TSIVOGLOU]          | REAMFG=1
+ Table-type OX-LEN-DELTH  if section HYDR inactive | (Tsivoglou) | if
                                     ---          | LKFG=0
+ [Table-type OX-TCGINV]      if REAMFG=2 (Owen/Churchill,etc.)
+ Table-type OX-REAPARM      if REAMFG=3
                                     ---

[Table-type OX-INIT]
```

Note: If any of the tables marked "+" above were supplied in your input for Section GQUAL, they must not be repeated here (these are the tables used to calculate the oxygen reaeration coefficient, which, under certain conditions, is also needed in Section GQUAL).

Explanation

The conditions under which data from the various tables are needed are indicated above. REAMFG is the reaeration method flag, defined in Table-type OX-FLAGS below.

The exact format of each of the tables above is detailed in the documentation which follows. Tables in brackets [] need not always be supplied; for example, because all of the inputs have default values.

4.4(3).8.1.1 Table-type OX-FLAGS -- Oxygen flags

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
OX-FLAGS
<-range><oxf>
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END OX-FLAGS
```

```
*****
Example
*****
```

```
OX-FLAGS
RCHRES REAM ***
# - #      ***
1   7   2
END OX-FLAGS
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<oxf>	REAMFG	I5	2	1	3	none	Both

Explanation

REAMFG indicates the method used to calculate the reaeration coefficient for free-flowing streams.

- 1 Tsivoglou method is used.
- 2 Owens, Churchill, or O'Connor-Dobbins method is used depending on velocity and depth of water.
- 3 Coefficient is calculated as a power function of velocity and/or depth; user inputs exponents for velocity and depth and an empirical constant (REAK).

4.4(3).8.1.2 Table-type OX-GENPARM -- General oxygen parameters

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
OX-GENPARM
<-range><-----ox-genparm----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END OX-GENPARM
```

```
*****
Example
*****
```

```
OX-GENPARM
  RCHRES      KBOD20      TCBOD      KODSET      SUPSAT***
  # - #       /hr        1.06      ft/hr        ***
  1   7       0.1        8.0        1.2
END OX-GENPARM
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<ox-genparm>	KBOD20	F10.0	none	1.0E-30	none	/hr	Both
	TCBOD	F10.0	1.075	1.0	2.0	none	Both
	KODSET	F10.0	0.0	0.0	none	ft/hr	Engl
			0.0	0.0	none	m/hr	Metric
	SUPSAT	F10.0	1.15	1.0	2.0	none	Both

Explanation

KBOD20 is the unit BOD decay rate @ 20 degrees C.
 TCBOD is the temperature correction coefficient for BOD decay.
 KODSET is the rate of BOD settling.
 SUPSAT is the maximum allowable dissolved oxygen supersaturation (expressed as a multiple of the dissolved oxygen saturation concentration).

4.4(3).8.1.3 Table-type ELEV -- RCHRES elevation above sea level

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
ELEV
<-range><--elev-->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END ELEV
```

Example

```
ELEV
  RCHRES      ELEV***
  # - #       ft***
  1   7       2100.
END ELEV
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<elev>	ELEV	F10.0	0.0	0.0	30000	ft	Engl
			0.0	0.0	10000	m	Metric

Explanation

ELEV is the mean RCHRES elevation above sea level.

4.4(3).8.1.4 Table-type OX-BENPARG -- Oxygen benthic parameters

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
OX-BENPARG
<-range><-----ox-benparm----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END OX-BENPARG
```

Example

```
*****
OX-BENPARG
  RCHRES      BENOD      TCBEN      EXPOD  BRBOD(1)  BRBOD(2)  EXPREL  ***
  # - #  mg/m2.hr                mg/m2.hr  mg/m2.hr                ***
  1   7      1.0
END OX-BENPARG
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<ox-benparm>	BENOD	F10.0	0.0	0.0	none	mg/m2.hr	Both
	TCBEN	F10.0	1.074	1.0	2.0	none	Both
	EXPOD	F10.0	1.22	0.1	none	none	Both
	BRBOD(1)	F10.0	72.	.0001	none	mg/m2.hr	Both
	BRBOD(2)	F10.0	100.	.0001	none	mg/m2.hr	Both
	EXPREL	F10.0	2.82	0.1	none	none	Both

Explanation

This table is used if BENRFG = 1 in Table-type BENTH-FLAG (see RQUAL section).

BENOD is the benthic oxygen demand at 20 degrees C (with unlimited DO concentration) (demand is, thus, proportional to the water temperature).?

TCBEN is the temperature correction coefficient for benthic oxygen demand.

EXPOD is the exponential factor in the dissolved oxygen term of the benthic oxygen demand equation.

BRBOD(1) is the benthic release rate of BOD under aerobic conditions, and BRBOD(2) is the increment to benthic release of BOD under anaerobic conditions.

EXPREL is the exponent in the DO term of the benthic BOD release equation.

4.4(3).8.1.5 Table-type OX-CFOREA -- Lake reaeration correction coefficient

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
OX-CFOREA
<-range><-cforea->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END OX-CFOREA
```

Example

```
OX-CFOREA
  RCHRES   CFOREA***
  # - #           ***
  1   7         0.8
END OX-CFOREA
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<cforea>	CFOREA	F10.0	1.0	.001	10.

Explanation

CFOREA is a correction factor in the lake reaeration equation; it accounts for good or poor circulation characteristics.

4.4(3).8.1.6 Table-type OX-TSIVOGLOU -- Parameters for the Tsivoglou calculation of reaeration rate

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
OX-TSIVOGLOU
<-range><---ox-tsivoglou--->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END OX-TSIVOGLOU
```

Example

```
OX-TSIVOGLOU
  RCHRES      REAKT      TCGINV***
  # - #       /ft       ***
  1   7       .07      1.1
END OX-TSIVOGLOU
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<ox-tsivoglou>	REAKT	F10.0	0.08	0.001	1.0	/ft	Both
	TCGINV	F10.0	1.047	1.0	2.0	none	Both

Explanation

This table is required if REAMFG is 1.

REAKT is the empirical constant in Tsivoglou's equation for reaeration (escape coefficient).

TCGINV is the temperature correction coefficient for surface gas invasion.

4.4(3).8.1.7 Table-type OX-LEN-DELTH -- Length and water elevation drop of reach

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
OX-LEN-DELTH
<-range><---ox-len-delth--->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END OX-LEN-DELTH
```

```
*****
Example
*****
```

```
OX-LEN-DELTH
  RCHRES      LEN      DELTH***
  # - #      miles      ft***
  1   7      10.       200.
END OX-LEN-DELTH
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<ox-len-delth>	LEN	F10.0	none	.01	none	miles	Engl
			none	.01	none	km	Metric
	DELTH	F10.0	none	0.00001	none	ft	Engl
			none	0.00001	none	m	Metric

Explanation

This table is only relevant if HYDR is inactive and REAMFG = 1.

LEN is the length of the RCHRES.

DELTH is the (energy) drop of the RCHRES over its length.

4.4(3).8.1.8 Table-type OX-TCGINV -- Owen/Churchill/O'Connor-Dobbins data
(temperature correction coefficient)

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
OX-TCGINV
<-range><-tcginv->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END OX-TCGINV
```

Example

```
OX-TCGINV
  RCHRES      TCGINV***
  # - #          ***
  1   7      1.07
END OX-TCGINV
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<tcginv>	TCGINV	F10.0	1.047	1.0	2.0

Explanation

This table is used when REAMFG = 2.

TCGINV is the temperature correction coefficient for surface gas invasion.

4.4(3).8.1.9 Table-type OX-REAPARM -- Parameters for user-supplied reaeration formula

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
OX-REAPARM
<-range><-----ox-reaparm----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END OX-REAPARM
```

Example

```
OX-REAPARM
  RCHRES   TCGINV   REAK   EXPRED   EXPREV***
  # - #           /hr           ***
  1   7       1.08   1.0     -2.0     0.7
END OX-REAPARM
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<ox-reaparm>	TCGINV	F10.0	1.047	1.0	2.0	none	Both
	REAK	F10.0	none	1.0E-30	none	/hr	Both
	EXPRED	F10.0	0.0	none	0.0	none	Both
	EXPREV	F10.0	0.0	0.0	none	none	Both

Explanation

This table is used when REAMFG = 3.

TCGINV - See explanation for Table-type OX-TSIVOGLOU.

REAK is the empirical constant in the equation used to calculate the reaeration coefficient.

EXPRED is the exponent to depth and EXPREV is the exponent to velocity in the reaeration coefficient equation.

4.4(3).8.1.10 Table-type OX-INIT -- Initial concentrations for the OXRX section

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
OX-INIT
<-range><-----ox-init----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END OX-INIT
```

```
*****
Example
*****
```

```
OX-INIT
  RCHRES      DOX      BOD      SATDO***
  # - #      mg/l     mg/l     mg/l***
  1   7      26.     17.2    43.
END OX-INIT
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<ox-init>	DOX	F10.0	0.0	0.0	20.0	mg/l	Both
	BOD	F10.0	0.0	0.0	none	mg/l	Both
	SATDO	F10.0	10.0	0.1	20.0	mg/l	Both

Explanation

DOX is the initial dissolved oxygen.
 BOD is the initial biochemical oxygen demand.
 SATDO is the initial dissolved oxygen saturation concentration.

4.4(3).8.2 RCHRES-BLOCK -- Section NUTRX input

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
[Table-type NUT-FLAGS]
[Table-type NUT-AD-FLAGS]
[Table-type CONV-VAL1]
[Table-type NUT-BENPARM]  if BENRFG=1 in Table-type BENTH-FLAG
  Table-type NUT-NITDENIT
[Table-type NUT-NH3VOLAT] if NH3 volatilization is simulated
                        (TAMFG=1 and AMVFG=1 in Table-type NUT-FLAGS)
[Table-type MON-PHVAL]   if NH3 is simulated and monthly values of pH are being
                        input (TAMFG=1 and PHFLAG=3 in Table-type NUT-FLAGS)
                        see section GQUAL for documentation
                        ---
[Table-type NUT-BEDCONC] |      if NH3 or PO4 adsorption is simulated
[Table-type NUT-ADSPARM] |--- ((TAMFG=1 and ADNHF=1) or
[Table-type NUT-ADSINIT] |      (PO4FG=1 and ADPOFG=1) in Table-type NUT-FLAGS)
                        ---
[Table-type NUT-DINIT]
*****
```

Explanation

The exact format of each of the tables above is detailed in the documentation which follows. Tables in brackets [] need not always be supplied; for example, because all of the inputs have default values.

BENRFG indicates whether or not benthic influences are considered. TAMFG indicates whether or not ammonia is simulated, and ADNHF indicates whether ammonia adsorption is considered. PO4FG indicates whether or not ortho-phosphorus is simulated, and ADPOFG indicates whether PO4 adsorption is considered.

4.4(3).8.2.1 Table-type NUT-FLAGS -- Nutrient flags

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
NUT-FLAGS
<-range><-----nut-flags----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END NUT-FLAGS
```

```
*****
Example
*****
```

```
NUT-FLAGS
  RCHRES  TAM  NO2  PO4  AMV  DEN  ADNH  ADPO  PHFL  ***
  # - #
  1   7   1         1
END NUT-FLAGS
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<nut-flags>	TAMFG,NO2FG, PO4FG,AMVFG, DENFG,ADNHFG, ADPOFG	I5	0	0	1
	PHFLG	I5	2	1	3

Explanation

- TAMFG - If on, total ammonia is simulated.
- NO2FG - If on, nitrite is simulated.
- PO4FG - If on, ortho-phosphorus is simulated.
- AMVFG - If on, ammonia volatilization is enabled.
- DENFG - If on, denitrification is enabled.
- ADNHFG - If on, NH4 adsorption is simulated.
- ADPOFG - If on, PO4 adsorption is simulated.
- PHFLAG - Source of pH data (1=time series, 2=constant, 3=monthly values).

4.4(3).8.2.2 Table-type NUT-AD-FLAGS -- Atmospheric deposition flags for nutrients

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
NUT-AD-FLAGS
<-range> <f><c> <f><c> <f><c> <f><c>
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END NUT-AD-FLAGS
```

Example

```
NUT-AD-FLAGS
RCHRES Atmospheric deposition flags ***
***      NO3      NH3      PO4
#*** # <F><C> <F><C> <F><C>
1      7  -1 10  -1 -1  11 12
END NUT-AD-FLAGS
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<f><c>	NUADFG(*)	(1X,2I3)	0	-1	none

Explanation

NUADFG is an array of flags indicating the source of atmospheric deposition data. Each nutrient has two flags. The first is for dry or total deposition flux, and the second is for wet deposition concentration. The flag values indicate:

- 0 No deposition of this type is simulated
- 1 Deposition of this type is input as time series NUADFX or NUADCN
- >0 Deposition of this type is input in the MONTH-DATA table with the corresponding table ID number.

4.4(3).8.2.3 Table-type CONV-VAL1 -- Conversion factors for nutrients

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
CONV-VAL1
<-range><-----conv-val1----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END CONV-VAL1
```

Example

```
CONV-VAL1
  RCHRES      CVBO      CVBPC      CVBPN      BPCNTC***
  # - #      mg/mg    mols/mol  mols/mol
  1   7      4.0      67.      33.      77.
END CONV-VAL1
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<conv-val1>	CVBO	F10.0	1.98	1.0	5.0	mg/mg	Both
	CVBPC	F10.0	106.	50.	200.	mols/mol	Both
	CVBPN	F10.0	16.	10.	50.	mols/mol	Both
	BPCNTC	F10.0	49.	10.	100.	none	Both

Explanation

- CVBO - Conversion from milligrams biomass to milligrams oxygen.
- CVBPC - Conversion from biomass expressed as phosphorus to carbon.
- CVBPN - Conversion from biomass expressed as phosphorus to nitrogen.
- BPCNTC - Percentage of biomass which is carbon (by weight).

4.4(3).8.2.4 Table-type NUT-BENPARM -- Nutrient benthic parameters

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
NUT-BENPARM
<-range><-----nut-benparm----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END NUT-BENPARM
```

```
*****
Example
*****
```

```
NUT-BENPARM
  RCHRES  BRTAM(1)  BRTAM(2)  BRPO4(1)  BRPO4(2)  ANAER***
  # - #  mg/m2.hr  mg/m2.hr  mg/m2.hr  mg/m2.hr  mg/l***
  1   7    10.    20.    1.0    4.0    .001
END NUT-BENPARM
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<nut-benparm>	BRTAM(1)	5F10.0	0.0	0.0	none	mg/m2.hr	Both
	BRTAM(2)		0.0	0.0	none	mg/m2.hr	Both
	BRPO4(1)		0.0	0.0	none	mg/m2.hr	Both
	BRPO4(2)		0.0	0.0	none	mg/m2.hr	Both
	ANAER		.005	.0001	1.0	mg/l	Both

Explanation

This table is used if BENRFG = 1 in Table-type BENTH-FLAG (see RQUAL section).

BRTAM(1) and BRTAM(2) are the benthic release rates of ammonia under aerobic and anaerobic conditions, respectively.

BRPO4(1) and BRPO4(2) are the benthic release rates of ortho-phosphorus. The subscripts are the same as BRTAM.

ANAER is the concentration of dissolved oxygen below which anaerobic conditions are assumed to exist.

4.4(3).8.2.5 Table-type NUT-NITDENIT -- Nitrification and denitrification parameters.

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
NUT-NITDENIT
<-range><-----nut-nitdenit----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END NUT-NITDENIT
```

Example

```
NUT-NITDENIT
  RCHRES   KTAM20   KNO220   TCNIT   KNO320   TCDEN   DENOXT ***
  # - #     /hr     /hr     1.1     /hr     1.08   mg/l ***
  1   7     .05     .05
END NUT-NITDENIT
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units
<nut-nitdenit>	KTAM20	6F10.0	none	0.001	none	/hr
	KNO220		none	0.001	none	/hr
	TCNIT		1.07	1.0	2.0	
	KNO320		none	0.001	none	/hr
	TCDEN		1.07	1.0	2.0	
	DENOXT		2.00	0.0	none	mg/l

Explanation

KTAM20 and KNO220 are the nitrification rates of ammonia and nitrite, respectively, at 20 degrees C.

KNO320 is the nitrate denitrification rate at 20 degrees C.

TCNIT and TCDEN are the temperature correction coefficients for nitrification and denitrification, respectively.

DENOXT is the dissolved oxygen concentration threshold for denitrification.

4.4(3).8.2.6 Table-type NUT-NH3VOLAT -- Ammonia volatilization parameters

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
NUT-NH3VOLAT
<-range><---nut-nh3volat--->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END NUT-NH3VOLAT
```

Example

```
NUT-NH3VOLAT
  RCHRES      EXPNVG      EXPNVL ***
  # - #              ***
  5   6          0.6      0.8
END NUT-NH3VOLAT
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<nut-nh3volat>	EXPNVG	F10.0	0.5	0.1	2.0	none	Both
	EXPNVL	F10.0	.6667	0.1	2.0	none	Both

Explanation

EXPNVG is the exponent in the gas layer mass transfer coefficient equation for NH3 volatilization.

EXPNVL is the exponent in the liquid layer mass transfer coefficient equation for NH3 volatilization.

4.4(3).8.2.7 Table-type NUT-BEDCONC -- Bed concentrations of adsorbed NH3 and PO4

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
NUT-BEDCONC
<-range><-----nut-bedconc----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END NUT-BEDCONC
```

```
*****
Example
*****
```

```
NUT-BEDCONC
  RCHRES      Bed concentrations of NH4 & PO4 (mg/kg)      ***
  # - # NH4-sand NH4-silt NH4-clay PO4-sand PO4-silt PO4-clay ***
  2   3   0.01   0.02   0.03   0.10   0.20   0.30
END NUT-BEDCONC
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units
<nut-bedconc>	BNH4(3)	3F10.0	0.0	0.0	none	mg/kg
	BPO4(3)	3F10.0	0.0	0.0	none	mg/kg

Explanation

BNH4(1-3) are the constant bed concentrations of ammonia-N adsorbed to sand, silt, and clay.

BPO4(1-3) are the constant bed concentrations of ortho-phosphorus-P adsorbed to sand, silt, and clay.

4.4(3).8.2.8 Table-type NUT-ADSPARM -- Adsorption coefficients for ammonia and ortho-phosphorus

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
NUT-ADSPARM
<-range><-----nut-adsparm----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END NUT-ADSPARM
```

```
*****
Example
*****
```

```
NUT-ADSPARM
RCHRES          Partition coefficients for NH4 AND PO4 (cm3/g)          ***
# - # NH4-sand  NH4-silt  NH4-clay  PO4-sand  PO4-silt  PO4-clay ***
2   3    0.10    0.30    0.50    0.10    0.50    0.80
END NUT-ADSPARM
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units
<nut-adsparm>	ADNHPM(3)	3F10.0	1.E-10	1.E-10	none	cm3/g
	ADPOPM(3)	3F10.0	1.E-10	1.E-10	none	cm3/g

Explanation

ADNHPM(1-3) are the adsorption coefficients (Kd) for ammonia-N adsorbed to sand, silt, and clay.

ADPOPM(1-3) are the adsorption coefficients for ortho-phosphorus-P adsorbed to sand, silt, and clay.

4.4(3).8.2.9 Table-type NUT-DINIT -- Initial concentrations of dissolved nutrients

```
*****
      1      2      3      4      5      6      7      8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
NUT-DINIT
<-range><-----nut-dinit----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END NUT-DINIT
```

```
*****
Example
*****
```

```
NUT-DINIT
  RCHRES      NO3      TAM      NO2      PO4      PHVAL  ***
  # - #      mg/l      mg/l      mg/l      mg/l  ph units  ***
  1   3      1.0      0.3      0.01     0.02     7.
END NUT-DINIT
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units
<nut-dinit>	NO3	5F10.0	0.0	0.0	none	mg/l
	TAM		0.0	0.0	none	mg/l
	NO2		0.0	0.0	none	mg/l
	PO4		0.0	0.0	none	mg/l
	PHVAL		7.0	0.0	14.0	pH units

Explanation

NO3, TAM, and NO2 are the initial concentrations of nitrate, total ammonia, and nitrite (as N).

PO4 is the initial concentration of ortho-phosphorus (as P).

PHVAL is the constant pH value if PHFLG=2, and the initial value of pH if PHFLG=1 or 3.

4.4(3).8.2.10 Table-type NUT-ADSINIT -- Initial concentrations of NH3 and PO4 adsorbed to suspended sediment

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
NUT-ADSINIT
<-range><-----nut-adsinit----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END NUT-ADSINIT
```

```
*****
Example
*****
```

```
NUT-ADSINIT
RCHRES          Initial suspended NH4 and PO4 concentrations (mg/kg) ***
# - # NH4-sand  NH4-silt  NH4-clay  PO4-sand  PO4-silt  PO4-clay ***
2   3    0.10    0.30    0.50    0.10    0.50    0.80
END NUT-ADSINIT
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units
<nut-adsinit>	SNH4(3)	3F10.0	0.0	0.0	none	mg/kg
	SPO4(3)	3F10.0	0.0	0.0	none	mg/kg

Explanation

SNH4(1-3) are the initial concentrations of ammonia-N adsorbed to sand, silt, and clay.

SPO4(1-3) are the initial concentrations of ortho-phosphorus-P adsorbed to sand, silt, and clay.

4.4(3).8.3.1 Table-type PLNK-FLAGS -- Plankton flags

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

PLNK-FLAGS

<-range><-----plnk-flags----->

.
(repeats until all operations of this type are covered)

.

END PLNK-FLAGS

Example

PLNK-FLAGS

RCHRES PHYF ZOOF BALF SDLT AMRF DECF NSFG ZFOO ***

- # ***

1 7 1 1 3

END PLNK-FLAGS

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<plnk-flags>	PHYFG,ZOOFG, BALFG,SDLTFG, AMRFG,DECFG, NSFG	I5	0	0	1
	ZFOOD	I5	2	1	3

Explanation

The following, except for ZFOOD, are the conditions when the flag is on:

- PHYFG - Phytoplankton are simulated.
- ZOOFG - Zooplankton are simulated.
- BALFG - Benthic algae are simulated.
- SDLTFG - Influence of sediment washload on light extinction is simulated.
- AMRFG - Ammonia retardation of nitrogen-limited growth is enabled.
- DECFG - Linkage between carbon dioxide and phytoplankton growth is decoupled.
- NSFG - Ammonia is included as part of available nitrogen supply in nitrogen limited growth calculations.
- ZFOOD - Indicates the quality of zooplankton food.

4.4(3).8.3.2 Table-type PLNK-AD-FLAGS -- Atmospheric deposition flags for refractory organics

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
PLK-AD-FLAGS
<-range> <f><c> <f><c> <f><c>
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PLK-AD-FLAGS
```

Example

```
PLK-AD-FLAGS
RCHRES Atmospheric deposition flags ***
***   ORN   ORP   ORC
#*** # <F><C> <F><C> <F><C>
1    7  -1 10  -1 -1  11 12
END PLK-AD-FLAGS
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<f><c>	PLADFG(*)	(1X,2I3)	0	-1	none

Explanation

PLADFG is an array of flags indicating the source of atmospheric deposition data. Each organic constituent has two flags. The first is for dry or total deposition flux, and the second is for wet deposition concentration. The flag values indicate:

- 0 No deposition of this type is simulated
- 1 Deposition of this type is input as time series PLADFX or PLADCN
- >0 Deposition of this type is input in the MONTH-DATA table with the corresponding table ID number.

4.4(3).8.3.3 Table-type SURF-EXPOSED -- Correction factor for solar radiation data

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
SURF-EXPOSED
<-range><surf-exp>
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END SURF-EXPOSED
```

Example

```
SURF-EXPOSED
  RCHRES    CFSAEX  ***
  # - #      ***
  1   7      .5
END SURF-EXPOSED
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<surf-exp>	CFSAEX	F10.0	1.0	0.001	1.0	none	Both

Explanation

This factor is used to adjust the input solar radiation to make it applicable to the RCHRES; for example, to account for shading of the surface by trees or buildings.

4.4(3).8.3.4 Table-type PLNK-PARM1 -- First group of general plankton parameters

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

PLNK-PARM1

<-range><-----plnk-parm1----->

.

(repeats until all operations of this type are covered)

.

END PLNK-PARM1

Example

PLNK-PARM1

```
  RCHRES   RATCLP   NONREF   LITSED   ALNPR   EXTB   MALGR***
  # - #
  1   7       .5       .3           .4       0.1
  /ft      /hr***
```

END PLNK-PARM1

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<plnk-parm1>	RATCLP	F10.0	.6	.01	none	none	Both
	NONREF	F10.0	.5	.01	1.0	none	Both
	LITSED	F10.0	0.0	0.0	none	l/mg.ft	Both
	ALNPR	F10.0	1.0	.01	1.0	none	Both
	EXTB	F10.0	none	.001	none	/ft	Engl
			none	.001	none	/m	Metric
	MALGR	F10.0	.3	.001	none	/hr	Both

Explanation

RATCLP is the ratio of chlorophyll A content of biomass to phosphorus content.
 NONREF is the non-refractory fraction of algae and zooplankton biomass.
 LITSED is the multiplication factor to total sediment concentration to determine sediment contribution to light extinction.
 ALNPR is the fraction of nitrogen requirements for phytoplankton growth that is satisfied by nitrate.
 EXTB is the base extinction coefficient for light.
 MALGR is the maximum unit algal growth rate.

4.4(3).8.3.5 Table-type PLNK-PARM2 -- second group of general plankton parameters

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

PLNK-PARM2

<-range><-----plnk-parm2----->

.
(repeats until all operations of this type are covered)

.

END PLNK-PARM2

Example

PLNK-PARM2

```
RCHRES *** CMLLT      CMMN      CMMNP      CMMP      TALGRH      TALGRL      TALGRM
# - # ***ly/min      mg/l      mg/l      mg/l      degF      degF      degF
1   7      .01      .05      .04      85.0      44.0      71.0
```

END PLNK-PARM2

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<plnk-parm2>	CMLLT	F10.0	.033	1.0E-6	none	ly/min	Both
	CMMN	F10.0	.045	1.0E-6	none	mg/l	Both
	CMMNP	F10.0	.0284	1.0E-6	none	mg/l	Both
	CMMP	F10.0	.015	1.0E-6	none	mg/l	Both
	TALGRH	F10.0	95.	50.	212.	degF	Engl
			35.	10.	100.	degC	Metric
	TALGRL	F10.0	43.	-120.	212.	degF	Engl
			6.1	-84.	100.	degC	Metric
	TALGRM	F10.0	77.	32.	212.	degF	Engl
			25.	0.0	100.	degC	Metric

Explanation

CMLLT is the Michaelis-Menten constant for light limited growth.
 CMMN is the nitrate Michaelis-Menten constant for nitrogen limited growth.
 CMMNP is the nitrate Michaelis-Menten constant for phosphorus limited growth.
 CMMP is the phosphate Michaelis-Menten constant for phosphorus limited growth.
 TALGRH is the temperature above which algal growth ceases.
 TALGRL is the temperature below which algal growth ceases.
 TALGRM is the temperature below which algal growth is retarded.

4.4(3).8.3.6 Table-type PLNK-PARM3 -- Third group of general plankton parameters

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
PLNK-PARM3
<-range><-----plnk-parm3----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PLNK-PARM3
```

Example

```
PLNK-PARM3
  RCHRES      ALR20      ALDH      ALDL      OXALD      NALDH      PALDH***
  # - #       /hr       /hr       /hr       /hr       mg/l       mg/l***
  1   7               .02               .04
END PLNK-PARM3
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<plnk-parm3>	ALR20	F10.0	.004	1.0E-6	none	/hr	Both
	ALDH	F10.0	.01	1.0E-6	none	/hr	Both
	ALDL	F10.0	.001	1.0E-6	none	/hr	Both
	OXALD	F10.0	.03	1.0E-6	none	/hr	Both
	NALDH	F10.0	0.0	0.0	none	mg/l	Both
	PALDH	F10.0	0.0	0.0	none	mg/l	Both

Explanation

ALR20 is the algal unit respiration rate at 20 degrees C.
 ALDH is the high algal unit death rate.
 ALDL is the low algal unit death rate.
 OXALD is the increment to phytoplankton unit death rate due to anaerobic conditions.
 NALDH is the inorganic nitrogen concentration below which high algal death rate occurs (as nitrogen).
 PALDH is the inorganic phosphorus concentration below which high algal death rate occurs (as phosphorus).

4.4(3).8.3.7 Table-type PHYTO-PARM -- Phytoplankton parameters

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
PHYTO-PARM
<-range><-----phyto-parm----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PHYTO-PARM
```

Example

```
*****
PHYTO-PARM
  RCHRES      SEED      MXSTAY      OREF      CLALDH      PHYSET      REFSET***
  # - #      mg/l      mg/l      ft3/s      ug/l      ft/hr      ft/hr***
  1   7      2.0      15.      8.0
END PHYTO-PARM
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<phyto-parm>	SEED	F10.0	0.0	0.0	none	mg/l	Both
	MXSTAY	F10.0	0.0	0.0	none	mg/l	Both
	OREF	F10.0	0.0001	0.0001	none	ft3/s	Engl
			0.0001	0.0001	none	m3/s	Metric
	CLALDH	F10.0	50.0	.01	none	ug/l	Both
	PHYSET	F10.0	0.0	0.0	none	ft/hr	Engl
			0.0	0.0	none	m/hr	Metric
	REFSET	F10.0	0.0	0.0	none	ft/hr	Engl
0.0			0.0	none	m/hr	Metric	

Explanation

SEED is the minimum concentration of plankton not subject to advection (i.e., at high flow).
 MXSTAY is the concentration of plankton not subject to advection at very low flow.
 OREF is the outflow at which the concentration of plankton not subject to advection is midway between SEED and MXSTAY.
 CLALDH is the chlorophyll A concentration above which high algal death rate occurs.
 PHYSET is the rate of phytoplankton settling.
 REFSET is the rate of settling for dead refractory organics.

4.4(3).8.3.8 Table-type ZOO-PARM1 -- First group of zooplankton parameters

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
ZOO-PARM1
<-range><-----zoo-parm1----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END ZOO-PARM1
```

```
*****
Example
*****
```

```
ZOO-PARM1
RCHRES    MZOEAT    ZFIL20    ZRES20    ZD        OXZD***
# - #    mg/l.hr  l/mgzoo.hr    /hr        /hr        /hr***
1    7        .098        0.2
END ZOO-PARM1
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<zoo-parm1>	MZOEAT	F10.0	.055	.001	none	mg phyto/ mg zoo/hr	Both
	ZFIL20	F10.0	none	0.001	none	l/mg zoo/hr	Both
	ZRES20	F10.0	.0015	1.0E-6	none	/hr	Both
	ZD	F10.0	.0001	1.0E-6	none	/hr	Both
	OXZD	F10.0	.03	1.0E-6	none	/hr	Both

Explanation

MZOEAT is the maximum zooplankton unit ingestion rate.
 ZFIL20 is the zooplankton filtering rate at 20 degrees C.
 ZRES20 is the zooplankton unit respiration rate at 20 degrees C.
 ZD is the natural zooplankton unit death rate.
 OXZD is the increment to unit zooplankton death rate due to anaerobic conditions.

4.4(3).8.3.9 Table-type ZOO-PARM2 -- Second group of zooplankton parameters

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
ZOO-PARM2
<-range><-----zoo-parm2----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END ZOO-PARM2
```

Example

```
ZOO-PARM2
  RCHRES   TCZFIL   TCZRES   ZEXDEL   ZOMASS***
  # - #
  1   7       1.2     1.1       0.8
END ZOO-PARM2
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<zoo-parm2>	TCZFIL	F10.0	1.17	1.0	2.0	none	Both
	TCZRES	F10.0	1.07	1.0	2.0	none	Both
	ZEXDEL	F10.0	0.7	.001	1.0	none	Both
	ZOMASS	F10.0	.0003	1.0E-6	1.0	mg/org	Both

Explanation

TCZFIL and TCZRES are the temperature correction coefficients for filtering and respiration, respectively.

ZEXDEL is the fraction of non-refractory zooplankton excretion which is immediately decomposed when the ingestion rate is greater than MZOEAT.

ZOMASS is the average weight of a zooplankton organism.

4.4(3).8.3.10 Table-type BENAL-PARM -- Benthic algae parameters

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
BENAL-PARM
<-range><-----benal-parm----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END BENAL-PARM
```

```
*****
Example
*****
```

```
BENAL-PARM
  RCHRES      MBAL      CFBALR      CFBALG***
  # - #      mg/m2
  1   7      520.      .56      .80
END BENAL-PARM
```

```
*****
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<benal-parm>	MBAL	F10.0	600.	.01	none	mg/m2	Both
	CFBALR	F10.0	1.0	.01	1.0	none	Both
	CFBALG	F10.0	1.0	.01	1.0	none	Both

Explanation

MBAL is the maximum benthic algae density (as biomass).

CFBALR and CFBALG are the ratios of benthic algal to phytoplankton respiration and growth rates, respectively.

4.4(3).8.3.11 Table-type PLNK-INIT -- Initial plankton conditions

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
PLNK-INIT
<-range><-----plank-init----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PLNK-INIT
```

Example

```
PLNK-INIT
RCHRES      PHYTO      ZOO      BENAL      ORN      ORP      ORC***
# - #      mg/l      org/l      mg/m2      mg/l      mg/l      mg/l***
1   7      .0001      .05      .002      .01      .02      .01
END PLNK-INIT
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<plank-init>	PHYTO	F10.0	.96E-6	1.0E-10	none	mg/l	Both
	ZOO	F10.0	.03	1.0E-6	none	org/l	Both
	BENAL	F10.0	1.0E-8	1.0E-10	none	mg/m2	Both
	ORN	F10.0	0.0	0.0	none	mg/l	Both
	ORP	F10.0	0.0	0.0	none	mg/l	Both
	ORC	F10.0	0.0	0.0	none	mg/l	Both

Explanation

PHYTO is the initial phytoplankton concentration, as biomass.
 ZOO is the initial zooplankton concentration.
 BENAL is the initial benthic algae density, as biomass.
 ORN is the initial dead refractory organic nitrogen concentration.
 ORP is the initial dead refractory organic phosphorus concentration.
 ORC is the initial dead refractory organic carbon concentration.

4.4(3).8.4 RCHRES-BLOCK -- Section PHCARB input

```
*****  
          1          2          3          4          5          6          7          8  
1234567890123456789012345678901234567890123456789012345678901234567890  
*****
```

Layout

[Table-type PH-PARM1]
[Table-type PH-PARM2]
[Table-type PH-INIT]

```
*****
```

Explanation

The exact format of each of the tables above is detailed in the documentation which follows. Tables in brackets [] need not always be supplied; for example, because all of the inputs have default values.

4.4(3).8.4.1 Table-type PH-PARM1 -- Flags for pH simulation

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
PH-PARM1
<-range><ph-parml>
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PH-PARM1
```

```
*****
Example
*****
```

```
PH-PARM1
  RCHRES PHCN ALKC***
  # - #          ***
  1   7   30    9
END PH-PARM1
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<ph-parml>	PHCNT	I5	25	1	100
	ALKCON	I5	1	1	10

Explanation

PHCNT is the maximum number of iterations used to solve for the pH.

ALKCON is the number of the conservative substance (in section CONS) which is used to simulate alkalinity. Alkalinity must be simulated in order to obtain valid results.

4.4(3).8.4.2 Table-type PH-PARM2 -- Parameters for pH simulation

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
PH-PARM2
<-range><-----ph-parm2----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PH-PARM2
```

Example

```
PH-PARM2
RCHRES      CFCINV   BRCO2(1)  BRCO2(2)***
# - #              mg/m2.hr  mg/m2.hr***
1   7           .901      72.0      65.1
END PH-PARM2
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<ph-parm2>	CFCINV	F10.0	.913	.001	1.0	none	Both
	BRCO2(1)	F10.0	62.	.01	none	mg/m2.hr	Both
	BRCO2(2)	F10.0	62.	.01	none	mg/m2.hr	Both

Explanation

CFCINV is the ratio of the carbon dioxide invasion rate to the oxygen reaeration rate (which is computed in section OXR).

BRCO2 is the benthic release rate of CO₂ (as carbon) for: (1) aerobic and (2) anaerobic conditions.

4.4(3).8.4.3 Table-type PH-INIT -- Initial conditions for pH simulation

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
PH-INIT
<-range><-----ph-init----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PH-INIT
```

```
*****
Example
*****
```

```
PH-INIT
  RCHRES      TIC      CO2      PH***
  # - #      mg/l      mg/l      ***
  1   7      2.0      .03      8.0
END PH-INIT
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<ph-init>	TIC	F10.0	0.0	0.0	none	mg/l	Both
	CO2	F10.0	0.0	0.0	none	mg/l	Both
	PH	F10.0	7.0	1.0	15.0	none	Both

Explanation

TIC is the initial total inorganic carbon.
 CO2 is the initial carbon dioxide (as carbon).
 PH is the initial pH.

4.4(11) COPY Block

```
*****  
          1          2          3          4          5          6          7          8  
1234567890123456789012345678901234567890123456789012345678901234567890  
*****
```

Layout

COPY
Table-type TIMESERIES
END COPY

```
*****
```

Explanation

The COPY module is used to copy one or more time series from one location (source) to another (target). See Section 4.2(11) in Part E for a detailed description of its function.

4.4(11).1 Table-type TIMESERIES -- Number of time series to be copied

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
TIMESERIES
<-range><npt><nmn>
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END TIMESERIES
```

Example

```
TIMESERIES
Copy-opn ***
  # - #  NPT  NMN***
  1   7   4
END TIMESERIES
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<npt>	NPT	I5	0	0	20
<nmn>	NMN	I5	0	0	20

Explanation

NPT is the number of point-valued time series to be copied.

NMN is the number of mean-valued time series to be copied.

4.4(12) PLTGEN Block

```

*****
      1      2      3      4      5      6      7      8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
PLTGEN
  Table-type PLOTINFO
  Table-type GEN-LABELS
  Table-type SCALING
  Table-type CURV-DATA (repeats for each time series to be written to PLTGEN file)
END PLTGEN
*****

```

Explanation

The PLTGEN module prepares one or more time series for display on a plotter. It writes the time series, and associated title and scaling information, to a "pltgen" file which must be input to a stand-alone program that translates the data into commands that drive the plotter. See Section 4.2(12) of Part E for further details.

4.4(12).1 Table-type PLOTINFO -- General plot information

```

*****
      1      2      3      4      5      6      7      8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
  PLOTINFO
  <-range><fil><npt><nmn><lab><pyr><piv>
  . . . . .
  (repeats until all operations of this type are covered)
  . . . . .
  END PLOTINFO
*****

```

Example

```

*****
  PLOTINFO
  Plot-opn  ***
  # - # FILE  NPT  NMN LABL  PYR PIVL  ***
  1   3           2
  END PLOTINFO
*****

```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<fil>	PLOTFL	I5	30	30	99
<npt>	NPT	I5	0	0	10
<nmn>	NMN	I5	0	0	10
<lab>	LABLFG	I5	0	-1	1
<pyr>	PYREND	I5	9	1	12
<piv>	PIVL	I5	1	-2	1440

Explanation

PLOTFL is the file unit number of the PLTGEN file (output of this operation).

NPT is the number of point-valued time series to be written to the file.

NMN is the number of mean-valued time series to be written to the file.

LABLFG indicates how the plot will be labeled:

-1 means no labels

0 means standard labeling; that is, one set of X and Y axes and associated labels will be drawn for entire plot.

1 means separate X and Y axes and labels will be drawn for each "frame" of the plot (e.g., each water year).

PYREND is the calendar month which terminates a plot frame (eg. a water year).

PIVL is the number of basic time intervals (DELT minutes each) to be aggregated to get to the interval of the data written to the PLTGEN file. A PIVL of -1 causes a monthly PLTGEN file to be written. A PIVL of -2 causes an annual PLTGEN file to be written.

4.4(12).2 Table-type GEN-LABELS -- General plot labels

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
GEN-LABELS
<-range><----- title ----->          <-----ylabl----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END GEN-LABELS
```

Example

```
GEN-LABELS
Plot-opn ***
  # - #  General title                               Y-axis label ***
  1   3  Reservoir inflow and outflow rates         Flow (ft3/sec)
END GEN-LABELS
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<title>	TITLE	10A4	none	none	none
<ylabl>	YLABL	5A4	none	none	none

Explanation

TITLE is the general plot title.

YLABL is the label to be placed on the Y-axis.

4.4(12).3 Table-type SCALING -- Scaling information

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
SCALING
<-range><--ymin--><--ymax--><--ivlin--><-thresh->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END SCALING
```

```
*****
Example
*****
```

```
SCALING
Plot-opn ***
# - #      YMIN      YMAX      IVLIN      THRESH ***
1   3              500.       48.
END SCALING
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<ymin>	YMIN	F10.0	0.0	none	none	See Note	Both
<ymax>	YMAX	F10.0	none	none	none	See Note	Both
<ivlin>	IVLIN	F10.0	none	0.0	none	ivl/in	Both
<thresh>	THRESH	F10.0	-1.0E30	none	none	See Note	Both

Note: Units are defined by the user, in field YLABL of Table-type GEN-LABELS

Explanation

YMIN and YMAX are the minimum and maximum ordinate (Y axis) values.

IVLIN is the horizontal (time) scale; that is, number of intervals (in pltgen file) per inch on graph.

THRESH is the write threshold value. If the value for any time series is greater than the threshold, a full record is written to the PLTGEN file for the current PLTGEN file time interval.

4.4(12).4 Table-type CURV-DATA -- Data for each time series on pltgen file
 (Table must be repeated for each time series on the pltgen file)

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
CURV-DATA
<-range>  <-----label----><lin><int><col> <tr>
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END CURV-DATA
```

 Example

```
CURV-DATA
Plot-opn   Curve label      Line Intg   Col Tran   ***
# - #      type      eqv code  code ***
  1   3     Inflow        10    1    1 AVER
END CURV-DATA
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<label>	LABEL	4A4	none	none	none
<lin>	LINTYP	I5	0	none	none
<int>	INTEQ	I5	0	0	13
<col>	COLCOD	I5	0	0	10
<tr>	TRAN	A4	SUM	none	none

Explanation

LABEL is a descriptive label for this particular curve (time series).

LINTYP describes the type of line to be drawn for this curve. It also determines the frequency of plotted symbols:

A zero value means points are connected by straight lines; no symbols are drawn at individual data points.

A positive value means points are connected by straight lines; the magnitude determines the frequency of plotted symbols (e.g., 4 means plot a symbol at every 4th point obtained from the pltgen file).

A negative value means no connecting lines are drawn. Only symbols are plotted; the absolute value determines the frequency (as above).

INTEQ is the integer equivalent of the symbols to be plotted for this curve (i.e., indicates which symbol to use). It is only meaningful if LINTYP is not zero. Value of 2 might mean a triangle, etc.

COLCOD is the color code for this curve. The meaning depends on how the stand-alone plot program is set up; e.g., 1 might mean red pen, 2 blue pen, etc.

TRAN is the transformation code used to aggregate data from the basic interval (internal time step) to the PLTGEN file interval. Valid values are: SUM, AVER, MAX, MIN, and LAST.

Note: The stand-alone program, which reads the pltgen file and drives the plotter, must translate these data into plotter commands.

4.4(13) DISPLY Block

```
*****  
          1          2          3          4          5          6          7          8  
1234567890123456789012345678901234567890123456789012345678901234567890  
*****
```

Layout

```
DISPLY  
  Table-type DISPLY-INFO1  
  [Table-type DISPLY-INFO2]  
END DISPLY
```

```
*****
```

Explanation

The DISPLY module summarizes a time series and presents the results in neatly formatted tables. Data can be displayed at any HSPF-supported interval. See Section 4.2(13) of Part E for further information.

4.4(13).1 Table-type DISPLY-INFO1 -- Contains most of the information necessary to generate data displays.

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
DISPLY-INFO1
<-range><-----title----->   <tr><piv>   d<fil><pyr>   d<fil><ynd>
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END DISPLY-INFO1
```

Example

```
DISPLY-INFO1
#through#***<-----Title----->           <-short-span->
***                                     <---disply---> <annual summary ->
***                                     TRAN PIVL DIG1 FIL1  PYR DIG2 FIL2 YRND
1   Daily precip in TSS #20 (in)           1   2   20   6
2   Simulated soil temp (Deg C)  AVER  4   1   21   1   1   22   6
END DISPLY-INFO1
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<title>	TITLE(*)	7A4	none	none	none
<tr>	TRAN	A4	SUM	none	none
<piv>	PIVL	I5	0	0	1440
d	DIGIT1	A1	0	0	7
<fil>	FILE1	I5	6	6	99
<pyr>	PYRFG	I5	0	0	1
d	DIGIT2	A1	0	0	7
<fil>	FILE2	I5	6	6	99
<ynd>	PYREND	I5	9	1	12

Explanation

TITLE is the title that will be printed at the top of each page of the display.

TRAN is the transformation code, used to aggregate data from the basic interval (internal time step) to the various display intervals (for both short- and long-span displays). Valid values are: SUM, AVER, MAX, MIN, LAST.

PIVL is the number of basic time intervals (DELT mins each) to be aggregated to get to the interval of the data printed in a short-span display (e.g., In the above example, if DELT were 15 mins for DISPLY operation #2, then the data in the short-span summary tables would be displayed at an interval of 1 hour (PIVL=4). If PIVL=0, a short-span display is not produced.

DIGIT1 and DIGIT2 are the number of decimal digits to be used to print data in the short-span and long-span displays, respectively. Note that it is up to the user to ensure that this value falls in the valid range 0-7. HSPF does not check this.

FILE1 and FILE2 are the file unit numbers of the files to which short-and long-span displays will be routed.

PYRFG indicates whether or not a long-span display (annual summary of daily values) is required. Value of 1 means it is, 0 means it is not.

PYREND is the calendar month which will appear at the right-hand extremity of an annual summary. This enables the user to decide whether the data should be displayed on a calendar year or some other (e.g., water year) basis.

4.4(13).2 Table-type DISPLY-INFO2 -- Additional optional information for module DISPLY.

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

DISPLY-INFO2

<-range><--mult--><---add--><-thresh1><-thresh2>

.

(repeats until all operations of this type are covered)

.

END DISPLY-INFO2

Example

DISPLY-INFO2

#through# Convert DegC to F Display negative data ***

 Mult Add THRESH1 ***

 2 5 1.8 32.0 -999.

END DISPLY-INFO2

Details

Symbol	Fortran name(s)	Format	Def	Min	Max	Units	Unit system
<mult>	A	F10.0	1.0	none	none	none	Both
<add>	B	F10.0	0.0	none	none	none	Both
<thresh1>	THRESH1	F10.0	0.0	none	none	none	Both
<thresh2>	THRESH2	F10.0	0.0	none	none	none	Both

Explanation

This table is usually not supplied.

A and B are parameters used to convert the data from internal units to display units:

$$\text{Display value} = A * (\text{internal value}) + B$$

The conversion is done before any aggregation of data to larger time steps (i.e., larger than the simulation time interval) is performed. Note that the default values of A and B result in no change.

THRSH1 and THRSH2 are threshold values for the short-span and long-span displays, respectively (THRSH2 is not presently used). THRSH1 can be used to reduce the quantity of printout produced in a short-span display; it functions as follows: When the individual values in a row of the display have been aggregated to get the "row value" (hour- or day-value, depending on the display interval), if the row-value is greater than THRSH1 the row is printed, else it is omitted. Thus, for example, the default of 0.0 will ensure that rows of data containing all zeros are omitted.

4.4(14) DURANL Block

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
DURANL
  Table-type GEN-DURDATA
  [Table-type SEASON]
  [Table-type DURATIONS]
  [Table-type LEVELS]
  [Table-type LCONC]
END DURANL
```

Explanation

The DURANL module performs duration and excursion analysis on a time series. For example, it analyzes the frequency with which N consecutive values in the time series exceed a specified set of values, called "levels". N is the "duration" of the excursion; up to 10 durations may be used in one duration analysis operation. The user may specify that only those data falling within a specified time in each year (analysis season) be processed. For further details see Section 4.2(14) of Part E.

4.4(14).1 Table-type GEN-DURDATA -- General information for duration analysis

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

GEN-DURDATA

<-range><-----title-----><-nd><-nl><-pr><-pu>

.

(repeats until all operations of this type are covered)

.

END GEN-DURDATA

Example

GEN-DURDATA

```
#through#<***-----title-----> NDUR NLEV PRFG  P- LCNU LCOU
      ***                               UNIT
```

```
  1      Simulated DO in Reach 40                5   2       2   0
```

END GEN-DURDATA

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<title>	TITLE(*)	10A4	none	none	none
<nd>	NDUR	I5	1	1	10
<nl>	NLEV	I5	1	1	20
<pr>	PRFG	I5	1	1	7
<pu>	PUNIT	I5	6	1	99
<lcn>	LCNUM	I5	0	0	5
<lco>	LCOUT	I5	0	0	1

Explanation

TITLE is the title which the user gives to the duration analysis operation; usually, something which identifies the time series being analyzed.

NDUR is the number of durations for which the time series will be analyzed.

NLEV is the number of user-specified levels which will be used in analyzing the time series.

PRFG is a flag which governs the quantity of information printed out. A value of 1 results in minimal (basic) output. Increasing the value (up to the maximum of 7) results in increased detail of output.

PUNIT is the file unit number to which the output of the duration analysis operation will be written. Each duration analysis operation must have a unique file unit number.

LCNUM indicates the number of lethal concentration curves to be used in the analysis. A zero means no lethality analysis is to be performed.

LCOUT is a flag which governs the printout of intermediate lethal event information (1=on).

4.4(14).2 Table-type SEASON -- The analysis season for the durational analysis

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
SEASON
<-range>      <---start-->      <----end---->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END SEASON
```

Example

```
SEASON
      ***      Start      End
      #through#***      mo da hr mn      mo da hr mn
      1  10      02      02
END SEASON
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<start>	SESONS(2-5)	4(1X,I2)	see below		
<end>	SESONE(2-5)	4(1X,I2)	see below		

Explanation

This table is used if one wishes to specify an analysis season; that is, only data falling between the specified starting and ending month/day/hour/minute (in each year) should be considered.

Note:

1. The defaults, minima, maxima and other values for specifying the starting and ending date/times are the same as those given in the discussion of the GLOBAL Block (Section 4.2). If any fields in the starting date/time are blank they default to the earliest meaningful value; for the ending date/time they default to the latest possible values. Thus, the analysis season in the example above includes the entire month of February.
2. Although it is not meaningful to provide for a "year" in the fields documented above (since the analysis season applies to every year in the run), the four spaces preceding both the <start> and <end> fields should be left blank because the system does, in fact, read the year and expects it to be blank or zero.
3. The defaults imply that, if this table is omitted, the analysis season extends from January 1 through December 31.

4.4(14).3 Table-type DURATIONS -- Durations to be used in the analysis

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
DURATIONS
<-range><-dl><-----others----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END DURATIONS
```

Example

```
DURATIONS
#through#***<---Durations----->
    *** 1    2    3    4    5
1    2    1   10   15   20   40
3          1   20   21   22
END DURATIONS
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<dl>	DURAT(1)	I5	1	1	1
<others>	DURAT(2-10)	9I5	2	2	none

Explanation

DURAT(*) is an array which contains the NDUR different durations for which the time series will be analyzed (NDUR was specified in Table-type GEN-DURDATA). The durations are expressed in multiples of the internal time step specified in the OPN SEQUENCE Block (Section 4.3). Thus, if DELT= 5 min and the duration is 3, the time series will be analyzed with a window of 15 minutes. The analysis algorithm requires that the first duration be 1 time step, but the others can have any integer value.

4.4(14).4 Table-type LEVELS -- Levels to be used in the analysis

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
LEVELS
<-range><----- first 14 ----->
<-range><----- last 6 ----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END LEVELS
```

Example

```
LEVELS
  #through#*** 2   3   4   5   6   7   8   9  10  11  12  13  14
15
  #through#***16 17  18  19  20  21
1   -30. -10.  0.  10.  20.  40.  80. 100. 200.1000. 2.E3 3.E3 5.E3 1.E4
1   2.E4 3.E4
  #through#*** 2   3   4   5
2   -20.  0.  20.  50.
END LEVELS
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<first14>	LEVEL(2-15)	14F5.0	0.0	none	none
<last6>	LEVEL(16-21)	6F5.0	0.0	none	none

Explanation

LEVEL(2 through 21) contains the 20 possible user-specified levels for which the input time series will be analyzed. (LEVEL(1) and LEVEL(22) are reserved for system use, and this does not affect the user since only LEVEL(2) through (21) can be specified). The actual number of levels (NLEV) was specified in Table-type GEN-DURDATA. If NLEV is greater than 14, the entry for a given operation must be continued to the next line; up to 2 lines may be required to cover all the levels. In the example above, operation 1 has 16 user-specified levels and thus requires 2 lines, but operation 2 only requires 1 line because it has only 4 user-specified levels.

When an entry has to be continued onto more than 1 line:

1. No blank or comment lines may be put between any of the lines for a continued entry. Put all comments ahead of the entry. (See operation 1 in above example).
2. The <range> specification must be repeated for each line onto which the entry is continued.

Note that the levels must be specified in ascending order. The system checks that this requirement is not violated.

4.4(14).5 Table-type LCONC -- Lethal concentrations to be used in the analysis
 Table repeats for each lethal concentration curve-LCNUM times

```
*****
      1      2      3      4      5      6      7      8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
LCONC
<-range><-----first-7----->
<-range><-----last-3----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END LCONC
```

 Example

```
LCONC
# - #***   LC1     LC2     LC3     LC4     LC5     LC6     LC7
# - #***   LC8     LC9     LC10
  1  2     1.     3.     6.     8.     15.    5.     8.
  1  2     20.    30.    60.
END LCONC
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<first-7>	LCONC(1-7,I)	7F10.0	0.0	none	none
<last-3>	LCONC(8-10,I)	3F10.0	0.0	none	none

Explanation

LCONC(*) is an array which contains the NDUR different lethal levels which are used in a lethal concentration analysis. If no lethality analysis is being done, this table may be omitted.

4.4(15) GENER Block

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
GENER
  Table-type OPCODE
  [Table-type NTERMS]    only required if OPCODE = 8
  [Table-type COEFFS]    only required if OPCODE = 8,
  [Table-type PARM]      only required if OPCODE = 9, 10, 11, 24, 25, or 26
```

END GENER

```
*****
```

Explanation

The GENER module generates a time series from one or two input time series. Usually, only Table-type OPCODE is required. However, if OPCODE = 8 (power series), you need to supply the number of terms in the power series and the values of the coefficients. If OPCODE = 9, 10, 11, 24, 25, or 26, then Table-type PARM is required to input the constant required in the operation.

4.4(15).1 Table-type OP CODE -- Operation code for time series generation

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
OPCODE
<-range><opn>
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END OPCODE
```

Example

```
OPCODE
#through# OP- ***
          CODE ***
  1     3     8
  5          20
END OPCODE
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<opn>	OPCODE	I5	none	1	26

Explanation

OPCODE is the operation code. If A and B are the input time series and C is the generated time series, the functions performed for the allowable range of values of OPCODE are:

OPCODE	Definition
1	C= Abs(A)
2	C= Sqrt(A)
3	C= Trunc(A)
4	C= Ceil(A)
5	C= Floor(A)
6	C= loge(A)
7	C= log10(A)
8	C= K(1)+K(2)*A+K(3)*A**2+(up to 7 terms)
9	C= K**A
10	C= A**K
11	C= A+K
12	C= Sin(A)
13	C= Cos(A)
14	C= Tan(A)
15	C= Sum(A)
16	C= A+B
17	C= A-B
18	C= A*B
19	C= A/B
20	C= Max (A,B)
21	C= Min (A,B)
22	C= A**B
23	C= cumulative departure of A below B
24	C= K
25	C= Max (A,K)
26	C= Min (A,K)

If OPCODE is less than 15, or OPCODE equals 25 or 26, only one input time series is required; if OPCODE is 24, no input time series are required; otherwise two input time series are required. Note that the operation is performed on the data when they are in internal form (timestep=DELT, units=internal units). For further details, see Section 4.2(15) of Part E.

4.4(15).2 Table-type NTERMS -- Number of terms in power series

```
*****
      1      2      3      4      5      6      7      8
123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
      NTERMS
      <-range><-nt>
      . . . . .
      (repeats until all operations of this type are covered)
      . . . . .
      END NTERMS
```

Example

```
      NTERMS
      #through#NTERMS ***
      1    2    4
      END NTERMS
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<nt>	NTERMS	I5	2	1	7

Explanation

This table is only relevant if OPCODE=8. NTERMS is the total number of terms in the power series:

$$C = K(1) + K(2)*A + K(3)*A**2 \text{ etc.}$$

The default value of 2 was chosen because this option will probably be used most often (to perform a linear transformation).

4.4(15).3 Table-type COEFFS -- Coefficients in generating power function

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
COEFFS
<-range><-----coeffs----->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END COEFFS
```

```
*****
Example
*****
```

```
COEFFS
  #through# ***      K1      K2      K3
    1      7      -2.0      1.5      0.2
END COEFFS
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<coeffs>	K(*)	7F10.0	0.0	none	none

Explanation

This table is only relevant if OPCODE=8. K(1 through NTERMS) are the coefficients in the power function:

$$C = K(1) + K(2)*A + K(3)*A**2 + \text{etc.}$$

4.4(15).4 Table-type PARM -- Constant for GENER operation

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
PARM
<-range><--con--->
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END PARM
```

Example

```
PARM
# - # ***      K
1   7          2.5
END PARM
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<con>	K	F10.0	1.0	none	none

Explanation

This table is only relevant if OPCODE is 9, 10, 11, 24, 25, or 26.

K is the constant required in the operation.

4.4(16) MUTSIN Block

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
MUTSIN
  Table-type MUTSINFO
```

END MUTSIN

```
*****
```

Explanation

The MUTSIN module is used to copy one or more time series from a PLTGEN file or its equivalent to one or more targets. The targets may be data sets in the TSS or WDM (specified in the EXT-TARGETS Block) or input time series in other operations (specified in the NETWORK Block). See Section 4.2(16) in Part E for a detailed description of MUTSIN's function.

4.4(16).1 Table-type MUTSINFO -- Information about time series to be copied

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
MUTSINFO
<-range><mfl><npt><nmn><nli><mis>
. . . . .
(repeats until all operations of this type are covered)
. . . . .
END MUTSINFO
```

Example

```
MUTSINFO
# - # MFL NPT NMN NLI MSFG ***
1   30  1  1  25  0
END MUTSINFO
```

Details

Symbol	Fortran name(s)	Format	Def	Min	Max
<mfl>	MUTFL	I5	30	30	99
<npt>	NPT	I5	0	0	10
<nmn>	NMN	I5	0	0	10
<nli>	NLINES	I5	25	1	none
<mis>	MISSFG	I5	0	0	3

Explanation

MUTFL is the file unit number of the PLTGEN-format file being input.
 NPT is the number of point-valued time series to be input.
 NMN is the number of mean-valued time series to be input.
 NLINES is the number of lines to skip at the beginning of the file.
 MISSFG is the missing data action flag.

- 0 - stop on missing data
- 1 - fill missing data with 0.0
- 2 - fill missing data with -1.0E30
- 3 - fill missing data with next value

4.5 FTABLES Block

```
*****
          1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

FTABLES

```
    FTABLE    <t>
<----ftab-parms---->
<----- row-of-values ----->
.....
line above repeats until function has been described through desired range
.....
    END FTABLE<t>
```

Any number of FTABLES may appear in the block

END FTABLES

```
*****
```

Details

Symbol	FORTTRAN Name(s)	Format	Comment
<t>	NUMBR	I3	User's ID number for this FTABLE.
<ftab-parms>	Fparms(4)	4I5	Up to 4 control parameters may be supplied for an Ftable, e.g. number of rows, number of columns, etc. Exact details depend on the FTABLE concerned.
<row-of-values>	VAL(*)	variable	Each column is dedicated to one of the variables in the function. Each row contains a full set of corresponding values of these variables, e.g., depth, surface area, volume, and outflow for a RCHRES.

Explanation

An FTABLE is used to specify, in discrete form, a functional relationship between two or more variables. For example, in the RCHRES module, it is assumed that there is a fixed relationship between depth, surface area, volume, and volume-dependent (F(vol)) discharge component. An FTABLE is used to document this non-analytic function in numerical form. Each column of the FTABLE is dedicated to one of the above variables, and each row contains corresponding values of the set. That is, each row contains the surface area, volume, and discharge for a given depth. The number of rows in the FTABLE will depend on the range of depth to be covered and the desired resolution of the function.

4.5(3) FTABLES for the RCHRES Application Module

4.5(3).1 FTABLE for HYDR section

The geometric and hydraulic properties of a RCHRES are summarized in a function table (FTABLE). Every RCHRES must be associated with one FTABLE; the association is done in Table-type HYDR-PARM2 (Section 4.4(3).2.2 above). Usually, every RCHRES will have its own FTABLE; however, if RCHRES's are identical they can share the same FTABLE. FTABLE's may be included in the user's input (FTABLES Block) or they may be stored in a WDM File.

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
FTABLE    <t>
<-nr><-nc>
<-depth--><--area--><-volume-><----- f(VOL)-values ----->
.....
The above row repeats until values have been supplied to cover the entire
cross-section at the desired resolution
.....
END FTABLE<t>
```

Example

```
FTABLE    103
rows cols          ***
   3     5
   depth      area   volume  outflow1  outflow2 ***
   (ft)      (acres) (acre-ft) ( ft3/s)  ( ft3/s) ***
   0.0        0.0     0.0     0.0       0.0
   5.0       10.0    25.0    20.5      10.2
  20.0     120.0   1000.0   995.0    200.1
END FTABLE103
*****
```

Details

Symbol	Name(s)	Format	Comment
<t>	see Sect. 4.5	I3	ID No. of F'TABLE
<nr>	NROWS	I5	Number of rows in F'TABLE
<nc>	NCOLS	I5	Number of columns in F'TABLE
<depth>	Depth	F10.0	Depth of RCHRES; Units: English = ft; Metric = m
<area>	Surface area	F10.0	Surface area of RCHRES; Units: English = acres; Metric = ha
<volume>	Volume	F10.0	Volume of RCHRES; The volume in the first row must be 0.0; Units: English= acre.ft; Metric= Mm3 (10**6 m3)
<f(vol)- values>	F(V)	(NCOLS-3)* F10.0	Units: English = ft3/s; Metric = m3/s

Explanation

This F'TABLE lists depth, surface area and, optionally, one or more other values (typically discharge rates) as functions of volume. HSPF interpolates between the specified values to obtain the geometric and hydraulic characteristics for intermediate values of volume.

The F'TABLE must satisfy the following conditions:

1. (NCOLS*NROWS) must not exceed 100
2. NCOLS must be between 3 and 8
3. There must be at least one row in the F'TABLE
4. The first row must have volume = 0.0
5. No negative values are permitted
6. The depth and volume fields may not decrease as the row number increases

In the example given above, we have a reach with two outflows, both of which are functions of volume. Thus, there are 5 columns in the F'TABLE.

The values for this type of F'TABLE can either be supplied directly by the user or generated by a subsidiary program from more basic information (e.g., by backwater analysis or Manning's equation for assumed uniform flow).

WDM F'TABLES are stored in WDM "table" data sets, and accessed directly by HSPF. These data sets may be created and modified through the use of the ANNIE program. WDM F'TABLES follow the same structure, and must satisfy the same conditions as F'TABLES contained in the UCI.

4.6 TIME SERIES LINKAGES

4.6.1 General Discussion

In the EXTERNAL SOURCES, NETWORK, EXTERNAL TARGETS, and SCHEMATIC/MASS-LINK blocks, the user specifies those time series which are to be passed between pairs of operations in the same INGRP or between individual operations and external sources/targets (WDM Data sets, DSS Data records, or sequential files). The blocks are arranged in the form of tables, each containing one or more entries (rows). Each entry contains source information, a multiplication factor, a transformation function, and target information.

The entries in these blocks may be in any order.

When a time series associated with a data set in a WDM file is referred to, the user supplies the data-set number and the data-set name. This information must agree with data supplied when the data set was created. WDM data sets and associated attributes are created using the interactive program ANNIE. The user should refer to the ANNIE User's manual for additional information.

Time series may also be associated with DSS data records in up to five different DSS files. Each record, or group of records, is identified by a pathname, which is specified in the PATHNAMES block, where it is associated with a data-set number in the context of the current UCI file. No data-set name is specified.

If a DSS record is accessed as an external target, it is not necessary that the record, or even the file, exist before the run. DSS records used as external sources, however, must be already present in the specified DSS file.

The user specifies time series which are input to, or output from, an operating module by supplying a group name (<sgrp>, <tgrp>) and a member name plus one or two subscripts (<smem><m#>, <tmem><m#>). The member information must be compatible with data given in the Time Series Catalog for the applicable operating module and group (Section 4.7).

The user may route the same source to several targets by making several separate entries in a block, each referring to the same source, or by making use of the "range" feature provided in the <tvol>< range> field. This latter feature does not apply to entries in the EXT TARGETS Block. In either case the implication is that data from the source will be used repetitively, and each time will be multiplied by the specified factor and added to whatever else has already been routed to the specified target. Conversely, several sources may be routed to a single target, except in the EXT TARGETS Block. This happens when several entries specify different sources but the same target. Here, the implication is that the data obtained from the several sources must be accumulated (added) before being used by the target.

4.6.1.1 WDM File Concepts

The WDM file is a binary, direct-access file that is organized into discrete data sets. Each data set consists of data as well as "attributes" that describe the data. Disk space for a WDM file is allocated as needed in 40,960-byte increments. Space from deleted data sets within a WDM file is reused as new data are added to the file. Thus the WDM file needs no special maintenance processing.

HSPF accesses WDM files for both input and output time series data. HSPF requires that a data set be created in an existing WDM file prior to any run that writes to the data set. Maintenance of WDM files and creation of new data sets is accomplished using the USGS's ANNIE program (Flynn, K.M., P.R. Hummel, A.M. Lumb, and J.L. Kittle, Jr. 1995. User*s Manual for ANNIE, Version 2, a Computer Program for Interactive Hydrologic Data Management. WRI Report 95-4085. U.S. Geological Survey, Reston, VA).

Within the HSPF UCI file, a WDM data set is referred to by its data-set number and its name (i.e., its TSTYPE attribute), which is a four-character alpha-numeric identifier. As stated above, WDM data-set attributes are created when the data set is first created using the ANNIE program. The attributes that are associated with time series data sets can be divided into two types: 1) those that describe how the data are stored in the data set, and 2) those that are purely descriptive or provide information about the data. Examples of the second type are station name (STANAM), station ID (STAID), latitude and longitude (LATDEG, LNGDEG), and data-set description (DESCRP). Attributes of the first type are more critical, and are considered "required" attributes for time series data sets. These attributes are defined below:

TCODE Time units code for defining the time interval of the data set (1-seconds, 2-minutes, 3-hours, 4-days, 5-months, 6-years); valid values in HSPF are 2, 3, 4, and 5.

TSSTEP Time interval of data set in TCODE units (used in combination with TCODE)

TSFORM Form of data; valid values in HSPF context are: (1-mean over time step, 2-total over time step, 3-instantaneous); 1 and 2 correspond to "mean" time series, and 3 corresponds to "point" time series.

TSBYR Starting year of data set; defaults to 1900; generally should be set to a year just prior to start of data.

TGROUP Unit for group pointers (3-hours, 4-days, 5-months, 6-years, 7-centuries); it may affect speed of data retrievals and total amount of data storage available in data set; see table in ANNIE manual for recommended values.

TSFILL Filler value for missing data; default = 0.0.

COMPFG Compression flag (1-data are compressed, 2-data are not compressed)

TOLR Compression tolerance; data values within TOLR are compressed.

VBTIME Variable time step flag; must be 1 (all data at same time step) for HSPF.

4.6.1.2 DSS File Concepts

DSS Pathnames

DSS files access time series data in a somewhat different manner than WDM files. The latter refers to a time series by a single data-set number. DSS files refer to time series by "pathnames", which follow different conventions for different kinds of data. HSPF uses only one of the allowed kinds, i.e., "Regular" Time Series. The PATHNAMES block is used to temporarily assign or associate a data-set number with each time series needed in the run. (See Section 4.6.6.)

An entire DSS time series is not necessarily stored in one logical piece in the DSS file. Data are broken up into separate records with definite sizes and starting dates, which depend on the time step of the data. For instance, hourly data is stored in records each containing one month of values and starting with the first hour of the month. Daily data, on the other hand, is stored yearly, in records starting on January 1st.

The pathname can consist of up to 80 characters; because of limitations on UCI line length, HSPF only allows 64 characters in DSS pathnames. Pathnames are separated into six parts (delimited by slashes "/"), which are referenced by the characters "A" through "F". For a "regular" time series, the conventions for the contents of the six parts are:

- A River basin or project name
- B Location or gage identifier
- C Data variable, e.g. FLOW, PRECIP
- D Starting date for block of data in the format 01JAN1980.
This part is not used by HSPF, and should be left empty.
- E Time interval - valid values are:
5MIN, 10MIN, 15MIN, 30MIN, 1HOUR, 2HOUR, 3HOUR, 4HOUR, 6HOUR,
12HOUR, 1DAY, 1WEEK, 1MON, 1YEAR
- F Additional user-defined descriptive information, e.g. OBSERVED, PLAN A

Any single part may contain up to 32 characters, but the total including slashes must remain less than 80 for general DSS use, and less than 64 characters for HSPF (leaving the D part empty). A typical HSPF pathname might be:

```
/PATUXENT/BRIGHTON DAM/DIVERSION//1DAY/OBSERVED-CFS/
```

Note the double slash indicating the empty D part. A D part may be provided by the user, but HSPF ignores it; this allows the DSS system to generate it, as needed, based on the starting and ending dates of the run. For additional information, users should refer to the HECDSS Users Guide (US Army Corps of Engineers Hydrologic Engineering Center, April 1990).

DSS Data Types

Each DSS data record also may have a data **type** string and/or a **units** string stored with it. Units strings are ignored by HSPF. Data type strings are used to determine whether the time series is point-valued or mean-valued in the context of HSPF. Valid values of the data type string are:

- INST-VAL - point-valued: instantaneous at end of interval
- PER-AVER - mean-valued: average over interval
- PER-CUM - mean-valued: total over interval

A fourth type, INST-CUM, which is used for mass curves, is not valid for HSPF. The data type string for each time series (input or output) must be specified in the PATHNAMES block.

The data type should not change over time (i.e. between subsequent records) for a given time series. If a data record already exists before the run, any value specified in the PATHNAMES block must match the stored value, if it exists. If a data record is created by the run, it is stored with the value given in the PATHNAMES block, if any. If neither the record itself nor the PATHNAMES block specifies a data type, the data is treated by the program as a mean-valued time series.

4.6.2 EXT SOURCES Block (External sources)

In this block the user specifies those time series which are to be supplied to operations in a RUN from sources external to it; external sources are WDM data sets, DSS data sets, and sequential (SEQ) files.

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
EXT SOURCES
<svol><s#> <exsm>qf <ss><sg><-mfact--><tr> <tvol>< range> <tgrp> <tmem><m#>
      or
      <sfmt>f#
```

.....
Above line repeats until all external sources have been specified
.....

END EXT SOURCES

Example

```
EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member-> ***
<Name>    # <Name> # tem strg<-factor->strg <Name>  #  #      <Name> # # ***
SEQ       3 HYDDAY ENGL          1.0    RCHRES  1    EXTNL  ICON
WDM1     22 PREC   METRZERO          SUM  IMPLND  2    EXTNL  PREC
DSS      132          ENGL          SAME  PLTGEN 10    INPUT  POINT  1
END EXT SOURCES
```

Details

Symbol	FORTTRAN Name(s)	Start Column	Format	Comment
<svol>	SVOL	1	A6	External source volume. Valid values are WDMn (Watershed Data Management System File, where n is 1-4 or blank), DSS (Data Storage System), and SEQ (sequential file).
<s#>	SVOLNO	7	I4	Data-set number if SVOL = WDMn, or DSS; file unit number if SVOL = SEQ
<exsm>	SMEMN	12 12	A6 A4	Data-set TSTYP attribute if SVOL = WDMn; blank for SVOL = DSS
<sfmt>	SFCLAS	12	A6	SFCLAS is a string indicating the class of format used in the sequential file.
qf	QLFG	18	I2	Quality-of-data flag if SVOL = WDMn; specifies the minimum quality of WDM data which will be accepted by HSPF; valid values = 0-31; default = 31
f#	SFNO	18	I2	SFNO identifies an object-time format supplied in the FORMATS Block. Default: standard format.
<ss>	SSYST	21	A4	Unit system of data in the source if SVOL = SEQ, WDMn, or DSS; valid values: ENGL and METR; default = ENGL
<sg>	SGAPST	25	A4	String indicating how missing lines in the sequential file, missing data in a DSS file, or WDM data of insufficient quality will be regarded; used if SVOL = SEQ, WDMn, or DSS. Valid values are ZERO (assign value 0) and UNDF (assign undefined value). Defaults to UNDF. See below for explanation.
<mfact>	MFACTR	29	F10.0	The factor by which data from the source will be multiplied before being added to the target. Default = 1.0
<tr>	TRAN	39	A4	String indicating which transformation function to use in transferring time series from source to target. See Section 4.6.7 for valid values and defaults.
<tvol>	TVOL	44	A6	TVOL is the Operation-type of the target.

Time Series Linkages

< range>	TOPFST	51	I3	TOPFST & TOPLST specify the range of operations
	TOPLST	55	I3	which are targets (e.g., PERLND 1 5). If TOPLST field is blank, the target is a single operation.
<tgrp>	TGRPN	59	A6	Group to which the target time series belong(s).
<tmem>	TMEMN	66	A6	Target time series member name.
<m#>	TMEMSB(2)	72	2A2	Target time series member name subscripts; may be 2-character CATEGORY tag if applicable; must be integer otherwise. See Time Series Catalog.

Explanation

If an entry specifies the source volume as SEQ, it is referring to a time series coming from a sequential file. The entry must therefore supply the file unit number and format information for the file.

If an entry specifies the source volume as WDMn or DSS, the user is referring to a time series contained in the corresponding direct access data file: a Watershed Data Management System file, or an HEC Data Storage System file. If the "n" portion of a WDM file reference is left blank, the program (by default) looks in the first WDM file only.?

Note: TSS functionality is not included in the documentation.

When data are read from a WDM data set, the user may optionally supply a data quality flag (QLFG), which will be compared with the data quality "tag" associated with all WDM time series data. Any data having lower quality than specified (value greater than QLFG) will be rejected and assigned the value specified by the WDM attribute TSFILL (if defined for the data set), or alternatively, if TSFILL is not available, by SGAPST.

When data are read from a sequential file the user supplies:

1. A "format class code". It fixes the nature and sequence of data in a typical record (e.g. day and hour, followed by 12 hourly values).
2. The number of an object-time format, situated in the FORMATS Block. It fixes the exact format of the data in a record. A default format can be selected by supplying the number 0, or leaving the field blank.

The format classes and associated default formats presently supported in the HSPF system are documented in Section 4.9.

Note: All character strings must be left-justified in their fields except WDM data set names (<exsm>) which must be justified in the same way that they were when the data-set label or WDM attribute TSTYP was created.

4.6.3 NETWORK Block

In this block the user specifies those time series which will be passed between operations via the internal scratch pad (INPAD). If there are no such linkages the block can be omitted. For many applications, particularly large or complex watersheds that have many entries in the NETWORK block, the alternative use of the SCHEMATIC/MASS-LINK blocks may provide a simpler and more conceptual format for specifying the linkages in the NETWORK block.

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
NETWORK
<svol><o#> <sgrp> <smem><m#><-mfact--><tr> <tvol>< range> <tgrp> <tmem><m#>
.....
Above line repeats until all network entries have been made
.....
END NETWORK
```

```
*****
Example
*****
```

```
NETWORK
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member-> ***
<Name> # <Name> # #<-factor->strg <Name> # # <Name> # # ***
RCHRES 1 HYDR ROVOL 0.5 RCHRES 2 EXTNL IVOL
RCHRES 2 HYDR ROVOL RCHRES 5 EXTNL IVOL
RCHRES 4 HYDR ROVOL RCHRES 5 EXTNL IVOL
END NETWORK
```

```
*****
```

Details

Symbol	FORTRAN Name(s)	Start Column	Format	Comment
<svol>	SVOL	1	A6	SVOL is the Operation-type of the source operation
<o#>	SVOLNO	7	I4	Source Operation-type number (e.g., PERLND 5)
<sgrp>	SGRPN	12	A6	Group to which the source time series belong(s).
<smem>	SMEMN	19	A6	Source time series member name; see Time Series Catalog.
<m#>	SMEMSB(2)	25	2A2	Source member name subscripts; may be 2-character CATEGORY tag if applicable; must be integer otherwise. See Time Series Catalog.
<mfact>	MFACTR	29	F10.0	The factor by which data from the source will be multiplied before being added to the target. Default (blank field)= 1.0
<tr>	TRAN	39	A4	String indicating which transformation function to use in transferring time series from source to target. See Section 4.6.7 for defaults, etc.
<tvol>	TVOL	44	A6	Operation-type of the target.
< range>	TOPFST, TOPLST	51 55	I3 I3	TOPFST & TOPLST specify the range of operations which are targets (e.g. PERLND 1 5). If TOPLST field is blank, the target is a single operation.
<tgrp>	TGRPN	59	A6	Group to which the target time series belong(s).
<tmem>	TMEMN	66	A6	Target member name; see Time Series Catalog.
<m#>	TMEMSB(2)	72	2A2	Target member name subscripts; may be 2-character CATEGORY tag if applicable; must be integer otherwise. See Time Series Catalog.

Explanation

The example above shows how this block is used to specify the connectivity of a set of reaches of stream channel (RCHRES 1 flows to RCHRES 2, RCHRES 2 and 4 flow to RCHRES 5). It can also be used to specify the flow of time series data from utility operations to simulation operations and vice versa. The network can be extremely complex, or non-existent (e.g., if the RUN involves only one operation).

Because the time series are transferred via the INPAD, each source and target pair must be in the same INGRP.

4.6.4 SCHEMATIC and MASS-LINK Blocks

The SCHEMATIC and MASS-LINK blocks work in tandem to allow the user to specify the watershed structure and linkages in a more efficient and conceptual manner than is possible using the NETWORK block.

The SCHEMATIC block contains global specifications of the watershed structure, i.e., connections of land segments to stream reaches and reach-reach connections. This block permits the user to input the area of a land segment that is tributary to a stream reach in a single entry, instead of including the area in multiple entries in the NETWORK block. Each entry in the SCHEMATIC block refers to a table in the MASS-LINK block where the detailed time series connections for that entry are specified.

The MASS-LINK block contains the specific time series to be transferred from one operation to another. This block also contains any required units conversion factors or other multiplication factors that may be needed in addition to the area. For example, when runoff from a land segment is transferred to a stream reach, a conversion factor of 1/12 (0.08333) is needed to convert the runoff from inches to acre-feet if the area units are acres. (The corresponding factor for metric units is 10^{-5} if the area units are hectares.) Each MASS-LINK table contains the set of time series transfers that are to be associated with one or more of the linkages in the SCHEMATIC block. The HSPF program combines the schematic linkages with the mass time series transfers and automatically generates all of the necessary time series connections; these time series connections are automatically included in the NETWORK block by the program.

The example shown below illustrates the use of these blocks. In this example, the watershed consists of three pervious land segments and two stream reaches. One of the land segments contributes loadings to both reaches. Loadings of flow, sediment, heat and one dissolved pesticide are being transferred from the land to the stream, and the sediment loading from the land surface is assumed to consist of 10% sand, 35% silt and 55% clay. The SCHEMATIC and MASS-LINK blocks to accomplish the required connections are shown below:

```
*****
      1         2         3         4         5         6         7
123456789012345678901234567890123456789012345678901234567890
*****
```

SCHEMATIC

```
<-Source->          <--Area-->      <-Target->      MSLK      ***
<Name>  #           <-factor-->    <Name>  #      Tbl#      ***
PERLND  1           200.             RCHRES  1       1
PERLND  2           120.             RCHRES  1       1
PERLND  2           235.             RCHRES  2       1
PERLND  3           360.             RCHRES  2       1
RCHRES  1                               RCHRES  2       2
END SCHEMATIC
```

MASS-LINK

```
<Volume>  <-Grp> <-Member-><--Mult-->  <-Target>      <-Grp> <-Member->***
<Name>      <Name> # #<-factor-->    <Name>      <Name> # #***
  MASS-LINK          1
PERLND    PWATER PERO          0.0833333  RCHRES      INFLOW IVOL
PERLND    SEDMNT SOSED  1    0.10        RCHRES      INFLOW ISED  1
PERLND    SEDMNT SOSED  1    0.35        RCHRES      INFLOW ISED  2
PERLND    SEDMNT SOSED  1    0.55        RCHRES      INFLOW ISED  3
PERLND    PWTGAS POHT
PERLND    PEST   TOPST
  END MASS-LINK      1

  MASS-LINK          2
RCHRES    ROFLOW
  END MASS-LINK      2

END MASS-LINK
```

```
*****
```

The SCHEMATIC block contains the global watershed linkages, i.e., PLS 1 provides loadings to Reach 1, PLS 2 provides loadings to Reaches 1 and 2, PLS 3 provides loadings to Reach 2, and Reach 1 is upstream of Reach 2. The areas of PLS's 1 and 3 are 200 acres and 360 acres, respectively, and the area of PLS 2 is 355 acres, of which 120 acres are tributary to Reach 1 and 235 acres are tributary to Reach 2.

The MASS-LINK block contains details of the individual time series connections that need to be specified for each of the watershed linkages. Each of the four PLS-to-Reach entries in the SCHEMATIC block refers to MASS-LINK Table 1, which contains six time series connections from the PLS to the Reach. The Reach 1-to-Reach 2 entry refers to MASS-LINK Table 2; this table contains the ROFLOW-INFLOW connection, which is automatically expanded by the program to generate all necessary time series connections from one reach to another.

The time series connections in the MASS-LINK block are combined with the SCHEMATIC linkages to generate the full set of connections needed in the simulation. In this

Time Series Linkages

process, the program sets up a set of connections for each [SCHEMATIC entry]/[MASS-LINK table] pair. The multiplication factor for each connection is obtained by combining the 'area' factor from the SCHEMATIC block and the 'units/other conversion' factor from the MASS-LINK block. The explicit time series connections generated by HSPF and included in the NETWORK Block for this example are shown below:

NETWORK

```

**** PLS 1 to RCH 1
PERLND  1 PWATER PERO           16.66 SAME RCHRES  1    INFLOW IVOL
PERLND  1 SEDMNT SOSED  1        20.  SAME RCHRES  1    INFLOW ISED  1
PERLND  1 SEDMNT SOSED  1        70.  SAME RCHRES  1    INFLOW ISED  2
PERLND  1 SEDMNT SOSED  1       110.  SAME RCHRES  1    INFLOW ISED  3
PERLND  1 PWTGAS POHT          200.  SAME RCHRES  1    INFLOW IHEAT
PERLND  1 PEST  TOPST          200.  SAME RCHRES  1    INFLOW IDQUAL 1

**** PLS 2 to RCH 1
PERLND  2 PWATER PERO           10.  SAME RCHRES  1    INFLOW IVOL
PERLND  2 SEDMNT SOSED  1        12.  SAME RCHRES  1    INFLOW ISED  1
PERLND  2 SEDMNT SOSED  1        42.  SAME RCHRES  1    INFLOW ISED  2
PERLND  2 SEDMNT SOSED  1        66.  SAME RCHRES  1    INFLOW ISED  3
PERLND  2 PWTGAS POHT          120.  SAME RCHRES  1    INFLOW IHEAT
PERLND  2 PEST  TOPST          120.  SAME RCHRES  1    INFLOW IDQUAL 1

**** PLS 2 to RCH 2
PERLND  2 PWATER PERO           19.58 SAME RCHRES  2    INFLOW IVOL
PERLND  2 SEDMNT SOSED  1        23.50 SAME RCHRES  2    INFLOW ISED  1
PERLND  2 SEDMNT SOSED  1        82.25 SAME RCHRES  2    INFLOW ISED  2
PERLND  2 SEDMNT SOSED  1       129.25 SAME RCHRES  2    INFLOW ISED  3
PERLND  2 PWTGAS POHT          235.  SAME RCHRES  2    INFLOW IHEAT
PERLND  2 PEST  TOPST          235.  SAME RCHRES  2    INFLOW IDQUAL 1

**** PLS 3 to RCH 2
PERLND  3 PWATER PERO           30.  SAME RCHRES  2    INFLOW IVOL
PERLND  3 SEDMNT SOSED  1        36.  SAME RCHRES  2    INFLOW ISED  1
PERLND  3 SEDMNT SOSED  1       126.  SAME RCHRES  2    INFLOW ISED  2
PERLND  3 SEDMNT SOSED  1       198.  SAME RCHRES  2    INFLOW ISED  3
PERLND  3 PWTGAS POHT          360.  SAME RCHRES  2    INFLOW IHEAT
PERLND  3 PEST  TOPST          360.  SAME RCHRES  2    INFLOW IDQUAL 1

**** RCH 1 to RCH 2 (HYDR, HTRCH, SEDTRN, and GQUAL sections are active)
RCHRES  1 ROFLOW ROVOL           1.0 SAME RCHRES  2    INFLOW IVOL
RCHRES  1 ROFLOW ROHEAT           1.0 SAME RCHRES  2    INFLOW IHEAT
RCHRES  1 ROFLOW ROSED  1          1.0 SAME RCHRES  2    INFLOW ISED  1
RCHRES  1 ROFLOW ROSED  2          1.0 SAME RCHRES  2    INFLOW ISED  2
RCHRES  1 ROFLOW ROSED  3          1.0 SAME RCHRES  2    INFLOW ISED  3
RCHRES  1 ROFLOW RODQAL           1.0 SAME RCHRES  2    INFLOW IDQAL  1
RCHRES  1 ROFLOW ROSQAL 1 1        1.0 SAME RCHRES  2    INFLOW ISQAL  1 1
RCHRES  1 ROFLOW ROSQAL 2 1        1.0 SAME RCHRES  2    INFLOW ISQAL  2 1
RCHRES  1 ROFLOW ROSQAL 3 1        1.0 SAME RCHRES  2    INFLOW ISQAL  3 1
END NETWORK

```

4.6.4.1 SCHEMATIC Block

In this block the user specifies the global linkages of land segments with stream reaches and between stream reaches. Each of these linkages is combined with the detailed time series connections specified in one of the MASS-LINK tables to generate a complete set of time series connections for the linkage.

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

SCHEMATIC

```
<svol>< #>          <-afact-->          <tvol>< #> <ML#>
```

.....
Above line repeats until all network entries have been made
.....

END SCHEMATIC

Example

SCHEMATIC

```
<-Source->          <--Mult-->          <-Target >   MSLK          ***
<Name> #           <-factor->          <Name> #   Tbl#          ***
PERLND  1           200.          RCHRES  2     1
PERLND  2           300.          RCHRES  5     1
RCHRES  4             1.          RCHRES  5     2
```

END SCHEMATIC

Details

Symbol	FORTRAN Name(s)	Start Column	Format	Comment
<svol>	SVOL	1	A6	SVOL is the Operation-type of the source operation.
< #>	SVOLNO	7	I4	SVOLNO is the source Operation-type number (e.g., PERLND 5)
<afact>	AFACTR	29	F10.0	The area factor by which data from the source will be multiplied before being added to the target. This factor will be combined with the factor in the MASS-LINK Block. Default (blank field)= 1.0
<tvol>	TVOL	44	A6	TVOL is the Operation-type of the target.
< #>	TVOLNO	50	I4	TVOLNO is the target Operation-type number (e.g., RCHRES 5)
<ml#>	MSLKNO	57	I4	MASS-LINK table number that will be used to generate the NETWORK entries for this linkage.

4.6.4.2 MASS-LINK Block

In this block the user specifies those time series connections which will be combined with the linkages in the SCHEMATIC Block to generate a set of time series connections in the NETWORK Block.

```
*****
      1      2      3      4      5      6      7      8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

MASS-LINK

```
      MASS-LINK      #
<svol>      <sgrp> <smem><m#><-mfact-->      <tvol>      <tgrp> <tmem><m#>
```

.....
Above line repeats until all mass-link entries have been made
.....

```
      END MASS-LINK      #
```

END MASS-LINK

Example

MASS-LINK

```
      MASS-LINK      1
<-Volume-> <-Grp> <-Member-><--Mult-->      <-Target vols> <-Grp> <-Member->      ***
<Name>      <Name> # #<-factor->      <Name> # #      <Name> # #      ***
PERLND      PWATER PERO      0.08333      RCHRES      INFLOW IVOL
PERLND      SEDMNT SOSED      RCHRES      INFLOW ISED      1
PERLND      PQUAL POQUAL 1      RCHRES      INFLOW OXIF      2
```

```
      END MASS-LINK      1
```

END MASS-LINK

Details

Symbol	FORTRAN Name(s)	Start Column	Format	Comment
<svol>	SVOL	1	A6	SVOL is the Operation-type of the source operation.
<sgrp>	SGRPN	12	A6	Group to which the source time series belong(s).
<smem>	SMEMN	19	A6	Source member name.
<m#>	SMEMSB(2)	25	2A2	Source member name subscripts; may be 2-character CATEGORY tag if applicable; must be integer otherwise. See Time Series Catalog.
<mfact>	MFACTR	29	F10.0	The factor by which data from the source will be multiplied before being added to the target. Default (blank field)= 1.0
<tvol>	TVOL	44	A6	TVOL is the Operation-type of the target.
<tgrp>	TGRPN	59	A6	Group to which the target time series belong(s).
<tmem>	TMEMN	66	A6	Target member name.
<m#>	TMEMSB(2)	72	2A2	Target member name subscripts; may be 2-character CATEGORY tag if applicable; must be integer otherwise. See Time Series Catalog.

4.6.5 EXT TARGETS Block (External targets)

In this block the user specifies those time series which will be output from the operations in a RUN, to data sets in the WDM or DSS Files. If there are no such transfers the block may be omitted.

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

```
EXT TARGETS
<svol><o#> <sgrp> <smem><m#><-mfact--><tr> <tvol><t#> <extm>qf <ts> <ag> <am>
```

.....
Above line repeats until all external targets have been specified
.....

END EXT TARGETS

Example

```
EXT TARGETS
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Volume-> <Member> Tsys Aggr Amd ***
<Name> # <Name> # <-factor->strg <Name> # <Name>qf tem strg strg***
RCHRES 6 GQUAL DQAL 3 1. AVER WDM4 25 CONC ENGL AGGR REPL
PERLND 301 NITR PONITR SUM DSS 122 ENGL REPL
END EXT TARGETS
```

Details

Symbol	FORTTRAN Name(s)	Start Column	Format	Comment
<svol>	SVOL	1	A6	SVOL is the Operation-type of the source operation.
<o#>	SVOLNO	7	I4	SVOLNO is the source Operation-type number (e.g., PERLND 5)
<sgrp>	SGRPN	12	A6	Group to which the source time series belong(s).
<smem>	SMEMN	19	A6	Source member name.
<m#>	SMEMSB(2)	25	2A2	Source member name subscripts; may be 2-character CATEGORY tag if applicable; must be integer otherwise. See Time Series Catalog.
<mfact>	MFACTR	29	F10.0	The factor by which data from the source will be multiplied before being added to the target. Default (blank field)= 1.0
<tr>	TRAN	39	A4	String indicating which transformation function to use in transferring time series from source to target. See Section 4.6.7 for defaults.
<tvol>	TVOL	44	A6	External target volume. Valid values are WDMn (Watershed Data Management System file, where n is 1-4 or blank) and DSS (Data Storage System).
<t#>	TVOLNO	50	I4	Data-set Number (if TVOL = WDMn, or DSS).
<extm>	TMEMN	55	A6 A4	Data-set TSTYP attribute (if TVOL = WDMn). (Blank if TVOL = DSS.)
qf	QLFG	61	I2	Quality-of-data (if TVOL = WDM); specifies the quality tag to be attached to data placed in a WDM data set; valid values = 0 - 31; default = 0.
<ts>	TSYST	64	A4	Unit system of data to be written to WDM or DSS data set; valid values = ENGL and METR; default = ENGL.
<ag>	AGGST	69	A4	String indicating whether the data should be aggregated when placed in a WDM data set having a time step greater than the source time step; valid value is AGGR; default is no aggregation.
<am>	AMDST	74	A4	String indicating how the target data set is to be accessed. Valid values are: ADD or REPL for a WDM or DSS file. See below for explanation.

Explanation

This block is similar to the EXT SOURCES Block, but serves the opposite purpose. Thus, the entries have similar formats (but are reversed). In addition, each entry in the EXT TARGETS Block has the <am> field, which indicates how the target data set will be accessed. The user should be aware of the differences between these options when the target data set is in a WDM or DSS file. The valid values and the meaning of each are:

ADD For a WDM data set, this option is designed to add data when no pre-existing data are present for any period after the starting time of the run, including times after the time span of the run.

For a DSS data record, this option preserves pre-existing data before and after the beginning of the run, and requires that no data pre-exist during the time span of the run.

REPL For a WDM data set, this option will result in the overwriting of any existing data which follows the starting time of the run, including data after the time span of the run.

For a DSS data record, pre-existing data during the time span of the run is overwritten, but pre-existing data before and after the run are preserved.

In summary, for a WDM data set, the ADD option is used to add data when no pre-existing data are present after the starting time of the run, while the REPL option results in overwriting existing data, both during and after the time span of the run.

Data placed in a WDM data set will normally have a time step equal to the time step of the run, **even if the data set has a different time step than the run**. However, the user may optionally specify that aggregation occur if the target data-set time step is an integer multiple (2 or greater) of the run time step. The time step of a WDM data set is specified by the TCODE and TSSTEP attributes of the data set. Disaggregation is not permitted when placing data in WDM data sets.

For a DSS data record, only data during the actual time span of the run are affected. The ADD option specifies that such data cannot pre-exist, while the REPL option allows any pre-existing data to be overwritten.

4.6.6 PATHNAMES Block

In this block the user associates data-set numbers with the time series to be accessed from the DSS (HEC Data Storage System) files, and specifies the data types of the time series.

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

PATHNAMES

```
<ds>f# <ctype-> <-----pathname----->
```

```
.....
Above line repeats until all external targets have been specified
.....
```

END PATHNAMES

Example

PATHNAMES

```
<ds>f# <ctype-> <*****pathname*****>
```

```
  41 1 PER-CUM /TEST/FARM COOP WS/EVAP//1DAY/OBSERVED-INCHES|DAY/
```

END PATHNAMES

```
*****
```

Details

```
-----
```

Symbol	FORTTRAN Name(s)	Start Column	Format	Comment
<ds>	DSSDSN	1	I4	DSSDSN is the temporary data-set number assigned to the DSS record(s) which make up the time series.
f#	DSSFL	5	I2	DSSFL is the index number for the DSS file containing these data record(s); it is assigned to each DSS file in the FILES block
<ctype->	CTYPE	8	A8	Data type string for the data record(s). Valid values are: INST-VAL, PER-AVER, PER-CUM.
pathname	CPATH	17	A64	Pathname for DSS record(s). It is recommended that the D part be left empty, as it is generated by HSPF as needed.

```
-----
```

Explanation

This section is required if any time series data are to be accessed from DSS files. In this section, unique ID numbers are assigned to "data sets" in the DSS file(s); these ID numbers are used in the EXT-SOURCES and EXT-TARGETS blocks to specify (i.e., identify) the data sets.

See Section 4.6.1.1 for further discussion of DSS concepts.

4.6.7 Time Series Transform Functions

Whenever time series are transferred from a source to a target, a "transformation" takes place. The user can specify the transformation function in field <tr>; if it is blank the default function is supplied. The range of permissible functions is:

Interval relation	Source Type	to	Target Type	<----- Functions ----->	
				Defaults	Others
SDELTA = TDELTA	Point	to	Point	SAME	none
	Mean	to	Mean	SAME	none
	Point	to	Mean	AVER	none
SDELTA > TDELTA (b)	Point	to	Point	INTP/AVER (a)	none
	Mean	to	Mean	DIV	SAME
	Point	to	Mean	AVER	none
SDELTA < TDELTA	Point	to	Point	LAST/AVER (a)	none
	Mean	to	Mean	SUM	AVER,MAX,MIN
	Point	to	Mean	AVER	SUM,MAX,MIN

Key: SDELTA Time interval of source time series
TDELTA Time interval of target time series
(a) Second default keyword applies to WDM source time series and all DSS external time series.
(b) This interval relation is invalid for WDM target; i.e., output disaggregation is not permitted to WDM data sets

Notes:

1. See below (Note 2 and next page) for explanations of the transform keywords.
2. For WDM data sets, TDELTA and SDELTA refer to the time step defined by the WDM attributes TCODE and TSSTEP; however, data may be stored in the data set at other time steps.

3. For WDM or DSS data sets, the functions AVER and SAME imply either AVER or SAME; and the functions SUM and DIV imply either SUM or DIV, whichever is appropriate for the actual time step of the data.
4. The type of WDM data sets is determined by the attribute TSFORM. If TSFORM = 1 or 2, the type is MEAN; if TSFORM = 3, the type is POINT.
5. The type of sequential (SEQ) time series is not defined; consequently, these time series are assumed to have the same type as the target time series.
6. The type of DSS data records is determined from the data type string. (See Section 4.6.1.1 above for discussion.) If none is specified, the time series is assumed to be mean-valued.
7. Keywords less than 4 characters long must be left-justified in the field.
8. For further information, see Appendix V and Time Series Catalog (Section 4.7 of this part).

The time series transform functions given above are completed before the multiplication factor given in the EXTERNAL SOURCES, EXTERNAL TARGETS and NETWORK blocks are applied. These transform functions are defined as follows:

- AVER Compute the integral of the source time series over each target time step, divide by the target time step and assign the value to the time step in the target time series. See Appendix V for definition of the integral of a time series.
- DIV Divide each mean value of the source time series by the ratio of the source time step to the target time step and assign the results to each of the target time steps contained in the source time step.
- INTP Interpolate linearly between adjacent point values in the source time series and assign the interpolated values to each time point in the target time series.
- LAST Take the value at the last time point of the source time series which belongs to the time step of the target time series and assign the value to the time step of the target time series. See Appendix V for a definition of the meaning of "belonging".
- MAX Find the maximum value of the source time series for all points belonging to the target time step (point-value time series) or find the maximum value of the source time series for all time steps contained within the target time step (mean-value time series). Assign the maximum value to the time step of the target time series. The definition of "belonging" (given in Appendix V) was motivated by the desire to make MAX and MIN unique for point-value time series.

- MIN** Find the minimum value of the source time series for all points belonging to the target time step (point-value time series) or find the minimum value of the source time series for all time steps contained within the target time series (mean-value time series). Assign the minimum value to the time step of the target time series.
- SAME** Take the value at each time step or time point of the source time series and assign the value to the corresponding time point (point-value time series), the corresponding time step (mean-value time series), or all the contained time steps (mean-value time series with time step less than the source time step) of the target time series.
- SUM** For point-value source time series: Compute the sum of the values for all points in the source time series belonging to the target series time step plus the value of the source time series at the initial point of the target time step and assign the sum to the target time step. For mean-value source time series: Compute the sum of the values for all time steps in the source time series contained within the target series time step and assign the sum to the target time step.

4.6.8 Warning

1. In this block it is not permissible to route several sources to the same external target. If you want to combine several time series and write the result to an external target, first use a utility operation (COPY) to combine the data, and then use this block to route the result to the external target.

4.7 Time Series Catalog

This section documents all the time series which are required by, and which can be output by, all the operating modules in the HSPF system.

The time series are arranged in groups. Thus, to specify an operation associated time series in the EXT SOURCES, NETWORK or EXT TARGETS Blocks, the user supplies a group name followed, optionally, by a member name and subscripts.

The time series documented in this section can be separated into three categories:

1. Input only. Some time series can only be input to their operating module (e.g. member PREC of group EXTNL in module PERLND).
2. Input or output. Some time series can either be input to their operating module or output from it, depending on the options in effect. For example, if snow accumulation and melt on a Previous Land-segment (PLS) is being simulated in a given RUN, time series WYIELD in group SNOW can be output to the WDM file. Then, if section SNOW is inactive but section PWATER is active in a subsequent RUN, the same time series WYIELD may be specified as an input to the PERLND module. This feature makes it possible to calibrate an application module in an incremental manner. First, the outputs from section 1 are calibrated to the field data; then the outputs from section 2 are calibrated using outputs from section 1 as inputs, etc. Sections calibrated in earlier runs need not be re-run if the needed outputs from them have been stored.
3. Output only. Some time series can be computed by and output from their operating module, but never serve as inputs to it (e.g. member ALBEDO of group SNOW in module PERLND).

To run an operating module, the user must ensure that all the input time series which it requires are made available to it. This is done by making appropriate entries in the EXT SOURCES or NETWORK blocks. To ascertain which time series are required, one should consult the Time Series Catalog for the appropriate module. For example, assume that sediment production and washoff/scour from a PLS are being simulated using the snow and water budget results from a previous RUN. In this scenario, section SEDMNT would be active, but sections ATEMP, SNOW and PWATER would not be active. Then, Table 4.7(1).5 shows the following:

1. member (time series) PREC of group EXTNL is a required input time series (member SLSED is optional)
2. members RAINF and SNOCOV of group SNOW are required inputs, because section SNOW is inactive
3. members SURO and SURS of group PWATER are required inputs, because section PWATER is inactive

The user can obtain further details on the above time series by consulting the table for the appropriate group (e.g. Table 4.7(1).1 for group EXTNL). Table 4.7(1).5 shows which time series are computed in the SEDMNT section of the PERLND module and may therefore be output (members DETS through SOSDB).

Thus, in the EXT SOURCES and/or NETWORK blocks, entries must appear which specify members PREC, RAINF, etc (groups EXTNL, SNOW, PWATER) as targets to which source time series are routed. Also, in the NETWORK and/or EXT TARGETS blocks, entries may appear which specify one or more of members DETS through SOSDB (of group SEDMNT) as source time series, which are routed to other operations or to the WDM.

The tables which follow are otherwise self explanatory, except for the abbreviation "ivld" which appears frequently in the "Units" fields. It means "interval of the data" (to distinguish it from the internal, or simulation interval). Thus, if a WDM or DSS data set containing 1-hour precipitation data is input to an operation with a DELT of two hours, ivld is 1 hour.

4.7.1 Connection of Surface and Instream Application Modules

In HSPF, the operational connection between the land surface and instream simulation modules is accomplished through the NETWORK Block and/or the SCHEMATIC/MASS-LINK Blocks. Time series of runoff, sediment, and pollutant loadings generated on the land surface are passed to the receiving stream for subsequent transport and transformation instream. This connection of the IMPLND and/or PERLND modules with the RCHRES module requires explicit definition of corresponding time series in the linked modules. A one-to-one correspondence exists between several land segment outflow time series and corresponding stream reach inflow time series (e.g. runoff, sediment, dissolved oxygen, etc.); however in order to maintain flexibility, some of the time series are more general, and no unique correspondence exists. Also, in some cases, a process or material simulated in the stream will have no corresponding land surface quantity. For example, the inflow of plankton to a stream occurs only from upstream reaches and not from a land segment.

4.7.2 Atmospheric Deposition of Water Quality Constituents

Input time series are available in HSPF to aid in the simulation of atmospheric deposition of quality constituents. Atmospheric deposition inputs can be specified in two possible ways depending on the form of the available data. If the deposition is in the form of a flux (mass per area per time), then it is considered "dry deposition". If the deposition is in the form of a concentration in rainfall, then it is considered "wet deposition", and the program automatically combines it with the input rainfall time series to compute the resulting flux. Either type of deposition data can be input as a time series, which covers the entire simulation period, or alternatively, as a set of monthly values that is used for each year of the simulation. The specific atmospheric deposition time series for each operational module (PERLND, IMPLND, RCHRES) are documented in the EXTNL table of the Time Series Catalog for that module.

Time Series Catalog

An additional use of these atmospheric deposition time series is the specification of agricultural chemical and fertilizer inputs to the soil. These input time series thus provide an alternative to the SPEC-ACTIONS block as a means for changing soil storages of chemicals in the AGCHEM sections of the program. For this purpose, "deposition" to the upper soil layer in addition to the surface soil layer is available in PERLND sections NITR, PHOS, and TRACER. (Section PEST has time series only for the surface layer, since pesticides are not normally incorporated into the soil as are fertilizers.) Depending on the complexity of the agricultural practices being modeled, the user should decide whether the SPEC-ACTIONS or the time series inputs are simpler to construct.

4.7(1) Catalog for PERLND module

The time series groups associated with this module are shown in Figure 4.7(1)-1.

The members contained within each group are documented in the following tables.

4.7(1).1 Group EXTNL

```

-----
<---- Member ----> K      Units
      Max subscr  i      (external)      Description/comment
Name      values  n
      1      2      d  Engl      Metr
-----

```

Time series always external (input only) to module PERLND:

Name	1	2	d	Engl	Metr	Description/comment
GATMP	1	1	-	Deg F	Deg C	Measured air temperature
PREC	1	1	-	in/ivld	mm/ivld	Measured precipitation
DTMPG	1	1	-	Deg F	Deg C	Measured dewpoint temperature
WINMOV	1	1	-	mi/ivld	km/ivld	Measured wind movement
SOLRAD	1	1	-	Ly/ivld	Ly/ivld	Measured solar radiation
CLOUD	1	1	-	tenths	tenths	Cloud cover (range: 0 - 10)
PETINP	1	1	-	in/ivld	mm/ivld	Input potential E-T
SURLI	1	1	-	in/ivld	mm/ivld	Surface lateral inflow
IFWLI	1	1	-	in/ivld	mm/ivld	Interflow lateral inflow
AGWLI	1	1	-	in/ivld	mm/ivld	Active groundwater lateral inflow
SLSSED	1	1	-	tons/ ac.ivld	tonnes/ ha.ivld	Lateral input of sediment
PQADFX	NQ	1	-	qty/ ac.ivld	qty/ ha.ivld	Dry or total atmospheric deposition of QUALOF
PQADCN	NQ	1	-	qty/ft3	qty/l	Concentration of QUALOF in rain for wet atmospheric deposition
PEADFX	NPST	3	-	lb/ ac.ivld	kg/ ha.ivld	Dry or total atmospheric deposition of pesticide. The first subscript indicates the pesticide; the second indicates the species: crystalline, adsorbed, or solution
PEADCN	NPST	3	-	mg/l	mg/l	Concentration of pesticide in rain for wet atmospheric deposition. Subscripts same as above.
NIADFX	3	2	-	lb/ ac.ivld	kg/ ha.ivld	Dry or total atmospheric deposition of nitrogen. First subscript indi- cates species: NO3, NH3, organic N; the second subscript indicates the affected soil layer: surface or upper.
NIADCN	3	2	-	mg/l	mg/l	Concentration of nitrogen in rain for wet atmospheric deposition. Subscripts as above.

Catalog for PERLND Module

PHADFX	2	2	-	lb/ ac.ivld	kg/ ha.ivld	Dry or total atmospheric deposition of phosphorus. The first subscript indicates species: PO4, organic P; the second subscript indicates the affected soil layer (see above)
PHADCN	2	2	-	mg/l	mg/l	Concentration of phosphorus in rain for wet atmospheric deposition. Subscripts as above.
TRADFX	2	1	-	lb/ ac.ivld	kg/ ha.ivld	Dry or total atmospheric deposition of tracer substance. Subscript indicates affected soil layer (see above)
TRADCN	2	1	-	mg/l	mg/l	Concentration of tracer in rain. Subscript as above.

4.7(1).2 Group ATEMP

<---- Member ---->		K	Units		Description/comment
Name	Max subscript values	i	(external)		
	1 2	d	Engl	Metr	

Time series computed by module section ATEMP:

AIRTMP	1	1	-	Deg F	Deg C	Estimated surface air temperature over the Land-segment
--------	---	---	---	-------	-------	---

Input time series required to compute the above:

Group EXTNL	always required
GATMP	gage air temperature
PREC	precipitation

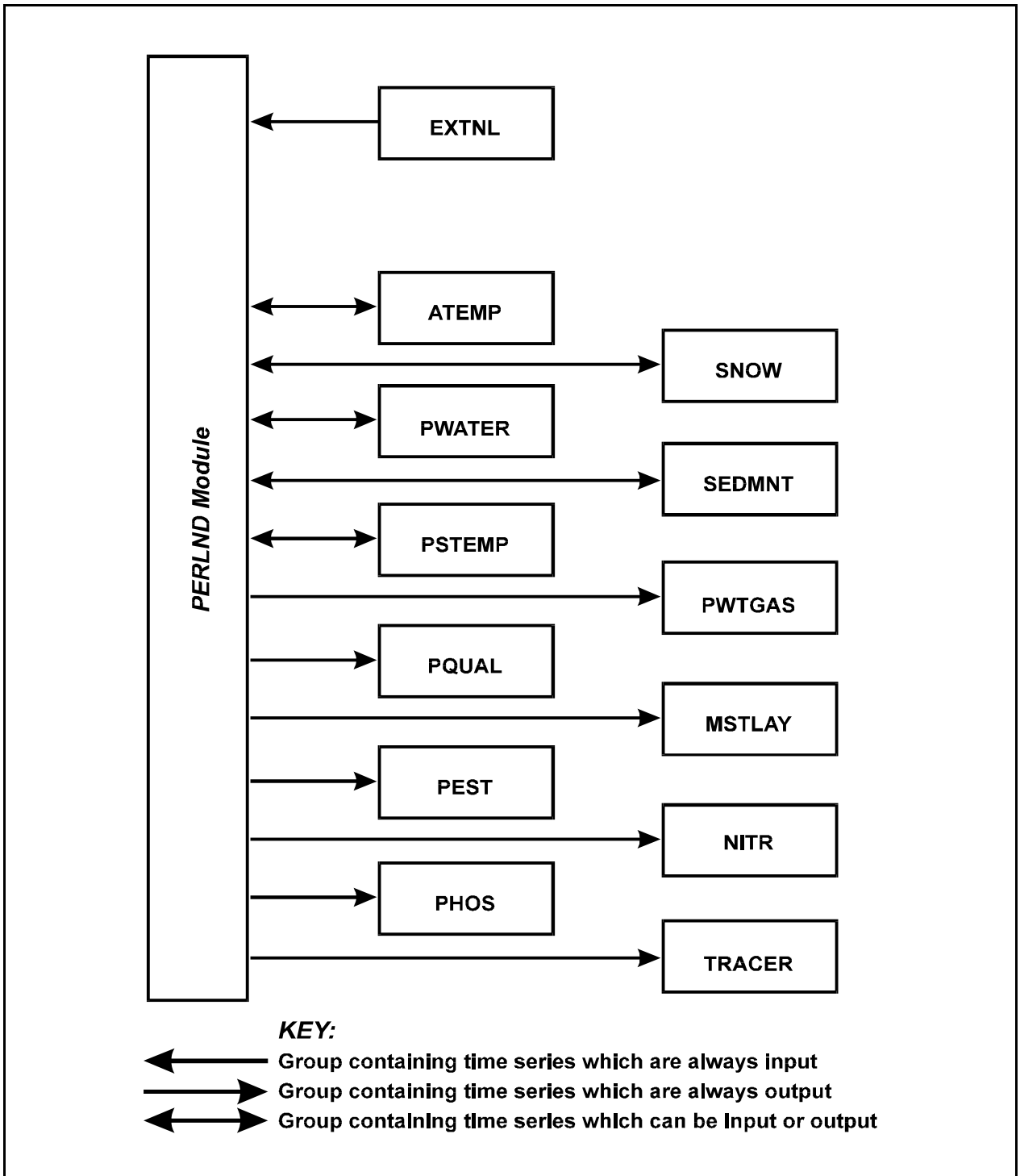


Figure 4.7(1)-1 Groups of time series associated with the PERLND Module

4.7(1).3 Group SNOW

Name	Member		K	Units		Description/comment
	1	2		(external)	Metr	

Time series computed by module section SNOW:

PACK	1	1	*	in	mm	Total contents of pack (water equiv)
PACKF	1	1	*	in	mm	Frozen contents of pack, ie. snow + ice (water equivalent)
PACKW	1	1	*	in	mm	Liquid water in pack
PACKI	1	1	*	in	mm	Ice in pack (water equivalent)
PDEPTH	1	1	*	in	mm	Pack depth
RDENPF	1	1	*	none	none	Relative density of frozen contents of pack (PACKF/PDEPTH)
SNOCOV	1	1	*	none	none	Fraction of Land-segment covered by pack
ALBEDO	1	1	*	none	none	Albedo of the pack
PAKTMP	1	1	*	Deg F	Deg C	Mean temperature of the pack
SNOWF	1	1	-	in/ivld	mm/ivld	Snowfall, water equivalent
SNOWE	1	1	-	in/ivld	mm/ivld	Evaporation from PACKF (sublimation), water equivalent
WYIELD	1	1	-	in/ivld	mm/ivld	Water yielded by the pack (released to the land-surface)
MELT	1	1	-	in/ivld	mm/ivld	Quantity of melt from PACKF (water equivalent)
RAINF	1	1	-	in/ivld	mm/ivld	Rainfall

Input time series required to compute the above:

Group EXTNL	always required
PREC	precipitation
DTMPG	dewpoint temperature
WINMOV	wind movement
SOLRAD	solar radiation
Group ATEMP	required if section ATEMP inactive
AIRTMP	air temperature

4.7(1).4 Group PWATER

Name	Max subscr values		K	Units		Description/comment
	1	2		(external)	Engr	

Time series computed by module section PWATER:

Land-segment-wide values:

PERS	1	1	*	in	mm	Total water stored in the PLS
CEPS	1	1	*	in	mm	Interception storage
SURS	1	1	*	in	mm	Surface (overland flow) storage
UZS	1	1	*	in	mm	Upper zone storage
IFWS	1	1	*	in	mm	Interflow storage
LZS	1	1	*	in	mm	Lower zone storage
AGWS	1	1	*	in	mm	Active groundwater storage
RPARM	1	1	-	in/ivld	mm/ivld	Current value of maximum lower zone E-T opportunity
SURO	1	1	-	in/ivld	mm/ivld	Surface outflow
IFWO	1	1	-	in/ivld	mm/ivld	Interflow outflow
AGWO	1	1	-	in/ivld	mm/ivld	Active groundwater outflow
PERO	1	1	-	in/ivld	mm/ivld	Total outflow from PLS
IGWI	1	1	-	in/ivld	mm/ivld	Inflow to inactive (deep) groundwater
PET	1	1	-	in/ivld	mm/ivld	Potential E-T, adjusted for snow cover and air temperature
CEPE	1	1	-	in/ivld	mm/ivld	Evap. from interception storage
UZET	1	1	-	in/ivld	mm/ivld	E-T from upper zone
LZET	1	1	-	in/ivld	mm/ivld	E-T from lower zone
AGWET	1	1	-	in/ivld	mm/ivld	E-T from active groundwater storage
BASET	1	1	-	in/ivld	mm/ivld	E-T taken from active groundwater outflow (baseflow)
TAET	1	1	-	in/ivld	mm/ivld	Total simulated E-T
IFWI	1	1	-	in/ivld	mm/ivld	Interflow inflow (excluding any lateral inflow)
UZI	1	1	-	in/ivld	mm/ivld	Upper zone inflow
INFIL	1	1	-	in/ivld	mm/ivld	Infiltration to the soil
PERC	1	1	-	in/ivld	mm/ivld	Percolation from upper to lower zone
LZI	1	1	-	in/ivld	mm/ivld	Lower zone inflow
AGWI	1	1	-	in/ivld	mm/ivld	Active groundwater inflow (excluding any lateral inflow)
SURI	1	1	-	in/ivld	mm/ivld	Surface inflow (including any lateral inflow)

Input time series required to compute the above:

Group EXTNL	
SURLI	optional
IFWLI	optional
AGWLI	optional
PETINP	
PREC	required if snow not considered (CSNOFG= 0)
Group ATEMP	
AIRTMP	only required if section ATEMP is inactive and CSNOFG= 1
Group SNOW	
RAINF	only required if section SNOW is inactive and snow is considered (CSNOFG= 1)
SNOCOV	
WYIELD	
PACKI	only required if ICEFG= 1
Group PSTEMP	
LGTMP	only required if section PSTEMP is inactive and IFFCFG= 2

4.7(1).5 Group SEDMNT

<---- Member ---->		K	Units		Description/comment
Name	Max subscr values	i	(external)		
	1 2	d	Engl	Metr	

Time series computed by module section SEDMNT:

Land-segment-wide values:

DETS	1	1	*	tons/ac	tonnes/ha	Storage of detached sediment
STCAP	1	1	*	tons/ ac.ivld	tonnes/ ha.ivld	Sediment transport capacity by surface runoff
WSSD	1	1	-	tons/ ac.ivld	tonnes/ ha.ivld	Washoff of detached sediment
SCRSD	1	1	-	tons/ ac.ivld	tonnes/ ha.ivld	Scour of matrix (attached) soil
SOSED	1	1	-	tons/ ac.ivld	tonnes/ ha.ivld	Total removal of soil and sediment
DET	1	1	-	tons/ ac.ivld	tonnes/ ha.ivld	Quantity of sediment detached from soil matrix by rainfall impact

Input time series required to compute the above:

Group EXTNL	always required
PREC	
SLSED	optional
Group SNOW	only required if section SNOW is inactive and snow is considered (CSNOFG= 1)
RAINF	
SNOCOV	
Group PWATER	only required if section PWATER is inactive
SURO	
SURS	

4.7(1).6 Group PSTEMP

Name	Member		K	Units		Description/comment
	Max	subscr		i	(external)	
	values	n				
	1	2	d	Engl	Metr	

Time series computed by module section PSTEMP:

AIRTC	1	1	-	Deg F	Deg C	Air temperature on the PLS
SLTMP	1	1	-	Deg F	Deg C	Surface layer soil temperature
ULTMP	1	1	-	Deg F	Deg C	Upper layer soil temperature
LGTMP	1	1	-	Deg F	Deg C	Lower and groundwater layer soil temperature

Input time series required to compute the above:

Group ATEMP	only required if section ATEMP is inactive
AIRTMP	

4.7(1).7 Group PWTGAS

Name	Member		K	Units		Description/comment
	Max	subscr		i	(external)	
	values	n				
	1	2	d	Engl	Metr	

Time series computed by module section PWTGAS:

SOTMP	1	1	*	Deg F	Deg C	Temperature of surface outflow
IOTMP	1	1	*	Deg F	Deg C	Temperature of interflow outflow
AOTMP	1	1	*	Deg F	Deg C	Temperature of active groundwater outflow
SODOX	1	1	*	mg/l	mg/l	DO concentration in surface outflow
SOCO2	1	1	*	mg/l	mg/l	CO2 concentration in surface outflow
IODOX	1	1	*	mg/l	mg/l	DO concentration in interflow outflow
IOCO2	1	1	*	mg/l	mg/l	CO2 concentration in interflow outflow
AODOX	1	1	*	mg/l	mg/l	DO concentration in active groundwater outflow

(continued)

AOCO2	1	1	*	mg/l	mg/l	CO2 concentration in active groundwater outflow
SOHT	1	1	-	BTU/ ac.ivld	kcal/ ha.ivld	Heat energy in surface outflow (relative to freezing point)
IOHT	1	1	-	BTU/ ac.ivld	kcal/ ha.ivld	Heat energy in interflow outflow
AOHT	1	1	-	BTU/ ac.ivld	kcal/ ha.ivld	Heat energy in active groundwater outflow
POHT	1	1	-	BTU/ ac.ivld	kcal/ ha.ivld	Heat energy in total outflow from PLS
SODOXM	1	1	-	lb/ ac.ivld	kg/ ha.ivld	Flux of DO in surface outflow
SOCO2M	1	1	-	lb/ ac.ivld	kg/ ha.ivld	Flux of CO2 in surface outflow
IODOXM	1	1	-	lb/ ac.ivld	kg/ ha.ivld	Flux of DO in interflow outflow
IOCO2M	1	1	-	lb/ ac.ivld	kg/ ha.ivld	Flux of CO2 in interflow outflow
AODOXM	1	1	-	lb/ ac.ivld	kg/ ha.ivld	Flux of DO in active groundwater outflow
AOCO2M	1	1	-	lb/ ac.ivld	kg/ ha.ivld	Flux of CO2 in active groundwater outflow
PODOXM	1	1	-	lb/ ac.ivld	kg/ ha.ivld	DO in total outflow from PLS
POCO2M	1	1	-	lb/ ac.ivld	kg/ ha.ivld	CO2 in total outflow from PLS

Input time series required to compute the above:

Group SNOW WYIELD	only required if section SNOW is inactive and snow is considered (CSNOFG= 1)
Group PWATER SURO IFWO AGWO	only required if section PWATER is inactive
Group PSTEMP SLTMP ULTMP LGTMP	only required if section PSTEMP is inactive

4.7(1).8 Group PQUAL

Name	Member		K	Units		Description/comment
	1	2		(external)	Metrc	

Time series computed by module section PQUAL:

SQO	NQOF	1	*	qty/ac	qty/ha	Storage of QUALOF on the surface
PQADDR	NQ	1	-	qty/ ac.ivld	qty/ ha.ivld	Dry or total atmospheric deposition of QUAL
PQADWT	NQ	1	-	qty/ ac.ivld	qty/ ha.ivld	Wet deposition of QUAL
WASHQS	NQSD	1	-	qty/ ac.ivld	qty/ ha.ivld	Removal of QUALSD by association with detached sediment washoff
SCRQS	NQSD	1	-	qty/ ac.ivld	qty/ ha.ivld	Removal of QUALSD by association with scour of matrix soil
SOQS	NQSD	1	-	qty/ ac.ivld	qty/ ha.ivld	Total flux of QUALSD from surface
SOQO	NQOF	1	-	qty/ ac.ivld	qty/ ha.ivld	Washoff of QUALOF from surface
SOQUAL	NQ	1	-	qty/ ac.ivld	qty/ ha.ivld	Total outflow of QUAL from the surface
IOQUAL	NQIF	1	-	qty/ ac.ivld	qty/ ha.ivld	Outflow of QUAL in interflow (QUALIF)
AOQUAL	NQGW	1	-	qty/ ac.ivld	qty/ ha.ivld	Outflow of QUAL in active ground- water outflow (QUALGW)
POQUAL	NQ	1	-	qty/ ac.ivld	qty/ ha.ivld	Total flux of QUAL from the PLS
SOQOC	NQOF	1	-	qty/ft3	qty/l	Concentration of QUALOF in surface outflow
SOQC	NQ	1	-	qty/ft3	qty/l	Concentration of QUAL (QUALSD+ QUALOF) in surface outflow
POQC	NQ	1	-	qty/ft3	qty/l	Concentration of QUAL (total) in total outflow from PLS

Input time series required to compute the above:

Group EXTNL	
PQADFX	only required if dry or total atmospheric deposition is being simulated
PQADCN	only required if wet atmospheric deposition is being simulated
PREC	

Catalog for PERLND Module

Group PWATER	only required if PWATER is inactive
SURO	only required if one or more QUALs are QUALOFs, or if SOQC is required for one or more QUALs
IFWO	only required if one or more QUALs are QUALIFs
AGWO	only required if one or more QUALs are QUALGws
PERO	only required if POQC is required for one or more QUALs
Group SEDMNT	only required if section SEDMNT is inactive and one or more QUALs are QUALSD's
WSSD	
SCRSD	

4.7(1).9 Group MSTLAY

<---- Member ---->	K	Units	
Max subscr	i	(external)	Description/comment
Name	values	n	
	1 2	d	Engl Metr

Time series computed by module section MSTLAY:

MST	5	1	*	lb/ac	kg/ha	Water in surface, upper principal, upper auxiliary, lower, and groundwater storages
FRAC	8	1	*	/ivl	/ivl	Fractional fluxes through soil: FSO, FSP, FII, FUP, FIO, FLP, FLDP, FAO

Input time series required to compute the above:

Group PWATER:	only required if section PWATER is inactive
SURI, LZS, IGWI, AGWI, AGWS, AGWO,	
SURS, SURO, INFIL, IFWI, UZI, UZS,	
PERC, IFWS, IFWO	

4.7(1).10 Group PEST

Name	Member		K	Units		Description/comment
	1	2		(external)	Metr	

Time series computed by module section PEST:

SPS	3	NPST	*	lb/ac	kg/ha	Amount of pesticide in surface storage
UPS	3	NPST	*	lb/ac	kg/ha	Amount of pesticide in upper principal storage
IPS		NPST 1	*	lb/ac	kg/ha	Amount of pesticide in upper auxiliary (interflow) storage
LPS	3	NPST	*	lb/ac	kg/ha	Amount of pesticide in lower layer storage
APS	3	NPST	*	lb/ac	kg/ha	Amount of pesticide in active groundwater layer storage
TPS	3	NPST	*	lb/ac	kg/ha	Total amount of pesticide in the soil

Note: SPS,UPS,LPS,APS and TPS give the storage of each pesticide by species. The first subscript indicates the species: crystalline, adsorbed, or solution, The second indicates the pesticide. For example, UPS(2,3) is the quantity of adsorbed pesticide in the upper layer principal storage, for the 3rd pesticide. The second subscript for IPS has a maximum value of one because only solution pesticide is modeled in the upper layer auxiliary (interflow) layer.

TOTPST	NPST	1	*	lb/ac	kg/ha	Total amount of pesticide in the soil (sum of all species).
PEADDR	NPST	3	-	lb/ ac.ivld	kg/ ha.ivld	Dry or total atmospheric deposition of pesticide. The second subscript indicates the species: crystalline, adsorbed, or solution.
PEADWT	NPST	3	-	lb/ ac.ivld	kg/ ha.ivld	Wet deposition of pesticide form. Subscripts as above.
SDPS	2	NPST	-	lb/ ac.ivld	kg/ ha.ivld	Outflow of sediment-associated pesticide (SDPSY and SDPSA for each pesticide)
TSPSS	5	NPST	-	lb/ ac.ivld	kg/ ha.ivld	Fluxes of solution pesticide for the topsoil layers: SOPSS,SPPSS, UPPSS,IIPSS,IOPSS
SSPSS	3	NPST	-	lb/ ac.ivld	kg/ ha.ivld	Fluxes of solution pesticide for the subsoil layers: LPPSS,LDPPSS, AOPSS

Catalog for PERLND Module

SDEGPS	NPST	1	-	lb/ ac.ivld	kg/ ha.ivld	Amt. of degradation in surface layer
UDEGPS	NPST	1	-	"	"	Amount of degradation in upper layer
LDEGPS	NPST	1	-	"	"	Amount of degradation in lower layer
ADEGPS	NPST	1	-	"	"	Amount of degradation in groundwater
TDEGPS	NPST	1	-	"	"	Total amount of degradation in soil
SOSDPS	NPST	1	-	"	"	Total outflow of sediment-associated pesticide (SDPSY + SDPSA)
POPST	NPST	1	-	"	"	Total outflow of solution pesticide from the PLS
TOPST	NPST	1	-	"	"	Total outflow of pesticide from the PLS

Note: The subscript with maximum value NPST selects the particular pesticide. For example, POPST(2,1) is the outflow from the PLS of the second pesticide (in solution).

Input time series required to compute the above:

Group EXTNL

PEADFX	only required if dry or total atmospheric deposition is being simulated
PEADCN	only required if wet atmospheric deposition is being simulated
PREC	

Group SEDMNT

SOSED	only required if section SEDMNT is inactive
-------	---

Group PSTEMP

SLTMP	only required if section PSTEMP is inactive and ADOFG = 1
ULTMP	
LGTMP	

Group MSTLAY

MST	only required if section MSTLAY is inactive
FRAC	

4.7(1).11 Group NITR

```

-----
<---- Member ----> K      Units
      Max subscr i      (external)      Description/comment
Name      values  n
      1      2      d  Engr      Metr
-----

```

Time series computed by module section NITR:

```

AGPLTN      1      1      *  lb/ac      kg/ha      N in above-ground plant storage
LITTRN      1      1      *      "      "      N in litter storage

```

The above time series are available only if ALPNFG= 1

```

SN          8      1      *  lb/ac      kg/ha      N in surface layer storage
UN          8      1      *      "      "      N in upper layer principal storage
LN          8      1      *      "      "      N in lower layer storage
AN          8      1      *      "      "      N in groundwater layer storage
TN          8      1      *      "      "      Total N in soil, by species

```

In the above, the first subscript selects the species of N: 1 means particulate labile organic N, 2 means adsorbed ammonium, 3 means solution ammonium, 4 means nitrate, 5 means plant N, 6 means solution labile organic N, 7 means particulate refractory organic N, 8 means solution refractory organic N

```

IN          4      1      *  lb/ac      kg/ha      N in upper layer auxiliary
                                     (interflow) storage

```

In the above, the first subscript selects the species of N: 1 means solution ammonium, 2 means nitrate, 3 means solution labile organic N, 4 means solution refractory organic N (only soluble species are modelled in this storage)

```

TOTNIT      1      1      *  lb/ac      kg/ha      Total N stored in the PLS (all
                                     species)
NDFCT       5      1      *  lb/ac      kg/ac      Deficit in yield-based plant uptake
                                     of N from the each soil layer:
                                     1-surface, 2-upper, 3-lower,
                                     4-active groundwater, 5-total
NUPTG       4      1      -  lb/      kg/
                                     ac.ivld  ha.ivld  Yield-based plant uptake target for
                                     N from each soil layer: 1-surface,
                                     2-upper, 3-lower, 4-active groundwater

```

Catalog for PERLND Module

NIADDR	3	2	-	lb/ ac.ivld	kg/ ha.ivld	Dry or total atmospheric deposition of nitrogen. The first subscript indicates the species: NO3, NH3, organic N; the second subscript indicates the affected soil layer: surface or upper.
NIADWT	3	2	-	"	"	Wet atmospheric deposition of nitrogen. Subscripts as above.
SEDN	3	1	-	"	"	Outflows of sediment-associated N

In the above, the first subscript selects the flux: 1 means labile organic N removal, 2 means adsorbed ammonium removal, 3 means refractory organic N removal.

SOSEDN	1	1	-	lb/ ac.ivld	kg/ ha.ivld	Total outflow of sediment-associated N (organic N + adsorbed ammonium)
TSAMS	5	1	-	"	"	Fluxes of solution ammonium in the topsoil
TSNO3	5	1	-	"	"	Fluxes of nitrate in the topsoil
TSSLN	5	1	-	"	"	Fluxes of solution labile organic N in the topsoil
TSSRN	5	1	-	"	"	Fluxes of solution refractory organic N in the topsoil

In the above, the first subscript selects the flux:

- 1 means outflow with surface water outflow
- 2 means percolation from surface to upper layer principal storage
- 3 means percolation from upper layer principal storage to lower layer storage
- 4 means flow from upper layer principal to upper layer auxiliary (interflow) storage
- 5 means outflow from PLS with water from upper layer auxiliary (interflow) storage

SSAMS	3	1	-	lb/ac.ivld	kg/ha.ivld	Fluxes of solution ammonium in the subsoil
SSNO3	3	1	-	"	"	Fluxes of nitrate in the subsoil
SSSLN	3	1	-	"	"	Fluxes of solution labile organic N in the subsoil
SSSRN	3	1	-	"	"	Fluxes of solution refractory organic N in the subsoil

In the above, the first subscript selects the flux:

- 1 means percolation from the lower layer to the active groundwater storage
- 2 means deep percolation, from the lower layer to inactive groundwater
- 3 means outflow from the PLS with water from the active groundwater storage

Catalog for PERLND Module

PONO3	1	1	-	lb/ac.ivld	kg/ha.ivld	Total outflow of NO3 from the PLS
PONH4	1	1	-	"	"	Total outflow of NH4 from the PLS
POORN	1	1	-	"	"	Total outflow of ORGN from the PLS
PONITR	1	1	-	"	"	Total outflow of N (NO3+NH4+ORGN) from the PLS.
TDENIF	1	1	-	"	"	Total denitrification in the PLS
NFIXFX	5	1	-	"	"	N fixation flux to the PLS
AMVOL	5	1	-	"	"	Ammonia volatilization from the PLS

In the above, the first subscript selects soil layer: 1-surface, 2-upper, 3-lower, 4-active groundwater, 5-total

Input time series required to compute the above:

Same as for section PEST, except NIADFX and NIADCN are required for atmospheric deposition. An input time series need only be supplied if section PEST and the section which computes it (SEDMNT, PSTEMP or MSTLAY) are inactive.

4.7(1).12 Group PHOS

```

-----
<---- Member ----> K      Units
                    Max subscr i  (external)      Description/comment
Pame      values  n
          1  2  d  Engr      Metr
-----

```

Time series computed by module section PHOS:

```

SP      4  1  *  lb/ac      kg/ha      P in surface layer storage
UP      4  1  *  "          "          P in upper layer principal storage
LP      4  1  *  "          "          P in lower layer storage
AP      4  1  *  "          "          P in groundwater layer storage
TP      4  1  *  "          "          Total P in soil, by species

```

In the above, the first subscript selects the species of P:

1 means organic P, 2 means adsorbed phosphate, 3 means solution phosphate, 4 means plant P derived from this layer

```

IP      1  1  *  lb/ac      kg/ha      P in upper layer auxiliary storage
                    (interflow) (solution PO4)
(only soluble species are modeled in this storage)

TOTPHO  1  1  *  lb/ac      kg/ha      Total P stored in the PLS (all
                    species)

SPDFC   1  1  *  lb/ac      kg/ac      Deficit in yield-based plant uptake
                    of P from the surface soil layer

PDFCT   5  1  *  lb/ac      kg/ac      Deficit in yield-based plant uptake
                    of P from the each soil layer:
                    1-surface, 2-upper, 3-lower,
                    4-active groundwater, 5-total

PUPTG   4  1  -  lb/          kg/
                    ac.ivld  ha.ivld    Yield-based plant uptake target for
                    P from each soil layer: 1-surface,
                    2-upper, 3-lower, 4-active groundwater

PHADDR  2  2  -  lb/          kg/
                    ac.ivld  ha.ivld    Dry or total atmospheric deposition
                    of phosphorus. The first subscript
                    indicates the species: PO4 or
                    organic P; the second subscript
                    indicates the affected soil layer:
                    surface or upper.

PHADWT  2  2  -  lb/          kg/
                    ac.ivld  ha.ivld    Wet atmospheric deposition of
                    phosphorus. Subscripts as above.

```

Catalog for PERLND Module

SEDP 2 1 - lb/ac.ivld kg/ha.ivld Outflows of sediment-associated P

In the above, the first subscript selects the flux: 1 means organic P removal, 2 means adsorbed phosphate removal

SOSEDP 1 1 - lb/ac.ivld kg/ha.ivld Total outflow of sediment-associated P (organic P + adsorbed phosphate)

TSP4S 5 1 - lb/ac.ivld kg/ha.ivld Fluxes of solution phosphate in the in the topsoil.

In the above, the first subscript selects the flux:

1 means outflow with surface water outflow

2 means percolation from surface to upper layer principal storage

3 means percolation from upper layer principal storage to lower layer storage

4 means flow from upper layer principal to upper layer auxiliary (interflow) storage

5 means outflow from PLS with water from upper layer auxiliary (interflow) storage

SSP4S 3 1 - lb/ac.ivld kg/ha.ivld Fluxes of solution phosphate in the subsoil.

In the above, the first subscript selects the flux:

1 means percolation from the lower layer to the active groundwater storage

2 means deep percolation, from the lower layer to inactive groundwater

3 means outflow from the PLS with water from the active groundwater storage

POPPOS 1 1 - lb/ac.ivld kg/ha.ivld Total outflow of P from the PLS.

Input time series required to compute the above:

Same as for section PEST, except PHADFX and PHADCN are required for atmospheric deposition. An input time series need only be supplied if sections PEST and NITR and the module section which computes it (SEDMNT, PSTEMP or MSTLAY) are inactive.

4.7(1).13 Group TRACER

```

-----
<---- Member ----> K      Units
                   Max subscr i  (external)      Description/comment
Name              values  n
                   1    2    d  Engl      Metr
-----

```

Time series computed by module section TRACER:

```

STRSU    1    1    *  lb/ac    kg/ha    Tracer in surface layer storage
UTRSU    1    1    *    "        "        Tracer in upper principal storage
ITRSU    1    1    *    "        "        Tracer in upper auxiliary storage
LTRSU    1    1    *    "        "        Tracer in lower layer storage
ATRSU    1    1    *    "        "        Tracer in groundwater layer storage
TRSU     1    1    *    "        "        Total tracer stored in the PLS
TRADDR   2    1    -  lb/      kg/      Dry or total atmospheric deposition
                   ac.ivld  ha.ivld  of tracer. The subscript indicates
                   the soil layer: surface or upper.
TRADWT   2    1    -    "        "        Wet atmospheric deposition of
                   tracer. Subscripts as above.
TSTRS    5    1    -  lb/ac.ivld kg/ha.ivld Fluxes of tracer in topsoil

```

In the above, the first subscript indicates the flux:

- 1 means outflow with surface water outflow
- 2 means percolation from surface to upper layer principal storage
- 3 means percolation from upper layer principal to lower layer storage
- 4 means flow from upper principal to upper auxiliary (interflow) storage
- 5 means outflow from the PLS from upper layer transitory (interflow) storage

```

SSTRS    3    1    -  lb/ac.ivld kg/ha.ivld Fluxes of tracer in subsoil

```

In the above, the first subscript indicates the flux:

- 1 means percolation from lower layer to active groundwater storage
- 2 means deep percolation, from lower layer to inactive groundwater
- 3 means outflow from the PLS from the active groundwater storage

```

POTRS    1    1    -  lb/ac.ivld kg/ha.ivld Total outflow of tracer from the PLS

```


Catalog for PERLND Module

Input time series required to compute the above:

Group EXTNL

TRADFX	only required if dry or total atmospheric deposition is being simulated
TRADCN	only required if wet atmospheric deposition is being simulated
PREC	

Group MSTLAY

MST	only required if MSTLAY, PEST, NITR and PHOS are all inactive; else these time series will already have been supplied
FRAC	

4.7(2) Catalog for IMPLND module

The time series groups associated with this application module are shown in Figure 4.7(2)-1. The members contained within each group are documented in the tables which follow.

4.7(2).1 Group EXTNL

```

-----
<---- Member ----> K      Units
      Max subscr  i      (external)      Description/comment
Name      values  n
      1      2      d  Engl      Metr
-----

```

Time series always external (input only) to module IMPLND:

```

GATMP      1      1      -  Deg F      Deg C      Measured air temperature
PREC       1      1      -  in/ivld   mm/ivld   Measured precipitation
DTMPG      1      1      -  Deg F      Deg C      Measured dewpoint temperature
WINMOV     1      1      -  mi/ivld   km/ivld   Measured wind movement
SOLRAD     1      1      -  Ly/ivld   Ly/ivld   Measured solar radiation
CLOUD      1      1      -  tenths    tenths    Cloud cover (range: 0 - 10)
PETINP     1      1      -  in/ivld   mm/ivld   Input potential E-T
SURLI      1      1      -  in/ivld   mm/ivld   Surface lateral inflow
SLSLD      1      1      -  tons/     tonnes/   Lateral input of solids
           ac.ivld  ha.ivld
IQADFX     10     1      -  qty/     qty/     Dry or total atmospheric deposition
           ac.ivld  ha.ivld   of QUALOF
IQADCN     10     1      -  qty/ft3  qty/l    Concentration of QUALOF in precip
           for wet atmospheric deposition
-----

```

4.7(2).2 Group ATEMP

Identical to group ATEMP in module PERLND. See Section 4.7(1).2 for documentation.

4.7(2).3 Group SNOW

Identical to group SNOW in module PERLND. See Section 4.7(1).3 for documentation.

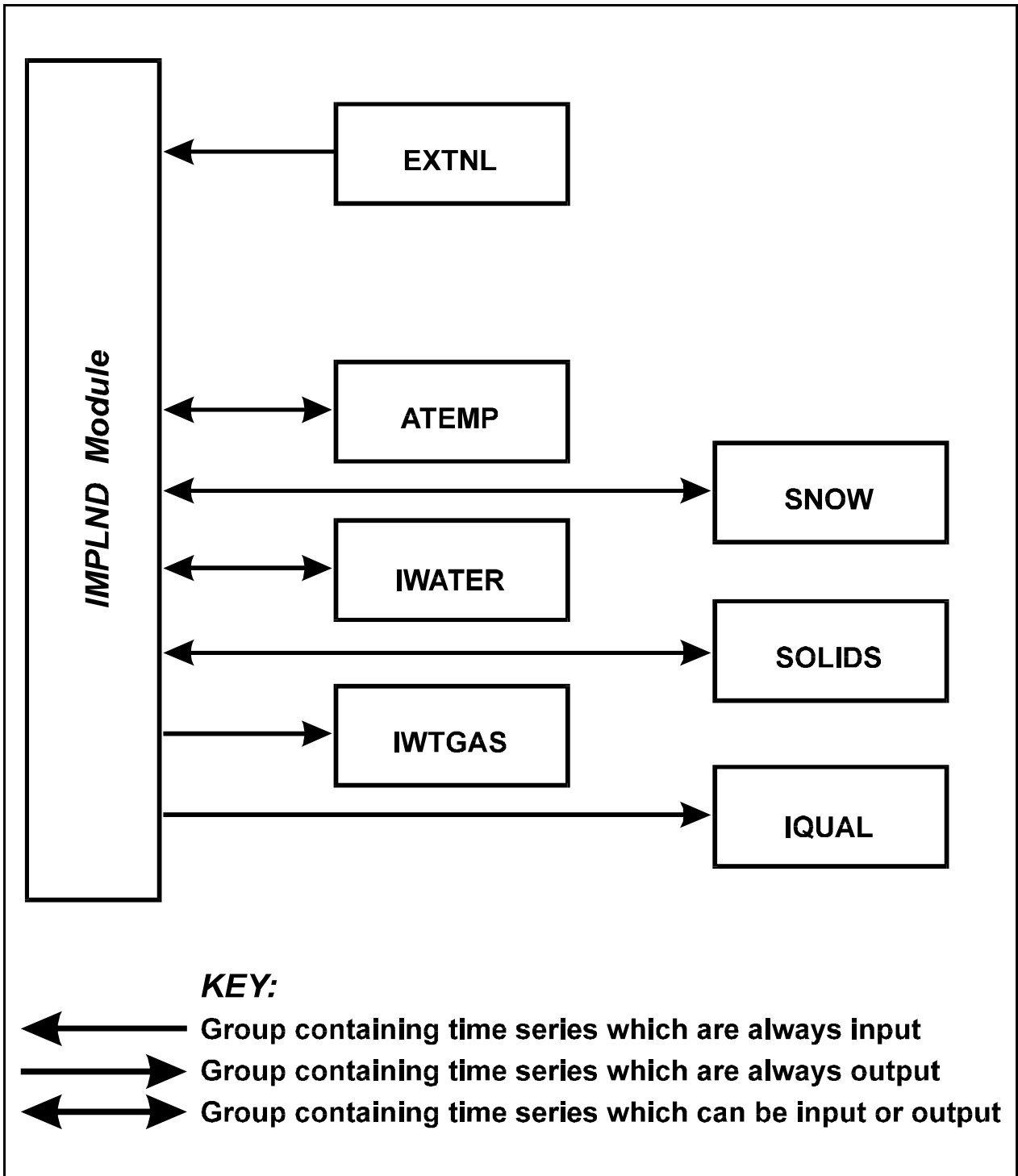


Figure 4.7(2)-1 Groups of time series associated with the IMPLND Module

4.7(2).4 Group IWATER

<---- Member ---->	K	Units	
Max subscr	i	(external)	Description/comment
Name	values	n	
	1	2	d Engl Metr

Time series computed by module section IWATER:

IMPS	1	1	*	in	mm	Total water stored in the ILS
RETS	1	1	*	in	mm	Retention storage
SURS	1	1	*	in	mm	Surface (overland flow) storage
SURO	1	1	-	in/ivld	mm/ivld	Surface outflow
PET	1	1	-	in/ivld	mm/ivld	Potential E-T, adjusted for snow cover and air temperature
IMPEV	1	1	-	in/ivld	mm/ivld	Total simulated E-T
SURI	1	1	-	in/ivld	mm/ivld	Surface inflow (including any lateral inflow if RTLIFG=1)

Input time series required to compute the above:

Group EXTNL

PETINP	
PREC	required if snow not considered (CSNOFG= 0)
SURLI	optional

Group ATEMP

AIRTMP	only required if section ATEMP is inactive and CSNOFG= 1
--------	--

Group SNOW

RAINF	only required if section SNOW is inactive and snow is considered (CSNOFG= 1)
SNOCOV	
WYIELD	

4.7(2).5 Group SOLIDS

<---- Member ---->		K	Units		Description/comment
Name	Max subscr values	i	(external)		
	1 2	d	Engl	Metr	

Time series computed by module section SOLIDS:

SLDS	1	1	*	tons/ac	tonnes/ha	Storage of solids on surface
SOSLD	1	1	-	tons/ ac.ivld	tonnes/ ha.ivld	Washoff of solids from surface

Input time series required to compute the above:

Group EXTNL	always required
PREC	
SLSLD	optional
Group IWATER	only required if section IWATER is inactive
SURO	
SURS	

4.7(2).6 Group IWTGAS

<---- Member ---->	K	Units	
Name	Max subscript	(external)	Description/comment
	values	n	
	1 2	d	Engl Metr

Time series computed by module section IWTGAS:

SOTMP	1	1	*	Deg F	Deg C	Temperature of surface outflow
SODOX	1	1	*	mg/l	mg/l	DO concentration in surface outflow
SOCO2	1	1	*	mg/l	mg/l	CO2 concentration in surface outflow
SOHT	1	1	-	BTU/ ac.ivld	kcal/ ha.ivld	Heat energy in surface outflow (relative to freezing point)
SODOXM	1	1	-	lb/ ac.ivld	kg/ ha.ivld	Flux of DO in surface outflow
SOCO2M	1	1	-	lb/ ac.ivld	kg/ ha.ivld	Flux of CO2 in surface outflow

Input time series required to compute the above:

Group ATEMP AIRTMP	only required if section ATEMP is inactive
Group SNOW WYIELD	only required if section SNOW is inactive and snow is considered (CSNOFG= 1)
Group IWATER SURO	only required if section IWATER is inactive

4.7(2).7 Group IQUAL

Name	Member		K	Units		Description/comment
	1	2		(external)	Engr	

Time series computed by module section IQUAL:

SQO	NQOF	1	*	qty/ac	qty/ha	Storage of QUALOF on the surface
IQADDR	NQ	1	-	qty/ ac.ivld	qty/ ha.ivld	Dry or total atmospheric deposition of QUAL
IQADWT	NQ	1	-	qty/ ac.ivld	qty/ ha.ivld	Wet deposition of QUAL
SOQS	NQSD	1	-	qty/ ac.ivld	qty/ ha.ivld	Total flux of QUALSD from surface
SOQO	NQOF	1	-	qty/ ac.ivld	qty/ ha.ivld	Washoff of QUALOF from surface
SOQUAL	NQ	1	-	qty/ ac.ivld	qty/ ha.ivld	Total outflow of QUAL from the surface
SOQOC	NQOF	1	-	qty/ft3	qty/l	Concentration of QUALOF in surface outflow
SOQC	NQ	1	-	qty/ft3	qty/l	Concentration of QUAL in surface outflow (QUALSD+QUALOF)

Input time series required to compute the above:

Group EXTNL		
IQADFX		only required if dry or total atmospheric deposition is being simulated
IQADCN		only required if wet atmospheric deposition is being simulated
PREC		
Group IWATER		only required if section IWATER is inactive
SURO		only required if one or more QUALs are QUALOFs, or if SOQC is required for one or more QUALs
Group SOLIDS		only required if section SOLIDS is inactive and one or more QUALs are QUALSDs
SOSLD		

4.7(3) Catalog for RCHRES module

The time series groups associated with this application module are shown in Figure 4.7(3)-1.

The members contained within each group are documented in the following tables.

Note: exit-specific, output time series are computed (available) only when NEXITS is greater than 1.

4.7(3).1 Group EXTNL

```

-----
<---- Member ---->  K      Units
                   Max subscr i  (external)      Description/comment
Name      values  n
          1    2   d  Engl      Metr
-----

```

Time series external to module RCHRES (input only):

```

PREC      1    1    -  in/ivld  mm/ivld  Precip on surface of the RCHRES
                                     (requires AUX1FG = 1)
POTEV     1    1    -  in/ivld  mm/ivld  Potential evaporation from the
                                     surface (requires AUX1FG = 1)
COLIND    NEXITS 1    -  none      none     Time series indicating which
                                     (pair of) columns in RCHTAB are
                                     used to evaluate f(VOL) component
                                     of outflow demand
OUTDGT    NEXITS 1    -  ft3/s    m3/s     g(t) component of outflow demand if
                                     no CATEGORY block is present.
COTDGT    NEXITS CAT -  ft3/s    m3/s     g(t) component of outflow demand by
                                     category if CATEGORY block is present
IVOL      1    1    -  ac.ft/   Mm3/
                                     ivld   ivld    Inflow to the RCHRES if no CATEGORY
                                     block is present (Mm3 = 10**6 m3)
CIVOL     CAT   1    -  ac.ft/   Mm3/
                                     ivld   ivld    Inflow of water belonging to each
                                     category if CATEGORY block is present
ICON      NCONS 1    -  qty/ivld qty/ivld Inflow of conservative constituents
SOLRAD    1    1    -  Ly/ivld  Ly/ivld  Solar radiation
CLOUD     1    1    -  tenths   tenths   Cloud cover (range 0 - 10)
DEWTMP    1    1    -  DegF     DegC     Dewpoint
GATMP     1    1    -  DegF     DegC     Air temperature at met. station
WIND      1    1    -  miles/   km/
                                     ivld   ivld    Wind movement

```


Catalog for RCHRES Module

TGRND	1	1	-	DegF	DegC	Temperature of ground beneath stream bed
PHVAL	1	1	-			pH (used in Section GQUAL)
ROC	1	1	-	moles/l	moles/l	Free radical oxygen concentration (used in Section GQUAL)
BIO	NGQUAL	1	-	mg(bio)/l	mg(bio)/l	Biomass active in biodegradation (used in Section GQUAL)
COADFX	NCONS	1	-	qty/ ac/ivld	qty/ ha/ivld	Dry or total atmospheric deposition of conservative
COADCN	NCONS	1	-	conc	conc	Concentration of conservative in rain for wet atmospheric deposition
GQADFX	NGQUAL	1	-	qty/ ac/ivld	qty/ ha/ivld	Dry or total atmospheric deposition of qual
GQADCN	NGQUAL	1	-	concu/l	concu/l	Concentration of qual in rain for for wet atmospheric deposition
NUADFX	3	1	-	lb/ ac.ivld	kg/ ha.ivld	Dry or total atmospheric deposition of inorganic nutrient. Subscript indicates: NO3, NH3, PO4.
NUADCN	3	1	-	mg/l	mg/l	Concentration of nutrient in rain for wet atmospheric deposition
PLADFX	3	1	-	lb/ ac/ivld	kg/ ha/ivld	Dry or total atmospheric deposition of organics. Subscript indicates: nitrogen, phosphorus, carbon
PLADCN	3	1	-	mg/l	mg/l	Concentration of organic in rain for wet atmospheric deposition. Subscript same as above.

Note: CAT = one of the two-character ID tags from the CATEGORY block

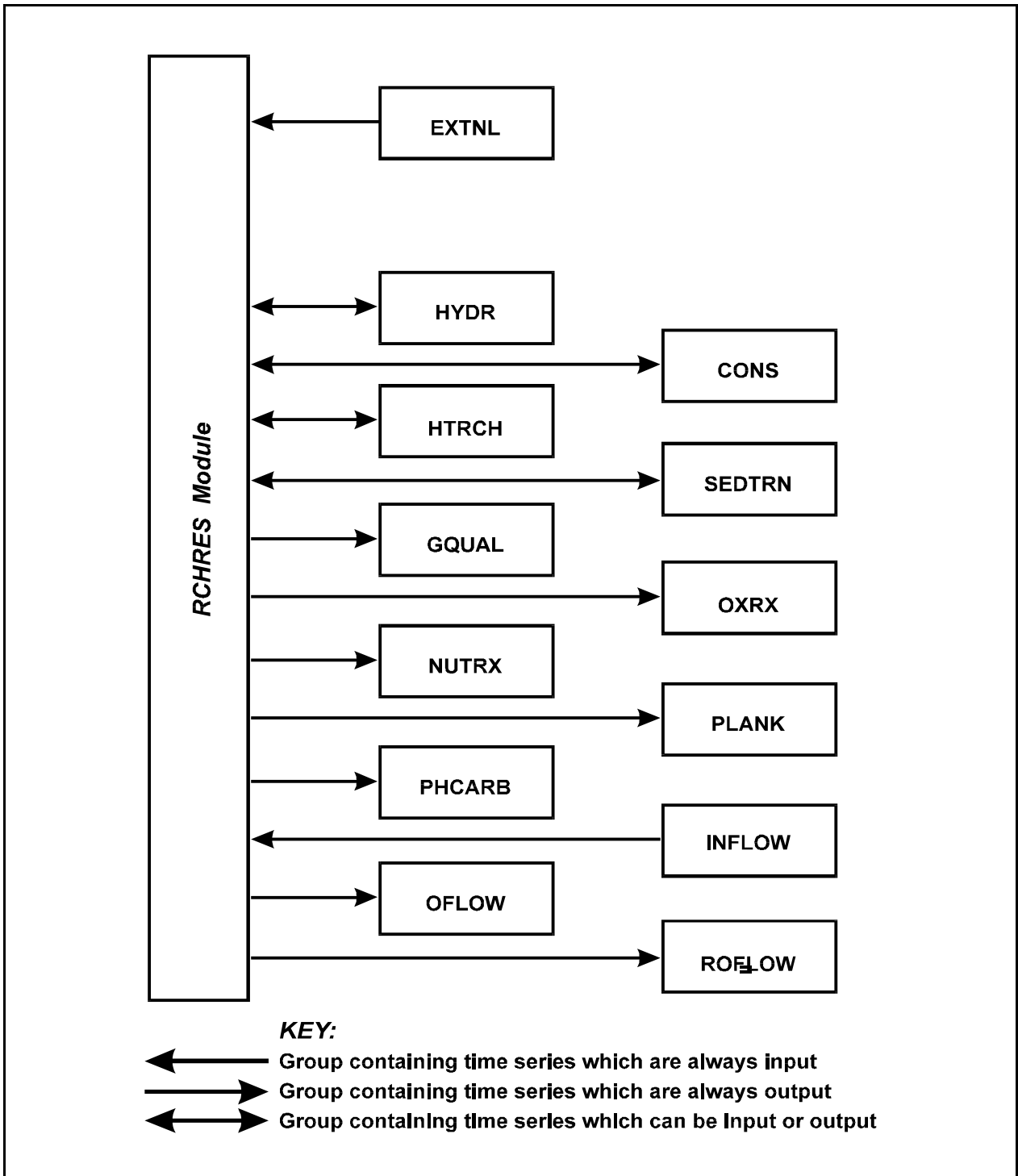


Figure 4.7(3)-1 Groups of time series associated with the RCHRES Module

4.7(3).2 Group HYDR

<---- Member ---->		K	Units		Description/comment
Name	Max subscr values	i	(external)		
	1 2	n	Engl	Metr	

Time series computed by module section HYDR:

VOL	1	1	*	ac.ft	Mm3	Volume of water in the RCHRES
AUX1FG must be 1 for next 5 members to be computed:						
DEP	1	1	*	ft	m	Depth at specified location
STAGE	1	1	*	ft	m	Stage (DEP+STCOR)
AVDEP	1	1	*	ft	m	Average depth (volume/surface area)
TWID	1	1	*	ft	m	Mean topwidth (surface area/length)
HRAD	1	1	*	ft	m	Hydraulic radius
SAREA	1	1	*	ac	ha	Surface area
AUX2FG must be 1 for next 2 members to be computed:						
AVVEL	1	1	*	ft/s	m/s	Average velocity (RO/VOL)
AVSECT	1	1	*	ft2	m2	Average cross-sectional area of RCHRES (VOL/length)
AUX3FG must be 1 for next 2 members to be computed:						
USTAR	1	1	*	ft/s	m/s	Shear velocity
TAU	1	1	*	lb/ft2	kg/m2	Bed shear stress
RO	1	1	*	ft3/s	m3/s	Total rate of outflow from RCHRES
CRO	CAT	1	*	ft3/s	m3/s	Rates of outflow of each category
O	NEXITS	1	*	ft3/s	m3/s	Rates of outflow through individual exits (available only if NEXITS > 1)
CO	NEXITS	CAT	*	ft3/s	m3/s	Rates of outflow through individual exits of each category
CDFVOL	NEXITS	CAT	*	ac.ft	Mm3	Current cumulative deficit of each category demand by exit
PRSUPY	1	1	-	ac.ft/ ivld	Mm3/ ivld	Volume of water contributed by precipitation on surface
VOLEV	1	1	-	ac.ft/ ivld	Mm3/ ivld	Volume of water lost by evaporation
ROVOL	1	1	-	ac.ft/ ivld	Mm3/ ivld	Total volume of outflow from RCHRES
CROVOL	CAT	1	-	ac.ft/ ivld	Mm3/ ivld	Total volume of outflow from RCHRES of each category
OVOL	NEXITS	1	-	ac.ft/ ivld	Mm3/ ivld	Volume of outflow through individual exits (available only if NEXITS > 1)
COVOL	NEXITS	CAT	-	ac.ft/ ivld	Mm3/ ivld	Volume of outflow through individual exits of each category

- Notes:
1. Mm3 = 10**6 m3
 2. Exit-specific time series are computed only if NEXITS > 1
 3. CAT = must be one of the two-character tags from the CATEGORY block rather than an integer

Input time series required to compute the above:

Group EXTNL

IVOL (also in group INFLOW)	optional - not used if CATEGORY block is present
CIVOL (also in group INFLOW)	optional - used only if CATEGORY block is present
PREC	optional
POTEV	optional
COLIND	required only if ODFVFG is negative for one or more outflow demands
OUTDGT	required only if ODGTFG is >0 for one or more outflow demands
COTDGT	required only if ODGTFG is >0 for one or more outflow demands

If there are any active categories, then the total inflow to a reach is the sum of all category inflows. These inflows are input as time series CIVOL, and IVOL is calculated (by the program) as their sum instead of being input.

4.7(3).3 Group ADCALC

<---- Member ---->	K	Units
Name	Max subscri	i (external)
Name	values	n
	1 2	d Engl Metr

Time series computed by module section ADCALC:

None of the computed time series are outputtable; they are passed internally to any active "quality" sections of the RCHRES module

Input time series required to compute the above:

Group HYDR	only required if section HYDR
VOL	is inactive
0	

4.7(3).4 Group CONS

```

-----
<---- Member ----> K      Units
                   Max subscr i  (external)      Description/comment
Name      values  n
          1    2   d  Engr      Metr
-----

```

Time series computed by module section CONS:

```

CON      NCONS  1    *  concid   concid   Concentration of conservative
                                         constituents
COADDR  NCONS  1    -  qty/ivld qty/ivld Dry or total atmospheric deposition
                                         of conservative
COADWT  NCONS  1    -  qty/ivld qty/ivld Wet atmospheric deposition of
                                         conservative
ROCON   NCONS  1    -  qty/ivld qty/ivld Total outflow of conservatives
OCON    NEXITS NCONS -  qty/ivld qty/ivld Outflow of conservatives through
                                         individual exits; available if
                                         NEXITS > 1

```

Input time series required to compute the above:

```

Group EXTNL
  COADFX          only required if dry or total
                  atmospheric deposition is being
                  simulated
  COADCN          only required if wet atmospheric
  PREC            deposition is being simulated
  ICON (also in group INFLOW) optional

Group HYDR
  SAREA          only required if atmospheric
                  deposition is being simulated
-----

```

4.7(3).5 Group HTRCH

<---- Member ---->		K	Units		Description/comment
Name	Max subscr values	i	(external)		
	1 2	n	Engl	Metr	

Time series computed by module section HTRCH:

TW	1	1	*	DegF	DegC	Simulated water temperature
AIRTMP	1	1	*	DegF	DegC	Air temperature, adjusted for elev. difference between gage and RCHRES
HTEXCH	1	1	-	BTU/ivld	kcal/ivld	Net heat exchanged with atmosphere and stream bed
ROHEAT	1	1	-	"	"	Total outflow of thermal energy through active exits
OHEAT	NEXITS	1	-	"	"	Outflow of thermal energy through individual exits
HTCF4	7	1	-	BTU/ft2/ ivld	kcal/m2/ ivld	Components of heat exchange per unit area of surface: 1) total, 2) solar radiation, 3) longwave radiation, 4) evaporation, 5) conduction, 6) percipitation, 7) bed exchange (positive = gain of heat).

Input time series required to compute the above:

Group INFLOW	optional
IHEAT	optional
Group EXTNL	always required
SOLRAD	
PREC	optional
CLOUD	
DEWTMP	
GATMP	
WIND	
Group HYDR	only required if section HYDR is inactive
AVDEP	

4.7(3).6 Group SEDTRN

```

-----
<---- Member ----> K      Units
                   Max subscr i  (external)      Description/comment
Name              values  n
                   1    2    d  Engr      Metr
-----

```

Time series computed by module section SEDTRN

```

SSED      4    1    *  mg/l      mg/l      Suspended sediment concentrations
RSED     10    1    *  ton       tonne     Sediment storages
BEDDEP    1    1    *  ft        m        Bed depth (thickness)
DEPSCR    4    1    -  ton/ivld  tonne/ivld Deposition (positive) or
                                         scour (negative)
ROSED     4    1    -    "        "        Total outflows of sediment
                                         from the RCHRES
OSED     NEXITS 4    -    "        "        Outflows of sediment through
                                         individual exits

```

Note: In the above, the subscript with maximum value =4 selects the sediment fraction - 1 for sand, 2 for silt, 3 for clay, and 4 for the sum of sand silt and clay. The subscript with maximum value =10 selects the following: 1 suspended sand, 2 suspended silt, 3 suspended clay, 4 bed sand, 5 bed silt 6 bed clay, 7 total sand, 8 total silt, 9 total clay, and 10 total of 7,8,9.

Input time series required to compute the above:

```

Group INFLOW
  ISED(*)          inflows of sand, silt, and clay
                   to the RCHRES; optional

Group HYDR
  TAU              only required if Section HYDR is
  AVDEP            inactive
  AVVEL
  RO              ---
  HRAD            | only required if SANDFG = 1 or 2
  TWID            ---

Group HTRCH
  TW              only required if Section HTRCH is
                   inactive and SANDFG = 1 or 2

```


4.7(3).7 Group GQUAL

<----	Member	---->	K	Units		Description/comment
Name	Max	subscr	i	(external)		
	values	n	n	Engl	Metr	
	1	2	d			

Time series computed by module section GQUAL:

DQAL	NGQUAL	1	*	concu/l	concu/l	Dissolved concentration of qual.
SQAL	6	NGQUAL	*	concu/mg	concu/mg	Concentration of qual on sediment. First subscript selects: 1 susp sand 2 susp silt 3 susp clay 4 bed sand 5 bed silt 6 bed clay
RDQAL	NGQUAL	1	*	qty	qty	Total storage of qual in dissolved form
RSQAL	12	NGQUAL	*	qty	qty	Storage of sediment-associated qual. First subscript selects: 1 susp sand 2 susp silt 3 susp clay 4 susp total 5 bed sand 6 bed silt 7 bed clay 8 bed total 9 total on sand 10 total on silt 11 total on clay 12 grand total
RRQAL	NGQUAL	1	*	qty	qty	Total storage of qual in the RCHRES
PDQAL	NGQUAL	1	-	qty/ivld	qty/ivld	Input to this qual in this RCHRES, from decay of parent quals
GQADDR	NGQUAL	1	-	qty/ivld	qty/ivld	Dry or total atmospheric deposition of qual
GQADWT	NGQUAL	1	-	qty/ivld	qty/ivld	Wet atmospheric deposition of qual
DDQAL	7	NGQUAL	-	qty/ivld	qty/ivld	Decay of dissolved qual. First subscript selects decay path: 1 hydrolysis 2 oxidation 3 photolysis 4 volatilization 5 biodegradation 6 general (other) 7 total of 1-6 .
RODQAL	NGQUAL	1	-	qty/ivld	qty/ivld	Total outflow of dissolved qual from the RCHRES
DSQAL	4	NGQUAL	-	qty/ivld	qty/ivld	Deposition/scour of qual. First subscript selects carrier: 1 sand 2 silt 3 clay 4 total
ROSQAL	4	NGQUAL	-	qty/ivld	qty/ivld	Total outflow of sediment-associated qual from RCHRES. First subscript selects carrier: 1 sand 2 silt 3 clay 4 total
SQDEC	7	NGQUAL		qty/ivld	qty/ivld	Decay of sediment-associated qual on: 1 susp sand 2 susp silt 3 susp clay 4 bed sand 5 bed silt 6 bed clay 7 total

Catalog for RCHRES Module

ADQAL	7	NGQUAL	-	qty/ivld	qty/ivld	Adsorption/desorption between dissolved state and: 1 susp sand 2 susp silt 3 susp clay 4 bed sand 5 bed silt 6 bed clay 7 total
ODQAL	NEXITS	NGQUAL-		qty/ivld	qty/ivld	Outflow of dissolved qual through individual exits.
OSQAL	NEXITS	NGQ3	-	qty/ivld	qty/ivld	Outflows of sediment-associated qual through individual exits. Second subscript selects: 1 sand, first qual 2 silt, first qual 3 clay, first qual (NGQ3= 4 sand, second qual NGQUAL*3) etc.

Input time series required to compute the above:

Group INFLOW

IDQAL	optional
ISQAL(*)	optional

Group EXTNL

GQADFX	only required if dry or total atmospheric deposition is being simulated
GQADCN	only required if wet atmospheric deposition is being simulated
PREC	
PHVAL	if there is hydrolysis, PHFLAG=1, and Section PHCARB is inactive
ROC	if there is free radical oxidation, and ROXFG=1
BIO(I)	if qual number I undergoes biodegradation and GQPM2(7,I)=1
CLOUD	if there is photolysis, and CLDFG=1
WIND	if there is volatilization and water body is a lake (LKFG=1)

Group HYDR

	only required if Section HYDR is inactive
AVDEP	See below
AVVEL	if volatilization is on and water body is a flowing stream (LKFG=0)
SAREA	only required if atmospheric deposition is being simulated

Group HTRCH

TW	only required if Section HTRCH inactive and TEMPFG=1
----	--

Group PLANK

only required if Section PLANK is inactive or PHYFG=0

Catalog for RCHRES Module

PHYTO	if there is photolysis and PHYTFG=1
Group SEDTRN	only required if Section SEDTRN is inactive
SSED(4)	if there is photolysis and SDFG=1

Note: AVDEP is required if Section HYDR is inactive and:

1. There is photolysis
- or 2. There is volatilization and
 - a. The water body is a lake
 - or b. The water body is a free-flowing stream and REAMFG>1

4.7(3).8.1 Group OXRX

<---- Member ---->		K	Units		Description/comment
Name	Max subscr values	i	(external)		
	1 2	n	Engl	Metr	

Time series computed by module section OXRX:

DOX	1	1	*	mg/l	mg/l	DO concentration
BOD	1	1	*	mg/l	mg/l	BOD concentration
SATDO	1	1	*	mg/l	mg/l	Saturation DO concentration
OXCF1	2	1	-	lb/ivld	kg/ivld	Total outflows of DO (OXCF1(1,1)) and BOD (OXCF1(2,1)) from the RCHRES
OXCF2	NEXITS	2	-	lb/ivld	kg/ivld	Outflows of DO and BOD through individual exits

In the above, the first subscript selects the exit. The second selects the constituent: 1 means DO, 2 means BOD.

Input time series required to compute the above:

Group INFLOW

IDOX	optional
IBOD	optional

Group EXTNL

WIND	only needed if LKFG=1 (lake)
------	------------------------------

Group HYDR

AVDEP	only required if section HYDR is inactive
AVDEP	

Group HTRCH

TW	only required if section HTRCH is inactive
----	--

4.7(3).8.2 Group NUTRX

Name	Member		K	Units		Description/comment
	Max	subscr		(external)		
	values		n	Engl	Metr	
	1	2	d			

Time series computed by module section NUTRX:

DNUST	6	1	*	mg/l	mg/l	Dissolved nutrient concentrations; Subscript 1: 1=NO3, 2=TAM, 3=NO2, 4=PO4, 5=NH4+, 6=NH3.
SNH4	3	1	*	mg/kg	mg/kg	Particulate NH4-N concentrations; Subscript 1: 1=sand, 2=silt, 3=clay
SPO4	3	1	*	mg/kg	mg/kg	Particulate PO4-P concentrations; Subscript 1: 1=sand, 2=silt, 3=clay
DNUST2	6	1	*	lbs	kg	Dissolved nutrient storages; same subscript values as DNUST
RSNH4	12	1	*	lbs	kg	Particulate NH4-N storages; 1-3= suspended sand, silt, clay, 4=total suspended, 5-7=bed sand, silt, clay, 8=total bed, 9-11=total sand, total silt, total clay, 12=grand total
RSPO4	12	1	*	lbs	kg	Particulate PO4-P storages; same subscript values as RSNH4
NUST	4	1	*	lbs	kg	Total nutrient storages in RCHRES, (dissolved + particulate); Subscript 1: 1=NO3, 2=TAM, 3=NO2, 4=PO4
NUADDR	3	1	-	lb/ivld	kg/ivld	Dry or total atmospheric deposition of nutrient; Subscript 1: 1=NO3, 2=TAM, 3=PO4
NUADWT	3	1	-	lb/ivld	kg/ivld	Wet atmospheric deposition of nutrient; Subscript same as NUADDR
NUCF1	4	1	-	lb/ivld	kg/ivld	Total outflow of dissolved nutrient; Same subscript values as NUST
NUCF2	4	2	-	lb/ivld	kg/ivld	Total outflow of particulate NH4 and PO4; Subscript 1: 1=(on) sand, 2=silt, 3=clay, 4=total; Subscript 2: 1 = NH4, 2 = PO4
NUCF3	4	2	-	lb/ivld	kg/ivld	Scour/deposition fluxes of particulate NH4 and PO4; + = scour, - = deposition; same subscript values as NUCF2

Catalog for RCHRES Module

NUCF4	6	1	-	lb/ivld	kg/ivld	Process fluxes for NO ₃ ; Subscript 1: 1=nitrification, 2=denitrification, 3=BOD decay, 4=phytoplankton growth/respir., 5=zooplankton death/respir., 6=benthic algae growth/respir.
NUCF5	7	1	-	lb/ivld	kg/ivld	Process fluxes for TAM; Subscript 1: 1=nitrification, 2=volatilization, 3=benthic release, 4=BOD decay, 5=phytoplankton growth/respir., 6=zooplankton death/respir., 7=benthic algae growth/respir.
NUCF6	1	1	-	lb/ivld	kg/ivld	Nitrification flux for NO ₂ ; (net gain (+) or loss (-) of NO ₂)
NUCF7	5	1	-	lb/ivld	kg/ivld	Process fluxes for PO ₄ ; Subscript 1: 1=benthic release, 2=BOD decay, 3=phytoplankton growth/respir., 4=zooplankton death/respir., 5=benthic algae growth/respir.
NUCF8	4	2	-	lb/ivld	kg/ivld	Adsorption (+) or desorption (-) of NH ₄ and PO ₄ ; Subscript 1: 1=sand, 2=silt, 3=clay; Subscript 2: 1=NH ₄ , 2=PO ₄
NUCF9	5	4	-	lb/ivld	kg/ivld	Outflow of dissolved nutrients through individual exits; Subscript 1 selects exit, Subscript 2: same as NUCF1
OSNH4	5	3	-	lb/ivld	kg/ivld	Outflows of particulate NH ₄ ; Subscript 1 selects exit, Subscript 2: 1=sand, 2=silt, 3=clay
OSPO4	5	3	-	lb/ivld	kg/ivld	Outflows of particulate PO ₄ -P; Subscript values same as OSNH4

Input time series required to compute the above:

Group INFLOW

INO3, ITAM, INO2,
IPO4, ISNH4, ISPO4

all optional

Group EXTNL

NUADFX

only required if dry or total
atmospheric deposition is being
simulated

NUADCN
PREC

only required if wet atmospheric
deposition is being simulated

Group HYDR

SAREA

only required if atmospheric
deposition is being simulated

4.7(3).8.3 Group PLANK

```

-----
<---- Member ----> K      Units
                   Max subscr i  (external)      Description/comment
Name              values  n
                   1    2    d  Engl      Metr
-----

```

Time series computed by module section PLANK:

```

PKST3      7    1    *  mg/l      mg/l      A group of state variables
In the above, the first subscript selects the state variable:
1 for dead refractory organic N (ORN)
2 for dead refractory organic P (ORP)
3 for dead refractory organic C (ORC)
4 for total organic N (TORN)
5 for total organic P (TORP)
6 for total organic C (TORC)
7 for potential BOD (POTBOD)

```

```

PHYTO      1    1    *  mg/l      mg/l      Phytoplankton concentration
ZOO         1    1    *  organism/l organism/l Zooplankton population
BENAL      1    1    *  mg/m2     mg/m2     Benthic algae
PHYCLA     1    1    *  ug/l      ug/l      Phytoplankton as chlorophyll a
BALCLA     1    1    *  ug/m2     ug/m2     Benthic algae as chlorophyll a

PLADDR     3    1    -  lb/ivld   kg/ivld   Dry or total atmospheric deposition
of organics
PLADWT     3    1    -  lb/ivld   kg/ivld   Wet atmospheric deposition of
organics

```

In the above, the first subscript selects the constituent:
1 for ORN, 2 for ORP, 3 for ORC

```

PKCF1      5    1    -  lb/ivld   kg/ivld   Total outflows from the RCHRES
In the above, the first subscript selects the constituent:
1 for phytoplankton, 2 for zooplankton, 3 for ORN, 4 for ORP, 5 for ORC

```

```

PKCF2 NEXITS 5    -  lb/ivld   kg/ivld   Outflows through individual exits
In the above, the first subscript selects the exit, the second selects the
constituent -- same code as for PKCF1.

```

Input time series required to compute the above:

```

Group INFLOW
  IPHYTO, IZOO, IORN,          all are optional
  IORP, IORC

```


Catalog for RCHRES Module

Group EXTNL	
SOLRAD	required
PLADFX	only required if dry or total atmospheric deposition is being simulated
PLADCN	only required if wet atmospheric deposition is being simulated
PREC	
Group HYDR	
SAREA	only required if atmospheric deposition is being simulated
Group HTRCH	
TW	only required if section HTRCH is inactive
Group SEDTRN	
SSED(2)	only required if section SEDTRN is inactive
SSED(3)	

NOTE: Phytoplankton, zooplankton and benthic algae may, or may not, be simulated, depending on the values the user assigns to PHYFG, ZOFG and BALFG. If a constituent is not simulated, those time series associated with it in this list should be ignored.

4.7(3).8.4 Group PHCARB

```

-----
<---- Member ----> K      Units
                   Max subscr i  (external)      Description/comment
Name              values  n
                   1    2    d  Engr      Metr
-----

```

Time series computed by module section PHCARB:

PHST 3 1 * see below State variables
 In the above, the first subscript selects the state variable:
 1 for total inorganic carbon (TIC) -- units mg/l
 2 for carbon dioxide (CO2) -- units mg/l
 3 for pH

PHCF1 2 1 - lb/ivld kg/ivld Total outflows of TIC and CO2
 In the above, the first subscript selects the constituent:
 1 for TIC, 2 for CO2

PHCF2 NEXITS 2 - lb/ivld kg/ivld Outflows of TIC and CO2 through
 individual exits
 In the above, the first subscript selects the exit and the second the
 constituent -- same code as for PHCF1

Input time series required to compute the above:

Group INFLOW

ITIC optional
 ICO2 optional

Group CONS

CON(ALKCON) only required if section CONS is
 inactive
 concentration units must be mg/l as
 CaCO3

Group HTRCH

TW only required if section HTRCH
 is inactive

4.7(3).10 Groups INFLOW, ROFLOW and OFLOW

The members in these groups represent the total inflow, total outflow and outflow through individual RCHRES exits of every simulated constituent. These groups were included in the catalog to make it easier for users to specify the linkages representing time series passed from one RCHRES to another. For example, assume the RCHRES's in a run have sections HYDR, HTRCH and OXRX active, and the NETWORK Block contains:

```
*****
NETWORK
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member-> ***
<Name> # <Name> # #<-factor->strg <Name> # # <Name> # # ***

RCHRES 1 ROFLOW RCHRES 2 INFLOW
RCHRES 2 OFLOW 2 RCHRES 3 INFLOW
*****
```

These entries mean that the entire outflow from RCHRES 1 goes to RCHRES 2, and that the outflow through exit 2 of RCHRES 2 goes to RCHRES 3. Because the "member name" fields have been left blank, HSPF will automatically expand the above entries, generating an entry for each member which is active in this run. In this case, there will be 4 generated entries because 4 constituents are being simulated (water, heat, DO and BOD). The second set of generated entries would be:

```
*****
NETWORK
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member-> ***
<Name> # <Name> # #<-factor->strg <Name> # # <Name> # # ***

RCHRES 2 OFLOW OVOL 2 1 1.0 RCHRES 3 INFLOW IVOL 1 1
RCHRES 2 OFLOW OHEAT 2 1 1.0 RCHRES 3 INFLOW IHEAT 1 1
RCHRES 2 OFLOW OXCF2 2 1 1.0 RCHRES 3 INFLOW OXIF 1 1
RCHRES 2 OFLOW OXCF2 2 2 1.0 RCHRES 3 INFLOW OXIF 2 1
*****
```

Thus, the user can specify the linkage between two RCHRES's with a single entry, instead of having to supply an entry for every constituent passed between them.

4.7(3).10.1 GROUP INFLOW

The members in this group represent the inflows to a RCHRES. Note that each member listed below is "available" for use only if the module section to which it belongs is active.

Name	Member		K	Units		Module section	Constituent
	Max	subscr		Units	(external)		
	1	2	n	Engl	Metr		
IVOL	1	1	-	ac.ft/ ivld	Mm3/ ivld	HYDR	Water (Note: Mm3=10**6 m3)
CIVOL	CAT	1	-	ac.ft/ ivld	Mm3/ ivld	HYDR	Water, by Category (Note: CAT=Category tag)
ICON	NCONS	1	-	qty/ ivld	qty/ ivld	CONS	Conservatives
IHEAT	1	1	-	BTU/ ivld	kcal/ ivld	HTRCH	Heat (relative to freezing)
ISED	3	1	-	ton/ ivld	tonne/ ivld	SEDTRN	Sand, silt, and clay
IDQAL	NGQUAL	1	-	qty/ ivld	qty/ ivld	GQUAL	Dissolved general quality constituents
ISQAL	3	NGQUAL	-	qty/ ivld	qty/ ivld	GQUAL	General quality const- ituent associated with: 1 Sand, 2 Silt, 3 Clay
OXIF	2	1	-	lb/ivld	kg/ivld	OXRX	1=DO, 2=BOD
NUIF1	4	1	-	lb/ ivld	kg/ ivld	NUTRX	1=NO3, 2=TAM, 3=NO2, 4=PO4
NUIF2	3	2	-	lb/ ivld	kg/ ivld	NUTRX	1=particulate NH4, 2=particulate PO4 on 1=sand, 2=silt, 3=clay
PKIF	5	1	-	lb/ ivld	kg/ ivld	PLANK	1=Phyto, 2=Zoo, 3=ORN, 4=ORP, 5=ORC
PHIF	2	1	-	lb/ivld	kg/ivld	PHCARB	1=TIC, 2=CO2

Catalog for RCHRES Module

4.7(3).10.2 Group ROFLOW

The members in this group represent the total outflow from a RCHRES. Note that a member is "available" for use only if the module section to which it belongs is active.

```

-----
<---- Member ----> K      Units
      Max subscr  i      (external)      Module      Constituent
      values     n
      1  2      d Engl      Metr      section
-----
ROVOL      1  1
CROVOL    CAT  1
ROCON     NCONS 1
ROHEAT     1  1
ROSED      3  1
RODQAL    NGQUAL 1
ROSQAL     3  NGQUAL
OXCF1     2  1
NUCF1     4  1
NUCF2     3  2
PKCF1     5  1
PHCF1     2  1
-----

```

See data for
corresponding
member in group
INFLOW

4.7(3).10.3 Group OFLOW

The members in this group represent the outflows through the individual exits of a RCHRES. Note that a member is available for use only if the module section to which it belongs is active. Also, these time series are available for use only if the number of exit gates (NEXITS) is greater than 1.

For each member, the RCHRES exit is selected by the value given to the first subscript.

```

-----
<---- Member ---->  K      Units
                    Max subscr i  (external)      Module      Constituent
Name      values  n
          1  2  d  Engl      Metr
-----
OVOL      NEXITS  1                                Water
CROVOL    NEXITS  CAT                                Water, by category
                                                (CAT=Category ID tag)
OCON      NEXITS  NCONS                            Conservatives
OHEAT     NEXITS  1                                Heat
OSED      NEXITS  3                                Sand, silt, and clay
ODQAL     NEXITS  NGQUAL                            See data for
                                                corresponding
OSQAL     NEXITS  NGQ3                            member in group
                                                INFLOW
OXCF2     NEXITS  2                                DO, BOD
NUCF9     NEXITS  4                                NO3, NH3, NO2, PO4
OSNH4     NEXITS  3                                Particulate NH4
                                                (sand, silt, clay)
OSPO4     NEXITS  3                                Particulate PO4
                                                (sand, silt, clay)
PKCF2     NEXITS  5                                Phyto, Zoo, ORN, ORP, ORC
PHCF2     NEXITS  2                                TIC, CO2
-----

```

4.7(11) Catalog for COPY module

The members contained within each group are documented in the tables which follow.

4.7(11).1 Group INPUT

<---- Member ---->		K	Units		Description/comment
Name	Max subscr values	i	(external)		
	1 2	n	Engl	Metr	

Time series input to module COPY:

POINT	NPT	1	*	anything	Point-valued input time series
MEAN	NMN	1	-	anything	Mean-valued input time series

4.7(11).2 Group OUTPUT

<---- Member ---->		K	Units		Description/comment
Name	Max subscr values	i	(external)		
	1 2	n	Engl	Metr	

Time series output by module COPY:

POINT	NPT	1	*	anything	Point-valued output time series
MEAN	NMN	1	-	anything	Mean-valued output time series

Input time series required to produce the above:

Group INPUT

POINT	required if NPT > 0
MEAN	required if NMN > 0

4.7(12) Catalog for PLTGEN module

There is only one time series group associated with this module; group INPUT, which contains all point-valued and/or mean-valued members that are to be plotted. This module does not have an output group because all its output goes to the "plot file", which is documented in Section 4.4(12) of Part E.

4.7(12).1 Group INPUT

```

-----
<----- Member -----> K      Units
      Max subscr i      (external)      Description/comment
Name      values  n
      1      2      d  Engl      Metr
-----

```

Time series input to module PLTGEN:

```

POINT      NPT      1      *      anything      Point-valued input time series
MEAN      NMN      1      -      anything      Mean-valued input time series
-----

```


4.7(13) Catalog for DISPLY module

There is only one time series group (INPUT) with one member (TIMSER) associated with this module since the module displays only one time series at a time. This module does not have an output group because all its output goes to the "display file" (printed).

4.7(13).1 Group INPUT

```

-----
<---- Member ----> K      Units
      Max subscr i      (external)      Description/comment
Name      values  n
      1      2      d  Engl      Metr
-----
Time series input to module DISPLY:

TIMSER    1      1      -      anything      A mean-valued input time series
-----

```

4.7(14) Catalog for DURANL module

There is only one time series group (INPUT) with one member (TIMSER) associated with this module since the module analyzes only one time series at a time. This module does not have an output group because all its output is printed. The format is documented in Section 4.2(14) of Part E.

4.7(14).1 Group INPUT

```

-----
<---- Member ----> K      Units
      Max subscr i      (external)      Description/comment
Name      values  n
      1      2      d  Engl      Metr
-----
Time series input to module DURANL:

TIMSER    1      1      -      anything      A mean-valued input time series
-----

```

4.7(15) Catalog for GENER module

This module has both input and output groups, like module COPY.

The members contained within each group are documented in the tables which follow.

4.7(15).1 Group INPUT

```

-----
<---- Member ----> K      Units
                   Max subscr i  (external)      Description/comment
Name      values  n
          1    2    d  Engl      Metr
-----
Time series input to module GENER:

ONE      1    1    -    anything      First input time series
TWO     1    1    -    anything      Second input time series
-----

```

4.7(15).2 Group OUTPUT

```

-----
<---- Member ----> K      Units
                   Max subscr i  (external)      Description/comment
Name      values  n
          1    2    d  Engl      Metr
-----
Time series output by module GENER:

TIMSER   1    1    -    anything      Output time series (mean-valued)

```

Input time series required to produce the above:

Group INPUT

```

ONE      Always required, unless OPCODE=24.
TWO     Only required if generation option
        needs two inputs.
-----

```

4.7(16) Catalog for MUTSIN module

The members contained within each group are documented in the tables which follow.

4.7(16).1 Group OUTPUT

```

-----
<---- Member ----> K      Units
                   Max subscr i  (external)      Description/comment
Name              values  n
                   1    2    d  Engl      Metr
-----
Time series output by module MUTSIN

POINT   NPT   1   *   anything      Point-valued output time series
MEAN    NMN   1   -   anything      Mean-valued output time series
-----

```

4.8 FORMATS Block

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

```
FORMATS
***
<ft><----- obj-fmt ----->
.
*** line immed above repeats until all formats have been covered
.
.
END FORMATS
```

Details

Symbol	FORTTRAN Name(s)	Format	Comment
<ft>	FMTCOD	I4	Identifying number which corresponds to format number in EXT SOURCES or TARGETS Blocks.
<obj-fmt>	FORM(19)	19A4	Standard FORTRAN object-time format.

Explanation

This block is only required if a user wishes to override the default format for reading data on a sequential file (see Section 4.9).

4.9 Sequential and PLTGEN/MUTSIN File Formats

Two types of ASCII file formats are available for transfer of data into/out of HSPF. "Sequential" files allow transfer into HSPF, and PLTGEN/MUTSIN files allow transfer into and out of HSPF. These file formats are documented below:

4.9.1 Format class HYDFIV - Sequential

It is used for the input of 5-minute data. The sequence of information is:

1. Alpha-numeric station number or identifier (this field is not read)
2. Last two digits of calendar year
3. Month
4. Day
5. Card number 1 is for midnight to 3 am.
2 is for 3 am to 6 am.
3 is for 6 am to 9 am.
4 is for 9 am to noon.
5 is for noon to 3 pm.
6 is for 3 pm to 6 pm.
7 is for 6 pm to 9 pm.
8 is for 9 pm to midnight.
6. 36 fields for 5-minute data.

The default format is: (1X,3I2,I1,36F2.0)

4.9.2 Format class HYDFIF - Sequential

It is used for the input of 15-minute data. The sequence of information is:

1. Alpha-numeric station number or identifier (this field is not read).
2. Last two digits of the calendar year
3. Month
4. Day
5. Card number (same as for HYDFIV above)
6. 12 fields for 15-minute data

The default format is: (1X,3I2,I1,12F6.0)

4.9.3 Format class HYDHR - Sequential

It is used for input of hourly observations. The sequence of information is:

1. Alpha-numeric station number or identifier. (This field is not read)
2. Last two digits of calendar year
3. Month
4. Day
5. Card no: 1 is for a.m. hours
 2 is for p.m. hours
6. Twelve fields for hourly data

The default format is: (10X,I2,1X,I2,1X,I2,1X,I1,12F5.0)

4.9.4 Format class HYDDAY - Sequential

It is used for input of daily observations. The sequence of information is:

1. Alpha-numeric station number or identifier. (This field is not read)
2. Last two digits of calendar year
3. Month
4. Card no: 1 is for days 1-10
 2 is for days 11-20
 3 is for days 21-
5. Ten fields, for the daily data (11 fields for card number 3)

The default format is: (7X,2I2,I1,11F6.0)

4.9.5 Format class HYDSMN - Sequential

It is used for input of semi-monthly observations.
The sequence of information is:

1. Alpha-numeric station number or identifier. (This field is not read)
2. Last two digits of calendar year
3. Card no: 1 for January through June
 2 for July through December
4. Twelve semi-monthly fields

The default format is: (7X,I2,I1,12F5.0)

Semi-monthly values are distributed to daily values with a transformation function of SAME.

4.9.6 Format class HYDMON - Sequential

It is used for input of monthly observations. The sequence of information is:

1. Alpha-numeric station number or identifier. (This field is not read)
2. Last two digits of calendar year
3. Twelve monthly fields

The default format is: (6X,I2,12F6.0)

Monthly values are distributed to daily values with a transformation function of SAME.

Note that the user can override the above default formats with his own format, supplied in the FORMATS BLOCK. However, the sequence of information within each record cannot be altered.

4.9.7 PLTGEN/MUTSIN File Format

Time series data can be transferred to or from ASCII files having the PLTGEN/MUTSIN format, i.e., the format of files created by the PLTGEN module and readable by the MUTSIN module. This file contains a header, which is 25 lines for PLTGEN and at least one line for MUTSIN. Each line of data contains a date-time and between one and ten data values (curves). The sequence of information for each data line is as follows:

1. Identifier (four characters)
 2. Year
 3. Month
 4. Day
 5. Hour
 6. Minute
 7. Value for curve 1, for this date/time
 8. Value for curve 2, for this date/time
- etc (repeats until data for all curves are supplied)

Format: A4,1X,I5,4I3,10(2X,G12.5)

4.10 SPEC-ACTIONS Block

```
*****
      1         2         3         4         5         6         7         8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

SPEC-ACTIONS

Action line:

```

                                <addrss>-----  ----<uvqn>
          dc ds                    d t      or                    or  tc ts num
<oper><f><-l><>< ><yr><m><d><h><m><><>< > <vari><1><2><3><a><-value--> <> < >< >
```

Distribute line:

```

          ds  ct  tc  ts
<kwr>< > < > <> < > <dff>  <frc><frc><frc><frc><frc><frc><frc><frc><frc><frc>
```

User-defined/multiple variable line:

```

          cnt                    act                    act
<kwr>  <unam>< > <vari><1><2><3> <frc> < >  <vari><1><2><3> <frc> < >
          or
          <addrss>-----
```

User-defined variable quantity line:

```

                                                lc ls ac as agfn
<kwr> <uqnm> <oper> <#> <vari><1><2><3><t><multfact> <>< > <>< > < >
          or
          <addrss>-----
```

Condition line (free format):

```

IF ( ( <quan> <comp> <quan> ) <logop> ( <quan> <comp> <quan> ) ) THEN
...
ELSE IF ( <quan> <comp> <quan> ) THEN
...
ELSE
...
END IF
```

```

.....
(repeats until all special actions have been specified)
.....
```

END SPEC-ACTIONS

Example

SPEC-ACTIONS

*** Distributions

```
*** kwd ds ct tc ts dff f1 f2 f3 f4 f5 f6 f7 f8 f9 f10
<****>< > < > < > < > <----> <----><----><----><----><----><----><----><----><---->
DISTRB 1 3 DY 7 ACCUM 0.25 0.5 0.25
```

*** User-Defined Target Variable Names

```
***          addr                      addr
***          <----->                <----->
*** kwd  varnam ct  vari  s1 s2 s3  frac oper  vari  s1 s2 s3  frac oper
<****> <-----><-> <-----><-><-><-> <----> <--> <-----><-><-><-> <----> <-->
UVNAME  MANURE  3  SAMSU          0.7 QUAN  SNO3          0.2 QUAN
          SORGN          0.3 QUAN
```

*** User-Defined Variable Quantity Lines

```
***          addr
***          <----->
*** kwd  varnam optyp  opn  vari  s1 s2 s3  tp multiply  lc ls ac as agfn ***
<****> <-----> <-----> <-> <-----><-><-><-><-><-----> <-><-> <-><-> <--> ***
UVQUAN  puncom  RCHRES  2  CVOL  tx          4
```

*** Action Lines

```
***          addr                      uvquan
***          <----->                <----->
***optyp range dc ds yr  mo da hr mn d t  vari  s1 s2 s3 ac  value  tc ts num
<****><-><--><>< ><--><-><-><-><-><-><-><-><-><-----> <-> <-> <-> <->
PERLND 1  DY 11991/03/15 16:00 1 3  MANURE          += 10.0 YR 1 5
IF (puncom > 10000) THEN
  RCHRES 2          4  CVOL  pw          +=  puncom
END IF
END SPEC-ACTIONS
```

Explanation

In the SPEC-ACTIONS block, the user can change the values of program variables at specified dates and times. This permits one to model such things as: 1) human intervention, i.e., plowing or application of fertilizer and pesticide; 2) changes to parameters in ways not possible with the standard inputs; and 3) conditional actions, i.e., those that are dependent on the value of another program variable.

Special Actions can be performed on variables in the PERLND, IMPLND, RCHRES, COPY, PLTGEN, and GENER modules. The user's input is contained in the SPEC-ACTIONS block of the UCI file. It is specified in the five different types of lines shown above and described fully in the following sections. Output is printed in the Run Interpreter Output (echo) file, and consists of two types: 1) a listing of all Special Actions as interpreted by the program, and 2) a summary of each Special Action (value of affected variable before and after the action) as it is implemented during the run.

Details of Action line (including REPEAT function)

Symbol	Fortran name(s)	Format	Comment																																																
<oper>	OPTYP	A6	operation type - valid values are PERLND, IMPLND, RCHRES, or PLTGEN																																																
<f>	TOPFST	I3	first operation to act upon																																																
<-l>	TOPLST	I4	last operation to act upon, 0 or blank means use first operation only																																																
dc	CTCODE(1)	A2	code specifying time units of deferral of action when an applicable logic condition fails - (MI,HR,DY,MO,YR)																																																
ds	TSTEP(1)	I3	number of CTCODE(1) intervals to defer the action																																																
<yr>	DATIM(1)	I4	year (see starting date field in GLOBAL block for more information) if the date is left blank, then the action is performed every interval of the run																																																
<m>	DATIM(2)	1X,I2	month																																																
<d>	DATIM(3)	1X,I2	day																																																
<h>	DATIM(4)	1X,I2	hour																																																
<m>	DATIM(5)	1X,I2	minute																																																
d	DSIND	I2	ID number of "DISTRB" line, blank if none																																																
t	TYPCOD	I2	2-INTEGGER, 3-REAL, 4-DOUBLE PRECISION																																																
<vari>	VNAME	A6	variable to act upon, left-justified																																																
<1><2><3>	CSUB(1-3)	3A3	subscripts for VNAME, blank if none may be 2-character CATEGORY tag if applicable must be integer otherwise																																																
<addrss>	ADDR	I8	memory location (in the OSV) of variable (optional method to specify variable)																																																
<a>	ACTCOD	A3	action code: id number (#) or character (ch). T= target variable, A= action value: <table border="1" style="margin-left: 40px;"> <thead> <tr> <th>#</th> <th>ch</th> <th>effect</th> <th>#</th> <th>ch</th> <th>effect</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>=</td> <td>T= A</td> <td>2</td> <td>+=</td> <td>T= T+ A</td> </tr> <tr> <td>3</td> <td>-=</td> <td>T= T- A</td> <td>4</td> <td>*=</td> <td>T= T*A</td> </tr> <tr> <td>5</td> <td>/=</td> <td>T= T/A</td> <td>6</td> <td>MIN</td> <td>T= Min(T,A)</td> </tr> <tr> <td>7</td> <td>MAX</td> <td>T= Max(T,A)</td> <td>8</td> <td>ABS</td> <td>T= Abs(A)</td> </tr> <tr> <td>9</td> <td>INT</td> <td>T= Int(A)</td> <td>10</td> <td>^=</td> <td>T= T^A</td> </tr> <tr> <td>11</td> <td>LN</td> <td>T= Ln(A)</td> <td>12</td> <td>LOG</td> <td>T= Log10(A)</td> </tr> <tr> <td>13</td> <td>MOD</td> <td>T= Mod(T,A)</td> <td></td> <td></td> <td></td> </tr> </tbody> </table>	#	ch	effect	#	ch	effect	1	=	T= A	2	+=	T= T+ A	3	-=	T= T- A	4	*=	T= T*A	5	/=	T= T/A	6	MIN	T= Min(T,A)	7	MAX	T= Max(T,A)	8	ABS	T= Abs(A)	9	INT	T= Int(A)	10	^=	T= T^A	11	LN	T= Ln(A)	12	LOG	T= Log10(A)	13	MOD	T= Mod(T,A)			
#	ch	effect	#	ch	effect																																														
1	=	T= A	2	+=	T= T+ A																																														
3	-=	T= T- A	4	*=	T= T*A																																														
5	/=	T= T/A	6	MIN	T= Min(T,A)																																														
7	MAX	T= Max(T,A)	8	ABS	T= Abs(A)																																														
9	INT	T= Int(A)	10	^=	T= T^A																																														
11	LN	T= Ln(A)	12	LOG	T= Log10(A)																																														
13	MOD	T= Mod(T,A)																																																	
<value>	RVAL or IVAL	F10.0 I10	"value" of the action to be taken - see notes below																																																
<uvqn>	UVQNAM	A6	name of User-defined variable quantity containing the "value" of the action																																																
tc	CTCODE(2)	A2	code specifying time units of "repeat" action - (MI,HR,DY,MO,YR)																																																
ts	TSTEP(2)	I3	number of CTCODE(2) intervals to skip before repeating the action																																																
num	NUMINC	I3	number of times to repeat action																																																

Details of Distribution line

Symbol	Fortran name(s)	Format	Comment
<kwrd>	-	A6	keyword (DISTRB) - specifies current line as a "Distribution" line
ds	DSIND	I3	index number - corresponds to the value specified on the standard line
ct	CNT	I3	number of separate actions or applications to divide the total application into
tc	CTCODE	A2	code specifying time units of the interval between separate applications or actions - (valid values: MI,HR,DY,MO,YR)
ts	TSTEP	I3	number of CTCODE intervals between separate applications (see CTCODE below)
<dff>	CDEFFG	A5	deferral flag - indicates how to treat deferral of the action(s) under a conditional situation - (valid values: SKIP, SHIFT, ACCUM; default = SKIP)
<frc>	FRACT(CNT)	10F5	fractions for each of the separate applications

Details of User-defined Variable Name line

Symbol	Fortran name(s)	Format	Comment
<kwrd>	-	A6	keyword (UVNAME) - specifies current line as a "User-defined variable name" line
<unam>	UNAME	A6	user-defined variable name
cnt	CNT	I3	number of actual variables included in aggregate group
Following inputs repeat CNT times (continuation lines if CNT>2)			
<vari>	VNAME	A6	actual variable name
<1><2><3>	CSUB(1-3)	3A3	subscripts for VNAME, blank if none may be 2-character CATEGORY tag if applicable must be integer otherwise
<addrss>	ADDR	I4	address of actual variable
<frc>	FRAC	F5.2	fraction of total application allocated to each of the actual variables
act	ACTCD	A4	action code - QUAN, MOV1, MOV2 (see notes on UVNAME action code options)

Details of User-defined Variable Quantity line

Symbol	Fortran name(s)	Format	Comment
<kwrd>	-	A6	keyword (UVQUAN) - specifies current line as a "User-defined variable quantity" line
<uqnm>	UVQNAM	A6	user-defined variable quantity name
<oper>	OPTYP	A6	operation type of base variable
<#>	OPTNO	I3	operation type number of variable
<vari>	VNAME	A6	actual variable name of variable
<1><2><3>	CSUB(1-3)	3A3	subscripts for VNAME, blank if none may be 2-character CATEGORY tag if applicable must be integer otherwise
<addrss>	ADDR	I4	address of actual variable
<t>	TYPCOD	I2	2-INTEGER, 3-REAL, 4-DOUBLE PRECISION
<multfact>	UVQMUL	F10.0	multiplier to apply to base variable
lc	CTCODE(1)	A2	code specifying time units of the period to lag base variable (valid values: MI,HR,DY,MO,YR)
ls	TSTEP(1)	I3	number of CTCODE intervals to lag base variable
ac	CTCODE(2)	A2	code specifying time units of the period to aggregate base variable (valid values: MI,HR,DY,MO,YR)
as	TSTEP(1)	I3	number of CTCODE intervals to aggregate base variable
agfn	CTRAN	A4	transformation function to use for aggregation of base variable (valid values: SUM, AVER, MAX, MIN.)

Details of Free-Format Conditional lines

Symbol	Fortran name(s)	Format	Comment
IF	-	-	Keyword specifying the beginning of a logical condition
<quan>	CITEM	free(10)	May be either a UVQUAN name (format A6) or a numeric value (format up to F10.0)
<comp>	CCODE	free(2)	Numerical comparison operator. Valid values are: = equal /= not equal > greater than >= greater than or equal > less than >= less than or equal
<logop>	CLOGOP	free(3)	Logical operator: AND or OR
THEN	-	-	Keyword specifying the end of a logical condition
ELSE	-	-	Keyword specifying that following special actions are an alternative to previous IFs and ELSE IFs
ELSE IF	-	-	Keyword specifying that following special actions are an alternative to previous IFs and ELSE IFs, provided that the additional condition is also satisfied. Exactly one space must occur between the two words.
END IF	-	-	Keyword specifying the end of a logical block. Exactly one space must occur between the two words.

*** free(N) denotes that the field may be any length up to N characters, and may appear in any column, subject to a maximum line length of 80 characters.

Notes:

The <value> field contains quantitative data for the action to be taken. If the variable or array element to be acted on is an integer (TYPCOD=2) <value> is read as an integer (IVAL); If it is REAL or DOUBLE PRECISION (TYPCOD=3 or 4), <value> is read as a real number (RVAL). Note that the value must be given in the units used internally for the quantity concerned, because no conversion is performed when it is read in. You can find the internal units by looking up the quantity in the Operations Status Vector (for the module concerned), contained in the Programmer's Supplement. For example:

1. Pesticide storage (module PERLND) has units of lb/ac (English) and kg/ha (Metric); the same units are used internally and externally.
2. Sediment storage (module PERLND) has internal units of tons/acre (in both English and Metric systems) but the external units (English and Metric) are tons/acre and tonnes/ha respectively.

Repeat definition

This feature allows a single Special Action to be repeated at regular intervals. The input that defines the repetition is contained entirely on the standard action line. The date-time specified on the line is the starting date-time. The repetition is specified by: 1) CTCODE(2), which defines the time units of the interval between repetitions, 2) TSTEP(2), which defines the number of CTCODE(2) time steps between repetitions, and 3) NUMINC, which is the number of times to perform the action (for example: if NUMINC is 3, the action will be performed three times, i.e., on the specified date-time and two repetitions).

Distribute definition

This option allows a single Special Action to be split into multiple actions. The primary purpose is to distribute a chemical application over time so that it is not all applied to the land segment at once. The additional information needed to define the distribution is specified on an "associated" line in the Special Actions block. An ID number (DSIND) is included on the standard Special Actions line which points to the associated line. This line contains: 1) the keyword "DISTRB", which identifies the line as a "distribution" definition line, 2) DSIND, the ID number corresponding to the value on the standard line, 3) CNT, the number of separate applications to divide the total application into, 4) CTCODE and TSTEP, which define the time interval between applications (see discussion of REPEAT definition above), and 5) FRACT(CNT), the fraction of the total application represented by each of the separate applications. Note, the total application is given by <value> (or RVAL), which is specified on the standard Special Action line.

User-defined variable (UVNAME)

This option allows the user to define a single name (UVNAME) for one or more standard variables to be used as the target of a Special Action. If a UVNAME is applied to multiple standard variables, then any action line referring to that UVNAME as a target will cause multiple Special Actions to occur. This line contains: 1) a user defined name (UNAME), limited to six characters; 2) the number (count) of standard variables that are included in the set; 3) the variable names; 4) the fractions of the total Special Action quantity that will be applied to each variable; and 5) and an optional action code. (See below.)

UVNAME action code options

- QUAN Specify multiple Special Action variables in one line. Each quantity specified in the UVNAME line is multiplied by the quantity in the corresponding standard line to generate the final quantity applied to each of the variables specified in the UVNAME line. This option is designed primarily to allow a total chemical amount to be applied to multiple soil layers with a single line. This is the default.
- MOVT Redistribute current total quantity contained in multiple variables using predetermined factors. Each quantity specified in the UVNAME line is multiplied by the total quantity obtained by summing the current values of the individual variables specified in the UVNAME line. This option is designed to simulate a plowing operation that completely mixes all material in two or more zones. This would be accomplished by using quantities that are the fractions of soil or depth in the individual layers. (This option does not use the "quantity" or Action Code specified in standard line.)
- MOV1, Redistribute two quantities in following manner: Variable No. 1 is computed
MOV2 by multiplying current value of variable No. 2 by quantity associated with Variable 1 in the UVNAME line. Variable No. 2 is computed by multiplying current value of Variable No. 2 by quantity associated with Variable No. 2 in the UVNAME line plus the current value of Variable No. 1. This option is designed to simulate a plowing operation that transfers the material in the surface zone to the upper zone, and results in the new surface zone having the original concentration of the upper zone. This would be accomplished by using the following two quantities: 1) ratio of amount of soil (or depth) in surface layer to amount in upper layer, and 2) subtract surface layer soil amount from upper layer soil amount and divide the result by the upper layer soil amount. (This option does not use the "quantity" or Action Code specified in standard line.)

User-defined variable quantity (UVQUAN)

This option creates a variable quantity which can be used either as an action value for a Special Action or as a value to be compared in a condition. A UVQUAN refers to a single "base variable" in a single operation. By default, the UVQUAN contains the last-calculated value of that base variable. Optionally, it may contain a lagged value (e.g. 5 hours ago); an aggregated value (e.g. the average over the previous day); or a combination (e.g. the sum over three days ending 24 hours ago). The resulting value can also be multiplied by a constant factor. It is important to note the difference between a UVQUAN and a UVNAME. A UVQUAN is a **value**, just like a constant. A UVNAME is a **target address** for a special action.

Logical conditions

Special Actions may depend on whether a user-specified logical condition is true or false, and can be either skipped or deferred if it is false. They can be grouped into logical blocks by placing IF, ELSE IF, ELSE, and END IF lines appropriately among the action lines. For example, actions placed between an IF line and the next logical delimiter are executed only if the condition specified on the IF line is true on the date and time of the each action.

A simple logical condition is defined as a comparison between two numerical values. Either or both of these values may be UVQUANs. For example:

```
month <= 2
6226.0 <= tstage
tfish < faradj
```

are all simple logical conditions. Complex conditions are built by connecting simple conditions together with the logical operators AND and OR:

```
[month = 10 OR (tstage >= 6226.0 AND {month >= 11 OR month <= 2} )]
```

Parentheses are used to specify the order of evaluation, just as in a programming language. By default, the logical operators are evaluated from right to left, but it is good practice to use them in all cases to ensure clarity. There are three types: round (), square [], and curly {}. They are equivalent, but the program requires that matching left-right pairs must be of the same type, in order to help the user prevent unintended effects in complicated conditions.

IF lines consist of the keyword IF, a logical condition, and the keyword THEN. The IF keyword may appear anywhere on the line, as long as it is the first non-blank. The condition may be simple or complex, and may span multiple physical lines. When an IF line is found, HSPF keeps reading lines until the THEN keyword is found. ELSE IF lines are processed in the same manner. ELSE and END IF are expected to appear alone on a line, and anything after the keyword is ignored. Note that the "ELSE IF" and "END IF" keywords must contain **exactly** one space between the two words.

SPEC- ACTIONS Block

The following example illustrates how HSPF decides whether to perform a special action. Each condition may be simple or complex. Note the effect of nesting IF-END IF blocks. They may be nested up to ten levels deep.

```

*** Condition A
IF month >= 9 THEN
  *** Action 1
  RCHRES130          4  CVOL  pw      +=      TAVLQ
  *** Action 2
  RCHRES130          4  CVOL  tx      -=      TAVLQ

*** Condition B
IF (tstage > 6226.0) THEN
  *** Action 3
  RCHRES100          4  CVOL  tx      +=      PUNCOM

*** Condition C
ELSE IF (tstage > 6225.0) THEN
  *** Action 4
  RCHRES100          4  CVOL  pw      +=      PUNCOM

ELSE
  *** Action5
  RCHRES130          4  CVOL  na      -=      PUNCOM
  *** Action6
  RCHRES130          4  CVOL  ac      +=      PUNCOM
END IF

*** Action7
RCHRES130          4  CVOL  sp      +=      TAVLQ

*** Condition D
ELSE IF month >= 6 THEN
  *** Action8
  RCHRES130          4  CVOL  tc      +=      TAVLQ

*** Condition E
ELSE IF (tfish <= 0.0) THEN
  *** Action9
  RCHRES130          1991/04/29 12:00  4  CVOL  pw      +=      PUNCOM
  *** Action10
  RCHRES130          1991/05/01 12:00  4  CVOL  tx      -=      PUNCOM

ELSE
  *** Action11
  RCHRES130          4  CVOL  na      -=      TAVLQ
END IF

*** Action12
RCHRES130          4  CVOL  ac      +=      TAVLQ

```

In this case:

Actions 1, 2, and 7 are performed only if Condition A is true.

Action 3 is performed only if Conditions A and B are both true.

Action 4 is performed only if Conditions A and C are true and Condition B is false.

Actions 5 and 6 are performed only if Condition A is true and Conditions B and C are false.

Action 8 is performed only if Condition A is false and Condition D is true.

Actions 9 and 10 are performed only if Conditions A and D are false and Condition E is true.

Action 11 is performed only if Conditions A, D, and E are false.

Action 12 is always performed.

Evaluation Order

Each IF or ELSE IF line is evaluated a maximum of once per interval, at the time of execution of the first Special Action that depends on it in that interval. The UVQUAN values used for the numerical comparisons are computed from the base variables at the point of evaluation, taking into account Special Actions appearing before the Condition line, but not those after it.

Assume that in the example above, **month** = 10, **tstage** = 6224.5, and **tfish** = 0. HSPF will:

- 1) Fetch the value of **month**.
- 2) Evaluate Condition A as true.
- 3) Perform Action 1, since A is true.
- 4) Perform Action 2, since A is true.
- 5) Fetch the value of **tstage**.
- 6) Evaluate Condition B as false.
- 7) Skip Action 3, since B is false.
- 8) Re-fetch the value of **tstage**.
- 9) Evaluate Condition C as false.
- 10) Skip Action 4, since C is false.
- 11) Perform Actions 5 and 6, since A is true, while B and C are both false.
- 12) Perform Action 7, since A is true.
- 13) Skip Action 8, since A is true. Note that Condition D does not need to be evaluated because the action is skipped regardless of D's value.
- 14) Ignore Actions 9 and 10, since they do not occur on this date.
- 15) Skip Action 11, since A is true. Conditions D and E can be ignored.
- 16) Perform Action 12, which is unconditional.

The use of dated special actions within logical blocks requires caution. For instance, for Actions 9 and 10 above, it is possible that the value of **tfish** changes between April 29 and May 1 such that one of the Actions is performed while the other is not, even though they have the same logical conditions. The user must make sure that this is the intended result.

Another situation requiring care is a Special Action that alters one of the variables which define the logical conditions upon which that Action depends. For instance, if Action 4 above changed the value of the UVQUAN **tstage** to 6224.0 by altering its base variable, then Actions 5 and 6 will still not be executed that interval, since Condition C is not re-evaluated until the following interval.

4.11 MONTH-DATA Block

```
*****
      1      2      3      4      5      6      7      8
123456789012345678901234567890123456789012345678901234567890
*****
Layout
*****
```

MONTH-DATA

```
MONTH-DATA      <t>
<val-><val-><val-><val-><val-><val-><val-><val-><val-><val-><val-><val->
END MONTH-DATA <t>
```

Up to 50 MONTH-DATA tables may appear in the block

END MONTH-DATA

```
*****
Example
*****
```

MONTH-DATA

```
MONTH-DATA      3
*** atmospheric deposition fluxes (kg/ha/month) of NO3-N
  1.3  1.5  2.0  2.1  2.2  2.2  3.0  2.3  2.0  2.0  1.7  1.4
END MONTH-DATA  3
```

END MONTH-DATA

Details

Symbol	FORTTRAN Name(s)	Format	Comment
<t>	NUMBR	I3	Users identifying number for this MONTH-DATA table
<val->	MTHVAL(12)	12F6.0	Monthly values

Explanation

A MONTH-DATA table is used to specify monthly-varying values for parameters that do not have specific input tables for that purpose. Currently, MONTH-DATA tables are implemented for atmospheric deposition inputs. See descriptions for table types PQL-AD-FLAGS, PEST-AD-FLAGS, etc. for further details.

4.12 CATEGORY Block

```
*****
      1          2          3          4          5          6          7          8
1234567890123456789012345678901234567890123456789012345678901234567890
*****
```

Layout

CATEGORY

<cat> <----catnam---->

.

Above line repeats until all categories have been specified

.

END CATEGORY

Example

CATEGORY

tag ***

<> <----catnam----> ***

UN UNCOMMITTED

WP WESTPAC CREDIT

CU CUI-UI CREDIT

CA CALIF CREDIT

TX TAHOE EXCHANGE

END CATEGORY

Details

Symbol	FORTRAN Name(s)	Start Column	Format	Comment
<cat>	CAT	4	A2	Category tag: a two-character identifier used wherever a subscript is called for. First character must be a letter. Tags are case-sensitive, and must be unique.
<catnam>	CATNAM	7	A16	Category name

Explanation

In this block the user declares and names active water categories.

The CATEGORY block is used to facilitate the modeling of water rights in the HYDR section of RCHRES. Each RCHRES in the run tracks the categories of all inflows, storages, demands, and outflows. Up to 100 categories may be specified. (See the discussion of Water Rights Categories in Part E, Section 4.2(3).1).

APPENDIX I
GLOSSARY OF TERMS

1.0 NATURE OF THE GLOSSARY

The glossary which follows is not exhaustive. Its function is to introduce terms which may be new and to assign definite meanings to ambiguous terms. It is not a dictionary. The goal is not to provide formally correct definitions but to supply explanations adequate for practical purposes. Thus in some cases, the definition of a term is followed by a further explanatory note.

2.0 GLOSSARY

The list that follows is arranged alphabetically. Any word enclosed in parentheses () may optionally be omitted from a term in everyday use, provided that the context ensures that its use is implied.

ACTUAL ARGUMENT

The name of an item (or set) of data which is being passed to (or retrieved from) a subprogram via an argument list. It can be:

- (1) a variable name
- (2) an array or array element name
- (3) any other expression
- (4) the name of an external procedure
- (5) a Hollerith constant

ANNIE

An interactive program designed for management of WDM files and their data. ANNIE functions include file creation, data set management, and data analysis, modification, and display.

APPLICATION MODULE

A module which simulates processes which occur in the real world (e.g., PERLND, IMPLND, RCHRES).

BUFFER

A portion of machine memory space used for the temporary storage of input or output-bound data.

COMPUTATIONAL ELEMENT

See "element."

CONCEPTUAL DATA STREAM

A stream of related data that are independent of any physical input-output device.

COPY

A utility module used to copy time series data. COPY is typically used to transfer data from a sequential file to the WDM file or DSS file.

DATA SET (TIME SERIES)

A data set in the WDM or DSS file.

DIRECT ACCESS FILE

A disk file whose records are read from or written to a specific location within the file. Any record in the file may be accessed at any time. Contrast with sequential file.

DIRECTED GRAPH

A group of processing units arranged with unidirectional paths between them. No bi-directional paths or cycles are allowed.

DISPLY

A utility module used to print time series data and summaries of the data.

DUMMY ARGUMENT

The local name (in a subprogram) for an actual argument which is passed to the subprogram.

DURANL

A utility module used to examine the behavior of a time series, computing a variety of statistics related to its' excursions above and below certain specified levels.

ELEMENT

A collection of nodes and/or zones, e.g. segment no. 1, reach no. 20.

ELEMENT TYPE

A name which describes elements having a common set of attributes, for example, Pervious Land-segment, Reach/Mixed Reservoir.

EXECUTABLE PROGRAM

A self contained computing procedure. It consists of a main program and its required subprograms.

FEEDBACK ELEMENT

An element which is situated in a loop in a network or which is connected to another element by one or more bi-directional flux linkages.

FEEDBACK REGION

A group of connected feedback elements. Information and constituent transfers across the boundaries of a feedback region are uni-directional, but internal fluxes can be bi-directional.

FLOWCHART

A schematic two-dimensional representation of the logic in a program or program unit. The level of detail in a flowchart depends on its purpose.

FLUX

The rate of transfer of fluid, particles or energy across a given surface.

FUNCTION (as used in program design, not in Fortran language)

A transformation which receives input and returns output in a predictable manner. Most functions within a program can be classified into one of three types: input, process, or output. Usually, there is a hierarchy of functions--high level functions contain subordinate functions.

GENER

A utility module used to perform any one of several transformations on one or more input time series.

IMPLND

An application module which simulates the water quantity and quality processes which occur on an impervious land segment.

INGRP

A group of HSPF operations which share the same internal scratch pad (INPAD).

INPAD

see INTERNAL SCRATCH PAD

INPAD AREA

The space available in memory for the storage of time series data in the INPAD. It is the difference between the area of the common block SCRTCH and the longest OSV in the INGRP.

INPAD WIDTH

The number of time intervals which are present in the INPAD during a run. This is the INPAD area divided by the maximum number of rows of the time series data. HSPF uses fewer disk input/output operations with longer INPAD widths.

INPUT TIME SERIES

Time series which are read in a given simulation run.

INSPAN

see INTERNAL SCRATCH PAD SPAN

INTER SECTION DATA TRANSFER (ISDT)

The movement of information from one section to another within a module.

INTERNAL SCRATCH PAD (INPAD)

The space in memory where time series data are accessed by modules. It functions as a large buffer for this data.

INTERNAL SCRATCH PAD SPAN (INSPAN)

The real world time which corresponds to the INPAD width.

IVL

See SIMULATION INTERVAL

JOB

The work performed by HSPF in response to the instructions found in a complete set of User's Control Input.

KIND

A descriptor which implies either point or mean with regard to a time series.

MEAN VALUED DATA

Data which represents the behavior of a time series over time intervals rather than at specific points in time.

MIXED RESERVOIR

A water body which is assumed to be completely mixed.

MODEL

A set of algorithms, set in a logical structure, which represents a process. A model is implemented using modules of code.

MODULE

A set of program units which performs a clearly defined function.

MODULE SECTION

A part of an Application Module which can be executed independently of the other parts. eg. SEDMNT in module PERLND.

MUTSIN

A utility module used to read a sequential external file which has the same format as the file produced by the PLTGEN module. MUTSIN makes the time series data on the external file available for use by other modules.

NETWORK

A group of connected processing units. Information and/or constituents flow between processing units through uni-directional linkages. That is, no processing unit may pass output which indirectly influences itself (no feedback loops). These constraints make it possible to operate on each processing unit separately, considering them in an "upstream" to "downstream" order.

NODE

A point in space where the value of a spatially variable function can be determined.

OPERATING MODULE (OM)

A set of HSPF program units which perform a series of process functions for a specified time on a given set of input time series and produce a specified set of output time series.

OPERATION

In HSPF: execution of code which transforms a set of input time series into a set of output time series, for example, execution of an application module or a utility module. See "simulation operation," "utility operation."

OPERATIONS STATUS VECTOR (OSV)

The data structure for an operating module. The OSV contains all the information (parameters, state variables) needed to describe the status of an operation and to restart it after an interruption.

OPERATIONS SUPERVISOR (OSUPER)

The HSPF program units which oversee the execution of operating modules and related time series movement.

OSV

see OPERATION STATUS VECTOR

OUTPUT TIME SERIES

Time series which are generated during a simulation run. They do not have to be stored in the WDM or DSS.

PARAMETER

A variable used in a function which determines the transformation of the input to the function to the output of the function.

PARTITION (an operation)

The execution of different sections of an application module in separate runs. Time series involved in inter section data transfers must be stored between runs.

PERLND

An application module which simulates the water quantity and quality processes which occur on a pervious land segment.

PERVIOUS LAND SEGMENT (PLS)

A segment of land with a pervious surface.

PHYSICAL PROCESS

A process occurring in the real world.

PLS

see PERVIOUS LAND SEGMENT

PLTGEN

A utility module used to write a sequential external file containing up to 10 time series and related commands for a stand alone plotting program.

POINT VALUED DATA

Data which represents the behavior of a time series at specific points in time rather than over time intervals.

PROCESS

In the real world: A continuing activity, for example, percolation, chemical reaction. See "physical process."

PROCESSING UNIT (PU)

An element or group of related elements which is simulated for a period of time. Input comes from external sources or Processing Units which have completed simulating for the given period of time. Output goes to other processing units of external targets.

PROGRAM

A complete set of code, consisting of one or more program units, the first of which is the "main" program unit.

PU

see PROCESSING UNIT

RCHRES

An application module which simulates the water quantity and quality processes which occur in a reach of open or closed channel or a completely mixed lake.

REACH

A free-flowing portion of a stream, simulated in HSPF using storage routing.

RUN

A set of operations which are performed serially and cover the same period of time.

RUN INTERPRETER

The HSPF module which reads and interprets the User's Control Input. It sets up internal information that instructs the system regarding the sequence of operations to be performed, stores parameters and state variables for each operation in the OSV, writes instructions related to the movement of time series data and performs other minor functions.

SECTION

see MODULE SECTION

SEGMENT

A portion of the land assumed to have areally uniform properties.

SEQUENTIAL FILE

A file whose records are organized on the basis of their successive physical positions, such as on magnetic tape or cards. A record may be accessed only after the previous record has been accessed.

SIMPLE ELEMENT

An element which is not a feedback element.

SIMULATION

Imitation of the behavior of a prototype, using a model. We implement the model on a computer using an application module.

SIMULATION INTERVAL

The internal time step used in an operation.

SIMULATION MODULE

See APPLICATION MODULE

SIMULATION (OPERATION)

Simulation of a specified prototype for a specified period.

STATE VARIABLE

A variable containing the current value of a storage or other measurable quantity. It may change through time.

STRUCTURE CHART

A diagram which documents the result of structured (program) design. It indicates the program units, their relationships (including hierarchy) and, optionally, the data passed between them.

SYSTEM DOCUMENTATION

A comprehensive set of documents which enable a user to understand and use a software product. It should include:

- (1) a discussion of the underlying principles
- (2) a discussion of the mathematical relations which the code implements
- (3) documentation of the structure of the code
- (4) a listing of the code
- (5) documentation of data and file structures, including the input required to run the program.

TIME SERIES

A series of chronologically ordered values giving a discrete representation of the variation in time of a given quantity.

(TIME SERIES) DATA SET

A data set in the WDM or DSS file.

TIME SERIES MANAGEMENT SYSTEM (TSMS)

The modules of HSPF which are concerned with manipulation of time series or the files used to store time series. It includes TSGET and TSPUT.

TIME SERIES STORE (TSS)

A direct access file used for medium/long term storage of time series. Active maintenance of the TSS system has ceased, and it has been removed from the documentation.

TIME SERIES STORE MANAGEMENT (TSSM)

The HSPF module which (in previous versions) maintained a User's Time Series Store (TSS) and performed maintenance tasks associated with the data sets in it. TSSM has been removed from the program and the documentation.

TSPUT

The HSPF module which moves time series data from the INPAD to a WDM file or DSS.

TSGET

The HSPF module which moves time series data from a WDM file, DSS, or sequential file to the INPAD.

TSS

see TIME SERIES STORE

TSSM or TSSMGR

see TIME SERIES STORE MANAGEMENT

UCI

see USER'S CONTROL INPUT

USER'S CONTROL INPUT

The file in which the user specifies the operations to be performed in a run, the parameters and initial conditions for each one, and the time series to be passed between them. HSPF reads this from an ASCII file.

UTILITY MODULE

A module which performs operations on time series which are peripheral to the simulation of physical processes, for example, data input, plot generation, statistical analysis.

UTILITY OPERATION

Execution of a utility module.

VOLUME

A source (WDM, DSS, sequential file or INPAD) or target (WDM or DSS) for the time series data.

Watershed Data Management (WDM) File

A direct-access, binary file containing multiple time series data sets. This file is the primary storage file for HSPF time series data. WDM files are created and maintained by the ANNIE program and related-software.

WORLD VIEW

A representation of the real world which includes simplifying assumptions of physical processes.

ZONE

A finite portion of the real world. It is usually associated with the integral of a spatially variable quantity.

APPENDIX II
TIME SERIES CONCEPTS

1.0 Time Series Concepts

A time series is a sequence of values ordered in time. The interval of time between successive values is called the time step or the time increment or the time interval of the time series. The time step for a time series is often a constant value but may also be variable. The implementation in HSPF restricts the variability in a manner discussed below. The values in the time series may represent the behavior of a process at a point in time or an average over the time step of the time series. A time series whose values represent behavior at points in time is called a point-valued time series and is represented symbolically by "*". Linear interpolation is used to define intermediate values in a point-valued time series. A time series whose values represent average or aggregated behavior over the time step are called mean-valued time series and are represented symbolically as "-". The meaning of "average" and "mean" is taken in a wide sense and includes any value assumed to be representative of behavior of the time series over the time step, rather than at a specific point in time.

The following figure shows the difference between the point and mean value time series in graphic form. It is important to note that only one value is needed to represent the behavior of a mean-valued time series for one time step. We visualize the value as being assigned to a time step in this case. On the other hand, two values are needed to represent the behavior of a point-valued time series over the same interval. We visualize the values as being assigned to the time points in this case. Each time point at which a value of the series is given in a point-valued time series is viewed as "belonging" to the time step which it ends. Time points belonging to all time steps contained within a larger time step are viewed as belonging to the larger time step also. For example, all time points in a point-valued time series except the first time point belong to the time interval spanning the time series duration. The first time point of a point-valued time series is viewed as belonging to the time step immediately preceding the first time step of the time series. This precise definition of belongingness for a time point is needed to avoid confusion in defining operations on the time series.

A number of operations on time series, discussed in Section 4.6 of Part F, preserve the integral of the time series between any two time points which end time steps in the time series. The integral may be visualized as the area under the broken line graph formed by connecting adjacent values in the point-valued time series or the area under the histogram representing the mean-valued time series. The trapezoidal rule applied to the point-valued time series yields the exact value of the integral whereas the simple rectangular rule yields the exact value for the mean-valued time series.

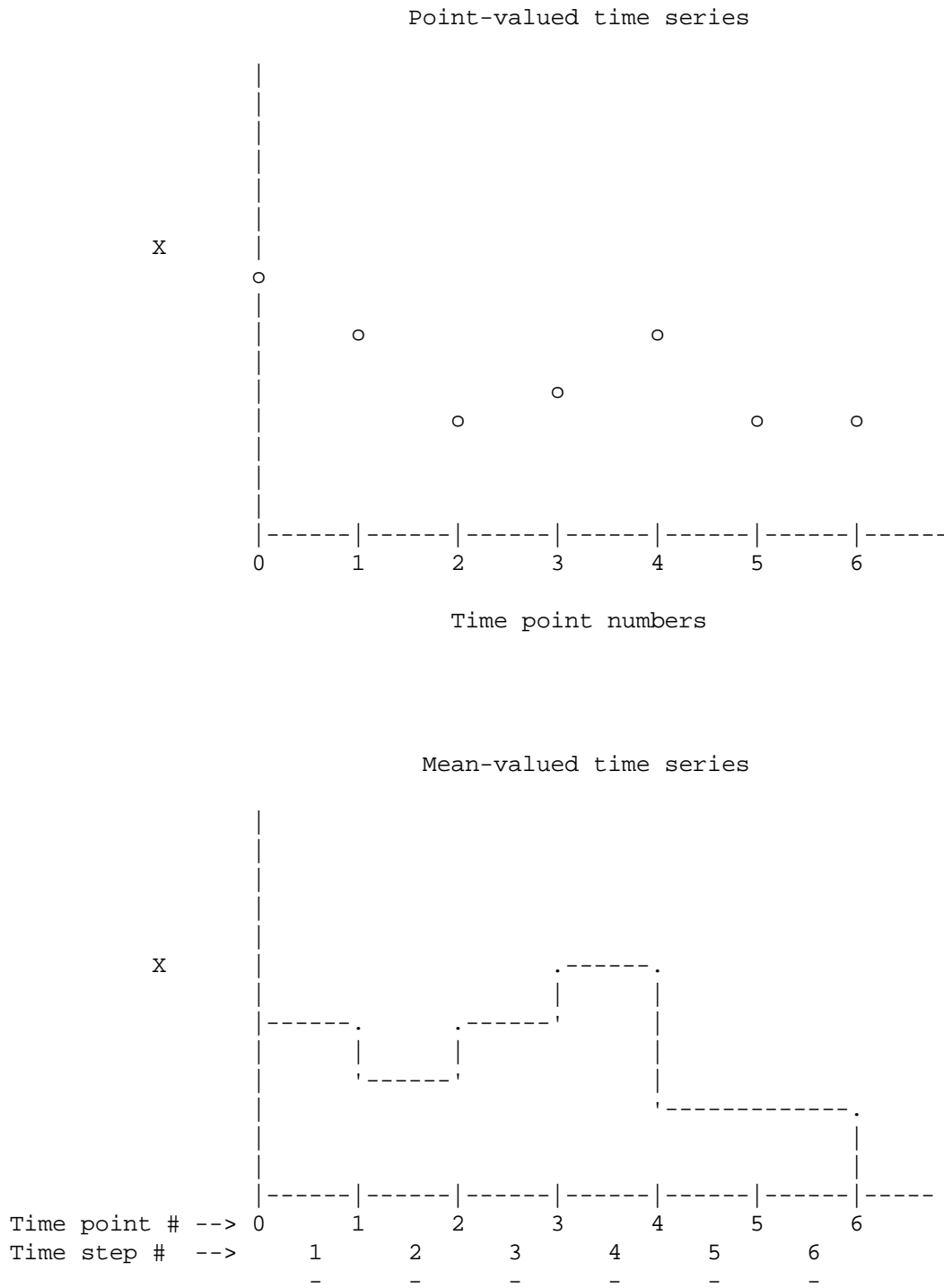


Figure 1. Comparison between point- and mean-valued time series

Time is given as year/month/day/hour/minute to completely specify either a time interval or a time point. The date/time given by the internal clock uses the "contained within" principle for all levels of the date/time. That is, each smaller interval is contained within the next larger interval. This is the conventional usage for year/month/day but is not conventional for the hour/minute. For example, the date string 1977/01/02 labels the second day of the first month of the 1977th year. On the other hand, in conventional usage the time string 10:15 refers to the end of the 15th minute after (not within) the 10th hour of the day. This change in meaning is eliminated in the internal date/time clock for HSPF. In the internal system, time string 10/15 labels the 15th minute of (ie. within) the 10th hour of the day. A comparable time to 10:15 in the conventional sense would be 11/15; that is, the 15th minute of the 11th hour of the day.

In summary, the internal clock convention labels time intervals at all levels of date/time whereas conventional usage labels time intervals for year/month/day but labels time points for hour/minute. In HSPF, time points are then referenced uniquely by the minute which ends at the time point in question.

The time steps in a time series are labelled with the minute which ends the time step. Thus, the values in a mean-valued time series are treated logically as having occurred at the end time point of the time step. Note that for purposes of the internal clock and for description of internal concepts each time point has one and only one label. This means that we refer to the instant in time forming the boundary between two days using the label associated with the first day even though our interest is centered on the second day. This convention is called the ending time convention.

A starting time convention is used externally for some purposes because traditional usage requires both conventions depending on the context of the statement about time. Users are more comfortable using the traditional clock and both a starting time and an ending time convention. The starting time convention is used when the start of some time span is in mind and the ending time convention is used when the end of some time span is in mind.

The time span associated with a time series must be defined. Logically, a time series is of infinite length. Realistically, every time series has a finite length and may be broken into short segments for convenience in recording the values on some medium such as the printed page, a magnetic tape, a data card or a magnetic disk. These shorter segments are made necessary by various software and hardware constraints. Therefore, a time span is associated with each medium used to record or store the time series.

Time Series Concepts

A further practical complication is created by the variety of representations used for time series. The user's most likely mental image is a line drawn in some coordinate system on the printed page. This method of representing time series is most convenient for the user but a series of discrete numbers is most convenient for the digital computer. The time series of indefinite length must be subdivided into shorter time spans to fit the card images or the records on the tape or disk. In some cases data for the time series may be incomplete (some values not present) or, in some cases, many of the values are zero so that not all values for the time series are stored on the medium. In such cases a date/time indicator is given on the record. As an example, think of the format used for data cards punched by the National Weather Records Center. The date/time information on each record of the medium permits the reconstruction of the complete time series (except for the missing values) even though not all values are recorded on the medium. However, conventions must be established so that missing records on a given recording medium are properly interpreted. For example, are the missing data merely zeros or did they occur because of instrument malfunction? If the data are missing, a "filler" should be inserted when the data are placed on the WDM or DSS so that it can be changed at a later time or so that such missing periods can be properly handled by other parts of the HSPF system. The filler value is called the TSFILL attribute in the WDM system.

The time step for a time series can vary in multiples of a basic time step established for the time series. The basic time step for the time series must be truly a constant value. For example, a time series at a monthly interval does not have a constant time step. Therefore, the basic time step assigned to such a time series is daily because a day is of constant length and is commensurable with all months.

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Modeling of Nonpoint Source Water Quality in Urban and Non-urban Areas

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Disclaimer

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Foreword

As environmental controls become more costly to implement and the penalties of judgment errors become more severe, environmental quality management requires more efficient analytical tools based on greater knowledge of the environmental phenomena to be managed. As part of this Laboratory's research on the occurrence, movement, transformation, impact, and control of environmental contaminants, the Assessment Branch develops management and engineering tools to help pollution control officials address environmental problems.

Pollutants in runoff and seepage from urban, agricultural, and forested areas contribute significantly to water pollution problems in many areas of the United States. The development and application of computer-operated mathematical models to simulate the movement of pollutants and thus to anticipate environmental problems has been the subject of extensive research by government agencies, universities, and private companies for many years. This review and model-selection guidance document was developed under the direction of EPA's Office of Water and Office of Research and Development to assist water quality planners in applying modeling techniques to the development of cost-effective nonpoint source controls.

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Abstract

Nonpoint source assessment procedures and modeling techniques are reviewed and discussed for both urban and non-urban land areas. Detailed reviews of specific methodologies and models are presented, along with overview discussions focussing on urban methods and models, and on non-urban (primarily agricultural) methods and models. Simple procedures, such as constant concentration, regression, statistical, and loading function approaches are described, along with complex models such as SWMM,

HSPF, STORM, CREAMS, SWRRB, and others. Brief case studies of ongoing and recently completed modeling efforts are described. Recommendations for nonpoint runoff quality modeling are presented to elucidate expected directions of future modeling efforts. This work was performed as Work Assignment No. 29 under EPA Contract No. 68-03-3513 with AQUA TERRA Consultants. Work was complete as of March 1990.

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Dr. Wayne Huber of the University of Florida performed the urban model review, and Mr. Anthony Donigian of AQUA TERRA Consultants performed the review of the non-urban models. Both authors reviewed the entire report. Mr. Avinash Patwardhan assisted Mr. Donigian with the information gathering and review of the non-urban models. Also, the draft final report was peer reviewed by Dr. Vladimir Novotny of Milwaukee, Wisconsin; and Dr. Matt C. Smith of the University of Georgia, Athens, Georgia. Their insightful comments and suggestions were sincerely appreciated.

Section 1.0

Nonpoint Source Modeling Objectives and Considerations

Studies and projects involving stormwater runoff quality from all categories of land use⁷ urban, agricultural cropland, pasture, forest⁷ can relate to many environmental problems. In the broadest sense, water quality studies may be performed to protect the environment under various state and federal legislation. For example, Section 304(l) of the Clean Water Act requires States to identify waterbodies impaired by both point and nonpoint source pollution and develop appropriate control strategies; while Section 405 will eventually require analysis of stormwater outfalls in all urban areas in the U.S. In a narrower sense, a study may address a particular water quality issue in a particular receiving water, such as bacterial contamination of a beach, release of oxygen demanding material into a stream or river, unacceptable aesthetics of an open channel receiving urban and non-urban runoff, eutrophication of a lake, contamination of basements from surcharged sewers due to wet-weather flooding, etc.

By no means should it be assumed that every water quality problem requires a water quality modeling effort. Some problems may be mostly hydraulic in nature, e.g., the basement flooding problem. That is, the solution may often reside primarily in a hydrologic or hydraulic analysis in which the concentration or load of pollutants is irrelevant. In some instances, local or state regulations may prescribe a nominal ⁷solution⁷ without recourse to any water quality analysis as such. For example, stormwater runoff in Florida is considered ⁷controlled⁷ through retention or detention with filtration of the runoff from the first inch of rainfall for areas of 100 acres or less. Other problems may be resolved through the use of measured data without the need to model. In other words, many problems do not require water quality modeling at all.

If a problem does require modeling, specific modeling objectives will need to be defined to guide the modeling exercise and approach. Models may be used

for objectives such as the following:

1. Characterize runoff quantity and quality as to temporal and spatial detail, concentration/load ranges, etc.
2. Provide input to a receiving water quality analysis, e.g., drive a receiving water quality model.
3. Determine effects, magnitudes, locations, combinations, etc. of control options.
4. Perform frequency analysis on quality parameters, e.g., to determine return periods of concentrations/loads.
5. Provide input to cost-benefit analyses.

Objectives 1 and 2 characterize the magnitude of the problem, and objectives 2 through 5 are related to the analysis and solution of the problem. Computer models allow some types of analysis, such as frequency analysis, to be performed that could rarely be performed otherwise since periods of water quality measurements are seldom very long. It should always be borne in mind, however, that use of measured data is usually preferable to use of simulated data, particularly for objectives 1 and 2 in which accurate concentration values are needed. In general, models are *not* good substitutes for good field sampling programs. On the other hand, models can sometimes be used to extend and extrapolate measured data.

Careful consideration should be given to objective number 2. The first urban runoff quality model (SWMM) inadvertently overemphasized the concept of simulation of detailed intra-storm quality variations, e.g., production of a ⁷pollutograph⁷ (concentration vs. time) at 5 or 10 minute intervals during a storm for input to a receiving water quality model. The early agricultural runoff quality models (e.g., ARM and ACTMO models) followed a similar

detailed approach primarily to evaluate and demonstrate the models' abilities to represent observed data from small (less than 10 hectare) monitored fields.

But the fact is that the quality response of most receiving waters is insensitive to such short-term variations, as illustrated in Table 1. In most instances, the total storm load will suffice to determine the receiving water response, eliminating the necessity of becoming embroiled in calibration against detailed pollutographs especially for conventional pollutants. Instead, only the total storm loads need be matched, a much easier task. Exceptions to this general observation may be appropriate when considering *toxic* pollutants, e.g., pesticides, when short-term concentrations may be lethal to aquatic organisms. Also, simulation of short time increment changes in concentrations and loads is generally necessary for analysis of control options, such as storage or high-rate treatment, whose efficiency may depend on the transient behavior of the quality constituents.

Any consideration of water quality modeling means that some additional data will be required for model input. As described later, such requirements may be as simple as a constant concentration, or much more complex such as soil nitrification or mineralization rates. Data may be obtained from existing studies or their acquisition may require

extensive field monitoring. For some conceptualizations of the urban quality cycle, e.g., buildup and washoff, it may not be routinely possible to physically measure fundamental input parameters, and such parameters will only be obtained through model calibration. Involvement in acquisition of quality data, be it through literature reviews or field surveys, profoundly escalates the level of effort required for the study. Details on data requirements for modeling will be deferred until modeling techniques are described.

Table 1. Required temporal detail for receiving water analysis

(After Driscoll, 1979, and Hydrosience, 1979)

Type of Receiving Water	Key Constituents	Response Time
Lakes, Bays	Nutrients	Weeks? Years
Estuaries	Nutrients, OD* Bacteria	Days? Weeks
Large Rivers	OD, Nitrogen	Days
Streams	OD, Nitrogen Bacteria	Hours? Days Hours
Ponds	OD, Nutrients	Hours? Weeks
Beaches	Bacteria	Hours

*OD = oxygen demand, e.g., BOD, that affects dissolved oxygen.

Section 2.0 Overview of Nonpoint Source Quality Modeling

2.1 Modeling Fundamentals

Modeling caveats and an introduction to modeling are presented by several authors including James and Burges (1982), Kibler (1982), Huber (1985, 1986) and summarized in a recent manual of practice (WPCF, 1989). Space does not permit a full presentation here; a few items are highlighted below.

1. Have a clear statement of project objectives. Verify the need for quality modeling. (Perhaps the objectives can be satisfied without quality modeling).
2. Use the simplest model that will satisfy the project objectives. Often a screening model, e.g., regression or statistical, can determine whether more complex simulation models are needed.
3. To the extent possible, utilize a quality prediction method consistent with available data. This would ordinarily rule against buildup-washoff formulations, although these might still be useful for detailed simulation, especially if calibration data exist.
4. Only predict the quality parameters of interest and only over a suitable time scale. That is, storm event loads and EMCs will usually be the most detailed prediction necessary, and seasonal or annual loads will sometimes be all that is required. Do not attempt to simulate intra-storm variations in quality unless it is necessary.
5. Perform a sensitivity analysis on the selected model and familiarize yourself with the model characteristics.
6. If possible, calibrate and verify the model results. Use one set of data for calibration and

another independent set for verification. If no such data exist for the application site, perhaps they exist for a similar catchment nearby.

2.2 Operational Models

Implementation of an off-the-shelf model or method will be easiest if the model can be characterized as 'operational' in the sense of:

1. Documentation. This should include a user's manual, explanation of theory and numerical procedures, data needs, data input format, etc. Documentation most often separates the many computerized procedures found in the literature from a model that can be accessed and easily used by others.
2. Support. This is sometimes provided by the model developer but often by a federal agency such as the HEC or EPA.
3. Experience. Every model must be used a 'first time' but it is best to rely on a model with a proven track record.

The models described in Sections 3.0 and 4.0 are all operational in this sense. New methods and models are constantly under development and should not be neglected simply because they lack one of these characteristics, but the user should be aware of potential difficulties if any characteristic is lacking.

2.3 Surveys and Reviews of Nonpoint Source Models

Several publications, often somewhat out of date, provide reviews of available models. Some models (e.g., SWMM, STORM, HSPF, CREAMS) have persisted for many years and are included in both older and newer reviews, while other models (e.g., USGS, Statistical, spreadsheet, AGNPS, SWRRB) are more recent. Reviews that consider surface runoff quality models include Huber and Heaney (1982), Kibler (1982), Whipple et al. (1983), Barnwell (1984, 1987), Huber (1985, 1986), Donigian and Beyerlein (1985), Bedient and Huber (1988), and Viessman et al. (1989). HEC models are described in detail by Feldman (1981). Descriptions of EPA nonpoint source water quality models are provided by Ambrose et al. (1988) and Ambrose and Barnwell (1989). Selected pesticide runoff models have been reviewed by Mulkey et al. (1986) and Lorber and Mulkey (1982). Agricultural nonpoint source models have been showcased in a number of conferences and symposia over the past few years, including a 1983 Symposium on Natural Resources Modeling (DeCoursey, 1985); a 1984 Conference on Agricultural Nonpoint source Pollution: Model Selection and Application, in Venice, Italy (Giorgini and Zingales, 1986); and a June 1988 International Symposium on Water Quality Modeling of Agricultural Nonpoint Sources (DeCoursey, In Press). Beasley and Thomas (1989) describe recent model enhancements and applications for five selected models to agricultural and forested watersheds in the southeastern U.S. These reports and proceedings provide a wealth of information on current efforts and recent developments in modeling nonpoint contributions and water quality impacts of agricultural activities.

2.4 Summary of Data Needs

In application of most models, there are two fundamental types of data requirements. First, there are the data needed simply to make the model function, that is, input parameters and timeseries data for the model. These typically include precipitation (rainfall) and other meteorologic information, drainage area, imperviousness, runoff coefficient and other quantity prediction parameters, plus quality prediction parameters such as constant concentration, constituent median and CV, regression relationships, buildup and washoff parameters, soil/chemical characteristics, partition coefficients, reaction rates, etc. In other words, each mode

will have a fundamental list of required input data. Although it is difficult to generalize for the entire universe of both simple and complex nonpoint source models, Novotny and Chesters (1981) have prepared a summary table of required input data from which Table 2 was adapted.

The second type of information is required for calibration and verification of more complex models, namely, sets of measured runoff and quality samples (coincident with the input precipitation and meteorologic data) with which to test the model. Such data exist (e.g., Huber et al., 1982; Driver et al. (1985), Noel et al., 1987) but seldom for the site of interest. If the project objectives absolutely require such data (e.g., if a model must be calibrated in order to drive a receiving water quality model), then expensive local monitoring may be necessary.

This summary relates primarily to *quality* prediction and may not represent a comprehensive statement of data needs for *quantity* prediction. However, since rainfall and runoff are required for virtually every study, certain quantity-related parameters are also necessary for various methods.

Table 2. Input data needs for nonpoint source models

(after Novotny and Chesters, 1981)

-
1. System Parameters
 - a. Watershed Size
 - b. Subdivision of the Watershed into Homogenous Subareas
 - c. Imperviousness of Each Subarea
 - d. Slopes
 - e. Fraction of Impervious Areas Directly Connected to a Channel
 - f. Maximum Surface Storage (depression plus interception storage)
 - g. Soil Characteristics Including Texture, Permeability, Erodibility, and Composition
 - h. Crop and Vegetation Cover
 - i. Curb Density or Street Gutter Length
 - k. Sewer System or Natural Drainage Characteristics
 2. State Variables
 - a. Ambient Temperature
 - b. Reaction Rate Coefficients
 - c. Adsorption/Desorption Coefficients
 - d. Growth Stage of Crops
 - e. Daily Accumulation Rates of Litter
 - f. Traffic Density and Speed
 - g. Potency Factors for Pollutants (pollutant strength on sediment)
 - h. Solar Radiation (for some models)
 3. Input Variables
 - a. Precipitation
 - b. Atmospheric Fallout
 - c. Evaporation Rates
-

Section 3.0

Overview of Available Urban Modeling Options

3.1 Introduction

Several quality modeling options exist for simulation of quality in urban storm and combined sewer systems. These have been reviewed by Huber (1985; 1986) and range from simple to involved, although some "simple" methods, e.g., the EPA statistical methods, can incorporate quite sophisticated concepts. The principal methods available to the contemporary engineer are outlined below, in a rough order of complexity. Their data requirements are summarized in Table 3. The methods are:

1. Constant concentration
2. Spreadsheet
3. Statistical
4. Rating curve or regression
5. Buildup/washoff

3.2 Constant Concentration or Unit Loads

As its name implies, all runoff is assumed to have the same, constant concentration for a given pollutant. At its very simplest, an annual runoff volume can be multiplied by a concentration to produce an annual runoff load. However, this option may be coupled with a hydrologic model, wherein loads (product of concentration and flow) will vary if the model produces variable flows. This option may be quite useful because it may be used with any hydrologic or hydraulic model to produce loads, merely by multiplying by the constant concentration. For instance, the highly sophisticated SWMM Extran Block may be used for hydraulic analysis of sewer

system, prediction of overflows and diversions to receiving waters, etc., yet it performs no quality simulation as such. In many instances, it may be most important to get the volume and timing of such overflows and diversions correctly, and simply estimate loads by multiplying by a concentration.

An obvious question is what (constant) concentration to use? The EPA NURP studies (EPA, 1983) have produced a large and invaluable data base from which to select numbers, but the 30 city coverage of NURP will most often not include a site representative of the area under study. Nonetheless, a large data base does exist from which to review concentrations. Another option is to use measured values from the study area. This might be done from a limited sampling program. However, the NURP study conclusively demonstrated the variation that exists in event mean concentrations (EMCs, total storm event load divided by total storm event runoff volume) at a site, within a city, and within a region or the country as a whole. Thus, while use of a constant concentration may produce *load* variations, EMC variations will not be replicated. These variations may be important in the study of control options and receiving water responses.

Unit loads are perhaps an even simpler concept. These consist of values of mass per area per time, typically lb/ac-yr or kg/ha-yr, for various pollutants, although other normalizations such as lb/curb-mile are sometimes encountered. Annual (or other time unit) loads are thus produced upon multiplication by the contributing area. Such loadings are obviously highly site-specific and depend upon both demographic and hydrologic factors. They must be based on an average or "typical" runoff volume and cannot vary from year to year, but they can conveniently be subject to reduction by best management practices (BMPs), if the BMP effect is known. Although early EPA references provide some information for various

land used (EPA, 1973; EPA, 1976a; McElroy et al., 1976), unit loading rates are exceedingly variable and difficult to transpose from one area to another. Constant concentrations can sometimes be used for this purpose, since $\text{mg}/1 \times 0.2265 = \text{lb}/\text{ac}$ per inch of runoff. Thus, if a concentration estimate is available, the annual loading rate, for example, may be calculated by multiplying by the inches per year of runoff. Finally, the Universal Soil Loss Equation (Wischmeier and Smith, 1978; Heaney et al., 1975) was developed to estimate tons per acre per year of sediment loss from land surfaces. If a pollutant may be considered as a fraction (?potency factor?) of suspended solids concentration or load, this offers another option for prediction of annual loads. Lager et al. (1977), Manning et al. (1977) and Zison (1980) provide summaries of such values.

3.3 Spreadsheets

Microcomputer spreadsheet software, e.g., Lotus, Quattro, Excel, is now ubiquitous in engineering practice. Very extensive and highly sophisticated engineering analysis is routinely implemented on spreadsheets, and water quality simulation is no exception. In essence, the spreadsheet may be used to automate and extend the concept of the constant concentration idea. In the usual manifestation of this spreadsheet application, runoff volumes are calculated very simplistically, usually using a runoff coefficient times a rainfall depth. The coefficient may vary according to land use, or an SCS procedure may be used, but the hydrology is inherently simplistic in the spreadsheet predictions. The runoff volume is then multiplied by a constant concentration to predict runoff loads. The advantage of the spreadsheet is that a mixture of land uses (with varying concentrations) may easily be simulated, and an overall load and flow-weighted concentration obtained from the study area (Walker et al., 1989). The study area itself may range from a single catchment to an entire urban area. The relative contributions of different land uses may be easily identified, and handy spreadsheet graphics tools used for display of the results.

As an enhancement, control options may be simulated by application of a constant removal fraction for an assumed BMP. Although spreadsheet computations can be amazingly complex, BMP simulation is rarely more complicated than a simple removal fraction because anything further would require simulation of

the dynamics of the removal device (e.g., a wet detention pond), which is usually beyond the scope of the hydrologic component of the spreadsheet model. Nonetheless, if simple BMP removal fractions can be believed, the spreadsheet can easily be used to estimate the effectiveness of control options. Loads with and without controls can be estimated and problem areas, by contributing basin and land use, can be determined. Since most engineers are familiar with spreadsheets, such models can be developed in-house in a logical manner.

The spreadsheet approach is best suited to estimation of long-term loads, such as annual or seasonal, because very simple prediction methods generally perform better over a long averaging time and poorly at the level of a single storm event. Hence, although the spreadsheet could be used at the microscale (at or within a storm event) it is most often applied for much longer time periods. It is harder to obtain the variation of predicted loads and concentrations using the spreadsheet method because this can ordinarily only be done by varying the input concentrations or rainfall values. A Monte Carlo simulation may be attempted (i.e., systematic variation of all input parameters according to an assumed frequency distribution) if the number of such parameters is not too large. These results may then be used to estimate the range and/or frequency distribution of predicted loads and concentrations.

In a generic sense, the spreadsheet idea may be used in methods programmed in other languages, e.g., Fortran. For example, comprehensive assessments of coastal zone pollution from urban areas are made by NOAA (1987) by assembling land use data with different runoff coefficients, predicting daily and seasonal runoff volumes from daily rainfall, and predicting seasonal pollutant loads using constant concentrations. Although the demographic data base and use of magnetic tapes may dictate use of mainframes, the computational concept is still that of a spreadsheet.

Again, the question arises of what concentrations to use, this time potentially for multiple land uses and subareas. And again, the NURP data base will usually be the first one to turn to, with the possibility of local monitoring to augment it.

3.4 Statistical Method

The so-called "EPA Statistical Method" is somewhat generic and until recently was not implemented in any off-the-shelf model or even very well in any single report (Hydroscience, 1979; EPA, 1983). A new FHWA study (Driscoll et al., 1989) partially remedies this situation. The concept is straightforward, namely that of a derived frequency distribution for EMCs. This idea has been used extensively for urban runoff quantity (e.g., Howard, 1976; Loganathan and Delleur, 1984; Zukovs et al., 1986) but not as much for quality predictions.

The EPA Statistical Method utilizes the fact that EMCs are not constant but tend to exhibit a lognormal frequency distribution. When coupled with an assumed distribution of runoff volumes (also lognormal), the distribution of runoff loads may be derived. When coupled again to the distribution of streamflow, an approximate (lognormal) probability distribution of in-stream concentrations may be derived (Di Toro, 1984) a very useful result, although assumptions and limitations of the method have been pointed out by Novotny (1985) and Roesner and Dendrou (1985). Further analytical methods have been developed to account for storage and treatment (Di Toro and Small, 1979; Small and Di Toro, 1979). The method was used as the primary screening tool in the EPA NURP studies (EPA, 1983) and has also been adapted to combined sewer overflows (Driscoll, 1981) and highway-related runoff (Driscoll et al., 1989). This latter publication is one of the best for a concise explanation of the procedure and assumptions and includes spreadsheet software for easy implementation of the method.

A primary assumption is that EMCs are distributed lognormally at a site and across a selection of sites. The concentrations may thus be characterized by their median value and by their coefficient of variation (CV = standard deviation divided by the mean). There is little doubt that the lognormality assumption is good (Driscoll, 1986), but similar to the spreadsheet approach, the method is then usually combined with weak hydrologic assumptions, e.g., prediction of runoff using a runoff coefficient. (The accuracy of a runoff coefficient increases as urbanization and imperviousness increase.) However, since many streams of concern in an urban area consist primarily of stormwater runoff during wet weather, the ability to predict the distribution of EMCs is very useful for

assessment of levels of exceedance of water quality standards. The effect of BMPs can again be estimated crudely through constant removal fractions that effect on the coefficient of variation. Overall, the method has been very successfully applied as a screening tool.

Input to the method as implemented for the FHWA (Driscoll et al., 1989) includes statistical properties of rainfall (mean and coefficient of variation of storm event depth, duration, intensity and interevent time), area, and runoff coefficient for the hydrologic component, plus EMC median and coefficient of variation for the pollutant. Generalized rainfall statistics have already been calculated for many locations in the U.S. Otherwise, the EPA SYNOP model (EPA, 1976b; Hydroscience, 1979; EPA, 1983; Woodward-Clyde, 1989) must be run on long-term hourly rainfall records. If receiving water impact is to be evaluated the mean and CV of the streamflow are required plus the upstream concentration. A Vollenweider-type lake impact analysis is also provided based on phosphorus loadings.

As with the first two methods discussed, the choice of median concentration may be difficult, and the Statistical Method requires a coefficient of variation as well. Fortunately, from NURP and highway studies, CV values for most urban runoff pollutants are fairly consistent, and a value of 0.75 is typical. If local and/or NURP data are not available or inappropriate, local monitoring may be required, as in virtually every quality prediction method. The estimation of the whole EMC frequency distribution for a pollutant is a definite advantage of the Statistical Method over some applications of constant concentration and simple spreadsheet approaches. Frequency analyses of water quantity and quality parameters may also be performed on the output of continuous simulation models such as HSPF, SWMM and STORM. The derived distribution approach of the Statistical Method avoids the considerable effort required for continuous simulation at the expense of simplifying assumptions that may or may not reflect the prototype situation adequately.

3.5 Regression? Rating Curve Approaches

With the completion of the NURP studies in 1983, there are measurements of rainfall, runoff and water quality at well over 100 sites in over 30 cities. Some regression analysis has been performed to try to relate

loads and EMCs to catchment, demographic and hydrologic characteristics (e.g., McElroy et al., 1976; Miller et al., 1978; Brown, 1984), the best of which are recent results of the USGS (Tasker and Driver, 1988; Driver and Tasker, 1988), to be described briefly below. Regression approaches have also been used to estimate dry-weather pollutant deposition in combined sewers (Pisano and Queiroz, 1977), a task at which no model is very successful. What are termed 'rating curves' herein are just a special form of regression analysis, in which concentration and/or loads are related to flow rates and/or volumes. This is an obvious exercise attempted at most monitoring sites and has a historical basis in sediment discharge rating curves developed as a function of flow rate in natural river channels.

A rating curve approach is most often performed using total storm event load and runoff volume although intra-storm variations can sometimes be simulated in this manner as well (e.g., Huber and Dickinson, 1988). It is usually observed (Huber, 1980; EPA, 1983; Driscoll et al., 1989) that concentration (EMC) is poorly or not correlated with runoff flow or volume, implying that a constant concentration assumption is adequate. Since the load is the product of concentration and flow, load is usually well correlated with flow regardless of whether or not concentration correlates well. Manifestation of spurious correlation (Benson, 1962) is often ignored in urban runoff studies. If load is proportional to flow to the first power (i.e., linear), then the constant concentration assumption holds; if not, some relationship of concentration with flow is implied. Rating curve results can be used by themselves for load and EMC estimates and can be incorporated into some models (e.g., SWMM, HSPF).

Rainfall, runoff and quality data were assembled for 98 urban stations in 30 cities (NURP and other) in the U.S. for multiple regression analysis by the USGS (Driver and Tasker, 1988; Tasker and Driver 1988). Thirty-four multiple regression models (mostly log-linear) of storm runoff constituent loads and storm runoff volumes were developed, and 31 models of storm runoff EMCs were developed. Regional and seasonal effects were also considered. The two most significant explanatory variables were total storm rainfall and total contributing drainage area. Impervious area, land use, and mean annual climatic characteristics also were significant explanatory variables in some of the models. Models for estimating loads of dissolved solids, total nitrogen,

and total ammonia plus organic nitrogen (TKN) generally were the most accurate, whereas models for suspended solids were the least accurate. The most accurate models were those for the more arid Western U.S., and the least accurate models were those for areas that had large mean annual rainfall.

These USGS equations represent the best generalized regression equations currently available for urban runoff quality prediction. Note that such equations do not require preliminary estimates of EMCs or local quality monitoring data except for the very useful exercise of verification of the regression predictions. Regression equations only predict the mean and do not provide the frequency distribution of predicted variable, a disadvantage compared to the statistical approach. (The USGS documentation describes procedures for calculation of statistical error bounds, however). Finally, regression approaches, including rating curves, are notoriously difficult to apply beyond the original data set from which the relationships were derived. That is, they are subject to very large potential errors when used to extrapolate to different conditions. Thus, the usual caveats about use of regression relationships continue to hold when applied to prediction of urban runoff quality.

3.6 Buildup and Washoff

In the late 1960s, a Chicago study by the American Public Works Association (1969) demonstrated the (assumed linear) buildup of 'dust and dirt' and associated pollutants on urban street surfaces. During a similar time frame, Sartor and Boyd (1972) also demonstrated buildup mechanisms on the surface as well as an exponential washoff of pollutants during rainfall events. These concepts were incorporated into the original SWMM model (Metcalf and Eddy et al., 1971) as well as into the STORM, USGS and HSPF models to a greater or lesser degree (Huber, 1985). 'Buildup' is a term that represents all of the complex spectrum of dry-weather processes that occur between storms, including deposition, wind erosion, street cleaning, etc. The idea is simply that all such processes lead to an accumulation of solids and perhaps other pollutants that are then 'washed off' during storm events.

Although ostensibly physically based, models that include buildup and washoff mechanisms really employ conceptual algorithms because the true physics is related to principles of sediment transport and erosion that are poorly understood in this framework. Furthermore, the inherent heterogeneity of urban surfaces leads to use of average buildup and washoff parameters that may vary significantly from what may occur in an isolated street gutter, for example. Thus, except in rare instances of measurements of accumulations of surface solids, the use of buildup and washoff formulations inevitably results in a calibration exercise against measured end-of-pipe quality data. It then holds that in the absence of such data, inaccurate predictions can be expected.

Different models offer different options for conceptual buildup and washoff mechanisms, with SWMM having the greatest flexibility. In fact, with calibration, good agreement can be produced between predicted and measured concentrations and loads with such models, including intra-storm variations that cannot be duplicated with most of the methods discussed earlier. (When a rating curve is used in SWMM instead of buildup and washoff, it is also possible to simulate intra-storm variations in concentration and load.) A survey of linear buildup rates for many pollutants by Manning et al. (1977) is probably the best source of generalized buildup data, and some information is available in the literature to aid in selection of washoff coefficients (Huber 1985; Huber and Dickinson, 1988). However, such first estimates may not even get the user in the ball park (i.e., quality, not quantity; predictions may be off by more than an order of magnitude); the only way to be sure is to use local monitoring data for calibration and verification. Thus, as for most of the other quality prediction options discussed herein, the buildup-washoff model may provide adequate comparisons of control measures, ranking of loads, etc. but cannot be used for prediction of absolute values of concentrations and loads, e.g., to drive a receiving water quality model, without adequate calibration and verification data. Since buildup and washoff are somewhat appealing conceptually, it is somewhat easier to simulate potential control measures such as street cleaning and surface infiltration using these mechanisms than with, say, a constant concentration or rating curve method. In the relatively unusual instance in which intra-storm variations in concentration and load must be simulated, as opposed to total storm event EMC or load, buildup and washoff

also offer the most flexibility. This is sometimes important for the design of storage facilities in which first-flush mechanisms may be influential.

As mentioned above, generalized data for buildup and washoff are sparse (Manning et al., 1977) and such measurements almost never conducted as part of a routine monitoring program. For buildup, normalized loadings, e.g., mass/day-area or mass/day per curb-length, or just mass/day, are required, along with an assumed functional form for buildup vs. time, e.g., linear, exponential, Michaelis-Menton, etc. For washoff, the relationship of washoff (mass/time) vs. runoff rate must be assumed, usually in the form of a power equation. When end-of-pipe concentration and load data are all that are available, all buildup and washoff coefficients end up being calibration parameters.

3.7 Related Mechanisms

In the discussion above, washoff is assumed proportional to the runoff rate, as for sediment transport. Erosion from pervious areas may instead be proportional to the rainfall rate. HSPF does the best job of including this mechanism in its algorithms for erosion of sediment from pervious areas. SWMM includes a weaker algorithm based on the Universal Soil Loss Equation.

Many pollutants, particularly metals and organics, are adsorbed onto solid particles and are transported in particulate form. The ability of a model to include ?potency factors? (HSPF) or ?pollutant fractions? (SWMM) enhance the ability to estimate the concentration or load of one constituent as a fraction of that of another constituent, e.g., solids (Zison, 1980).

The groundwater contribution to flow in urban areas can be important in areas with unlined and open channel drainage. Of the urban models discussed, HSPF far and away has the most complex mechanisms for simulation of subsurface water quality processes in both the saturated and unsaturated zones. Although SWMM includes subsurface flow routing, the quality of subsurface water can only be approximated using a constant concentration.

The precipitation load may be input in some models

(SWMM, HSPF), usually as a constant concentration. Point source and dry-weather flow (baseflow) loads and concentrations can also be input to SWMM, STORM and HSPF to simulate background conditions. Other quality sources of potential importance include catchbasins (SWMM) and snowmelt (SWMM, STORM, HSPF).

Scour and deposition within the sewer system can be very important in combined sewer systems and some separate storm sewer systems. The state of the art in simulation of such processes is poor (Huber, 1985). SWMM offers a crude but calibratable attempt at simulation of such processes.

Table 3. Data needs for various quality prediction methods

Method	Data	Potential Source
Unit Load	Mass per time per unit tributary area.	Derive from constant concentration and runoff. Literature values.
Constant Concentration	Runoff prediction mechanism (simple to complex).	Existing model; runoff coefficient or simple method.
	Constant concentration for each constituent.	NURP; local monitoring.
Spreadsheet	Simple runoff prediction mechanism.	e.g., runoff coefficient, perhaps as function of land use.
	Constant concentration or concentration range.	NURP; local monitoring.
	Removal fractions for controls.	NURP; Schueler (1987); local and state publications.
Statistical	Rainfall statistics.	NURP; Driscoll et al. (1989); Woodward-Clyde (1989); EPA SYNOP model.
	Area, imperviousness. Pollutant median and CV.	NURP; Driscoll (1986); Driscoll et al. (1989); local monitoring.
	Receiving water characteristics and statistics.	Local or generalized data.
Regression	Storm rainfall, area, imperviousness, land use.	Local data.
Rating Curve	Measured flow rates/volumes and quality EMCs/loads.	NURP; local data.
Buildup	Loading rates and rate constants.	Literature values [*] .
	Street cleaning removals.	Literature values.
Washoff	Power relationship with runoff.	Literature values [*] .

^{*}Usually must be calibrated using end-of-pipe monitored quality data.

Section 4.0

Overview of Available Non-urban Modeling Options

As with the options for modeling nonpoint source pollutants from urban areas, a wide range of techniques are available for modeling these contributions from non-urban land uses, from simple annual 'loading functions' to detailed process simulation models. The key issue in estimating nonpoint pollution loads from a watershed, or parcel of land, is the type and extent of human activities occurring (or *not* occurring) on the land. The same hydrologic, physical, and chemical/biological processes that determine nonpoint pollutant loads occur on all land surfaces (and in the soil profile) whether it is urban, forest, agricultural cropland, pasture, mining, etc. The relative importance and magnitude of these processes, in determining nonpoint loads, will vary among land use categories and associated human activities. Even within an urban region, the parameters required for the various modeling options described in Section 4 will differ for commercial, industrial, transportation, and various densities of residential land. Many of these same urban modeling options have been used for non-urban land areas with parameters (e.g., constant concentrations) estimated for the specific non-urban land use.

The focus of the majority of non-urban nonpoint source estimation procedures and models has been on agricultural cropland, although the procedures and models have often been adapted and applied to many other land use categories. The agricultural research community, comprised of the U.S. Department of Agriculture (including the Soil Conservation Service and Agricultural Research Service) regional laboratories and state universities, have developed a significant body of knowledge of soil processes and procedures for estimating runoff and soil erosion that have formed the 'building blocks' for loading functions and nonpoint source models. This section discusses some of the loading function procedures available for agricultural and other non-urban areas and general concepts underlying the more detailed

process simulation models. The individual detailed models will be discussed briefly in Section 5.2 with additional details provided in the Appendix.

4.1 Nonpoint Source Loading Functions

The term 'loading function' has been used in the nonpoint pollution literature to describe simple calculational procedures usually for estimating the *average annual load*, and sometimes the storm event load, of a pollutant from an individual land use category. A number of different loading functions have been developed and proposed over the past two decades, the most widely used of which are the EPA Screening Procedures, also referred to as the EPA Water Quality Assessment Methodology. These procedures are described below, followed by a brief discussion of a few other loading functions in the literature.

4.1.1 EPA Screening Procedures

The EPA Screening Procedures (Mills et al., 1985; Mills et al., 1982) are a revision and expansion of water quality assessment procedures initially developed for nondesignated 208 areas (Zison et al., 1977). The Procedures have been expanded and revised to include consideration of the accumulation, transport, and fate of toxic chemicals, in addition to conventional pollutants included in the earlier versions. The manual includes a separate chapter describing calculation procedures for estimating nonpoint loads for urban and non-urban land areas in addition to chapters on procedures for rivers and streams, impoundments, and estuaries. The most recent update includes consideration of toxics loadings and fate/transport in groundwater systems.

The procedures for nonpoint load assessments described in the manual are essentially a compilation

and integration of techniques developed earlier by Midwest Research Institute (MRI) (McElroy et al., 1976), Amy et al. (1974), Heaney et al. (1976) and Haith (1980). However, the presentation of the procedures is well-integrated, supplemented with additional parameter estimation guidance, and includes sample calculations. The procedures for non-urban areas are derived from the MRI loading functions for average annual estimates based on the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978), while the storm event procedures use the Modified USLE (Williams, 1975) and the SCS Runoff Curve Number procedure (Mockus, 1972) for storm runoff volume. Pollutant concentrations in runoff and soil, and enrichment ratios are required for estimating pollutant loads; precipitation contributions of nutrients can be included. Specific information is included for estimation of salinity loads in irrigation return flows. Separate equations are provided for estimating loads for sorbed pollutants, dissolved pollutants, and partitioned pollutants (i.e., both sorbed and dissolved phases); this latter category is primarily for pesticides for which the procedures were developed by Haith (1980) for storm event loads. Guidance is provided for estimating *all* required parameters.

The primary strengths and advantages of the EPA Screening Procedures are as follows:

- a. Excellent user documentation and guidance, including occasional workshops sponsored by the EPA Center for Exposure Assessment Modeling, in Athens, GA.
- b. No computer requirements since the procedures can be performed on hand calculators; associated programs have been developed for river quality analyses (Mills et al., 1979).
- c. Loading calculations and procedures can be linked to water quality procedures in other chapters to assess water quality impacts of nonpoint source loads.
- d. Relatively simple procedures with minimal data requirements that can be satisfied from the user manual when site-specific data are lacking.

These screening procedures are well suited for general screening-level assessments; however, they suffer from the same disadvantages as all such gross estimation techniques. As with the urban options

discussed above, the accuracy of the loads depends on the accuracy of the user-assumed pollutant concentration; the impacts of management options is usually represented by a simple, constant 'removal fraction'; snowmelt and associated loadings are not represented; and calculations can be tedious and time consuming for complex multi-land use basins. In spite of these disadvantages and limitations, the EPA Screening Procedures are appropriate for many types of nonpoint load assessments. They have enjoyed wide popularity, partly due to the availability of training workshops sponsored by EPA, and have been applied in a number of regions, including the Sandusky River in northern Ohio and the Patuxent, Ware, Chester, and Occoquan basins in the Chesapeake Bay region (Davis et al., 1981; Dean et al., 1981a; Dean et al., 1981b). Although the procedures are quite amenable to a computerized or spreadsheet implementation, to our knowledge no effort has been made to implement such a format.

4.1.2 Other Loading Functions

As noted earlier, other loading functions have been developed and proposed by various groups and authors, though none have the support nor have they demonstrated the longevity of the EPA Screening Procedures. The WRENS handbook (Water Resources Evaluation of Nonpoint Silvicultural Sources, U.S. Forest Service (1980)) is similar to the EPA procedures but its focus is directed to the effects of forestry activities on water quality. The handbook provides quantitative techniques for estimating potential changes in streamflow, surface erosion, soil mass movement, total potential sediment discharge, and water temperature for comparative analyses of alternative silvicultural management practices. Runoff and erosion estimation techniques are similar to those used in the EPA Screening Procedures with parameters modified for forestry conditions.

Haith and Tubbs (1981) developed watershed loading functions as a screening tool to evaluate agricultural nonpoint source pollution in large watersheds. These functions also use the SCS Curve Number procedure for runoff estimation and the USLE for erosion; then, based on user-defined pollutant concentrations in runoff and attached to sediment, the procedures allow calculation of loadings to receiving waters. These functions have been added to the most recent update of the EPA Screening Procedures manual (i.e., 1985). A validation of the loading functions for a 850 km² watershed is described by Haith and Shoemaker

(1987).

More recently, Li et al. (1989) have proposed loading functions for estimating the average annual pesticide loads in surface runoff. They developed regression equations derived from 100-year simulations of daily pesticide runoff using the Haith (1980) pesticide model. The regression equation coefficients are based on pesticide half life and soil partition coefficients, and are tabulated in the article for a wide range of values. Two different regressions are described: one based simply on mean annual soil erosion, and the other based on mean annual soil erosion and surface runoff volume during the month of pesticide application.

4.1.3 Discussion

The loading functions discussed above, and other similar techniques in the literature, differ from the simulation models primarily in time scale definition and their simplified, mostly empirical techniques for estimating nonpoint loads. They are used primarily to estimate average annual or event loads, and potential changes in these loads with land use and management practice. These procedures and associated calculations can usually be performed with a hand calculator, and with proliferation of personal computers and advances in computer technology we can expect to see more and more of these techniques available on PCs. However, users should not interpret the aura of implementation on a PC as an improvement in the capabilities, accuracy, or validity of these techniques. There are significant limitations in these procedures, because of their simplified nature, especially for evaluation of the impacts of management practices. As described above, they often require user-specified concentrations of pollutants in runoff and/or attached to sediment; some assume the total pollutant load can be estimated as a function of sediment alone.

Unfortunately, a comprehensive data base, comparable to the NURP data base for urban areas, does not exist for estimating the needed input concentrations for the wide range of non-urban land use categories. Also, there appears to be much greater variability in runoff concentrations from non-urban land than from urban land areas; consequently, extrapolation of concentrations from other sites may be less appropriate for non-urban land categories. Agricultural cropland is especially difficult to represent by single-valued 'representative' concentrations due to differences in crops, fertilizer

applications, tillage practices, agronomic practices, soils characteristics, etc.

In spite of these limitations, loading functions can be useful for general screening assessments to identify relative nonpoint contributions under different conditions as long as their assumptions and limitations are recognized. They are more popular than the detailed simulation models and have thus been applied more frequently, primarily because of their ease of use. Also, the loading functions are a very useful precursor to more detailed modeling studies for general problem assessment and identification and to determine if such detailed studies are warranted.

4.2 Simulation Models

The primary differences between nonpoint runoff simulation models and the loading functions described above relate to the temporal and spatial detail of the analysis, along with (usually) a more refined representation of the processes that determine nonpoint pollutant loadings. Whereas the loading functions can be used with only a hand calculator (or spreadsheet), the added detail of most simulation models requires a computer code, computer facilities, and significantly more input data, such as daily rainfall and possibly other meteorologic timeseries. These models are most often computerized procedures that perform hydrologic (runoff), sediment erosion, and pollutant (chemical/ biological) calculations on short time intervals, usually ranging from one hour to one day, for many years. The resulting values for each time interval, e.g., runoff, sediment, pollutant load or concentration, can be analyzed statistically and/or aggregated to daily, monthly, or annual values for estimates of nonpoint loadings under the conditions simulated.

As with the urban models, a wide range of nonpoint models appropriate for non-urban areas are available and have been used for many different types of land categories. The available models also cover a large range of complexity depending on the extent to which hydrologic, sediment erosion, and chemical/ biological processes are modeled in a mechanistic manner or based on empirical procedures. Similar to urban modeling, many of the same simple procedures and assumptions used in the loading functions are also incorporated into a number of simulation

models, e.g., USLE, SCS Curve Number, constant pollutant concentration. Section 5.2 provides brief summaries of a number of the more widely used and 'operational' non-urban models, along with a brief discussion of relative strengths and weaknesses; additional details for each of the models is provided in the Appendix.

In the remainder of this section, we discuss the two major modeling efforts that have dominated the non-urban (primarily agricultural) nonpoint modeling arena over the past two decades as a basis for describing the types of modeling techniques used for non-urban land uses. In addition, we will briefly discuss the key differences between urban and non-urban models and identify a number of ongoing model development efforts.

4.2.1 HSPF and CREAMS Model Development

The 1970's and early 1980's was a period of increasing pollution, and corresponding development of mathematical models to both characterize the pollutant loadings and water quality impacts, and evaluate alternative means of control. During this period the EPA, through the Athens-ERL, sponsored a number of model development and testing efforts (i.e., PTR, ARM, NPS, WEST) culminating in the HSPF model² Hydrologic Simulation Program-Fortran (Johanson et al, 1980). Barnwell and Johanson (1981) discuss the various model development and testing efforts leading to the initial release of HSPF in 1980; HSPF is currently in Release No. 9 (Johanson et al., 1984) as a result of numerous enhancements and code corrections. The focus of the model development was the ability to represent contributions of sediment, pesticides, and nutrients from agricultural areas, and evaluate resulting water quality conditions at the watershed scale considering both nonpoint contributions and instream water quality processes. Only the nonpoint capabilities of HSPF (i.e., PERLND and IMPLND modules) are discussed in this report.

Coincident with the HSPF (and predecessor models) development, the U.S. Department of Agriculture through the Agricultural Research Service (ARS) assembled a group of ARS scientists to refine, improve, and integrate existing models into a package for representing runoff, sediment, nutrient, and pesticide runoff from agricultural fields. The effort was initiated in 1977 and the resulting CREAMS model (Chemicals, Runoff, and Erosion from Agricultural Management Systems) (Knisel, 1980) was

first published in 1980. Since its initial release, CREAMS has undergone testing and application and a companion version, called GLEAMS (Leonard et al., 1986) has been developed with special emphasis on vadose zone processes to represent movement of chemicals to groundwater.

CREAMS and HSPF PERLND are the most detailed, operational models of agricultural runoff available at the current time. In many ways, they are more alike than they are different. Both models simulate runoff and erosion from field size areas, using different methods, and both simulate land surface and soil profile chemical/biological processes (using similar methods) that determine the fate and transport of pesticides and nutrients. Figure 1 shows the structure of the various subroutines that comprise the HSPF PERLND module; note that the Agrichemical Modules of PERLND perform the soil chemical/biological process simulation. Figure 2 conceptually shows the structure and processes simulated for pesticides and nutrients in the ARM model which was the basis for the HSPF Agrichemical Modules. Figure 3 includes analogous diagrams for CREAMS, showing the structure of the model and the processes involved in estimating nutrient losses in runoff and through leaching. Although the hydrology and sediment algorithms are different for the two models, the soil processes that determine the availability of chemicals for runoff and leaching are quite similar; both consider sorption/desorption, plant uptake, soil transformations (e.g., mineralization, nitrification), attenuation/decay, etc. that control the fate and migration of chemicals in the soil.

The two models differ primarily in their scope and level of detail, largely as a result of their historical origins. HSPF PERLND was derived from the Stanford Watershed Model (SWM) which was subsequently used as the basis for the HSP, ARM, and NPS models forming the predecessor components for HSPF. This model development effort originated in the hydrologic research community with emphasis on not only runoff modeling but also on watershed scale modeling, including both runoff and hydraulic routing needed for large watersheds and river basins. When EPA selected SWM as the basis for modeling nonpoint pollutant runoff, their ultimate goal was to be able to evaluate the downstream water quality impacts of pesticide and nutrient runoff from agricultural lands. Consequently, HSPF considers *all* streamflow components² surface runoff, interflow,

baseflow⁷ **and** their pollutant contributions (as shown in Figure 2), and then allows direct linkage of these contributions to an instream water quality model. Also, since HSP and NPS included algorithms for urban runoff loadings, and since most large watersheds would include a variety of land use types, HSPF includes many of the simplified options (described above in Section 4.1) for modeling runoff from *any* land category, including both pervious and impervious urban categories.

On the other hand, CREAMS is a product of the agricultural research community with specific emphasis on representing soil profile and field-scale processes at the level of detail appropriate for design of field-based agricultural management systems. Thus, CREAMS allows more detailed representation of field terraces, drainage systems, field topography, etc. and associated sediment erosion processes. A detailed hydrology option is available, requiring breakpoint rainfall (i.e., short time interval rainfall, hourly or less), or the popular SCS Curve Number procedure can be used with daily rainfall. Because of its field-scale focus, CREAMS is limited to representing only *surface runoff* contributions; subsurface and leaching losses of chemicals are simply removed from the system. The original CREAMS documentation published in 1980 indicated that an effort to expand the model to a basin-scale was underway. The SWAM model (DeCoursey, 1982; Alonso and DeCoursey, 1985) uses CREAMS as a source area component and adds the capabilities to consider watershed and basin scale analyses; however, the model development effort is still underway at this time and SWAM is not currently considered 'operational' in terms of documentation and use by non-developers (DeCoursey, personal communication, 1990). CREAMS has been used as the source area model by a number of investigators for specific studies (e.g. SWRRB (Williams et al., 1985), ADAPT (Ward et al., 1988), ARDBSN (Devaurs et al., 1988)) but no fully integrated, operational package with CREAMS for use at the basin/watershed scale is available comparable to HSPF.

4.2.2 Other Non-Urban Nonpoint Models

Many other non-urban nonpoint models exist in the modeling community and have been used to varying degrees, but each has been used by the developers, a few, by outside users. A comprehensive review of *all* available and relevant nonpoint models was well beyond the scope of this review effort. Below we discuss a few additional models, selected by the authors, that have been applied more often than typical 'research' models, but they may not fully satisfy the definition of an 'operational' model described in Section 2.2. The ANSWERS, AGNPS, PRZM, SWRRB/PRS, and UTM-TOX models are discussed briefly below; a paragraph description is included in Section 5.2 and additional details are provided in the Appendix.

The ANSWERS model (Areal Nonpoint Source Watershed Environment Response Simulation) developed by Beasley and Huggins (1981) at Purdue University differs from most other nonpoint models in that it is an 'event', distributed-parameter model, as opposed to a continuous, lumped parameter modeling approach. ANSWERS is designed primarily to simulate single storm events, and requires that the watershed be subdivided into grid elements with parameter information provided for each element; most continuous nonpoint models only require specification of average or mean parameter values for a watershed or subwatershed area. The ANSWERS approach imposes greater computational burden and spatial data requirements, thus limiting most analyses to single 'design' storms. However, the additional spatial detail allows greater evaluation of source areas within a specific watershed area if required by the problem assessment. ANSWERS is primarily a runoff and sediment model; the nutrient simulation is based on simple correlations between concentration and sediment yield/runoff volume; soil nutrient processes are not simulated.

The AGNPS model (Agricultural Nonpoint Source Pollution Model) developed by the USDA Agricultural Research Service (Young et al., 1986) is one of the most recent nonpoint models and thus has limited demonstrated experience. It is designed to simulate runoff, sediment, and nutrients from watershed-scale areas for either single event or continuous periods. It uses a distributed approach, similar to ANSWERS, whereby the watershed area is divided into cells, model computations are done at the cell level, and runoff, sediment, and nutrients are

routed from cell to cell from the watershed boundaries to the outlet. AGNPS uses the SCS curve number approach combined with a unit hydrograph routing procedure, the Modified USLE, and simple correlations of extraction coefficients of nutrients in runoff and sediment. AGNPS can accommodate point source inputs from feedlots, wastewater treatment plants, and user-defined stream bank and gully erosion. Because of its distributed approach, its spatial data requirements are similar to ANSWERS.

The PRZM model (Pesticide Root Zone Model) (Carsel et al., 1984) was developed by the EPA Athens laboratory for modeling the fate of pesticides within the crop root zone, and subsequent leaching to groundwater. However, it includes a runoff and erosion component based on the SCS curve number and Modified USLE, respectively. PRZM represents dissolved, adsorbed, and vapor phase chemical concentrations in the soil by modeling the processes of surface runoff, erosion, evapotranspiration, plant uptake, soil temperature, pesticide decay, volatilization, foliar washoff, advection, dispersion, and decay. The most recent version of PRZM is included in an integrated root/vadose/groundwater model called RUSTIC recently released by the EPA Athens Laboratory (Dean et al., 1989). PRZM is currently limited to simulation of organic chemicals like pesticides, but its runoff and erosion components are similar to many other nonpoint models.

The SWRRB model (Simulator for Water Resources in Rural Basins) was developed by USDA (Williams et al., 1985; Arnold et al., 1989) for basin scale water quality modeling. Its runoff (SCS curve number) and erosion (Modified USLE) components are similar to the other nonpoint models, but SWRRB also includes channel processes and subsurface flow components to allow representation of large basin areas. It performs calculations on a daily timestep, and simulates hydrology, crop growth, sediment erosion, sediment transport, and nitrogen/phosphorus/pesticide movement in runoff. Its nutrient and pesticide

capabilities are derived from CREAMS; these are the most recent additions to the model and they are still undergoing testing and validation by the developers.

The UTM-TOX model (Unified Transport Model for Toxic Materials) (Patterson et al., 1983), developed by the Oak Ridge National Laboratory for the U.S. EPA Office of Pesticides and Toxic Substances, is a multimedia model that combines hydrologic, atmospheric, and sediment transport in one computer code. It is similar to HSPF in many ways, in terms of its comprehensive scope; its representation of soil, land surface, and channel processes; and its use of the Stanford Watershed Model as its hydrologic module. UTM-TOX provides a more detailed simulation of soil-plant processes, includes atmospheric transport and deposition, and is designed primarily for organic chemicals; no specific capabilities are included for nutrients or agricultural conditions. UTM-TOX, to our knowledge, has had limited application, possibly because of its relatively complex nature and the lack of user support.

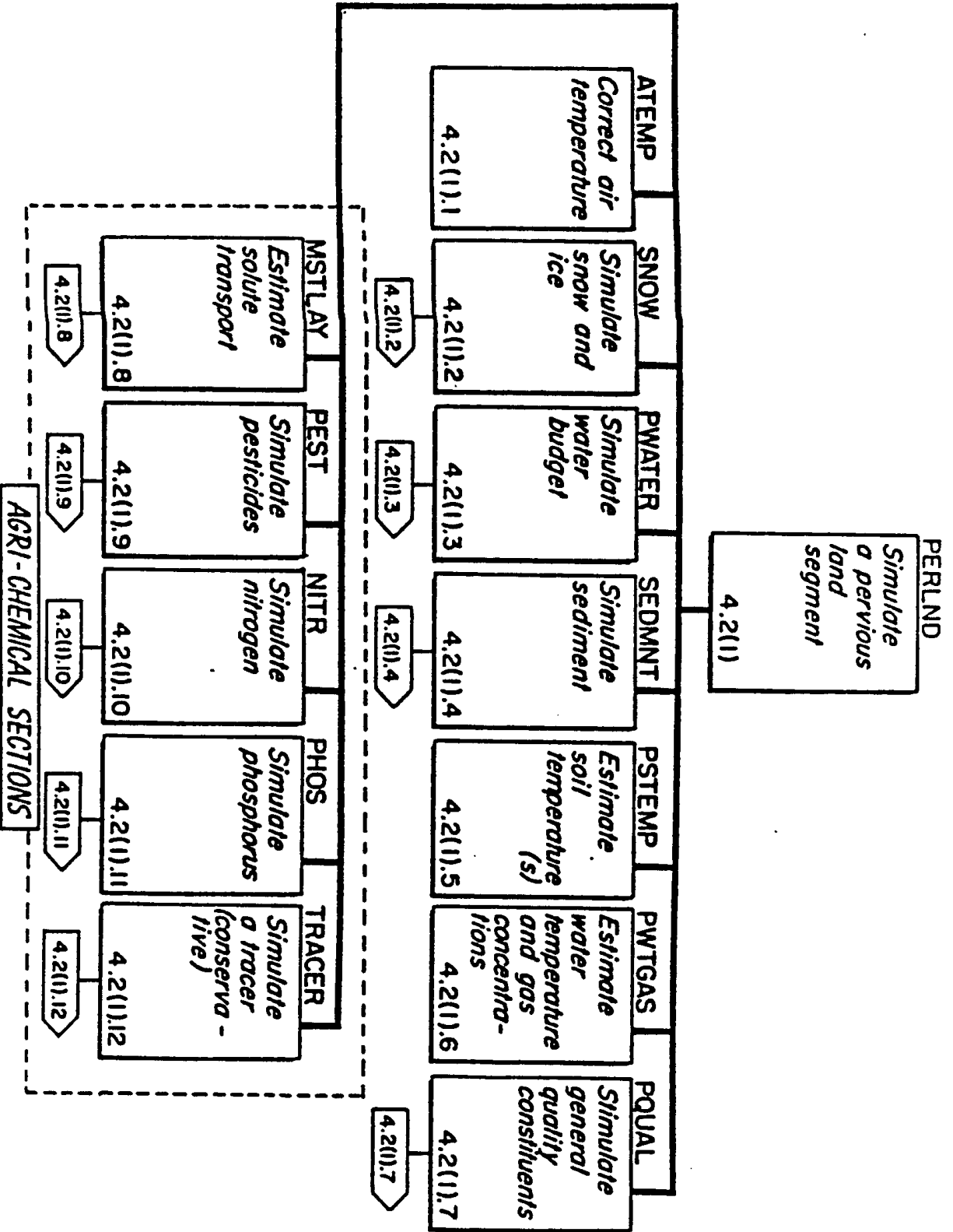
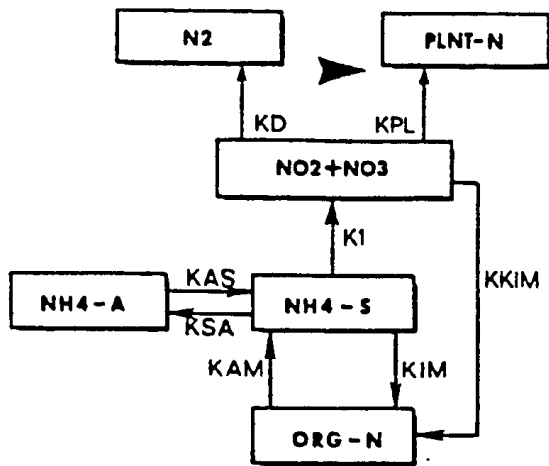
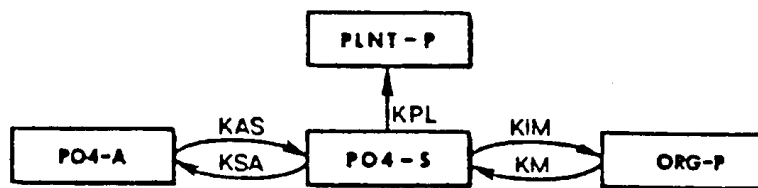


Figure 1. Subroutine structure for HSPF PERLND.

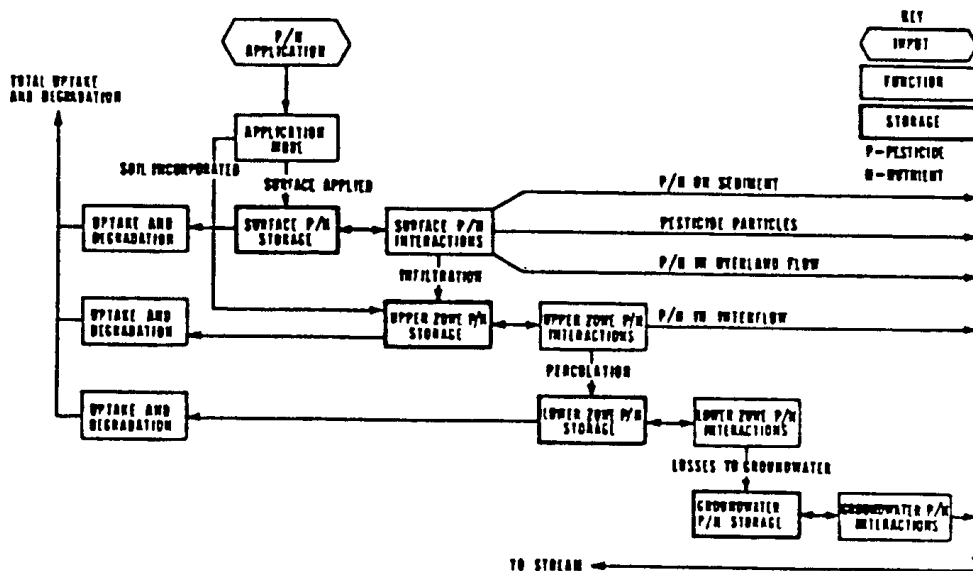


A. Nitrogen transformations in ARM model



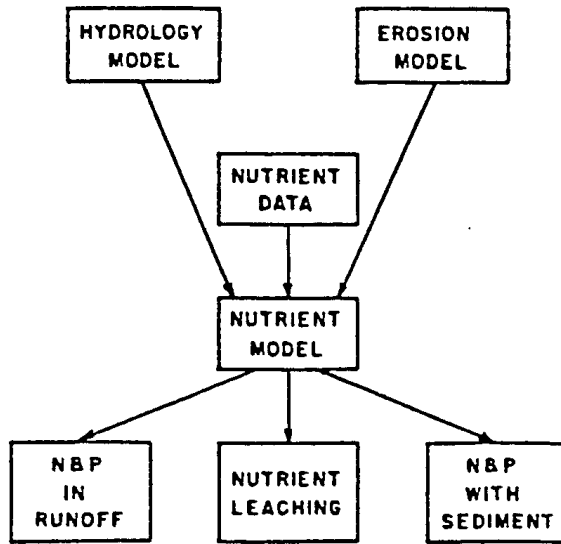
B. Phosphorus transformations in ARM model

Nutrient transformations in the ARM model



Pesticide (P) and nutrient (N) movement in the ARM model

Figure 2. ARM Model pesticide and nutrient and nutrient simulation included in HSPF PERLND.



Flow diagram of input and output for the nutrient model

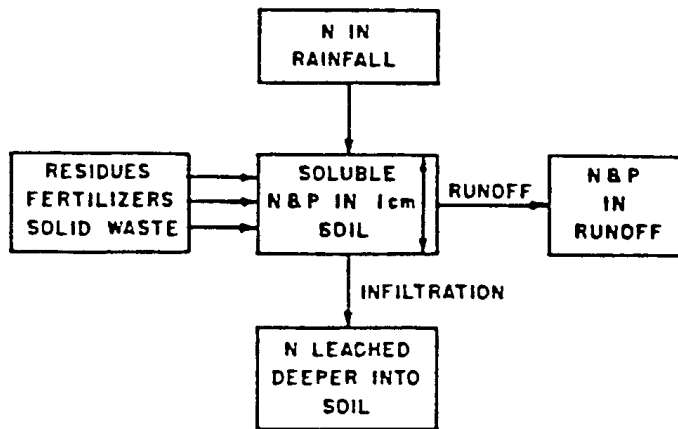


Diagram for estimating nutrient losses in runoff

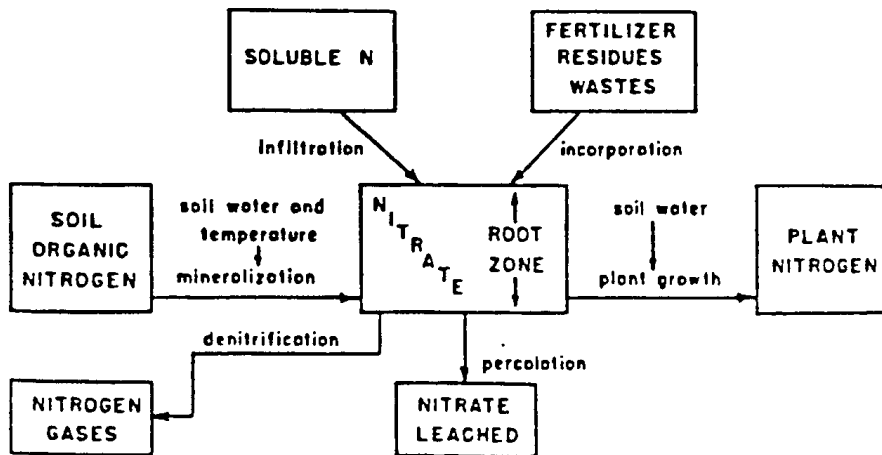


Diagram for estimating nitrate leaching

Figure 3. Nutrient simulation in CREAMS.

Section 5.0

Nonpoint Source Runoff Quality Simulation Models and Methods

5.1 Urban Runoff Quality Models

5.1.1 Introduction

Four models (USGS, HSPF, STORM, SWMM) will be described briefly at this point; extensive details about the four models may be found in the Appendix. These four models essentially make up the best choice of full-scale simulation models for urban areas. Other models have been adapted from SWMM (e.g., FHWA, RUNQUAL) and STORM (e.g., SEMSTORM) and given modified names, but the principles are fairly similar. Still other models, such as the Illinois State Water Survey ILLUDAS model (Terstriep and Stall, 1974) have sometimes been adapted for water quality simulation for a specific project (Noel and Terstriep, 1982), but such modifications and quality procedures remain undocumented, and the quality model can be considered not operational. At least two European models are available that simulate water quality. These are described briefly at the end of this section. Finally, there are many models well known in the hydrologic literature, such as those developed by the HEC and SCS, that might be useful in the hydrologic aspect of water quality studies but that do not simulate water quality directly. This review is limited to models that directly simulate water quality. A general comparison of model attributes is given in Table 4. This table includes the EPA Statistical Method since with the publication of the recent FHWA study, it can be considered a formalized procedure (Driscoll et al., 1989). The constant concentration, spreadsheet, and regression approaches described earlier are more generic in nature and not included in Table 4, but their attributes were provided in the earlier text.

5.1.2 DR3M-QUAL

A version of the USGS Distributed Routing Rainfall Runoff Model that includes quality simulation

(DR3M-QUAL) is available from that agency for general use (Alley and Smith, 1982a, 1982b). Runoff generation and subsequent routing use the kinematic wave method, and parameter estimation assistance is included in the model. Quality is simulated using buildup and washoff functions, with settling of solids in storage units dependent on a particle size distribution. The model has been used in some of the NURP studies that were conducted by the USGS (see the Appendix and Alley, 1986). No microcomputer version is available.

5.1.3 HSPF

The Hydrological Simulation Program² Fortran (HSPF) is the culmination of hydrologic routines that originated with the Stanford Watershed Model in 1966 and eventually incorporated many nonpoint source modeling efforts of the EPA Athens laboratory (Johanson et al., 1984). This model has been widely used for non-urban nonpoint source modeling and is described additionally in that section of this report as well as in detail in the Appendix. The user's manual includes information on all hydrologic and water quality routines, including the IMPLND (impervious land) segment for use in urban area. Additional guidelines for application are provided by Donigian et al. (1984). The model has special provisions for management of time series that result from continuous simulation. A microcomputer version is available.

5.1.4 STORM

The first significant use of continuous simulation in urban hydrology came with the Storage, Treatment, Overflow, Runoff Model (STORM), developed by the Corps of Engineers Hydrologic Engineering Center (HEC, 1977; Roesner et al., 1974) for application to the San Francisco master plan for CSO pollution abatement. The HEC also provides application

guidelines (Abbott, 1977). The current version includes dry-weather flow input for combined sewer simulation. The support of the HEC led to the wide use of STORM for planning purposes, especially for evaluation of the trade-off between treatment and storage as control options for CSOs (e.g., Heaney et al., 1977). Statistics of long-term runoff and quality time series permit optimization of control measures.

STORM utilizes simple runoff coefficient, SCS and unit hydrograph methods for generation of hourly runoff depths from hourly rainfall inputs. No flow routing is performed, but runoff may be routed through a constant-rate treatment device, with excess flow diverted to a storage device. Flows exceeding the treatment rate cause CSOs when storage is filled. The build-up and wash-off formulations are used for simulation of six pre-specified pollutants. However, the model can be manipulated to provide loads for arbitrary conservative pollutants (e.g., Najarian et al., 1986). The model is hampered somewhat by lack of an operational microcomputer version. However, various individual consultants have adapted the nonproprietary code to their own project needs.

5.1.5 SWMM

The original version of the Storm Water Management Model (SWMM) was developed for EPA as single-event model specifically for the analysis of CSOs (Metcalf and Eddy et al., 1971), but its scope has vastly broadened since the original release. Version 4 (Huber and Dickinson, 1988; Roesner et al., 1988) of the model performs both continuous and single-event simulation throughout the whole model, can simulate backwater, surcharging, pressure flow and looped connections (by solving the complete dynamic wave equations) in its Extran Block, and has a variety of options for quality simulation, including traditional build-up and wash-off formulations as well as rating curves and regression techniques. Subsurface flow routing (constant quality) may be performed in the Runoff Block in addition to surface quantity and quality routing, and treatment devices may be simulated in the Storage/Treatment Block using removal functions and sedimentation theory. A hydraulic design routine is included for sizing of pipes, and a variety of regulator devices may be simulated, including orifices (fixed and variable), weirs, pumps, and storage. A bibliography of SWMM usage is available (Huber et al., 1986) that contains many references to case studies.

SWMM is segmented into the Runoff, Transport,

Extran, Storage/Treatment and Statistics blocks for rainfall-runoff, routing, and statistical computations. Water quality may be simulated in all blocks except Extran, and metric units are optional. Since the model is non-proprietary, portions have been adapted for various specific purposes and locales by individual consultants and other federal agencies, e.g., FHWA. A microcomputer version is available.

5.1.6 Two European Models

The four U.S. models discussed above do not take advantage of graphics and other 'user-friendly' capabilities of microcomputers. Two well-known and commercially-available European models, MOUSE and Wallingford, are excellent examples of application of the full power of the microcomputer when used in conjunction with recent programming languages and graphics hardware and software. Both models feature menu-driven pre-processors for data input, graphical display and interactive editing of catchment boundaries and sewer networks, and post-processing of predicted hydrographs and pollutographs, including graphical displays and statistical analysis. Although the quality algorithms are relatively simple, the hydrologic and hydraulic components of both models are relatively sophisticated. The cost of each model is approximately \$15,000, including training and documentation but not the source code.

The Danish Hydraulic Institute, in cooperation with various other laboratories and private software firms has produced the MOUSE (Modeling of Urban Sewers) model. Included in the package are modules for generation of runoff from rainfall, sewer routing (the S11S model, comparable to the SWMM Extran Block), and a simple quality routine that uses the constant concentration approach (Jacobsen et al., 1984; Johansen et al., 1984). Further information on MOUSE is available from Danish Hydraulic Institute, Agern Alle 5, DK-2970 Hørsholm, Denmark.

The Wallingford model is maintained by Hydraulics Research Ltd. in the United Kingdom. It also consists of a cluster of modules, including runoff generation from rainfall (WASSP), simple and fully-dynamic sewer routing (WALLRUS and SPIDA, respectively), and a quality routine (MOSQUITO) featuring processes similar to those in SWMM (Henderson and Moys, 1987). Further information on the group of Wallingford models is available from Hydraulics Research Ltd., Wallingford, Oxfordshire OX10 8BA, United Kingdom.

5.2 Non-urban Runoff Quality Models and Methods

In this section we provide brief summaries of the primary non-urban runoff quality models reviewed; as noted earlier additional details on each model are provided in the Appendix. Below summaries are presented for HSPF, CREAMS/GLEAMS, ANSWERS, AGNPS, PRZM, SWRRB, and UTM-TOX, and Table 5 shows a comparison of selected model attributes and capabilities.

5.2.1 HSPF

The Hydrological Simulation Program²FORTRAN (HSPF) (Johanson et al., 1981; 1984) is a comprehensive package for simulation of watershed hydrology and water quality for both conventional and toxic organic pollutants. HSPF incorporates the watershed scale ARM and NPS models into a basin-scale analysis framework that includes fate and transport in one-dimensional stream channels. It is the only comprehensive model of watershed hydrology and water quality that allows the integrated simulation of land and soil contaminant runoff processes with instream hydraulic, water temperature, sediment transport, nutrient, and sediment-chemical interactions. The runoff quality capabilities include both simple relationships (i.e. empirical buildup/washoff, constant concentrations) and detailed soil process options (i.e., leaching, sorption, soil attenuation and soil nutrient transformations).

The result of this simulation is a time history of the runoff flow rate, sediment load, nutrient, pesticide, and/or user-specified pollutant concentrations, along with a time history of water quantity and quality at any point in a watershed. HSPF simulates three sediment types (sand, silt, and clay) in addition to a single organic chemical and transformation products of that chemical. The instream nutrient processes include DO, BOD, nitrogen and phosphorus reactions, pH, phytoplankton, zooplankton, and benthic algae.

The organic chemical transfer and reaction processes included are hydrolysis, oxidation, photolysis, biodegradation, a volatilization, and sorption. Sorption is modeled as a first-order kinetic process in which the user must specify a desorption rate and an equilibrium partition coefficient for each of the three

solid types. Resuspension and settling of silts and clays (cohesive solids) are defined in terms of shear stress at the sediment-water interface. For sands, the capacity of the system to transport sand at a particular flow is calculated and resuspension or settling is defined by the difference between the sand in suspension and the capacity. Calibration of the model requires data for each of the three solids types. Benthic exchange is modeled as sorption/desorption and desorption/scour with surficial benthic sediments. Underlying sediment and pore water are not modeled.

5.2.2 CREAMS/GLEAMS

Chemicals, Runoff, and Erosion from Agricultural Management Systems (CREAMS) was developed by the U.S. Department of Agriculture² Agricultural Research Service (Knisel, 1980; Leonard and Ferreira, 1984) for the analysis of agricultural best management practices for pollution control. CREAMS is a field scale model that uses separate hydrology, erosion, and chemistry submodels connected together by pass files.

Runoff volume, peak flow, infiltration, evapotranspiration, soil water content, and percolation are computed on a daily basis. If detailed precipitation data are available then infiltration is calculated at histogram breakpoints. Daily erosion and sediment yield, including particle size distribution, are estimated at the edge of the field. Plant nutrients and pesticides are simulated and storm load and average concentrations of sediment-associated and dissolved chemicals are determined in the runoff, sediment, and percolation through the root zone (Leonard and Knisel, 1984).

User defined management activities can be simulated by CREAMS. These activities include aerial spraying (foliar or soil directed) or soil incorporation of pesticides, animal waste management, and agricultural best management practices (minimum tillage, terracing, etc.).

Calibration is not specifically required for CREAMS simulation, but is usually desirable. The model provides accurate representation of the various soil processes. Most of the CREAMS parameter values are physically measurable. The model has the capability of simulating 20 pesticides at one time.

Groundwater Loading Effects of Agricultural Management Systems (GLEAMS) was developed by the United States Department of

Agriculture? Agriculture Research Service (Leonard et al., 1987) to utilize the management oriented physically based CREAMS model (Knisel, 1980) and incorporate a component for vertical flux of pesticides. GLEAMS is the vadose zone component of the CREAMS model.

GLEAMS consists of three major components namely hydrology, erosion/sediment yield, and pesticides. Precipitation is partitioned between surface runoff and infiltration and water balance computations are done on a daily basis. Surface runoff is estimated using the Soil Conservation Service Curve Number Method as modified by Williams and Nicks (1982). The soil is divided into various layers, with a minimum of 3 and a maximum of 12 layers of variable thickness are used for water and pesticide routing (Knisel et al., 1989)

5.2.3 ANSWERS

Areal Nonpoint Source Watershed Environment Response Simulation (ANSWERS) was developed at the Agricultural Engineering Department of Purdue University (Beasley and Huggins, 1981). It is an event based, distributed parameter model capable of predicting the hydrologic and erosion response of agricultural watersheds. Application of ANSWERS requires that the watershed to be subdivided into a grid of square elements. Each element must be small enough so that all important parameter values within its boundaries are uniform. For a practical application element sizes range from one to four hectares. Within each element the model simulates the processes of interception, infiltration, surface storage, surface flow, subsurface drainage, and sediment drainage, and sediment detachment, transport, and deposition. The output from one element then becomes a source of input to an adjacent element.

As the model is based on a modular program structure it allows easier modification of existing program code and/or addition of user supplied algorithms. Model parameter values are allowed to vary between elements, thus, any degree of spatial variability within the watershed is easily represented.

Nutrients (nitrogen and phosphorus) are simulated using correlation relationships between chemical concentrations, sediment yield and runoff volume. A research version (Amin-Sichani, 1982) of the model uses ?clay enrichment? information and a very descriptive phosphorus fate model to predict total, particulate, and soluble phosphorus yields.

5.2.4 AGNPS

Agricultural Nonpoint Source Pollution Model (AGNPS) was developed by the U.S. Department of Agriculture? Agriculture Research Service (Young et al., 1986) to obtain uniform and accurate estimates of runoff quality with primary emphasis on nutrients and sediments and to compare the effects of various pollution control practices that could be incorporated into the management of watersheds.

The AGNPS model simulates sediments and nutrients from agricultural watersheds for a single storm event or for continuous simulation. Watersheds examined by AGNPS must be divided into square working areas called cells. Grouping of cells results in the formation of subwatersheds, which can be individually examined. The output from the model can be used to compare the watershed examined against other watersheds to point sources of water quality problems, and to investigate possible solutions to these problems.

AGNPS is also capable of handling point source inputs from feedlots, waste water treatment plant discharges, and stream bank and gully erosion (user specified). In the model, pollutants are routed from the top of the watershed to the outlet in a series of steps so that flow and water quality at any point in the watershed may be examined. The Modified Universal Soil Loss Equation is used for predicting soil erosion, and a unit hydrograph approach used for the flow in the watershed. Erosion is predicted in five different particle sizes namely sand, silt, clay, small aggregates, and large aggregates.

The pollutant transport portion is subdivided into one part handling soluble pollutants and another part handling sediment attached pollutants. The methods used to predict nitrogen and phosphorus yields from the watershed and individual cells were developed by Frere et al. (1980) and are also used in CREAMS (Knisel, 1980). The nitrogen and phosphorus calculations are performed using relationships between chemical concentration, sediment yield and runoff volume.

Data needed for the model can be classified into two categories: watershed data and cell data. Watershed data includes information applying to the entire watershed which would include watershed size, number of cells in the watershed, and if running for a single storm event then the storm intensity. The cell

data includes information on the parameters based on the land practices in the cell.

Additional model components that are under development are unsaturated/saturated zone routines, economic analysis, and linkage to Geographic Information System.

5.2.5 PRZM

Pesticide Root Zone Model (PRZM) was developed at the U.S. EPA Environmental Research Laboratory in Athens, Georgia by Carsel et al. (1984). It is a one-dimensional, dynamic, compartmental model that can be used to simulate chemical movement in unsaturated zone within and immediately below the plant root zone. The model is divided into two major components namely, the hydrology (and hydraulics) and chemical transport. The hydrology component which calculates runoff and erosion is based upon the Soil Conservation Service curve number procedure and the Universal Soil Loss Equation respectively. Evapotranspiration is estimated directly from pan evaporation or by an empirical formula if pan evaporation data is not available. Soil-water capacity terms including field capacity, wilting point, and saturation water content are used for simulating water movement within the unsaturated zone. Irrigation application is also within model capabilities.

Pesticide application on soil or on the plant foliage are considered in the chemical transport simulation. Dissolved, adsorbed, and vapor-phase concentrations in the soil are estimated by simultaneously considering the processes of pesticide uptake by plants, surface runoff, erosion, decay, volatilization, foliar washoff, advection, dispersion, and retardation. The user has two options to solve the transport equations using the original backward difference implicit scheme or the method of characteristics (Dean et al., 1989). As the model is dynamic it allows considerations of pulse loads.

PRZM is an integral part of a unsaturated/saturated zone model RUSTIC (Dean et al., 1989). RUSTIC (Risk of Unsaturated/Saturated Transport and Transformation of Chemical Concentrations) links three subordinate models in order to predict pesticide fate and transport through the crop root zone, and saturated zone to drinking water wells through PRZM, VADOFT, SAFTMOD.

VADOFT is a one-dimensional finite element model

which solves Richard's equation for water flow in the unsaturated zone. VADOFT can also simulate the fate and transport of two parent and two daughter products. SAFTMOD is a two-dimensional finite element model which simulates flow and transport in the saturated zone in either an X-Y or X-Z configuration. The three codes PRZM, VADOFT, and SAFTMOD are linked together through an execution supervisor which allows users to build models for site specific situation. In order to perform exposure assessments, the code is equipped with a Monte Carlo pre and post processor (Dean et al., 1989).

5.2.6 SWRRB

Simulator for Water Resources in Rural Basins (SWRRB) was developed by Williams et al. (1985), and Arnold et al. (1989) for evaluating basin scale water quality. SWRRB operates on a daily time step and simulates weather, hydrology, crop growth, sedimentation, and nitrogen, phosphorous, and pesticide movement. The model was developed by modifying the CREAMS (Knisel, 1980) daily rainfall hydrology model for application to large, complex, rural basins.

Surface runoff is calculated using the Soil Conservation Service Curve Number technique. Sediment yield is computed for each basin by using the Modified Universal Soil Loss Equation (Williams and Berndt, 1977). The channel and floodplain sediment routing model is composed of two components operating simultaneously (deposition and degradation). Degradation is based on Bagnold's stream power concept and deposition is based on the fall velocity of the sediment particles (Arnold et al., 1989).

Return flow is calculated as a function of soil water content and return flow travel time. The percolation component uses a storage routing model combined with a crack flow model to predict the flow through the root zone. The crop growth model (Arnold et al., 1989) computes total biomass each day during the growing season as a function of solar radiation and leaf area index.

The pollutant transport portion is subdivided into one part handling soluble pollutants and another part handling sediment attached pollutants. The methods used to predict nitrogen and phosphorus yields from the rural basins are adopted from CREAMS (Knisel, 1980). The nitrogen and phosphorus calculations are performed using relationships between chemical

concentration, sediment yield and runoff volume. The nutrient capabilities are still undergoing testing and validation at this time.

The pesticide component is directly taken from Holst and Kutney (1989) and is a modification of the CREAMS (Smith and Williams, 1980) pesticide model. The amount of pesticide reaching the ground or plants is based on a pesticide application efficiency factor. Empirical equations are used for calculating pesticide washoff which are based on threshold rainfall amount. Pesticide decay from the plants and the soil are predicted using exponential functions based on the decay constant for pesticide in the soil, and half life of pesticide on foliar residue.

The Pesticide Runoff Simulator (PRS) was developed for the U.S. EPA Office of Pesticide and Toxic Substances by Computer Sciences Corporation (1980) to simulate pesticide runoff and adsorption into the soil on small agricultural watersheds. PRS is based on SWRRB. Thus, the PRS hydrology and sediment simulation is based on the USDA CREAMS model, and the SCS curve number technique is used to predict surface runoff. Sediment yield is simulated using a modified version of the Universal Soil Loss Equation and a sediment routing model.

The pesticide component of PRS is a modified version of the CREAMS pesticide model. Pesticide application (foliar and soil applied) can be removed by atmospheric loss, wash off by rainfall, and leaching into the soil. Pesticide yield is divided into a soluble fraction and an adsorbed phase based on an enrichment ratio.

The model includes a built in weather generator based on temperature, solar radiation, and precipitation statistics. Calibration is not specifically required, but is usually desirable.

5.2.7 UTM-TOX

Unified Transport Model for Toxic Materials (UTM-TOX) was developed by Oak Ridge National Laboratory for the U.S. EPA Office of Pesticides and Toxic Substances, Washington, D.C. (Patterson et al., 1983). UTM-TOX is a multimedia model that combines hydrologic, atmospheric, and sediment transport in one computer code. The model calculates rates of flux of a chemical from release to the atmosphere, through deposition on a watershed, infiltration and runoff from the soil, to flow in a stream channel and associated sediment transport.

From these calculations mass balances can be established, chemical budgets made, and concentrations in the environment estimated. The atmospheric transport model (ATM) portion of UTM-TOX is a Gaussian plume model that calculates dispersion of pollutants emitted from point (stack), area, or line sources. ATM operates on a monthly time step, which is longer than the hydrologic portion of the model and results in the use of an average chemical deposition falling on the watershed.

The Terrestrial Ecology and Hydrology Model (TEHM) describes soil-plant water fluxes, interception, infiltration, and storm and groundwater flow. The hydrologic portion of the model is from the Wisconsin Hydrologic Transport Model (WHTM), which is a modified version of the Stanford Watershed Model (SWM). WHTM includes all of the hydrologic processes of the SWM and also simulates soluble chemical movement, litter and vegetation interception of the chemical, erosion of sorbed chemical, chemical degradation in soil and litter, and sorption in top layers of the soil. Stream transport includes transfer between three sediment components (suspended, bed, and resident bed).

5.3 Discussion

The models discussed briefly here (and more extensively in the Appendix) do not represent all of the modeling options available for runoff quality simulation, but they are certainly the most notable, widely used and most operational. Selection from among these models is often made on the basis of personal preference and familiarity, in addition to needed model capabilities. For example, for urban modeling various in-house versions of STORM are still used by consultants even though the 'official' HEC version has not been updated since 1977, because these versions have been adapted to the needs of the firm and because STORM has proven to provide useful continuous simulation results. The USGS DR3M-QUAL model has perhaps been used the least by persons outside that agency, but has worked satisfactorily in several applications documented in the Appendix. Support for both STORM and DR3M-QUAL would be minimal. CREAMS has been used most extensively for field-scale agricultural runoff modeling because of its agricultural origins and ties to the agricultural research community.

HSPF and SWMM are probably the most versatile and most widely applicable of the models, with the nod to SWMM if the urban hydrology and hydraulics must be simulated in detail. On the other hand, the water quality routines in HSPF for sediment erosion, pollutant interaction and groundwater quality are superior in HSPF, and the capability to efficiently handle *all* types of land uses and pollutant sources, (including urban and agriculture, point and non-point), is a definite advantage when needed for large complex basins. Both models appear somewhat overwhelming in terms of size to the novice user, but only the components of interest of either model need be used in a given study, and the catchment schematization can often be coarse for purposes of simulation of water quality at the outlet. Thus, although the installation of these models on a microcomputer may occupy several megabytes of a hard disk, they may be applied in simple ways (i.e., applied to a simplified schematization of the catchment) with a significant reduction in data requirements. Furthermore, the several quality modeling options within SWMM permit simple conceptual water quality simulation using constant concentration and rating curves as well as the more formidable buildup-washoff methods. Similarly for HSPF, the ability to use the simple SWMM-type formulations for urban and non-agricultural areas, and detailed soil/runoff process simulation for agricultural areas provides the user with great flexibility in representing the watershed system.

Continuing model development and testing within the agricultural research community will likely lead to further enhancements and development of many of the agricultural models, like CREAMS, SWRRB, and AGNPS. In fact, USDA has supported, and continues to support, a wide range of model development work in individual research facilities, many of which are (or at least appear to be) very similar in terms of using similar algorithms or model formulations (e.g. EPIC (Williams et al., 1984), Opus (V. Ferreira, 1989, personal communication), SWAM (DeCoursey, 1982)). The SWRRB development effort appears to be focussing in on a middle ground (in terms of complexity) between HSPF and the detailed field-scale models which are limited to small areas; its use of daily rainfall, as opposed to smaller time interval measurements (usually hourly is needed for HSPF) is seen as a definite advantage by many users. However, most of

these efforts still focus primarily on agricultural areas, with limited abilities to be used in large, complex multi-land use basins.

Regression, spreadsheet, statistical methods, and loading functions are most useful as screening tools. Indeed if the Statistical Method or EPA's Screening Procedures, indicate that there should be no water quality problem (as defined by exceedance of a specified concentration level with a specified frequency), then more detailed water quality simulation may not be required at all. If sensitivity analyses and 'worst-case' evaluations further support the conclusions, detailed water quality modeling will probably not be needed.

Table 4. Comparison of urban model attributes

Attribute	Model: DR3M-QUAL	HSPF	Statistical ^a	STORM	SWMM
Sponsoring agency	USGS	EPA	EPA	HEC	EPA
Simulation type ^b	C,SE	C,SE	N/A	C	C,SE
No. pollutants	4	10	Any	6	10
Rainfall/runoff analysis	Y	Y	N ^c	Y	Y
Sewer system flow routing	Y	Y	N/A	N	Y
Full, dynamic flow routing equations	N	N	N/A	N	Y ^d
Surcharge	Y ^e	N	N/A	N	Y ^d
Regulators, overflow structures, e.g., weirs, orificies, etc.	N	N	N/A	Y	Y
Special solids routines	Y	Y	N	N	Y
Storage analysis	Y	Y	Y ^f	Y	Y
Treatment analysis	Y	Y	Y ^f	Y	Y
Suitable for screening (S), design (D)	S,D	S,D	S	S	S,D
Available on micro-computer	N	Y	Y ^g	N	Y
Data and personnel requirements ^h	Medium	High	Medium	Low	High
Overall model complexity ⁱ	Medium	High	Medium	Medium	High

^aEPA procedure.

^bC = continuous simulation, SE = single event simulation.

^cRunoff coefficient used to obtain runoff volumes.

^dFull dynamic equations and surcharge calculations only in Extran Block of SWMM.

^eSurcharge simulated by storing excess inflow at upstream end of pipe. Pressure flow not simulated.

^fStorage and treatment analyzed analytically.

^gFHWA study, Driscoll et al. (1989)

^hGeneral requirements for model installation, familiarization, data requirements, etc. To be interpreted only very generally.

ⁱReflection of general size and overall model capabilities. Note that complex models may still be used to simulate very simple systems with attendant minimal data requirements.

Table 5. Comparison of non-urban model attributes

Attribute	AGNPS	ANSWERS	CREAMS	HSPF	PRZM	SWRRB	UTM-TOX
Sponsoring Agency	USDA	Purdue	USDA	EPA	EPA	USDA	ORNL & EPA
Simulation type	C,SE	SE	C,SE	C,SE	C	C	C,SE
Rainfall/Runoff analysis	Y	Y	Y	Y	Y	Y	Y
Erosion Modeling	Y	Y	Y	Y	Y	Y	Y
Pesticides	Y	N	Y	Y	Y	Y	N
Nutrients	Y	Y	Y	Y	N	Y	N
User-Defined Constituents	N	N	N	Y	N	N	Y
Soil Processes							
Pesticides	N	N	Y	Y	Y	Y	N
Nutrients	N	N	Y	Y	N	Y	N
Multiple Land Type Capability	Y	Y	N	Y	N	Y	Y
Instream Water Quality Simulation	N	N	N	Y	N	N	Y
Available on Micro-computer	Y	Y	Y	Y	Y	Y	N
Data and Personnel Requirements	M	M/H	H	H	M	M	H
Overall Model Complexity	M	M	H	H	M	M/H	H

Y = yes, N = no, M = Moderate, H = High
C = Continuous, SE = Storm Event

Section 6.0

Brief Case Studies

How are quality processes being simulated in studies of urban and rural runoff quality problems? Below, the authors draw upon their personal knowledge of a few ongoing and recently completed studies (listed alphabetically).

6.1 Urban Model Applications

6.1.1 Boston

CH2M-Hill (Gainesville, FL) used continuous SWMM modeling for the development of TSS and BOD loads from CSOs to Boston Harbor (Morrissey and Harleman, 1989). After first estimates from Sartor and Boyd (1972) and Pitt (1979), buildup and washoff functions were calibrated to estimates of annual totals based on monitoring. A 'typical' five years of hourly precipitation data selected from 40 years of available record were input to SWMM to develop CSO loads, and the effectiveness of street cleaning and catchbasin cleaning BMPs was studied using the model (V. Adderly, CH2M-Hill, Inc., Gainesville, FL, Personal Communication, 1989).

6.1.2 Delevan Lake, Wisconsin

A joint project of the USGS (Madison) and the University of Wisconsin investigated suspended solids and phosphorus loads to 1800-ac Delevan Lake in southeastern Wisconsin (Walker et al., 1989). A spreadsheet approach was implemented using Multiplan, with unit load estimates for the surrounding basin (agricultural, urban, industrial). The Universal Soil Loss Equation was used for sediment loads from agricultural areas. Some calibration was possible using measurements on four tributaries. The cost-effectiveness of agricultural control options was evaluated based on cost estimates for various agricultural BMPs.

6.1.3 Hackensack River Basin

Pollution problems in the lower and estuarine portion of the Hackensack River in New Jersey are being studied by Najarian and Associates (Eatontown, NJ) using SWMM coupled with monitoring data from four CSO and five storm sewered areas (Huang and DiLorenzo, 1990; Najarian et al., 1990). The pollutants of primary interest are BOD and ammonia for input to a dynamic receiving water quality model of the river and estuary, with emphasis upon the relative contributions of CSOs, separate storm sewered areas and point sources. Although rating curve results were very good predictors for the monitored catchments from which they were derived, it was found that they could not be extrapolated (transferred) to the ungaged catchments. Hence, Michaelis-Menton buildup and exponential washoff parameters were calibrated for the basins and transferable generalized coefficients developed as a function of land use. Intra-storm variations were simulated in order to use SWMM to drive a short time increment dynamic model of the river and estuary.

6.1.4 Jacksonville

Camp, Dresser and McKee (Jacksonville) will use SWMM for quantity predictions and both a spreadsheet and SWMM or STORM with constant concentrations for load estimates to the St. Johns River (Camp, Dresser and McKee, Inc., 1989). The constant concentrations are based on NURP data and limited Florida data. If SWMM or STORM is used to drive a receiving water quality model for the river, local data will be used for better calibration. At the moment, CDM feels that both quantity and quality control options can be compared on the basis of present data, with a minimum of expensive local sampling.

6.1.5 Orlando

To help alleviate nonpoint source pollution to lakes downstream from the Boggy Creek Watershed south of Orlando, Camp, Dresser and McKee (Orlando) developed a spreadsheet model to assess nutrient loadings resulting from existing and future land uses (Camp, Dresser and McKee, 1987). Runoff coefficients were calibrated to match measured creek runoff volumes, and EMCs as a function of land use were estimated from sampling in Orlando and Tampa. An overall calibration factor was used to obtain agreement between the total estimated TN and TP loads produced by the product of flows and EMCs for the various land uses and measured annual nutrient loads in Boggy Creek. Thus, relative contributions from various land uses remained the same while the overall loads were adjusted. BMP removal efficiencies were applied in conjunction with changing land uses to obtain control strategies for future watershed development.

6.1.6 Providence

SWMM is being used by Greeley and Hanson (Philadelphia) to simulate CSO loads from Providence using three monitored storms for calibration and verification (R. Janga, Greeley and Hansen, Inc., Philadelphia, PA, Personal Communication, 1989). Quality is being simulated using constant concentration in the Runoff Block and the quality routing routines in the Transport Block. SWMM may be used to drive a receiving water model before the project is completed. Extran is also being used to simulate some of the overflow hydraulics.

6.1.7 San Francisco Bay

Woodward-Clyde (Oakland) is using SWMM to simulate loads from the Santa Clara Valley into South San Francisco Bay (P. Mangarella, Woodward-Clyde Consultants, Oakland, CA, Personal Communication, 1989). Measured runoff and flow data are being used to calibrate the Runoff Block quantity routines, and constant concentrations are being used (no buildup or washoff) based on one year of monitoring of a selection of land use types. The model may not be used to drive a receiving water model but it will be used to compare alternatives to reduce loads of toxics to the Bay.

6.1.8 Tallahassee

The Northwest Florida Water Management District

(Havana, FL) is using SWMM to develop the stormwater master plan for Tallahassee and Leon County (R. Ortega, Northwest Florida Water Management District, Havana, FL, Personal Communication, 1989). Extensive use of the model has already been made for quantity predictions. The present plan is to develop rating curve relationships on the basis of considerable quality monitoring data gathered during the study for input into SWMM. BMPs will also be studied with the model, especially storage. Final control decisions will be made on the basis of 28-year SWMM simulations using 15-min rainfall data.

6.2 Non-urban Model Applications

6.2.1 Chesapeake Bay Program

The EPA Chesapeake Bay Program has been using the HSPF model as the framework for modeling total watershed contributions of flow, sediment, and nutrients (and associated constituents such as water temperature, DO, BOD, etc.) to the tidal region of the Chesapeake Bay (Donigian et al., 1986; 1990). The watershed modeling represents pollutant contributions from an area of more than 68,000 sq. mi., and provides input to drive a fully dynamic three-dimensional, hydrodynamic/water quality model of the Bay. The watershed drainage area is divided into land segments and stream channel segments; the land areas modeled include forest, agricultural cropland (conventional and conservation tillage systems), pasture, urban (pervious and impervious areas), and uncontrolled animal waste contributions. The stream channel simulation includes flow routing and oxygen and nutrient biochemical modeling (through phytoplankton) in order to account for instream processes affecting nutrient delivery to the Bay.

Currently, buildup/washoff type algorithms are being used for urban impervious areas, potency factors for all pervious areas, and constant (or seasonally variable) concentrations for all subsurface contributions and animal waste components. Enhancements are underway to utilize the detailed process (i.e. Agri-chemical modules) simulation for cropland areas to better represent the impacts of agricultural BMPs. The watershed modeling is being used to evaluate nutrient management alternatives for attaining a 40% reduction in nutrient loads delivered to the Bay, as defined in a joint agreement among the

governors of the member states.

6.2.2 Alachlor Special Review

The EPA Office of Pesticide Programs performed a 'Special Review' of the herbicide alachlor, which is widely used on corn and soybeans, to determine estimated concentrations in surface waters resulting from agricultural applications. HSPF was applied to selected watersheds in three separate agricultural regions⁷Iowa River Basin, IA; Honey Creek, OH; and Little River, GA⁷ under different usage assumptions to evaluate a likely range of both mean annual and maximum daily alachlor concentrations (Mulkey and Donigian, 1984). The modeling results provided input to the human health risk assessment in which EPA decided to allow continued use of alachlor in the U.S.

6.2.3 CREAMS Application in Pennsylvania

The CREAMS model was applied by the University of Maryland Department of Agriculture and Engineering to selected subbasins of the Susquehanna and Potomac river basins in Pennsylvania to evaluate the effects of agricultural BMPs on nutrient loadings to surface water and to groundwater (Shirmohammadi and Shoemaker, 1988). The study was sponsored by the Interstate Commission on the Potomac River to evaluate the relative nutrient loading impacts of a wide range of potential BMPs, including no till, contouring, terracing, strip cropping, diversions, grass waterways, nutrient management, and various joint combination scenarios. Although the model was applied without calibration or observed runoff/leaching data for comparison, the results showed the *relative* effectiveness of the alternatives analyzed. The study was performed in support of efforts to evaluate alternative means of achieving the 40% reduction goal of the Chesapeake Bay Agreement.

6.2.4 Use of SWRRB in NOAA's National Coastal Pollutant Discharge Inventory

The National Oceanic and Atmospheric Administration (NOAA) is using the SWRRB model to evaluate pollutant loadings to coastal estuaries and embayments as part of its National Coastal Pollutant Discharge Inventory (NOAA, 1987a; 1987b). SWRRB is being used for loadings from all non-urban areas, while a separate procedure is proposed for all urban areas. SWRRB has been run for all major estuaries on the East Coast, Gulf Coast, and West Coast for a wide range of pollutants.

6.2.5 Use of AGNPS in Virginia

The Virginia Department of Soil and Water Conservation is applying the AGNPS model to evaluate sediment erosion and nutrient loadings from land uses within the Owl Creek and Nomini Creek watersheds. Both watersheds have been instrumented to monitor runoff quality from forest, agricultural cropland, and animal feedlot areas. AGNPS is being applied to the watersheds to analyze potential reductions in nutrient loadings for alternative management scenarios (M. Flagg, Virginia Dept. of Soil and Water Conservation, Richmond, VA, Personal Communication, 1990). The results of these applications, and planned use of the calibrated HSPF model resulting from the Chesapeake Bay Program application noted above, will be used to evaluate the means of achieving Virginia's 40% nutrient reductions required by the Chesapeake Bay Agreement.

6.2.6 Use of HSPF in Metropolitan Washington

The Metropolitan Washington Council of Governments has used HSPF in a number of modeling studies to evaluate water quality impacts of nonpoint sources, potential changes resulting from proposed urban stormwater management practices, and water quality changes resulting from alternative wastewater treatment levels (Sullivan and Schueler, 1982; Schueler, 1983; Metropolitan Washington Council of Governments, 1985). Studies on Piscataway and Seneca Creeks demonstrated reasonable agreement with observed instream water quality variables, and then the calibrated model was used to analyze water quality impacts of alternative scenarios including increased street sweeping, stormwater detention, and stormwater treatment. Since the watershed areas are primarily urban, the buildup/washoff algorithms were used to calculate loadings from all land areas. In a separate study, the HSPF instream module was used with pre-defined nonpoint and point source loadings to evaluate the impacts of proposed alternative wastewater treatment levels on the segment of the Potomac River near Washington, D.C.

6.2.7 Patuxent River Nonpoint Source Management Study

The Maryland Department of the Environment is conducting a study of the Patuxent River to quantify nonpoint source contributions and evaluate alternative means of improving downstream water

quality in the Patuxent River Estuary (Summers, 1986). The study includes a 7-year monitoring program that involves observations of runoff quantity and quality at both field size (single land use) locations and instream, multi-land use sites. HSPF is being applied to calculate nonpoint loadings from the forest, agricultural, and urban land areas of the watershed and the instream water quality throughout the river system. The Patuxent is a microcosm of the larger Chesapeake Bay, a complex watershed with multiple land uses, point and nonpoint sources, and reservoirs draining to a tidal estuary. Like the larger Chesapeake Bay study, both simple and complex nonpoint runoff algorithms will be used to represent all land uses and effects of potential management practices.

6.2.8 European Case Studies in Application of the CREAMS Model

Svetlosanov and Knisel (1982) provide a compendium of case studies describing applications of CREAMS in Europe. The work was sponsored by the International Institute of Applied Systems Analysis in Laxenburg, Austria, with the dual objectives of demonstrating the use of CREAMS for quantitative evaluation of the impacts of agricultural management in different countries, and performing model testing and validation studies. The report describes applications in Finland, West Germany, Poland, Sweden, the United Kingdom, and the Soviet Union; comparisons of model results with observations were made in a few of the studies, while in others CREAMS was used without comparison to observed data to investigate alternative practices. Analysis of the case studies identified some of the potential benefits from the model applications, and elucidated some of the generic model weaknesses (e.g., snowmelt) and specific refinements needed for European conditions.

Section 7.0

Summary and Recommendations for Nonpoint Source Runoff Quality Modeling

Simulation of runoff quality will increase in importance as regulation and control of nonpoint sources increases in the next several years. The implementation of Section 405 of the Clean Water Act is especially important if stormwater outfalls will be required to have NPDES permits. The EPA is currently establishing guidelines for data collection, quality monitoring and forms of analysis such that urban areas can meet their obligations under these regulations. Waste load allocations and appropriate control strategies required under Section 303 (d) and 319 will demand more detailed analyses of nonpoint contributions for comprehensive water quality management.

Some form of modeling will almost assuredly become part of routine analyses performed at some portion of the thousands upon thousands of CSO and stormwater discharge locations around the country. Several modeling options exist, but none of them are truly "deterministic" in the sense of fully characterizing the physical, chemical and biological mechanisms that underlie conceptual buildup, erosion, transport and degradation processes that occur in an urban drainage system. Even if fully deterministic models were available, it is doubtful that they could be routinely applied without calibration data. But this is essentially true of almost all methods. Because a method is simple, e.g., constant concentration, does not make it more correct. Rather, the assumption is made that there will be some error in prediction regardless of the method, and there may be no point in compiling many hypothetical input parameters for a more complex model lacking a guarantee of a better prediction. For example, a study in Denver showed that regression equations could predict about as well as DR3M-QUAL given the available quality information (Ellis and Lindner-Lunsford, 1986). But physically-based (conceptual) models do have certain advantages, discussed later.

Physically-based urban models depend upon conceptual buildup and washoff processes incorporated into the quality algorithms. Such models have withstood the test of time and have been applied in major urban runoff quality studies. However, the relative lack of fundamental data on buildup and washoff parameters has led to simpler methods more often being applied, starting with the assumption of a constant concentration and becoming more complex. For example, the derived distribution approach of the EPA Statistical Method provides very useful screening information with minimal data⁷ but more than are required by just assuming a constant concentration. With the mass of NURP and other data, regression approaches are now more viable but still subject to the usual restrictions of regression analysis. Spreadsheets are ubiquitous on microcomputers and serve as a convenient mechanism to implement several of the simple approaches, especially those that rely upon sets of coefficients and EMCs as a function of land use or other demographic information. For example, the EPA Screening Procedures could easily be implemented in a spreadsheet format, and would be an appropriate tool for nonpoint source wasteload allocation assessments, at least for screening purposes.

Minimal data requirements and ease of application are the principal advantages of simpler simulation methods (constant concentration, statistical, regression, loading functions). However, in spite of their more complex data requirements, conceptual models (DR3M-QUAL, HSPF, STORM, SWMM, CREAMS, SWRRB) have advantages in terms of simulation of routing effects and control options as well as superior statistical properties of continuous time series. For example, the EPA Statistical Method assumes that stream flow is not correlated with the urban runoff flow. This may or may not be true in a given situation, but it is not necessary to require such an assumption when running a model such as HSPF or SWMM. The urban and non-urban conceptual

models discussed in detail all have a means of simulating storage and treatment effects, and/or impacts of a significant number of management options. Other than a constant removal, this is difficult to do with the simpler methods. The conceptual models generally have very much superior hydrologic and hydraulic simulation capabilities (not true for STORM except that it can also use real rainfall hyetographs as input). This alone usually leads to better prediction of loads (product of flow times concentration). It should also be borne in mind that even complex models such as SWMM can be run with minimal quality (and quantity) data requirements, such as using only a constant concentration. Finally, some of the case studies imply that transferability of coefficients and parameters is easier with buildup and washoff than with rating curve and constant concentration methods.

If a more complex conceptual model is to be applied, which one should it be from among the ones described herein? SWMM is certainly the most widely used and probably the most versatile for urban areas, but all have their advocates. HSPF may be more appropriate in large multiple land use watersheds, in areas with more open space where groundwater contributions increase in importance, where rainfall-induced erosion occurs, or where quality interactions are important along the runoff pathway. The simplicity of STORM remains attractive, and various consultants have utilized their own version as a planning tool. The USGS DR3M-QUAL model has been successfully applied in several USGS studies but has not seen much use outside the agency. It contains useful techniques for quality calibration.

SWMM and HSPF retain limited support from the EPA Center for Exposure Assessment Modeling (CEAM) at Athens, Georgia, and a similar level of support is available for CREAMS from the USDA Southeast Watershed Research Laboratory in Tifton, Georgia. Unfortunately, this support is limited mainly to distribution and implementation on a computer system. STORM and DR3M-QUAL will remain useful, but it is unlikely that either of these two models will enjoy enhancements or support from their sponsoring agencies in the near future. Extramural support for all major operational models is highly desirable for maintenance and improvements, especially in light of the general models in nonpoint source studies in the U.S. **No model can exist for long without continuing sustenance in the form of user support, maintenance, and refinements in response to changing technology.** All agencies who have spon-

sored, or are currently sponsoring, model development efforts need to recognize the critical importance of these activities if their efforts are to produce 'operational' models with associated widespread usage.

Agricultural model development will continue largely under the continuing sponsorship of the U.S.D.A. Currently, CREAMS is the most used model for strictly agricultural land, but a number of model development efforts are ongoing at various agricultural research stations across the country. The continuing development and testing of the SWRRB model will likely lead to its increased use in a number of non-urban studies; its use of a daily time step is attractive to users because of the less intensive data needs than for HSPF. However, for large complex watersheds, involving both urban and non-urban areas, HSPF will remain the model of choice for many users. Ongoing agricultural research will likely lead to improved understanding of processes, with improved algorithms that should be incorporated into current models. For example, the U.S.D.A. effort to develop a more process-oriented replacement for the USLE (i.e. the WEPP? Watershed Erosion Prediction Project) will likely lead to improved soil erosion algorithms that may be appropriate for incorporation into current models.

What is a reasonable approach to simulation of runoff quality? The main idea, for both urban and non-urban areas, is to use the simplest approach that will address the project objectives at the time. This usually means to start simple with a screening tool such as constant concentration (usually implemented in a spreadsheet), regression, statistical, or loading function approach. If these methods indicate that more detailed study is necessary or if they are unable to address all the aspects of the problem, e.g., the effectiveness of control options or management alternatives, then one of the more complex models must be run. No method currently available (or likely to be available) can predict absolute (accurate) values of concentrations and loads without local calibration data, including complex buildup and washoff models for urban areas, and soil process models for agricultural croplands. Thus, if a study objective is to provide input loads to a receiving water quality model, local site-specific data will probably be required. On the other hand, several methods and models might be able to compare the relative contributions from different source areas, or to determine the relative effectiveness of control and/or management options (if the controls can be characterized by simple removal fractions).

When used for purposes such as these, the methods, including buildup and washoff models, can usually be applied on the basis of NURP data (for urban models) and/or the best currently available source of quality data, such as data from agricultural research stations for the non-urban models.

When properly applied and their assumptions respected, models can be tremendously useful tools in analysis of urban and non-urban runoff quality problems. Methods and models are evolving that utilize the large and currently expanding data base of quality information. As increasing attention is paid to runoff problems in the future, the methods and models can only be expected to improve.

Section 8.0

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Section 9.0
Appendix
Detailed Model Descriptions

Urban
SWMM
STORM
DR3M-QUAL

Non-Urban
EPA Screening Procedures
AGNPS
ANSWERS
CREAMS/GLEAMS
HSPF
PRZM
SWRRB
UTM-TOX

Nonpoint Source Model Review

1. Name of Method

Storm Water Management Model (SWMM)

2. Type of Method

Surface Water Model: Simple Approach
xx Surface Water Model: Refined Approach
xx Soil (Groundwater) Model: Simple Approach
Soil (Groundwater) Model: Refined Approach

3. Purpose/Scope

Purpose: Predict rainfall/runoff/quality processes in urban and other areas. Predict hydrographs and pollutographs (concentration vs. time) in

xx runoff waters
xx surface waters
xx ground waters

Source/Release Types:

xx Continuous xx Intermittent
xx Single xx Multiple xx Diffuse

Level of Application:

xx Screening xx Intermediate xx Detailed

Types of Chemicals:

xx Conventional xx Organic xx Metals

Unique Features:

xx Addresses degradation products
xx Integral database/database manager
xx Integral uncertainty analysis capabilities
Interactive input/execution manager

4. Level of Effort

System setup: xx mandays xx manweeks manmonths
Assessments: mandays xx manweeks xx manmonths

(Estimates reflect order-of-magnitude values and depend heavily on the experience and ability of the assessor.)

5. Description of the Method/Techniques

The *Storm Water Management Model (SWMM)* consists of several modules or 'blocks' designed to simulate most quantity and quality processes in the urban hydrologic cycle. Storm sewers, combined sewers, and natural drainage systems can be simulated. For generation of hydrographs, the Runoff Block simulates the rainfall-runoff process using a nonlinear reservoir approach, with an option for snowmelt simulation. Groundwater and unsaturated zone flow and outflow are simulated using a simple lumped storage scheme. A water balance is maintained between storms, and the entire model may be used for both continuous and single event simulation. Flow routing is accomplished in order of increasing complexity in the Runoff Block (nonlinear reservoir), Transport Block (kinematic wave) and/or Extran Block (complete dynamic equations). The Extran Block is the most comprehensive simulation program available in the public domain for a drainage system domain and is capable of simulating backwater, surcharging, looped sewer connections and a variety of hydraulic structures and appurtenances. The Storage/Treatment Block may be used for storage-indication flow routing. Output from all blocks includes both flow and stage hydrographs.

Quality processes in the Runoff Block include generation of surface runoff constituent loads through a variety of options: 1) build-up of constituents during dry weather and wash-off during wet weather, 2) 'rating curve' approach in which load is proportional to flow rate to a power, 3) constant concentration (including precipitation loads), and/or 4) Universal Soil Loss Equation. Removal of 'built-up' loads can occur by street cleaning during dry weather, and special options are available for snow. One constituent can be taken as a fraction ('potency factor') of another to simulate adsorption onto solids, for example. The concentration of groundwater outflow may only be treated as a constant. Routing and first-order decay may be simulated in the Runoff and Transport Blocks. (Extran includes no quality simulation.) The Transport Block may also be used to simulate scour and deposition within the sewer system based Shield's criterion for initiation of motion, and generation of dry-weather flow and quality. The Storage/Treatment Block simulates removal in storage/treatment devices by 1) first-order decay coupled with complete mixing or plug flow, 2) removal functions (e.g., solids deposition as a function of detention time), or 3) sedimentation

dynamics. Residuals (e.g., sludge) are accounted for. Any constituent may be simulated, but sediment processes, e.g., scour and deposition, are generally weak with the exception of the Storage/Treatment Block.

The blocks can be run independently or in any sequence. Additional blocks are available for statistical analysis of the output time series (Statistics Block), input and manipulation of precipitation, evaporation, and temperature time series (Rain and Temp Blocks), line printer graphics (Graph Block), and output time series manipulation (Combine Block).

6. Data Needs/Availability

SWMM can be run in a very simple configuration, e.g., a single subcatchment and no drainage network, or in a very detailed configuration, e.g., many subcatchments and channels and pipes. The volume of data varies accordingly, but at a minimum will require information on area, imperviousness, slope, roughness, depression storage and infiltration characteristics at the desired level of detail. Channel/pipe data include shapes, dimensions, slopes or invert elevations, roughnesses, etc. Quantity data are usually available from the urban municipality in the form of contour maps and drainage plans.

If quality is generated in the Runoff Block using a build-up/wash-off formulation, then build-up coefficients are needed for alternative build-up formulations (i.e., linear, power, exponential or Michaelis-Menton) as well as for wash-off equations. Due to lack of data availability for these conceptual mechanisms, users often resort to rating curves that may be more readily derived from measurements, or to constant concentrations.

Precipitation input can be in the form of hyetographs for individual storm events, or long-term hourly or 15-minute precipitation (or arbitrary time interval) records from the National Climatic Data Center. Measured hydrographs and pollutographs (or storm event loads or event mean concentrations) are required for calibration and verification. Quantity results are often reasonably good with little or no calibration, whereas quality results need local, site-specific measurements to ensure accurate predictions. Since quality measurements are expensive and sparse, reliance is often placed on generalized data from other sites, e.g., EPA Nationwide Urban Runoff Program (NURP) data,

from which reasonable comparative assessments may usually be made. However, if SWMM (or any urban nonpoint source model) is used to drive a receiving water quality model, local, site-specific quality measurements are normally required.

7. Output of the Assessment

SWMM produces a time history of flow, stage and constituent concentration at any point in the watershed. Seasonal and annual summaries are also produced, along with continuity checks and other summary output. The Statistics Block may be used for storm event separation and frequency analysis of any of the time series. Somewhat crude (by today's standards) line printer graphics are available for hydrograph and pollutograph plots, including comparison with measured data.

8. Limitations

The simulation methods used in various blocks are extensively described in the SWMM documentation and need to conceptually represent the prototype watershed for a satisfactory simulation. Experience has shown SWMM quantity simulations to compare favorably with measurements and with other conventional hydrologic methods, e.g., unit hydrographs. Quality simulation is especially weak in representation of the true physical, chemical and biological processes that occur in nature and is often a calibration or curve-fitting exercise. This accounts for the tendency for users to bypass build-up/wash-off formulations in favor of constant concentrations or rating curves that may be more easily calibrated. Perhaps the weakest component of the model is simulation of solids transport, although it should be borne in mind that this is difficult to do in any model. The microcomputer version of the program is not especially 'user friendly' and lacks good graphics routines. However, on-screen messages are provided during program execution to inform the user of the current program status.

9. Hardware/Software Requirements

SWMM is written in ANSI standard Fortran 77. Executable code prepared using the Ryan-McFarland Fortran compiler is distributed for IBM XT/AT-compatibles. A hard disk is required and a math co-processor is usually required (see Contact section, below). No special peripherals other than a

printer are required. Over 200 sample input files are also distributed, along with the Fortran source code. The program is also maintained for DEC/VAX systems; however, the user must perform his/her own compilation from the Fortran source code. Input files must be prepared using an editor capable of producing an ASCII file as output. No automatic or menu-driven input routine is available. The program can be obtained in either floppy disk format for MS-DOS applications or on a 9-track magnetic tape (from EPA only) with installation instructions for the DEC/VAX VMS environment. SWMM has been installed on many computers world-wide with no or minor modifications.

10. Experience

The original version of SWMM was developed in 1969-71 by a consortium of Metcalf and Eddy, Inc., Water Resources Engineers, Inc. (now a part of Camp, Dresser and McKee, Inc.), and the University of Florida (Metcalf and Eddy et al., 1971). The program was maintained intermittently for several years at the University of Florida under the sponsorship first of the EPA Storm and Combined Sewer Branch (Cincinnati) and later by the EPA Center for Exposure Assessment Modeling (Athens, GA). Limited (un-sponsored) maintenance and development work continues at the University of Florida. Continuing updates to the Extran Block have been placed in the public domain by Camp, Dresser and McKee, Inc. and incorporated into the model. The most current version of the model is Version 4 (Huber and Dickinson, 1988; Roesner et al., 1988) following earlier Version 2 (Heaney et al., 1975; Huber et al., 1975) and Version 3 (Huber et al., 1981; Roesner et al., 1981). A SWMM bibliography (Huber et al., 1985) contains over 200 SWMM-related references, including many references to case studies. The model is often referenced in texts (e.g., Viessman et al., 1989) and has been used in applications ranging from routine drainage design to highly complex hydraulic routing and analysis to large nonpoint and point source pollution abatement studies, e.g., Boston, Detroit, Washington DC.

Maintaining SWMM as a non-proprietary model and in the public domain has produced massive user feedback to the model developers and led to many improvements (Huber, 1989). This has been greatly facilitated by approximately semi-annual meetings of the Storm and Water Quality Model Users Group and publication of proceedings by EPA. The model has achieved the status of a 'standard of comparison' for

modelers wishing to develop new and improved techniques.

SWMM has been applied to urban hydrologic quantity and quality problems in many locations world-wide, including probably over 100 locations in the U.S. and Canada. Applications in major U.S. cities include Albuquerque, Atlanta, Boston, Chicago, Cincinnati, Denver, Detroit, Hartford, Jacksonville, New Haven, New Orleans, Newark, New York, Philadelphia, Providence, Rochester, San Jose, San Francisco, Seattle, Syracuse, Tallahassee, Tampa, Washington DC.

Because SWMM is in the public domain, portions of the model have been adapted for related modeling purposes. A model similar to SWMM in many ways was developed for the Federal Highway Administration (Dever et al., 1981, 1983). It contains components of the Runoff and Extran Blocks along with specialized hydraulic simulation capabilities for highway drainage. Because SWMM contains much more versatile water quality routines, the FHWA model will not be discussed further here; however, some of its characteristics are compared to those of other models by Huber (1985).

11. Validation/Review

The program has been calibrated and verified on many independent data sets, and the model algorithms have been validated through extensive outside analysis and review during the 20 years of model history. Several comparisons of SWMM and other models have been conducted (e.g., Heaps and Mein, 1974; Brandstetter, 1977; Huber and Heaney, 1982; Huber, 1985; Water Pollution Control Federation, 1989). In 1982 the U.S. Office of Technology Assessment said that its [?]reliability and widespread availability have made SWMM the most widely used model of its type in the United States and Canada, and have been important in increasing the use of models by engineers and planners. The SWMM User's Group [now the Storm and Water Quality Model Users Group, sponsored by the EPA CEAM] has been instrumental in achieving the widespread dissemination and acceptance enjoyed by this important modeling tool.[?] (Office of Technology Assessment, 1982).

A final caveat about water quality predictions is still in order: neither SWMM or any other urban nonpoint model can predict accurate concentrations and loads

in urban runoff without local, site-specific data. Such data would likely be required in order to drive a receiving water quality model, for example. However, relative values and comparison of alternatives can usually still be studied from approximate quality predictions.

12. Contact

SWMM is available from the EPA Center for Exposure Assessment Modeling (CEAM) at no charge. It can be downloaded from the CEAM electronic bulletin board, from Internet node earth1.epa.gov via anonymous ftp, or obtained on floppy disks (on two high-density disks). The CEAM also maintains the Fortran source code for a DEC/VAX VMS version. The same program is also available for \$50 from the Department of Civil Engineering, Oregon State University. The Oregon and CEAM versions for PCs require a math co-processor. For further information at the CEAM, contact

Model Distribution Coordinator
Athens Environmental Research Laboratory
U.S. Environmental Protection Agency
960 College Station Road
Athens, Georgia 30605
(706) 546-3549

Documentation (Huber et al., 1988; Roesner et al., 1988) can be obtained from the NTIS or from Oregon State University:

Dr. Wayne C. Huber
Dept. of Civil Engineering
Oregon State University Apperson Hall 202
Corvallis, OR 97331-2302
(503) 737-4934

13. References

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Nonpoint Source Model Review

1. Name of Method

Storage, Treatment, Overflow, Runoff Model (STORM)

2. Type of Method

xx Surface Water Model: Simple Approach
Surface Water Model: Refined Approach
Soil (Groundwater) Model: Simple Approach
Soil (Groundwater) Model: Refined Approach

3. Purpose/Scope

Purpose: Predict rainfall/runoff/quality processes in urban areas. Predict hydrographs and pollutographs (concentration vs. time) in

xx runoff waters
surface waters
ground waters

Source/Release Types:

xx Continuous Intermittent
Single Multiple xx Diffuse

Level of Application:

xx Screening Intermediate Detailed

Types of Chemicals:

xx Conventional Organic Metals

Unique Features:

Addresses degradation products
Integral database/database manager
xx Integral uncertainty analysis capabilities
Interactive input/execution manager

4. Level of Effort

System setup: xx mandays xx manweeks manmonths
Assessments: mandays xx manweeks xx manmonths

(Estimates reflect order-of-magnitude values and depend heavily on the experience and ability of the assessor.)

5. Description of Method/Techniques

The Storage, Treatment, Overflow, Runoff Model (STORM) contains simplified hydrologic and water quality routines for continuous simulation in urban areas. Hourly runoff depths are computed by means of an area-weighted runoff coefficient for the pervious and impervious portions, with recovery of depression storage between events. Alternatively, the SCS method can be used to generate hourly runoff volumes. There is no flow routing as such. Runoff passes through a treatment device up to its capacity and is otherwise diverted to a storage unit. If treatment is at capacity and the storage is full, an "overflow" occurs to the receiving water. This scheme results from the origins of the model for simulation of combined sewer overflows. At the end of the storm, remaining storage is routed through treatment. The program is driven by hourly precipitation records obtained from the National Climatic Data Center, and snowmelt can be simulated using the degree-day method. Dry-weather flows can also be simulated; these provide a baseflow and are mixed with stormwater runoff during a storm event.

Linear build-up and first-order exponential wash-off is used to simulate concentrations of up to six pre-specified pollutants (suspended solids, settleable solids, BOD, total coliforms, ortho-phosphate, and nitrogen). Because build-up and wash-off parameters are adjustable, other conservative pollutants could be simulated under the guise of the above names. Erosion may be simulated using the Universal Soil Loss Equation. Runoff is mixed with dry-weather flow, if any, and transported without quality routing or decay to the treatment device. Flows passing through treatment are not included as loads to receiving waters (i.e., treatment releases are handled as if there is 100% removal). However, a summary is maintained of concentrations and loads that bypass the storage/treatment option and overflow to the receiving water. No treatment occurs in the storage device.

6. Data Needs/Availability

Data needs are somewhat less for STORM than for comparable continuous simulation models because of its simple hydrologic and water quality routines. Runoff coefficients may be estimated from standard handbooks and textbooks, and SCS parameters are widely available if the soil types are known. Build-up and wash-off parameters are less flexible than in

models such as SWMM, HSPF or DR3M-QUAL and no more easy to estimate. Calibration is advisable but somewhat awkward because the model is primarily set up to run in only a continuous mode. However, since STORM is usually run only in a screening or planning mode, comparative evaluations can usually be made without calibration.

7. Output of the Assessment

Output includes storm event summaries of runoff volume, concentrations and loads plus summaries of storage and treatment utilization and total overflow loads and concentrations. Hourly hydrographs and pollutographs (concentration vs. time) may be computed but rarely are because there is no way to do this for only brief periods during a long, continuous simulation. Useful statistical summaries on an annual and total simulation period basis that enable an estimation of "percent control," i.e., percentage of runoff passing through storage and also the number of overflows, both as a function of the treatment rate and storage capacity. The storage-treatment combination can then be optimized. The utilization of storage is also summarized, which helps in defining the duration of critical events, e.g., time required between events for complete drainage of the storage.

8. Limitations

STORM's hydrologic routines (runoff coefficient, SCS, no routing) are the simplest of any simulation model considered. Although they lead to minimal data requirements, they also lead to less flexibility in matching observed hydrographs. Similarly, STORM uses the quality routines embodied in the original SWMM program (Metcalf and Eddy et al., 1971) with very few modifications. These have been shown to be relatively inflexible in matching observed pollutographs and have been updated in SWMM and other models. Only hourly precipitation inputs are possible, making it difficult to work with more recent continuous records of 15-minute precipitation data or arbitrary input hyetographs, e.g., measured rainfall and runoff data. Lack of an agency-supported microcomputer version currently hampers the model's use.

9. Hardware/Software Requirements

STORM is written in Fortran IV and must be compiled by the user on a mainframe. It is available

only on a 9-track magnetic tape and has been installed on IBM and CDC systems, among others. Although individual users have prepared versions for IBM PC/AT-compatibles, the model developer does not sell or support such a version.

10. Experience

STORM represents the first significant use of continuous simulation, especially quality applications, in the urban setting. (The Stanford Watershed Model, incorporated into HSPF, was the first continuous model.) The model was developed by the Army Corps of Engineers, Hydrologic Engineering Center (HEC) originally for application to the San Francisco master drainage plan (Roesner et al., 1974; HEC, 1977) for abatement of combined sewer overflows (CSOs) into San Francisco Bay (McPherson, 1974). Sixty-two years of hourly rainfall data were analyzed with STORM to provide optimal combinations of storage and treatment for the master plan. The HEC also provides additional guidelines for model application (Abbott, 1977).

The support of the HEC, renowned for the suite of hydrologic models, led to extensive use of STORM in the late 70s and early 80s, but the lack of HEC updates in recent years has caused a decline in model use. Nonetheless, many applications may be found, including Heaney et al. (1977) for a nationwide assessment, Shubinski et al. (1977) for the Detroit area, and Najarian et al. (1986) in New Jersey. A simplified receiving water quality model was developed for streams for use with the STORM model (Medina, 1979), although Medina's model could also be driven by other continuous simulation models.

A very similar model to STORM was developed by Lager et al. (1976) for application in San Francisco and Rochester, known as 'Simplified SWMM.' This model is not currently available, and STORM is essentially a substitute.

11. Validation/Review

STORM has been used in many applications although seldom compared against measured rainfall-runoff data; one such comparison is by Abbott (1978) in which model predictions compared favorably with hourly runoff values. The model's many applications by diverse users serve as a form of validation.

12. Contact

In 1989, the distribution of the most popular of the HEC programs, e.g., HEC-1 and HEC-2 and some others, was transferred to selected private vendors. Direct HEC support for these programs is limited to Corps of Engineers or other federal agencies. However, STORM is still available directly only from the HEC for \$200 on a 9-track magnetic tape. No microcomputer version is available. Only the Fortran IV source code is distributed; the user must perform the compilation. Contact

The Hydrologic Engineering Center
Corps of Engineers
609 Second Street
Davis, California 95616

13. References

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Shubinski, R.P., A.J. Knepp and C.R. Bristol. 1977. Computer Program Documentation for the Continuous Storm Runoff Model SEM-STORM, Report to the Southeast Michigan Council of Governments, Detroit, MI.

Nonpoint Source Model Review

1. Name of Method

Distributed Routing Rainfall Runoff Model? Quality DR3M-QUAL

2. Type of Method

Surface Water Model: Simple Approach
xx Surface Water Model: Refined Approach
Soil (Groundwater) Model: Simple Approach
Soil (Groundwater) Model: Refined Approach

3. Purpose/Scope

Purpose: Predict rainfall/runoff/quality processes in urban and other areas. Predict hydrographs and pollutographs (concentration vs. time) in

xx runoff waters
xx surface waters
ground waters

Source/Release Types:

xx Continuous Single xx Intermittent Multiple xx Diffuse

Level of Application:

Screening xx Intermediate xx Detailed

Types of Chemicals:

xx Conventional xx Organic xx Metals

Unique Features:

xx Addresses degradation products
Integral database/database manager
Integral uncertainty analysis capabilities
Interactive input/execution manager

4. Level of Effort

System setup: xx mandays xx manweeks manmonths
Assessments: mandays xx manweeks xx manmonths

(Estimates reflect order-of-magnitude values and depend heavily on the experience and ability of the assessor.)

5. Description of the Method/Techniques

The Distributed Routing Rainfall Runoff Model² Quality (DR3M-QUAL) incorporates water quality routines into an updated version of an earlier U.S. Geological Survey (USGS) urban hydrologic model (Dawdy et al., 1972). Runoff is generated from rainfall using the kinematic wave method over multiple subcatchments and routed through drainage pathways by the same technique. Storage-indication routing is available for storage basins. The model can be run over any time period and is sometimes used to simulate a group of storms while bypassing simulation of the intervening dry periods (although a moisture balance is maintained). A built-in optimization routine aids in estimation of quantity parameters.

Quality is simulated for arbitrary parameters using exponential build-up functions plus wash-off functions determined from experience with model calibration. Considerable guidance is provided for parameter estimation. Removal of built-up solids can occur during dry weather by street cleaning. Erosion is simulated using empirical equations relating sediment yield to runoff volume and peak. Some guidance is provided for the erosion parameters using relationships based on the Universal Soil Loss Equation. Concentrations of other constituents can be taken as a fraction (?potency factors?) of sediment concentration. Precipitation can contribute a constant concentration.

Quality routing through the drainage network is done by a Lagrangian scheme to simulate plug flow and no decay. Plug flow routing is also performed in storage basins, with settling based on sedimentation theory and dependent on a particle size distribution.

6. Data Needs/Availability

Data needs depend on the degree of schematization. Quantity parameters for a subcatchment include area, imperviousness, length, slope, roughness and infiltration parameters. Channels are characterized by trapezoidal or circular dimensions and kinematic wave parameters. Storage basins require stage-area-discharge relationships. Quality parameters include build-up and wash-off coefficients. Rainfall input can be for single or multiple storms.

Quantity data are similar in form to those required by

other urban hydrologic models and may be derived from contour maps and drainage plans available from municipalities. Build-up and wash-off parameters are very difficult to estimate a priori and require local, site-specific quality measurements for calibration if accurate quality predictions are needed, e.g., to drive a receiving water quality model.

7. Output of the Assessment

DR3M-QUAL produces a time history of runoff hydrographs and quality pollutographs (concentration or load vs. time) at any location in the drainage system. Summaries for storm events are provided as well as line printer graphics for hydrographs and pollutographs.

8. Limitations

The kinematic wave is perhaps as good a conceptual model as exists for overland flow but approximations are always inherent in its application, as for any conceptual model. The quantity model can be expected to perform reasonably well with minimal calibration. No interaction among quality parameters exists (other than the ability to treat one pollutant as a fraction of sediment concentration). Except for the sedimentation algorithm within storage units, simulation of sediment transport processes is weak, as with virtually all other models of this type. Generally, quality predictions must be calibrated if accurate concentrations and loads are required, e.g., to drive a receiving water quality model. On the other hand, relative comparisons can be made using generalized U.S. data for calibration purposes.

9. Hardware/Software Requirements

The program is written in Fortran 77 for IBM or Prime mainframes. Source code is provided on a 9-track magnetic tape for compilation and installation on the user's computer.

10. Experience

The basis for the hydrologic components of DR3M-QUAL is the earlier modeling work of Dawdy et al. (1972) that was updated first for the quantity portion of the model (Dawdy et al., 1978; Alley and Smith, 1982a) and then for additional quality routines (Alley and Smith, 1982b). Much of the emphasis on the form and calibration of build-up and wash-off

parameters is based on research done by Alley et al. (1980), Alley (1981), and Alley and Smith (1981). The program has received extensive internal review within the USGS and has been applied to their urban modeling studies in South Florida (Doyle and Miller, 1980), Rochester (Kappel et al., 1985; Zarriello, 1988), Anchorage (Brabets, 1986), Denver (Lindner-Lunsford and Ellis, 1987), and Fresno (Guay and Smith, 1988). A summary of experience with the model is given by Alley (1986).

11. Validation/Review

The program has undergone the extensive internal peer review process of the USGS and has been tested and compared with field data on at least 37 catchments by various individuals (Alley, 1986). It has primarily been used by persons within the USGS although it is freely available to anyone.

12. Contact

The Fortran 77 source code and documentation are available on a 9-track magnetic tape (to be supplied by the user) from the USGS National Center:

Ms. Kate Flynn
U.S. Geological Survey
410 National Center
Reston, Virginia 22092
(703) 648-5313

Minimal support is available from the program authors (Alley and Smith).

13. References

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Lindner-Lunsford, J.B. and S.R. Ellis. 1987. Comparison of Conceptually Based and Regression Rainfall-Runoff Models, Denver Metropolitan Area, Colorado, and Potential Applications in Urban Areas, USGS Water-Resources Investigations Report 87-4104, Denver, CO.

Zarriello, P.J. 1988. Simulated Water-Quality Changes in Detention Basins. In Design of Urban Runoff Quality Controls, L.A. Roesner, B. Urbonas and M.B. Sonnen, eds., Proc. of Engineering Foundation Conference, Potosi, MO, ASCE, New York, pp. 268-277.

Nonpoint Source Model Review

1. Name of the Method

EPA Screening Procedures

2. Type of Method

<u>xxx</u> Surface Water Model:	Simple Approach
Surface Water Model:	Refined Approach
Air Model:	Simple Approach
Air Model:	Refined Approach
Soil (Groundwater) Model:	Simple Approach
Soil (Groundwater) Model:	Refined Approach
Multi-media Model:	Simple Approach
Multi-media Model:	Refined Approach

3. Purpose/Scope

Purpose: Predict concentrations of contaminants in

xxx runoff waters
xxx surface waters
ground waters

Source/Release Types:

Continuous	Intermittent	
Single	<u>xxx</u> Multiple	<u>xxx</u> Diffuse

Level of Application:

<u>xxx</u> Screening	Intermediate	Detailed
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Type of Chemicals:

<u>xxx</u> Conventional	<u>xxx</u> Organic	<u>xxx</u> Metals
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Unique Features:

- Addresses degradation products
- Integral Database/Database manager
- Integral Uncertainty Analysis Capabilities
- Interactive Input/Execution Manager

4. Level of Effort

System setup:	<u>xx</u> mandays	manweeks	manmonths	manyear
Assessments:	<u>xx</u> mandays	<u>xx</u> manweeks	manmonths	manyear

(Estimates reflect order-of-magnitude values and depend heavily on the experience and ability of the assessor.)

5. Description of the Method/Techniques

EPA Screening Procedures (Mills et al., 1982, 1985) are a revision and expansion of water quality assessment procedures initially developed for nondesignated 208 areas (Zison et al., 1977). The procedures have been expanded and revised to include consideration of the accumulation, transport, and fate of toxic chemicals, in addition to conventional pollutants included in the earliest version. The manual includes a separate chapter describing calculation procedures for estimating NPS loads for urban and nonurban land areas in addition to chapters on procedures for rivers and streams, impoundments, and estuaries. A useful overview chapter on the aquatic fate processes of toxic organisms is also included.

The procedures for NPS load assessments described in the manual are essentially a compilation and integration of estimation techniques developed earlier by Midwest Research Institute (McElroy et al., 1976), Amy et al. (1974), Heaney et al. (1976) (i.e., SWMM-Level I), and Haith (1980). However, the presentation of the procedures is well integrated, supplemented with additional parameter estimation information, and includes sample calculations. The procedures for nonurban areas are derived from MRI loading functions for average annual estimates based on Universal Soil Loss Equation (Wischmeier and Smith, 1978), while the storm event procedures use the modified USLE (Williams, 1975) and the SCS Runoff Curve Number procedure (Mockus, 1972) for storm runoff. Pollutant concentrations in soils and enrichment ratios are required for estimating pollutant loads; precipitation contributions of nutrients can be included. Specific information is included for estimation of salinity loads in irrigation return flows, and storm event pesticide losses are estimated separately based on procedures developed by Haith (1980).

Annual and storm event loads from urban areas follow the procedures included in the SWMM-Level I (Heaney et al., 1976) and Amy et al. (1974) respectively. The basic procedures are relatively standard for urban areas, calculating pollutant loads as a function of solids accumulation and washoff.

The EPA Screening Procedures have excellent user documentation and guidance, including occasional workshops sponsored by the EPA Water Quality Modeling Center, Athens, Georgia.

6. Data Needs/Availability

The data requirement is minimal and is also available from the manual when site specific data is lacking. Soil and land use data is required for estimating runoff and sediment yield. This data is readily available from USDA-SCS soil survey reports. Tables for estimating water quality input parameters for nitrogen, phosphorous, heavy metals, and pesticides are included in the manual.

7. Output of the Assessment

Output available from the model include predicted stream concentrations of BOD, DO, total N, total P, temperature, and conservative and organic pollutants by reach; total lake concentrations, organic pollutants eutrophic status, and hypolimnion DO deficit; and estuary concentrations of BOD, DO, total N, total P, and conservative pollutants by reach. As calculations are done on a hand calculator they can be arranged according to user's convenience.

8. Limitations

It is a very simplified procedure requiring the user to estimate pollutant concentrations. Its use is very limited while evaluating impacts of various management practices. As calculations are done on a hand calculator, they can be tedious and time consuming for complex multi-media use basins. Snowmelt runoff and loadings are ignored.

9. Hardware/Software Requirements

No computer requirement, calculations can be done by hand calculators.

10. Experience

These procedures have enjoyed wide popularity, partly due to the availability of training workshops sponsored by EPA, and have been applied in a number of regions, including the Sandusky River in northern Ohio and the Patuxent, Ware, Chester, and Occuquan basins in the Chesapeake Bay region (Davis et al., 1981; Dean et al., 1981a; and Dean et al., 1981b).

11. Validation/Review

12. Contact

For copies of the manual contact

Center for Exposure Assessment Modeling
U.S. Environmental Protection Agency
Environmental Research Laboratory
Athens, GA. 30605
(706) 546-3549

13. References

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Wischmeier, W.H. and D.D. Smith. 1978. Predicting Rainfall-Erosion Losses: A Guide to Conservation Planning. U.S. Department of Agriculture, Agriculture Research Service.

Zison, S.W., K. Haven and W.B. Mills. 1977. Water Quality Assessment: A Screening Methodology for Nondesignated 208 Areas. EPA-600/6-77-023, U.S. EPA, Athens, GA.

Nonpoint Source Model Review

1. Name of the Method

Agricultural NonPoint Source Pollution Model? (AGNPS)

2. Type of Method

Surface Water Model:	Simple Approach
<u>xxx</u> Surface Water Model:	Refined Approach
Air Model:	Simple Approach
Air Model:	Refined Approach
Soil (Groundwater) Model:	Simple Approach
Soil (Groundwater) Model:	Refined Approach
Multi-media Model:	Simple Approach
Multi-media Model:	Refined Approach

3. Purpose/Scope

Purpose: Predict concentrations of contaminants in

xxx runoff waters
xxx surface waters
 ground waters

Source/Release Types:

Continuous	Intermittent	
Single	<u>xxx</u> Multiple	<u>xxx</u> Diffuse

Level of Application:

<u>xxx</u> Screening	<u>xxx</u> Intermediate	<u>xxx</u> Detailed
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Type of Chemicals:

<u>xxx</u> Conventional	Organic	Metals
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Unique Features:

- Addresses degradation products
- Integral Database/Database manager
- Integral Uncertainty Analysis Capabilities
- xxx Interactive Input/Execution Manager

4. Level of Effort

System setup:	<u>xx</u> mandays	<u>xx</u> manweeks	manmonths	many year
Assessments:	mandays	<u>xx</u> manweeks	<u>xx</u> manmonths	many year

(Estimates reflect order-of-magnitude values and depend heavily on the experience and ability of the assessor.)

5. Description of the Method/Techniques

Agricultural Nonpoint Source Pollution Model (AGNPS) was developed by the U.S. Department of Agriculture's Agriculture Research Service (Young et al., 1986) to obtain uniform and accurate estimates of runoff quality with primary emphasis on nutrients and sediments and to compare the effects of various pollution control practices that could be incorporated into the management of watersheds.

The AGNPS model simulates sediments and nutrients from agricultural watersheds for a single storm event or for continuous simulation. Watersheds examined by AGNPS must be divided into square working areas called cells. Grouping of cells results in the formation of subwatersheds, which can be individually examined. The output from the model can be used to compare the watershed examined against other watersheds to point sources of water quality problems, and to investigate possible solutions to these problems.

AGNPS is also capable of handling point source inputs from feedlots, waste water treatment plant discharges, and stream bank and gully erosion (user specified). In the model, pollutants are routed from the top of the watershed to the outlet in a series of steps so that flow and water quality at any point in the watershed may be examined. The Modified Universal Soil Loss Equation is used for predicting soil erosion, and a unit hydrograph approach used for the flow in the watershed. Erosion is predicted in five different particle sizes namely sand, silt, clay, small aggregates, and large aggregates.

The pollutant transport portion is subdivided into one part handling soluble pollutants and another part handling sediment attached pollutants. The methods used to predict nitrogen and phosphorus yields from the watershed and individual cells were developed by Frere et al. (1980) and are also used in CREAMS (Knisel, 1980). The nitrogen and phosphorus calculations are performed using relationships between chemical concentration, sediment yield and runoff volume.

Data needed for the model can be classified into two categories: watershed data and cell data. Watershed data includes information applying to the entire watershed which would include watershed size, number of cells in the watershed, and if running for a single storm event then the storm intensity. The cell

data includes information on the parameters based on the land practices in the cell.

Additional model components that are under development are unsaturated/saturated zone routines, economic analysis, and linkage to Geographic Information System.

6. Data Needs/Availability

The input data needed are extensive however, can be obtained through visual field observations, maps (topographic and soils) and from various publications, table and graphs (Young et al. 1986). Meteorologic data consisting of daily rainfall is needed for hydrology simulation. The model also has an option to evaluate watershed response to a single storm event. Data on soil and land use can be obtained from local USDA-SCS field offices.

7. Output of the Assessment

The model provides estimates of: (1) hydrology, with estimates of both runoff volume and peak runoff rate; (2) sediment, with estimates of upland erosion, channel erosion, and sediment yield; and nutrients (both sediment attached and dissolved), with estimates of pollution loadings to receiving cells. A graphics option in the program allows the user to plot different variables within the watershed.

8. Limitations

The model does not handle pesticides. The pollutant transport component needs further field testing. Nutrient transformation and instream processes are not within model capabilities.

9. Hardware/Software Requirements

The program is written in standard FORTRAN 77 and has been installed on IBM PC/AT and compatibles. A hard disk is required for operation of the program and a math co-processor is highly recommended. Executable code prepared with Ryan-McFarland compiler and is available only for MS/DOS environment. Source code is only available for MS/DOS environment.

10. Experience

The model is being used extensively within United States to evaluate nonpoint source pollution by various government agencies and consultants. The model has been used by Shi (1987) to perform economic assessment of soil erosion and water quality in Idaho. Setia and Magleby (1987) and Setia et al. (1988) used AGNPS for evaluating the economic effect of nonpoint pollution control alternatives. The model

has also been used by Koelliker and Humbert (1989) for water quality planning. APNPS was used by Frevert and Crowder (1987) to analyze agricultural nonpoint pollution control options in the St. Albans Bay watershed.

11. Validation/Review

The model has been validated using field data from agricultural watersheds in Minnesota, Iowa, and Nebraska (Young et al., 1986). Lee (1987) validated the model in an Illinois watershed using the single storm option of the model. The author found that the simulated and observed data for runoff volume and sediment yield were well represented when compared with observed data.

12. Contact

The copies of the AGNPS program and the manual are available from

Dr. Robert Young
USDA-ARS
North Central Research Laboratory
Morris, MN 56267
Phone: (612) 589-3411

13. References

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Young, R.A., C.A. Onstad, D.D. Bosch and W.P. Anderson. 1986. Agricultural Nonpoint Source Pollution Model: A Watershed Analysis Tool. Agriculture Research Service, U.S. Department of Agriculture, Morris, MN.

Nonpoint Source Model Review

1. Name of the Method

Areal Nonpoint Source Watershed Environment Response Simulation? (ANSWERS)

2. Type of Method

Surface Water Model:	Simple Approach
<u>xxx</u> Surface Water Model:	Refined Approach
Air Model:	Simple Approach
Air Model:	Refined Approach
Soil (Groundwater) Model:	Simple Approach
<u>xxx</u> Soil (Groundwater) Model:	Refined Approach
Multi-media Model:	Simple Approach
Multi-media Model:	Refined Approach

3. Purpose/Scope

Purpose: Predict concentrations of contaminants in

xxx runoff waters
surface waters
ground waters

Source/Release Types:

Continuous Single	Intermittent Multiple	<u>xxx</u> Diffuse
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Level of Application:

<u>xxx</u> Screening	<u>xxx</u> Intermediate	Detailed
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Type of Chemicals:

<u>xxx</u> Conventional	Organic	Metals
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Unique Features:

Addresses degradation products
xxx Integral Database/Database manager
Integral Uncertainty Analysis Capabilities
Interactive Input/Execution Manager

4. Level of Effort

System setup:	<u>xx</u> mandays	<u>xx</u> manweeks	manmonths	manyear
Assessments:	mandays	<u>xx</u> manweeks	<u>xx</u> manmonths	manyear

(Estimates reflect order-of-magnitude values and depend heavily on the experience and ability of the assessor.)

5. Description of the Method/Techniques

Areal Nonpoint Source Watershed Environment Response Simulation (ANSWERS) was developed at the Agricultural Engineering Department of Purdue University (Beasley and Huggins, 1981). It is an event based, distributed parameter model capable of predicting the hydrologic and erosion response of agricultural watersheds.

Application of ANSWERS requires that the watershed to be subdivided into a grid of square elements. Each element must be small enough so that all important parameter values within its boundaries are uniform. For a practical application element sizes range from one to four hectares. Within each element the model simulates the processes of interception, infiltration, surface storage, surface flow, subsurface drainage, and sediment drainage, and sediment detachment, transport, and deposition. The output from one element then becomes a source of input to an adjacent element.

As the model is based on a modular program structure it allows easier modification of existing program code and/or addition of user supplied algorithms. Model parameter values are allowed to vary between elements, thus, any degree of spatial variability within the watershed is easily represented.

Nutrients (nitrogen and phosphorus) are simulated using correlation relationships between chemical concentrations, sediment yield and runoff volume. A research version (Amin-Sichani, 1982) of the model uses ²clay enrichment² information and a very descriptive phosphorus fate model to predict total, particulate, and soluble phosphorus yields.

6. Data Needs/Availability

Data need comprise of detailed description of the watershed topography, drainage network, soils, and land use. Most of the data can be obtained from USDA-SCS soil surveys, land use and cropping surveys.

7. Output of the Assessment

The model can evaluate alternative erosion control management practices for both agricultural land and construction sites (Dillaha et al., 1982). Output can be obtained on an element basis or for the entire

watershed in terms of flow and sediment. The ANSWERS program comes with a plotting program.

8. Limitations

For a simulation run of ANSWERS on a large watershed a mainframe computer is required. However, for smaller watersheds a IBM-PC compatible version of ANSWERS is available. The model is a storm event model and the input data file is quite complex to prepare. Snowmelt processes or pesticides cannot be simulated by the model. The water quality constituents modeled are limited to nitrogen and phosphorous. These constituents are represented by relationships between chemical concentrations with sediment yield and runoff volume. No transformation of nitrogen and phosphorus is accounted for in the model.

9. Hardware/Software Requirements

The program is written in standard FORTRAN 77 and has been installed on IBM PC/AT and compatibles. A hard disk is required for operation of the program and a math co-processor is highly recommended. Executable code prepared with Ryan-McFarland compiler.

10. Experience

The model has been successfully applied in Indiana on an agricultural watershed and a construction site to evaluate best management practices by Beasley (1986).

11. Validation/Review

Individual components of the model have been validated by the developers.

12. Contact

To obtain copies of the model please write or call Dr. David Beasley at the following address:

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P.O. Box 748
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(912) 386-3377

13. References

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Nonpoint Source Model Review

1. Name of the Method

Chemicals, Runoff, and Erosion from Agricultural Management Systems? (CREAMS)
Groundwater Loading Effects of Agricultural Management Systems? (GLEAMS)

2. Type of Method

Surface Water Model:	Simple Approach
<u>xxx</u> Surface Water Model:	Refined Approach
Air Model:	Simple Approach
Air Model:	Refined Approach
Soil (Groundwater) Model:	Simple Approach
<u>xxx</u> Soil (Groundwater) Model:	Refined Approach
Multi-media Model:	Simple Approach
Multi-media Model:	Refined Approach

3. Purpose/Scope

Purpose: Predict concentrations of contaminants in

xxx runoff waters

surface waters

xxx ground waters (vadose and root zone)

Source/Release Types:

Continuous
Single

Intermittent
xxx Multiple

xxx Diffuse

Level of Application:

xxx Screening

xxx Intermediate

xxx Detailed

Type of Chemicals:

xxx Conventional

xxx Organic

Metals

Unique Features:

xxx Addresses degradation products

Integral Database/Database manager

Integral Uncertainty Analysis Capabilities

Interactive Input/Execution Manager

4. Level of Effort

System setup:	<u>xx</u> mandays	<u>xx</u> manweeks	manmonths	manyear
Assessments:	mandays	<u>xx</u> manweeks	<u>xx</u> manmonths	manyear

(Estimates reflect order-of-magnitude values and depend heavily on the experience and ability of the assessor.)

5. Description of the Method/Techniques

Chemicals, Runoff, and Erosion from Agricultural Management Systems (CREAMS) was developed by the U.S. Department of Agriculture? Agricultural Research Service (Knisel, 1980; Leonard and Ferreira, 1984) for the analysis of agricultural best management practices for pollution control. CREAMS is a field scale model that uses separate hydrology, erosion, and chemistry submodels connected together by pass files.

Runoff volume, peak flow, infiltration, evapotranspiration, soil water content, and percolation are computed on a daily basis. If detailed precipitation data are available then infiltration is calculated at histogram breakpoints. Daily erosion and sediment yield, including particle size distribution, are estimated at the edge of the field. Plant nutrients and pesticides are simulated and storm load and average concentrations of sediment-associated and dissolved chemicals are determined in the runoff, sediment, and percolation through the root zone (Leonard and Knisel, 1984).

User defined management activities can be simulated by CREAMS. These activities include aerial spraying (foliar or soil directed) or soil incorporation of pesticides, animal waste management, and agricultural best management practices (minimum tillage, terracing, etc.).

Calibration is not specifically required for CREAMS simulation, but is usually desirable. The model provides accurate representation of the various soil processes. Most of the CREAMS parameter values are physically measurable. The model has the capability of simulating 20 pesticides at one time.

Groundwater Loading Effects of Agricultural Management Systems (GLEAMS) was developed by the United States Department of Agriculture? Agriculture Research Service (Leonard et al., 1987) to utilize the management oriented physically based CREAMS model (Knisel, 1980) and incorporate a component for vertical flux of pesticides in the root zone. A nitrogen component for the root zone is in development.

GLEAMS consists of three major components namely hydrology, erosion/sediment yield, and pesticides. Precipitation is partitioned between surface runoff and infiltration and water balance computations are done on a daily basis. Surface runoff is estimated using the Soil Conservation Service Curve Number

Method as modified by Williams and Nicks (1982). The soil is divided into various layers, with a minimum of 3 and a maximum of 12 layers of variable thickness are used for water and pesticide routing (Knisel et al., 1989).

6. Data Needs/Availability

The data needed for CREAMS are quite detailed. As CREAMS is a continuous simulation model the data needs are extensive. Meteorologic data consisting of daily or breakpoint precipitation is required for hydrology simulation. Monthly solar radiation and air temperature data is also needed for estimating components of the hydrological cycle. Data regarding soil type and properties along with information on crops to be grown is needed. A broad range of values for various model parameters can be obtained from the user's manual.

7. Output of the Assessment

Various output options are available for hydrology and nutrient simulations, including storm, monthly, or annual summary. Output for each segment of the overland flow and channel elements is available from areas in the watershed where intense erosion or deposition can be identified.

8. Limitations

The maximum size of the simulated area is limited to a field plots. A watershed scale version (Opus) of CREAMS/GLEAMS is currently under development (Ferreira, personal communication). The model is limited in data management and handling. The model cannot simulate instream processes. Although CREAMS has been applied in a wide range of climatic regimes, there is concern regarding its simulation capability for snow accumulation, melt, and resulting runoff, and hydrologic impacts of frozen ground conditions (see Jamieson and Clausen, 1988; Kauppi, 1982; Knisel et al., 1983).

9. Hardware/Software Requirements

The program is written in standard FORTRAN 77 and has been installed on IBM PC/AT-compatibles. A hard disk is required for operation of the program and a math co-processor is highly recommended. The program can be obtained on floppy disk for MS/DOS operating systems.

10. Experience

CREAMS has been extensively applied in a wide variety of hydrologic settings with good success. CREAMS has been used for in a wide variety of hydrologic and water quality studies (Smith and Williams, 1980; Morgan and Morgan, 1982; Lane and Ferreira, 1980; Kauppi, 1982; Knisel et al., 1983; and Jamieson and Clausen, 1988). Crowder et al. (1985) have used CREAMS in conjunction with an economic model to evaluate effects of conservation practices.

11. Validation/Review

The model has been validated by the developers along with independent experts. Erosion/sedimentation component of the CREAMS model has been verified by Foster and Ferreira (1981). Smith and Williams (1980) have validated the hydrology submodel at 46 sites in the southern and midwestern portions of United States. GLEAMS model has been validated with field data for Fenamiphos and its metabolites by Leonard et al., 1990. The authors report satisfactory comparison between observed and simulated results.

12. Contact

To obtain copies of the model please write or call Dr. Walt Knisel or Frank Davis at the following address:

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13. References

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Smith, R.E. and J.R. Williams. 1980. ?Simulation of the Surface Water Hydrology.? In: CREAMS: A Field-Scale Model for Chemicals, Runoff, and Erosion from Agricultural Management Systems. W.G. Knisel (editor). U.S. Department of Agriculture, Conservation Report No. 26, U.S. Government Printing Office, Washington, D.C., pp. 13-35.

Nonpoint Source Model Review

1. Name of the Method

Hydrological Simulation Program?Fortran (HSPF)
Stream Transport and Agricultural Runoff of Pesticides for Exposure Assessment (STREAM)

2. Type of Method

Surface Water Model:	Simple Approach
<u>xxx</u> Surface Water Model:	Refined Approach
Air Model:	Simple Approach
Air Model:	Refined Approach
Soil (Groundwater) Model:	Simple Approach
<u>xxx</u> Soil (Groundwater) Model:	Refined Approach
Multi-media Model:	Simple Approach
Multi-media Model:	Refined Approach

3. Purpose/Scope

Purpose: Predict concentrations of contaminants in

xxx runoff waters
xxx surface waters
xxx ground waters

Source/Release Types:

xxx Continuous
xxx Single

xxx Intermittent
xxx Multiple

xxx Diffuse

Level of Application:

xxx Screening

xxx Intermediate

xxx Detailed

Type of Chemicals:

xxx Conventional

xxx Organic

Metals

Unique Features:

xxx Addresses degradation products

xxx Integral Database/Database manager
Integral Uncertainty Analysis Capabilities

xxx Interactive Input/Execution Manager

4. Level of Effort

System setup: xx mandays

xx manweeks

manmonths

manyear

Assessments: mandays

xx manweeks

xx manmonths

manyear

(Estimates reflect order-of-magnitude values and depend heavily on the experience and ability of the assessor.)

5. Description of the Method/Techniques

Hydrological Simulation Program² FORTRAN (HSPF) is a comprehensive package for simulation of watershed hydrology and water quality for both conventional and toxic organic pollutants. HSPF incorporates the watershed scale ARM and NPS models into a basic-scale analysis framework that includes fate and transport in one-dimensional stream channels. It is the only comprehensive model of watershed hydrology and water quality that allows the integrated simulation of land and soil contaminant runoff processes with instream hydraulic and sediment-chemical interactions.

The result of this simulation is a time history of the runoff flow rate, sediment load, and nutrient and pesticide concentrations, along with a time history of water quantity and quality at any point in a watershed. HSPF simulates three sediment types (sand, silt, and clay) in addition to a single organic chemical and transformation products of that chemical. The transfer and reaction processes included are hydrolysis, oxidation, photolysis, biodegradation, a volatilization, and sorption. Sorption is modeled as a first-order kinetic process in which the user must specify a desorption rate and an equilibrium partition coefficient for each of the three solid types. Resuspension and settling of silts and clays (cohesive solids) are defined in terms of shear stress at the sediment-water interface. For sands, the capacity of the system to transport sand at a particular flow is calculated and resuspension or settling is defined by the difference between the sand in suspension and the capacity. Calibration of the model requires data for each of the three solids types. Benthic exchange is modeled as sorption/desorption and desorption/scour with surficial benthic sediments. Underlying sediment and pore water are not modeled.

6. Data Needs/Availability

Data needs for HSPF are extensive. HSPF is a continuous simulation program and requires continuous data to drive the simulations. As a minimum, continuous rainfall records are required to drive the runoff model and additional records of evapotranspiration, temperature, and solar intensity are desirable. A large number of model parameters can also be specified although default values are provided where reasonable values are available. HSPF is a general-purpose program and special attention has been paid to cases where input parameters are

omitted. Option flags allow bypassing of whole sections of the program where data are not available.

7. Output of the Assessment

HSPF produces a time history of the runoff flow rate, sediment load, and nutrient and pesticide concentrations, along with a time history of water quantity and quality at any point in a watershed. Simulation results can be processed through a frequency and duration analysis routine that produces output compatible with conventional toxicological measures (e.g., 96-hour LC50).

8. Limitations

HSPF assumes that the ²Stanford Watershed Model² hydrologic model is appropriate for the area being modeled. Further, the instream model assumes the receiving water body model is well-mixed with width and depth and is thus limited to well-mixed rivers and reservoirs. Application of this methodology generally requires a team effort because of its comprehensive nature.

9. Hardware/Software Requirements

The program is written in standard FORTRAN 77 and has been installed on systems as small as IBM compatibles (80386/486). A hard disk is required for operation of the program and a math co-processor is required. No special peripherals other than a printer are required. The program is maintained for both the IBM PC-compatible and the DEC/VAX with VMS operating system. Executable code prepared with the Lahey FORTRAN compiler and Phar Lap DOS extender is available for the MS/DOS environment. Source code only is available for the VAX environment.

The program can be obtained in either floppy disk format for MS/DOS operation systems, or through the CEAM BBS or the CEAM Internet node earth1.epa.gov with interactive installation program. This program has been installed on a wide range of computers world-wide with no or minor modifications.

10. Experience

HSPF and the earlier models from which it was developed have been extensively applied in a wide

variety of hydrologic and water quality studies (Barnwell and Johanson, 1981; Barnwell and Kittle, 1984) including pesticide runoff testing (Lorber and Mulkey, 1981), aquatic fate and transport model testing (Mulkey et al., 1986; Schnoor et al., 1987) analyses of agricultural best management practices (Donigian et al., 1983a; 1983b; Imhoff et al., 1983) and as part of pesticide exposure assessments in surface waters (Mulkey and Donigian, 1984).

An application of HSPF to five agricultural watersheds in a screening methodology for pesticide review is given in Donigian (1986). The Stream Transport and Agricultural Runoff for Exposure Assessment (STREAM) Methodology applies the HSPF program to various test watersheds for five major crops in four agricultural regions in the U.S., defines a "representative watershed" based on regional conditions and an extrapolation of the calibration for the test watershed, and performs a sensitivity analysis on key pesticide parameters to generate cumulative frequency distributions of pesticide loads and concentrations in each region. The resulting methodology requires the user to evaluate only the crops and regions of interest, the pesticide application rate, and three pesticide parameters: the partition coefficient, the soil/sediment decay rate, and the solution decay rate.

11. Validation/Review

The program has been validated with both field data and model experiments and has been reviewed by independent experts. Numerous citations for model applications are included in the References below. Recently, model refinements for instream algorithms related to pH and sediment-nutrient interactions have been sponsored by the USGS and the EPA Chesapeake Bay Program, respectively.

12. Contact

The model is available from the Center for Exposure Assessment Modeling at no charge. Mainframe versions of the programs compatible with the DEC VAX systems are available on standard on-half inch, 9-track magnetic tape. When ordering tapes, please specify the type of computer system that the model will be installed on (VAX, PRIME, HP, Cyber, IBM, etc.), whether the tape should be non-labeled, if non-labeled specify the storage format (EBCDIC or ASCII), or if the tape should be formatted as a VAX files-11, labeled (ASCII) tape for DEC systems. Model

distributions tapes contain documentation covering installation instructions on DEC systems, FORTRAN source code files, and test input data sets and output files that may be used to test and confirm the installation of the model on your system. Users are responsible for installing programs.

Requests for PC versions of the models should be accompanied by 6 formatted double-sided, high-density (DS/HD), error free diskettes. Please do not send 5.25" diskettes. Model distribution diskettes contain documentation covering installation instructions on PC systems, DOS batch files for compiling, linking, and executing the model, executable task image(s) ready for execution of the model(s), all associated runtime files, and test input data sets and corresponding output files that may be used to test and confirm the installation of the model on your PC or compatible system.

To obtain copies of the models, please send appropriate number of formatted diskettes to the attention of Model Distribution Coordinator at the following address:

Center for Exposure Assessment Modeling
U.S. Environmental Protection Agency
Athens Environmental Research Laboratory
Athens, Georgia 30605
(706) 546-3549
USA

Program and/or user documentation, or instructions on how to order documentation, will accompany each response.

13. References

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Nonpoint Source Model Review

1. Name of the Method

Pesticide Root Zone Model²PRZM

2. Type of Method

<u>xxx</u> Surface Water Model:	Simple Approach
Surface Water Model:	Refined Approach
Air Model:	Simple Approach
Air Model:	Refined Approach
Soil (Groundwater) Model:	Simple Approach

xxx Soil (Groundwater) Model: Refined Approach
 Multi-media Model: Simple Approach
 Multi-media Model: Refined Approach

3. Purpose/Scope

Purpose: Predict concentrations of contaminants in

xxx runoff waters
 surface waters

xxx ground waters (vadose and root zone)

Source/Release Types:

Continuous Single	<u>xxx</u> Intermittent <u>xxx</u> Multiple	<u>xxx</u> Diffuse
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Level of Application:

<u>xxx</u> Screening	<u>xxx</u> Intermediate	<u>xxx</u> Detailed
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Type of Chemicals:

Conventional	<u>xxx</u> Organic	Metals (pesticides)
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Unique Features:

xxx Addresses degradation products
 Integral Database/Database manager
 Integral Uncertainty Analysis Capabilities
 Interactive Input/Execution Manager

4. Level of Effort

System setup:	<u>xx</u> mandays	<u>xx</u> manweeks	manmonths	manyear
Assessments:	mandays	<u>xx</u> manweeks	<u>xx</u> manmonths	manyear

(Estimates reflect order-of-magnitude values and depend heavily on the experience and ability of the assessor.)

5. Description of the Method/Techniques

Pesticide Root Zone Model (PRZM) was developed at the U.S. EPA Environmental Research Laboratory in Athens, Georgia by Carsel et al. (1984). It is a one-dimensional, dynamic, compartmental model that can be used to simulate chemical movement in unsaturated zone within and immediately below the plant root zone. The model is divided into two major components namely, the hydrology (and hydraulics) and chemical transport. The hydrology component which calculates runoff and erosion is based upon the Soil Conservation Service curve number procedure and the Universal Soil Loss Equation respectively. Evapotranspiration is estimated directly from pan evaporation or by an empirical formula if pan evaporation data is not available. Soil-water capacity terms including field capacity, wilting point, and saturation water content are used for simulating water movement within the unsaturated zone. Irrigation application is also within model capabilities.

Pesticide application on soil or on the plant foliage are considered in the chemical transport simulation. Dissolved, adsorbed, and vapor-phase concentrations in the soil are estimated by simultaneously considering the processes of pesticide uptake by plants, surface runoff, erosion, decay, volatilization, foliar washoff, advection, dispersion, and retardation. The user has two options to solve the transport equations using the original backward difference implicit scheme or the method of characteristics (Dean et al., 1989). As the model is dynamic it allows considerations of pulse loads.

PRZM is an integral part of a unsaturated/saturated zone model RUSTIC (Dean et al., 1989). RUSTIC (Risk of Unsaturated/Saturated Transport and Transformation of Chemical Concentrations) links three subordinate models in order to predict pesticide fate and transport through the crop root zone, and saturated zone to drinking water wells through PRZM, VADOFT, SAFTMOD.

VADOFT is a one-dimensional finite element model which solves Richard's equation for water flow in the unsaturated zone. VADOFT can also simulate the fate and transport of two parent and two daughter products. SAFTMOD is a two-dimensional finite element model which simulates flow and transport in the saturated zone in either an X-Y or X-Z configuration. The three codes PRZM, VADOFT, and

SAFTMOD are linked together through an execution supervisor which allows users to build models for site specific situation. In order to perform exposure assessments, the code is equipped with a Monte Carlo pre and post processor (Dean et al., 1989).

6. Data Needs/Availability

The meteorological data needed by the model consist of daily rainfall, potential evaporation, and air temperature. If pesticide volatilization is to be simulated then additional meteorological data consisting daily wind speed and solar radiation are needed. Soils and land use data are required which can be obtained from local USDA-SCS field offices. The data regarding pesticide input parameters can be obtained from the user's manual or from published research.

7. Output of the Assessment

Predictions are made on a daily basis. Output can also be summarized for a daily, monthly, or annual period. Daily time series values of various fluxes and soil storages can be written to sequential files for further evaluation. In addition, a 'Special Action' option allows the user to output soil profile pesticide concentrations at user specified times (Dean et al., 1989).

8. Limitations

One of the model limitation is that it one-dimensional in the vertical direction and hence does not handle lateral flow. PRZM only simulates downward movement of water and does not account for diffusive movement due to soil water gradients. This process has been identified to be important when simulating the effects of volatilization by Jury et al. (1984). The model only simulates organic chemicals, for example pesticides.

9. Hardware/Software Requirements

The program is written in standard FORTRAN 77 and has been installed on IBM PC/AT-compatibles. A hard disk is required for operation of the program and a math co-processor is required. The program can be obtained on floppy disk for MS/DOS operating systems.

10. Experience

PRZM has been used to study Aldicarb application to citrus in Florida (Jones et al., 1983), and potatoes in New York (Carsel et al., 1985) and Wisconsin (Jones, 1983). It has also been used for Metalaxyl application to tobacco in Florida and Maryland (Carsel et al., 1986) and to Atrazine and chloride application to corn in Georgia (Carsel et al., 1985).

11. Validation/Review

The PRZM model has undergone testing with field data in New York and Wisconsin (potatoes), Florida (citrus), and Georgia (corn) (Carsel, et al., 1985, Jones 1983, Jones et al., 1983). The results of these tests demonstrate that PRZM is a useful tool for evaluating groundwater threats for pesticide use.

12. Contact

To obtain copies of the user's manual and the computer program contact

Center for Exposure Assessment Modeling
U.S. Environmental Protection Agency
Environmental Research Laboratory
Athens, GA. 30605
(706) 546-3549

13. References

Carsel, R.F., C.N. Smith, L.A. Mulkey, J.D. Dean and P. Jowise. 1984. User's Manual for the Pesticide Root Zone Model (PRZM): Release 1. EPA-600/3-84-109. U.S. Environmental Protection Agency. Environmental Research Laboratory, Athens, GA.

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Dean, J.D., P.S. Huyakorn, A.S. Donigian, Jr., K.A. Voos, R.W. Schanz, Y.J. Meeks and R.F. Carsel. 1989.

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Jones, R.L., P.S.C. Rao and A.G. Hornsby. 1983. ?Fate of Aldicarb in Florida Citrus Soil 2, Model Evaluation.? Presented at the Conference on Characterization and Monitoring of Vadose (Unsaturated) Zone, December 8-10, Las Vegas, NV.

Nonpoint Source Model Review

1. Name of the Method

Simulator for Water Resources in Rural Basins? (SWRRB)
Pesticide Runoff Simulator? (PRS)

2. Type of Method

Surface Water Model:	Simple Approach
<u>xxx</u> Surface Water Model:	Refined Approach
Air Model:	Simple Approach
Air Model:	Refined Approach
Soil (Groundwater) Model:	Simple Approach
<u>xxx</u> Soil (Groundwater) Model:	Refined Approach
Multi-media Model:	Simple Approach
Multi-media Model:	Refined Approach

3. Purpose/Scope

Purpose: Predict concentrations of contaminants in

xxx runoff waters
 surface waters
xxx ground waters

Source/Release Types:

Continuous	Intermittent	
Single	Multiple	<u>xxx</u> Diffuse

Level of Application:

<u>xxx</u> Screening	<u>xxx</u> Intermediate	<u>xxx</u> Detailed
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Type of Chemicals:

<u>xxx</u> Conventional	<u>xxx</u> Organic	Metals
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Unique Features:

Addresses degradation products
Integral Database/Database manager
xxx Integral Uncertainty Analysis Capabilities
Interactive Input/Execution Manager

4. Level of Effort

System setup:	<u>xx</u> mandays	<u>xx</u> manweeks	manmonths	manyear
Assessments:	mandays	<u>xx</u> manweeks	<u>xx</u> manmonths	manyear

(Estimates reflect order-of-magnitude values and depend heavily on the experience and ability of the assessor.)

5. Description of the Method/Techniques

Pesticide Runoff Simulator (PRS) was developed for the U.S. EPA Office of Pesticide and Toxic Substances by Computer Sciences Corporation (1980) to simulate pesticide runoff and adsorption into the soil on small agricultural watersheds. PRS is based on SWRRB (Simulator for Water Resources in Rural Basins) originally developed by Williams et al. (1985) at the USDA.

The PRS hydrology and sediment simulation is based on the USDA CREAMS model. The SCS curve number technique is used to predict surface runoff. Sediment yield is simulated using a modified version of the Universal Soil Loss Equation and a sediment routing model.

The pesticide component of PRS is a modified version of the CREAMS pesticide model. Pesticide application (foliar and soil applied) can be removed by atmospheric loss, wash off by rainfall, and leaching into the soil. Pesticide yield is divided into a soluble fraction and an adsorbed phase based on an enrichment ratio.

The model includes a built in weather generator based on temperature, solar radiation, and precipitation statistics. Calibration is not specifically required, but is usually desirable.

Simulator for Water Resources in Rural Basins (SWRRB) was developed by Williams et al. (1985), and Arnold et al., (1989) for evaluating basin scale water quality. SWRRB operates on a daily time step and simulates weather, hydrology, crop growth, sedimentation, and nitrogen, phosphorous, and pesticide movement. The model was developed by modifying the CREAMS (Knisel, 1980) daily rainfall hydrology model for application to large, complex, rural basins.

Surface runoff is calculated using the Soil Conservation Service Curve Number technique. Sediment yield is computed for each basin by using the Modified Universal Soil Loss Equation (Williams and Berndt, 1977). The channel and floodplain sediment routing model is composed of two components operating simultaneously (deposition and degradation). Degradation is based on Bagnold's stream power concept and deposition is based on the fall velocity of the sediment particles (Arnold et al., 1989).

Return flow is calculated as a function of soil water content and return flow travel time. The percolation component uses a storage routing model combined with a crack flow model to predict the flow through the root zone. The crop growth model (Arnold et al., 1989) computes total biomass each day during the growing season as a function of solar radiation and leaf area index.

The pollutant transport portion is subdivided into one part handling soluble pollutants and another part handling sediment attached pollutants. The methods used to predict nitrogen and phosphorus yields from the rural basins are adopted from CREAMS (Knisel, 1980). The nitrogen and phosphorus calculations are performed using relationships between chemical concentration, sediment yield and runoff volume.

The pesticide component is directly taken from Holst and Kutney (1989) and is a modification of the CREAMS (Smith and Williams, 1980) pesticide model. The amount of pesticide reaching the ground or plants is based on a pesticide application efficiency factor. Empirical equations are used for calculating pesticide washoff which are based on threshold rainfall amount. Pesticide decay from the plants and the soil are predicted using exponential functions based on the decay constant for pesticide in the soil, and half life of pesticide on foliar residue.

6. Data Needs/Availability

Meteorologic data comprising of daily precipitation and solar radiation are required for hydrology simulations. Another set of input data consists of soils, land use, fertilizer, and pesticide application. The soils and land use data can be obtained from USDA-SCS soil survey maps. Some guidance is available in the manual for estimating parameters required for nutrient and pesticide simulation.

7. Output of the Assessment

The model predicts daily runoff volume and peak rate, sediment yield, evapotranspiration, percolation, return flow, and pesticide concentration in runoff and sediment.

8. Limitations

There is very minimal model documentation. In the hydrology component the snow accumulation

processes are ignored, and for the case of pesticides no comprehensive instream simulation is available. Nutrient transformations along with pesticide daughter products are not accounted for in the model.

9. Hardware/Software Requirements

The PRS model is operational on the EPA National Computer Center on an IBM 370/168 computer under MVS. The model may be accessed via WYLBUR for modification of the source code, creation or modification of input datasets, and submission of batch executions of the model.

The SWRRB program is written in standard FORTRAN 77 and has been installed on IBM PC/AT and compatibles. A hard disk is required for operation of the program and a math co-processor is highly recommended.

10. Experience

The SWRRB model has been used by the Exposure Assessment Branch, Hazard Evaluation Division, and the Office of Pesticide Programs of the USEPA (Arnold et al., 1989).

11. Validation/Review

SWRRB was tested on 11 large watersheds by Arnold and Williams (1987). These watersheds were located at eight Agricultural Research Service locations throughout the United States. The results showed that SWRRB can realistically simulate water and sediment yield under a wide range of soils, climate, land-use, topography, and management systems.

12. Contact

For copies of the SWRRB program and the user manual contact

Nancy Sammons
808 East Blackland Road
Temple, Texas 76502
(817) 770-6512

13. References

Arnold, J.G., J.R. Williams, A.D. Nicks and N.B. Sammons. 1989. ?SWRRB, A Basin Scale Simulation

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Nonpoint Source Model Review

1. Name of the Method

Unified Transport Model for Toxic Materials? UTM-TOX

2. Type of Method

Surface Water Model:	Simple Approach
<u>xxx</u> Surface Water Model:	Refined Approach
Air Model:	Simple Approach
<u>xxx</u> Air Model:	Refined Approach
Soil (Groundwater) Model:	Simple Approach
<u>xxx</u> Soil (Groundwater) Model:	Refined Approach
Multi-media Model:	Simple Approach
<u>xxx</u> Multi-media Model:	Refined Approach

3. Purpose/Scope

Purpose: Predict concentrations of contaminants in

xxx runoff waters
xxx surface waters
ground waters (vadose and root zone)

Source/Release Types:

<u>xxx</u> Continuous	Intermittent	
Single	<u>xxx</u> Multiple	<u>xxx</u> Diffuse

Level of Application:

Screening	Intermediate	<u>xxx</u> Detailed
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Type of Chemicals:

<u>xxx</u> Conventional	<u>xxx</u> Organic	<u>xxx</u> Metals
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Unique Features:

- Addresses degradation products
- Integral Database/Database manager
- Integral Uncertainty Analysis Capabilities
- Interactive Input/Execution Manager

4. Level of Effort

System setup:	<u>xx</u> mandays	<u>xx</u> manweeks	manmonths	manyear
Assessments:	mandays	<u>xx</u> manweeks	<u>xx</u> manmonths	manyear

(Estimates reflect order-of-magnitude values and depend heavily on the experience and ability of the assessor.)

5. Description of the Method/Techniques

Unified Transport Model for Toxic Materials (UTM-TOX) was developed by Oak Ridge National Laboratory for the U.S. EPA Office of Pesticides and Toxic Substances, Washington, D.C. (Patterson et al., 1983). UTM-TOX is a multimedia model that combines hydrologic, atmospheric, and sediment transport in one computer code.

The model calculates rates of flux of a chemical from release to the atmosphere, through deposition on a watershed, infiltration and runoff from the soil, to flow in a stream channel and associated sediment transport. From these calculations mass balances can be established, chemical budgets made, and concentrations in the environment estimated.

The atmospheric transport model (ATM) portion of UTM-TOX is a Gaussian plume model that calculates dispersion of pollutants emitted from point (stack), area, or line sources. ATM operates on a monthly time step, which is longer than the hydrologic portion of the model and results in the use of an average chemical deposition falling on the watershed.

The Terrestrial Ecology and Hydrology Model (TEHM) describes soil-plant water fluxes, interception, infiltration, and storm and groundwater flow.

The hydrologic portion of the model is from the Wisconsin Hydrologic Transport Model (WHTM), which is a modified version of the Stanford Watershed Model (SWM). WHTM includes all of the hydrologic processes of the SWM and also simulates soluble chemical movement, litter and vegetation interception of the chemical, erosion of sorbed chemical, chemical degradation in soil and litter, and sorption in top layers of the soil. Stream transport includes transfer between three sediment components (suspended, bed, and resident bed).

6. Data Needs/Availability

The input data includes monthly wind, hourly precipitation, solar radiation, daily maximum and minimum temperatures, soil characteristics, topographic information, surface water characteristics, sediment characteristics, and the physiochemical properties and transformation rates associated with the chemical.

7. Output of the Assessment

The output can be obtained in terms of plots and tables summarizing the average monthly and annual chemical concentrations in the 8 wind sectors, in saturated and unsaturated soil layers, in runoff, out of each reach, and in the stems, leaves, roots and fruits of vegetation.

8. Limitations

The model ignores the interaction between chemicals and sediment in streams. There is a large time and spatial resolution of ATM portion of the model relative to the hydrologic processes. The model is quite complex and requires significant user expertise.

9. Hardware/Software Requirements

UTM-TOX is large computer program and is written in FORTRAN IV. The program was developed for IBM 370/3033 or VAX 11/780 systems.

10. Experience

An earlier version of the model has been applied by Munro et al. (1976) to evaluate the movement of lead, cadmium, zinc, copper and sulphur through Crooked Creek Watershed. This earlier version was also used by Huff et al. (1977) to Walker Branch Watershed. One of the current application of the model is reported by Patterson (1986) for estimating lead transport budget in the Crooked Creek Watershed. No current references since 1986 on the application of the model are available.

11. Validation/Review

The model components have been field validated by several researchers (Culkowski and Patterson, 1976; Munro et al., 1976; and Raridon, Fields, and Henderson, 1976).

12. Contact

To obtain copies of the model and the manual contact

Dr. M.R. Patterson
Oak Ridge National Laboratory
Mail Stop 6243
Oak Ridge, Tennessee 37831
(615) 574-5442

13. References

Culkowski, W.M. and M.R. Patterson. 1976. A Comprehensive Atmospheric Transport and Diffusion Model. ORNL/NSF/EATC-17.

Huff, D.D., G.S. Henderson, C.L. Begovich, R.L. Luxmoore and J.R. Jones. 1977. The Application of Analytic and Mechanistic Hydrologic Models to the Study of Walker Branch Watershed. In: Watershed Research in Eastern North America. A Workshop to Compare Results. D.L. Corell (editor). Vol. II, pp. 741-766.

Munro, J.K., R.J. Luxmoore, C.L. Begovich, K.R. Dixon, A.P. Watson, M.R. Patterson and D.R. Jackson. 1976. Application of the Unified Transport Model to the Movement of Pb, Cd, Zn, Cu, and S through the Crooked Creek Watershed. ORNL/NSF/EATC-28.

Patterson, M.R., T.J. Sworski, A.L. Sjoreen, M.G. Browman, C.C. Coutant, D.M. Hetrick, B.D. Murphy and R.J. Raridon. 1983. A User's Manual for UTM-TOX, A Unified Transport Model. Draft. Prepared by Oak Ridge National Laboratory, Oak Ridge, TN, for U.S. EPA Office of Toxic Substances, Washington, DC.

Patterson, M.R. 1986. Lead Transport Budget in Crooked Creek Watershed. In: *Pollutants in Multimedia Environment*. Plenum Press. 1986. pp. 93-118.

Raridon, R.J., D.E. Fields and G.S. Henderson. 1976. Hydrologic and Chemical Budgets on Walker Branch Watershed? Observations and Modeling Applications. ORNL/NSF/EATC-24.