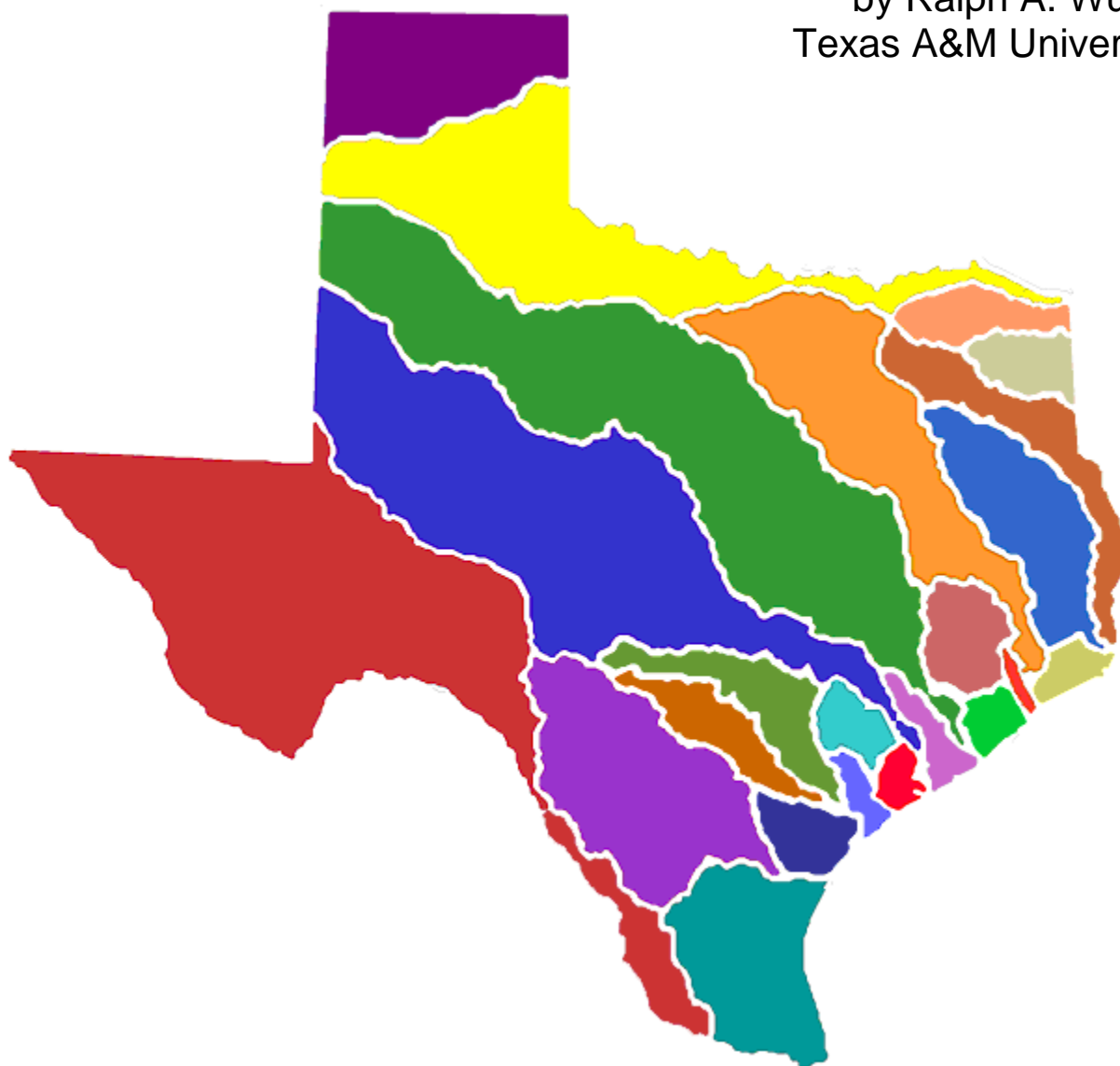


# Fundamentals of Water Availability Modeling with WRAP

by Ralph A. Wurbs  
Texas A&M University



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| CO          | 81   | Control Point Output | COMM           | 95   | Comments              |
| CP          | 84   | Control Point        | ENDF           | 96   | End of File           |
| ED          | 75   | End of Data          | IDEN           | 102  | Identifiers           |
| EV          | 93   | Evaporation-Precip   | PAGE           | 95   | Title Page            |
| FY          | 78   | Firm Yield           | TITL           | 95   | Table Title           |
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## CHAPTER 1 WRAP MODELING SYSTEM

Water resources development, water allocation, and river/reservoir system operations are simulated with the Water Rights Analysis Package (WRAP) using sequences of historical naturalized stream flows and reservoir surface net evaporation less precipitation rates to represent river basin hydrology. The generalized simulation modeling system is used to assess hydrologic and institutional water availability and reliability in satisfying requirements for environmental instream flows, water supply diversions, hydroelectric energy generation, and reservoir storage. Flood control reservoir operations may also be modeled. Salinity simulation capabilities are provided. Basin-wide impacts of water resources development projects and changes in water use and management practices are evaluated. The model is generalized for application to any river/reservoir/water-use system, with input datasets being developed for the particular river basin or region of concern.

The statewide Water Availability Modeling (WAM) System implemented and maintained by the Texas Commission on Environmental Quality (TCEQ) consists of the generalized WRAP modeling system and input datasets for all of the river basins of Texas. WRAP may be applied either in conjunction with the WAM System or independently thereof. In applying the WAM System, model users modify the already-created WRAP input data files available from the TCEQ to model the alternative water resources development plans, water management strategies, and water use scenarios being investigated in their studies. For river basins outside of Texas, model users must develop the input datasets required for their particular applications.

WRAP applications vary from quite simple to very complicated. The complexity of the modeling system is due primarily to requirements for flexibility in modeling diverse water management strategies and reservoir/river system operating practices and the physical and institutional interrelationships between numerous water users and river regulation objectives. WRAP contains a comprehensive array of optional features for modeling the complexities of diverse water management practices. Flexibility is also provided for compiling input data and organizing simulation results in a variety of alternative formats. However, easy-to-learn fundamentals account for a significant portion of practical modeling applications.

This *Fundamentals Manual* serves as an introductory tutorial helping new users to apply the modeling system quickly for simpler water availability modeling applications. With this example-centered abbreviated manual covering only select features, within a few hours, first-time users can become proficient in fundamental aspects of applying WRAP. The *Fundamentals Manual* also provides a quick reference to basics for experienced users. The basics covered in the *Fundamentals Manual* are fundamental for any WRAP application and represent all of the capabilities needed for many applications. The other manuals cited below are required for proficiency in applying broader ranges of WRAP modeling capabilities.

### WRAP Manuals

The following technical reports provide comprehensive detailed documentation of the modeling system. This *Fundamentals Manual* combines and condenses the much more extensive and detailed *Reference Manual* and *Users Manual*.

*WRAP Modeling System Reference Manual*, TWRI TR-255, 12th Edition, May 2019.

*WRAP Modeling System Users Manual*, TWRI TR-256, 12th Edition, May 2019.

*WRAP Daily Modeling System*, TWRI TR-430, 3rd Edition, May 2019.

*WRAP River System Hydrology*, TWRI TR-431, 3rd Edition, May 2019.

*Salinity Simulation with WRAP*, TWRI TR-317, July 2009.

The *Reference Manual* describes the methods incorporated in WRAP and the conceptual framework of the modeling system. The *Users Manual* covers the detailed mechanics of applying the WRAP programs. The modeling capabilities outlined in the *Reference* and *Users Manuals* are routinely applied in conjunction with the Texas Water Availability Modeling (WAM) System in preparation and evaluation of water right permit applications and in regional and statewide planning studies. The other manuals cover modeling features that have not yet been as widely applied. The manuals include many examples with datasets distributed with the computer programs. The *Reference Manual* cites other technical reports and publications that further explore and illustrate various aspects of WRAP.

This *Fundamentals Manual* covers a subset of the modeling capabilities documented by the *Reference* and *Users Manuals*. The selected WRAP features covered in the *Fundamentals Manual* comprise a modeling system capable of addressing many practical applications. The *Fundamentals Manual* provides quick access to basic WRAP features which by themselves comprise a complete river/river system simulation model as well as being foundational to the much more comprehensive modeling system covered in its entirety by the other manuals. Complexities of WRAP are due largely to its comprehensive array of flexible options for modeling large complex river/reservoir systems with diverse water resources development, allocation, management, and use strategies/practices. WRAP and this *Fundamentals Manual* are simplified by omitting many of these modeling options and focusing on the basics.

The WRAP modeling system is organized within a framework of computer programs, input and output files, and data records comprising the files. WRAP is a set of computer programs that are executed as separate individual programs but interact as a modeling system. The structure and format of the data files associated with the programs are designed to be both efficiently manipulated by the computer and conveniently managed by the people that use the model. Application of WRAP involves creating and modifying input datasets, executing computer programs, and organizing, analyzing, and displaying simulation results.

This manual is likewise organized within the framework of computer programs, files, and data records comprising the files. Chapter 1 is an introductory overview of programs, files, and modeling capabilities. This *Fundamentals Manual* covers the three programs *WinWRAP*, *SIM*, and *TABLES*, which are the subjects of Chapters 2, 3, and 4, respectively. The manual focuses on an example river/reservoir system simulation that illustrates application of programs *SIM* and *TABLES*. The *SIM* and *TABLES* input and output files for the example are presented as Appendices A and B. Instructions for preparing input file records are provided as Appendices C and D. The descriptions of input record content and format found in Appendices C and D comprise a selected subset of the record types covered in the *Users Manual*. Chapter 5 outlines features for locating the input error to be corrected when program execution terminates due to an input error.

## WRAP Programs

WRAP consists of the computer programs listed in Table 1.1. Executable files are available for use on desktop computers with the Microsoft Windows operating system. The public domain software and documentation may be freely copied. The programs *WinWRAP*, *SIM*, and *TABLES* are introduced in Chapters 2, 3, and 4. *WinWRAP* is a user interface that connects executable programs and data files. *SIM* is the basic simulation model. *TABLES* is a post-simulation program used to organize simulation results. The other programs described in Table 1.1 are not included in this *Fundamentals Manual*.

Table 1.1  
WRAP Programs

| Program   | Description   |
|-----------|---|
| WinWRAP   | Interface for applying WRAP on personal computers with the Microsoft Windows operating system.  |
| SIM       | Monthly time step model for simulating water resources development, allocation, regulation, management, and use.  |
| SIMD      | Expanded version of SIM with additional features for daily time steps, flow forecasting and routing, environmental pulse flows, and flood control reservoir system operations.                                    |
| TABLES    | Post-simulation program for developing frequency relationships, reliability indices, and various user-specified tables and tabulations for organizing, summarizing, analyzing, and displaying simulation results. |
| HYD       | Pre-simulation program for developing monthly naturalized stream flow and reservoir net evaporation-precipitation rate data for <i>SIM</i> hydrology input files.   |
| DAY, DAYH | Pre-simulation programs for calibrating routing parameters and compiling daily flows for <i>SIMD</i> input.   |
| SALT      | Salinity simulation component of WRAP modeling system.  |

The executable (filename extension *exe*) WRAP programs listed in Table 1.1 are ready to run without any set-up procedure. The programs can be executed using any of the optional means provided by Microsoft Windows. Each individual executable file can be activated with a click of a mouse, the run window, or a desktop shortcut icon. The programs can be run as individual executable programs without using *WinWRAP*. However, the Windows interface program *WinWRAP* described in Chapter 2 provides a convenient means for automatically connecting multiple programs and data files. The WRAP programs are all normally stored in the same Microsoft Windows folder (directory) to facilitate execution with *WinWRAP*.

## **HEC-DSS and HEC-DSSVue**

The Hydrologic Engineering Center (HEC) of the U.S. Army Corps of Engineers (USACE) has developed a suite of generalized hydrologic, hydraulic, and water management simulation models that are applied extensively by numerous agencies and consulting firms throughout the United States and abroad. The HEC-DSS (Data Storage System) is used routinely with HEC simulation models and also with other non-HEC modeling systems including WRAP. Database management capabilities provided by the HEC-DSS are designed for large sets of sequential time series data such as WRAP hydrology input data and simulation results.

The HEC-DSS Visual Utility Engine (*HEC-DSSVue*) is employed to manage, view, edit, plot, mathematically manipulate, and statistically analyze data in DSS files. The public domain *HEC-DSSVue* software and detailed users manual may be downloaded from the Hydrologic Engineering Center website: <http://www.hec.usace.army.mil/>

DSS files are in a binary format that can be accessed only by software that incorporates DSS features such as *HEC-DSSVue* and the WRAP programs *SIM*, *SIMD*, *HYD*, *DAY*, and *TABLES*. The simulation models *SIM* and *SIMD* read hydrology input datasets from a DSS file. *SIM*, *SIMD*, and *TABLES* include routines for storing simulation results as DSS files. Data records in DSS files are referenced by pathnames in a standard format. Pathnames are assigned automatically by the *WRAP* programs. *HEC-DSSVue* is documented in detail by a users manual available from the HEC. WRAP applications of HEC-DSS and *HEC-DSSVue* are described in the *WRAP Users Manual* and the other WRAP manuals. Graphs plotted with *HEC-DSSVue* are included in the example presented later in this *Fundamentals Manual*.

## **Other Auxiliary Programs**

The WRAP programs provide comprehensive computational capabilities but have no editing or graphics capabilities. The only required auxiliary software is an editor such as WordPad to create and modify input files and view simulation results stored in output files. However, WRAP modeling and analysis capabilities are enhanced by use of other supporting software for developing input datasets and analyzing and displaying simulation results.

Microsoft WordPad, Notepad, and Word are used routinely in creating and editing WRAP input files and viewing and displaying simulation results. Microsoft Excel provides data management and computational capabilities that can be useful for application with WRAP. These programs can be accessed directly from the *WinWRAP* interface. *TABLES* has options for tabulating essentially any of the time series variables included in the *SIM*, *SIMD*, and *SALT* simulation results in a format designed to be conveniently accessed by Microsoft Excel.

Geographic information system (GIS) software is useful in dealing with spatial aspects of compiling WRAP input data and displaying simulation results. ArcGIS marketed by the Environmental Systems Research Institute (ESRI) is a popular GIS software package that is often applied with WRAP. An ArcGIS tool for spatially displaying WRAP simulation results is available from the TCEQ which uses a dynamic link library in ArcGIS to display WRAP water supply reliabilities, flow and storage frequencies, and other simulation results on a map by location in the river basin. GIS applications are not addressed in this *Fundamentals Manual*.

## WRAP Data Files

A complete listing of input and output data files for the WRAP computer programs is provided as Table 1.2 of the *Users Manual*. Selected files pertinent to the *Fundamentals Manual* are listed in Table 1.2 below.

Table 1.2  
Input and Output Files

| File Type                         | File Name    | Description   |
|-----------------------------------|--------------|---|
| <u><i>SIM Input Files</i></u>     |              |   |
| DAT                               | root1.DAT    | Required input file containing data describing water resources development, management, and use.            |
| FLO                               | root2.FLO    | Monthly naturalized river flows.  |
| EVA                               | root2.EVA    | Monthly net evaporation-precipitation depths.   |
| DIS                               | root2.DIS    | Watershed parameters for distributing naturalized flows from gaged to ungaged control points.               |
| DSS                               | root2HYD.DSS | Hydrology input as DSS records in a DSS file.   |
| <u><i>SIM Output Files</i></u>    |              |   |
| MSS                               | root1.MSS    | Message file with trace, warning, and error messages.   |
| OUT                               | root1.OUT    | Main simulation results output file read by <i>TABLES</i> .   |
| SOU                               | root1.SOU    | Main simulation results output in columnar tables.  |
| DSS                               | root1.DSS    | Main simulation results file read by <i>HEC-DSSVue</i> .  |
| YRO                               | root1.YRO    | Yield-reliability analysis output table.  |
| <u><i>TABLES Input Files</i></u>  |              |   |
| TIN                               | root.TIN     | Specifications controlling selection and format of tables or data listings to be created by <i>TABLES</i> . |
| DSS                               | root.DSS     | DSS file with monthly, daily, or annual times series.   |
| OUT                               | root.OUT     | <i>SIM</i> main simulation results output file.   |
| DAT                               | root.DAT     | <i>SIM</i> input file.  |
| <u><i>TABLES Output Files</i></u> |              |   |
| TMS                               | root.TMS     | Message file with trace, warning, and error messages.   |
| TOU                               | root.TOU     | Main output file with organized simulation results.   |
| DSS                               | root.DSS     | File created by <i>TABLES</i> to be read by <i>HEC-DSSVue</i> .   |

The WRAP programs are generalized for application any place, with the particular river basin hydrology and pertinent systems of rivers, reservoirs, water use requirements, and water management strategies and practices being described by sets of input data. A simulation is performed with *SIM* using input files describing water resources development, allocation, and management (DAT file) and hydrology (DSS, FLO, EVA, DIS files) provided by the model user.

Monthly naturalized flows and reservoir evaporation-precipitation depths are read by *SIM* from alternatively either a DSS hydrology input file or FLO and EVA files. *SIM* stores the same simulation results in its OUT text file read by *TABLES* and DSS binary output file read by *HEC-DSSVue*. *TABLES* reads the *SIM* output OUT file and organizes the simulation results in formats specified in a *TABLES* input TIN file. The results are written to a *TABLES* output TOU file. Likewise, simulation results stored in a DSS file are managed, analyzed, and displayed using *HEC-DSSVue*. The programs create message files with filename extensions MSS and TMS that track computations and alert users to input data irregularities and errors. The executable WRAP programs and data files are interfaced through *WinWRAP* within the Microsoft Windows operating system in combination with use of Microsoft software to access and edit WRAP input and output files.

Simulation results are written to files for analysis, incorporation into reports, or export to auxiliary programs for plotting or further manipulation, analysis, and display. With the exceptions of the binary DSS files and an optional binary version of the OUT file, the input files read or output files created by WRAP programs are ordinary text files that may be viewed and edited with essentially any editor such as Microsoft WordPad. DSS files are viewed, edited, manipulated, analyzed, and displayed with *HEC-DSSVue*.

File names are in the format *root.extension*. The root is an arbitrary name assigned by the model user. The 3-character extensions listed in Table 1.2 define the type of data contained in the files. Extensions are set by naming conventions incorporated in the programs. File types are referenced by their filename extensions. The filename root is specified by the model-user through the beginning-of-execution log-in procedures commonly managed within *WinWRAP*. All of the files used in a simulation may be named with the same root. Certain files used in a single execution must have the same filename root. Shared or different filename roots may be assigned to files as follows.

- The same root may be used for all files associated with a particular simulation. The extension serves to differentiate between the different types of files that play various roles in the simulation.
- Assigning a different root (root2 in Table 1.2) for hydrology (DSS, FLO, EVA, DIS) files may be convenient though not required. In typical modeling studies, the hydrology files remain unchanged while the DAT file is varied in multiple simulations to reflect alternative water resources development plans, reservoir system operating strategies, or water use scenarios.
- Assigning different roots for *TABLES* input (extension TIN) and output (extensions TOU and TMS) files may be convenient though not required when building selected sets of tables for various applications. Particular TIN files may be designed to create specific sets of tables in certain formats.

Files are composed of lines of data called records. The records contained in the input data files for the WRAP programs are organized by record type. An identifier entered at the beginning of each input data record defines the type of record. The various input data record types for *SIM* and *TABLES* are described in Chapters 3 and 4, respectively, and Appendices C and D, respectively, of this manual. *SIM* input records begin with one of the two-character record identifiers listed in Table 3.1 of Chapter 3. *TABLES* input records begin with the four-character identifiers listed in Table 4.1.

## Illustrative Example

An example is presented in this *Fundamentals Manual* and further expanded in the other manuals. Input files for all the manual examples are available along with the executable programs and manuals. The *SIM* input and output files presented in Appendix A are explained in Chapter 3. *TABLES* input and output files for the example are reproduced as Appendix B and discussed in Chapter 4. The example was created by taking selected hydrology and reservoir data from the TCEQ WAM System dataset for the Brazos River Basin and adding other hypothetical water rights data to develop a realistic but reasonably simple illustrative example.

The WRAP modeling system combined with a *SIM* input dataset from the TCEQ WAM System for a particular river basin is called a water availability model (WAM). The Brazos WAM is described by a May 2019 report prepared for the TCEQ by Wurbs entitled *Daily Water Availability Model for the Brazos River Basin and San Jacinto-Brazos Coastal Basin*. The authorized use scenario Brazos WAM has 77 primary control points, over 3,700 secondary control points, 67 sets of reservoir evaporation-precipitation depths, 678 reservoirs, 1,643 water right *WR* records, and 122 instream flow *IF* records. The example adopts naturalized flows at 11 of the Brazos WAM primary control points and actual storage capacity data and net evaporation-precipitation depths for six of the reservoirs. The other water rights data are fabricated, reflecting realistic quantities but not directly representing any particular actual water right permits.

The hydrologic period-of-analysis for the example is January 1940 through December 2017. Monthly naturalized flows in the example represent observed flows at the U.S. Geological Survey (USGS) gaging stations listed in Table 1.3 adjusted to reflect natural conditions without human water resources development and use. The naturalized flows illustrate the extreme variability characteristic of stream flow throughout Texas that includes multiple-year droughts and intense flood events as well as seasonal and continuous less dramatic flow fluctuations. The six reservoirs are located just near but are assumed to be located exactly at Table 1.3 gage sites.

Table 1.3  
Naturalized Flow Sites Adopted for the Example

| USGS Gage Identifier | Location by Stream and Nearest Town | Watershed Area<br>(square miles) | TCEQ WAM Control Point | Example Control Point |
|----------------------|-------------------------------------|----------------------------------|------------------------|-----------------------|
| 08088600             | Brazos River near Graford           | 14,030                           | SHGR26                 | PK                    |
| 08093100             | Brazos River near Aquilla           | 17,750                           | BRAQ33                 | Whit                  |
| 08095600             | Bosque River near Waco              | 1,660                            | BOWA40                 | WacoL                 |
| 08096500             | Brazos River near Waco              | 20,060                           | BRWA41                 | WacoG                 |
| 08098290             | Brazos River near Highbank          | 20,900                           | BRHB42                 | High                  |
| 08102500             | Leon River near Belton              | 3,580                            | LEBE49                 | Belton                |
| 08104700             | NF San Gabriel, Georgetown          | 248                              | NGGE54                 | George                |
| 08105700             | San Gabriel River, Laneport         | 737                              | GALA57                 | Grang                 |
| 08106500             | Little River at Cameron             | 7,100                            | LRCA58                 | Camer                 |
| 08109000             | Brazos River near Bryan             | 30,020                           | BRBR59                 | Bryan                 |
| 08111500             | Brazos River near Hempstead         | 34,370                           | BRHE68                 | Hemp                  |

## WRAP Capabilities Not Covered in this Manual

The WRAP modeling system is documented in detail by *Reference*, *Users*, *Daily*, *Hydrology*, *Salinity*, and *Programming Manuals* containing a total of over 1,500 pages. The *Reference Manual* includes a list of references that includes the WRAP manuals as well as other technical reports, journal papers, and other publications that explore various aspects of the WRAP modeling system and applications thereof. This *Fundamentals Manual* is a greatly condensed consolidation of the combined *Reference* and *Users Manuals*. The basic aspects of WRAP covered in the *Fundamentals Manual* represent all of the capabilities needed for many applications and are the basic foundation of all WRAP capabilities. The fundamentals covered here focus on some but not all water availability modeling capabilities that have been routinely applied for many years in administration of the water rights permit system and regional and statewide planning in Texas. The following WRAP modeling capabilities are not covered in this *Fundamentals Manual*.

- The *Reference* and *Users Manuals* describe an array of options for modeling the complexities of water resources development, allocation, management, and use that are routinely applied but are not covered in the *Fundamentals Manual*. Many of the other *SIM* simulation options not covered in this manual are activated by auxiliary records in the *SIM* input DAT file that expand modeling of water rights defined by water right *WR* records and instream flow *IF* records.
- The *Reference* and *Users Manuals* explain methods for distributing naturalized flows from primary (gaged inputted flow) control points to secondary (ungaged) control points within *SIM* based on input on control point *CP*, watershed parameter *WP*, and flow distribution *FD* records.
- Various alternative options for formatting and organizing input and output data can be adopted as outlined in the *Reference* and *Users Manuals*.
- Conditional reliability modeling (CRM) capabilities of *SIM* and *TABLES* covered in the *Reference* and *Users Manuals* are designed for assessing short-term water supply reliabilities and storage and flow frequencies over the next several months or perhaps a year or longer conditioned on preceding reservoir storage contents.
- The *Hydrology Manual* describes capabilities provided by program *HYD* for developing and updating the hydrology data contained in the *SIM* input DSS, FLO, and EVA files.
- The daily modeling system documented by the *Daily and Users Manuals*, consisting of programs *SIMD*, *DAY*, and *DAYH* and the daily features of *TABLES*, includes a daily computational time step, disaggregation of naturalized flows from monthly to daily, disaggregation of water use requirements from monthly to daily, flow forecasting, flow routing, environmental pulse flow requirements, and reservoir operations for flood control.
- Program *SALT* described in the *Salinity Manual* combines the results of a *SIM* simulation with a salinity input file and tracks salt loads and concentrations through the river/reservoir system.
- *TABLES* provides an extensive assortment of optional tables and tabulations for organizing, analyzing, summarizing, and displaying simulation results as explained in the *Reference*, *Users*, *Daily*, and *Salinity Manuals*. *HEC-DSSVue* also provides an array of options for mathematical, statistical, and graphical analyses and display of WRAP simulation input and output data.



## CHAPTER 2 WINWRAP INTERFACE

The *WinWRAP* interface is designed for executing the WRAP programs within Microsoft Windows in an integrated manner along with use of Microsoft programs to access and edit input and output files and use of *HEC-DSSVue* to manage and analyze simulation results. The model user creates or obtains previously created files describing hydrology and water management in the river basin or region of concern along with specifications controlling the simulation. The input files are attached through *WinWRAP* to the generalized simulation model. *WinWRAP* provides an interface between the user, executable computer programs, and data files.

The WRAP programs (executable files) being employed should be in the same folder (directory) as *WinWRAP*. The program *WinWRAP* is activated with any of the normal Microsoft Windows options for running programs including a mouse click of the executable *WinWRAP* file, the run window, or a desktop shortcut icon. The other programs are executed from *WinWRAP*, with the user providing the filename roots of the input and output data files. The *WinWRAP* menu structure provides the user the options shown in Table 2.1.

Table 2.1  
*WinWRAP* Interface

| Files by Type     | WRAP Programs | MS Programs | Information          | Aids         | Exit |
|-------------------|---------------|-------------|----------------------|--------------|------|
| All Files         | SIM-TAB       | NotePad     | WinWRAP Instructions | Clear Screen |      |
| All WRAP Files    | SALT-TAB      | WordPad     | WinWRAP Version      | Exit         |      |
| Main Input Files  | HYD           |             | WRAP Documentation   |              |      |
| Main Output Files | DAY           |             |                      |              |      |
| Hydrology Files   | -----         |             | TAMU WRAP Website    |              |      |
| Special Files     | Terminate     |             | TCEQ WAM Website     |              |      |
| Message Files     |               |             | TWRI Website         |              |      |
| DAT Files         |               |             | HEC Website          |              |      |
| TIN Files         |               |             |                      |              |      |
| TOU Files         |               |             |                      |              |      |
| DSS Files         |               |             |                      |              |      |

The WRAP programs can be executed independently of *WinWRAP*. However, *WinWRAP* provides enhanced convenience and efficiency in applying the modeling system. Most of the utility of *WinWRAP* is reflected in the *WRAP Programs* pull-down menu shown as the second column of Table 2.1 and the *Files by Type* pull-down menu shown as the first column of Table 2.1. WRAP programs are executed through the *WRAP Programs* menu. Input and output files are accessed through the *Files by Type* menu. The features outlined in Table 2.1 are described as follows.

### Editors for Accessing WRAP Files

The time series data in the hydrology input DSS and simulation results DSS files are managed, viewed, analyzed, and plotted with *HEC-DSSVue*. The other WRAP input files and output files are in text format that may be viewed and edited with any editor. Programs provided by

Microsoft in their Windows and Office software packages are used to create, view, and modify WRAP datasets. *WordPad* or *NotePad* are used for editing input files and viewing simulation results. These Microsoft programs are accessed within the *WinWRAP* interface, typically by clicking a file through the *Files by Type* pull-down menu but optionally by opening *WordPad* or *NotePad* through the *WinWRAP* pull-down menu labeled *MS Programs*.

*Notepad++* is an enhanced text editor that is similar to Microsoft *Notepad* and *WordPad* but provides additional features which are useful in creating and editing WRAP input data files. *Notepad++* is available free-of-charge at: <http://notepad-plus-plus.org> or [http://portableapps.com/apps/development/notepadpp\\_portable](http://portableapps.com/apps/development/notepadpp_portable)

*SIM*, *TABLES*, and *HEC-DSSVue* have options for tabulating any and all of the time series variables included in the input datasets and simulation results in a format designed to be conveniently accessed by *Microsoft Excel*.

As shown in Table 2.1, the first pull-down menu on the *WinWRAP* desktop is labeled *Files by Type*. This pull-down menu provides access to data files through a Microsoft Windows window. Files are organized by type as defined by filename extensions. Clicking or selecting/opening a data file activates the program such as *NotePad* or *WordPad* associated with the extension of the file.

The Microsoft Windows operating system provides mechanisms described in Windows Help for designating the program associated with any particular file extension. An extension can be assigned to *WordPad*, *Notepad*, *Notepad++*, or other programs within Windows by selecting any file with that extension. A right mouse click activates a menu that includes an *open with* option that activates a dialog box containing a check-box indicating that the file extension is to always be associated with the selected program. If *HEC-DSSVue* is installed on the computer, a mouse click on a DSS file automatically activates *HEC-DSSVue*.

The *MS Programs* pull-down menu is designed for opening the Microsoft programs *WordPad* and *NotePad*. A mouse click or select/open button activates the selected program which can be used to create new WRAP input files or edit or view input or output files. However, the *Files by Type* menu is usually the quickest and most convenient way to access the Microsoft programs, *HEC-DSSVue*, *Notepad++*, or other editors for viewing and editing existing files.

### **WRAP Programs**

Referring again to Table 2.1, the second pull-down menu on the *WinWRAP* desktop is labeled *WRAP Programs*. Any and all of the WRAP programs may be activated from this menu. A dialog box allows the user to select programs or combinations of programs and to enter filename roots. *SIM* and *TABLES* may be executed either separately or together. Instructions for executing the programs are provided with the *Information* pull-down menu and replicated in Table 2.2.

All WRAP programs including *SIM* and *TABLES* can also be activated individually, without *WinWRAP*, like any executable file. The programs can be executed independently of *WinWRAP* and each other by Windows options such as a mouse-click of the executable file. Program execution begins with a simple log-in session during which the user types the filename root or roots.

## **HEC-DSSVue**

The program *HEC-DSSVue*, if installed on the computer, is directly accessible through *WinWRAP* by simply mouse clicking a DSS file accessed through the *Files by Type* menu. *HEC-DSSVue* can also be easily applied with DSS file datasets created with *WRAP-SIM* or *TABLES* without using *WinWRAP*. The *WinWRAP* pull-down menu simply allows all the multiple programs being used in an application to be accessed from a common interface for convenience.

The Hydrologic Engineering Center (HEC) Data Storage System (DSS) is introduced in the preceding Chapter 1. The HEC-DSS Visual Utility Engine (*HEC-DSSVue*) allows users to plot, tabulate, edit, and manipulate data, such as WRAP simulation results, stored in a HEC-DSS database file. The customizable graphics produced by *HEC-DSSVue* can be saved in various formats, printed, or copied to the clipboard for inclusion in reports. *HEC-DSSVue* also incorporates various statistical and mathematical functions and provides utility functions for database management. The public domain *HEC-DSSVue* software and detailed users manual may be downloaded from the HECenter website: <http://www.hec.usace.army.mil>. Application of *HEC-DSSVue* with the WRAP modeling system is described in Chapter 6 of the *WRAP Users Manual*.

## **Information**

Referring once again to Table 2.1, the fourth pull-down menu on the *WinWRAP* desktop is labeled *Information*. The first selection in this menu, labeled *WinWRAP Instructions*, provides the text reproduced as Table 2.2. The second selection, *WinWRAP Version*, simply provides the date of the version of *WinWRAP* being used. The third selection cites the WRAP manuals. The last four entries in the *Information* pull-down menu activate websites. The WRAP software and documentation can be downloaded from the referenced Texas A&M University (TAMU) website. The Texas Commission on Environmental Quality (TCEQ) Water Availability Modeling (WAM) website has the datasets for all the river basins of Texas and various information regarding the WAM System. Information available for download from the Texas Water Resources Institute (TWRI) includes a number of technical reports related to WRAP. *HEC-DSSVue* software and documentation are available at the USACE Hydrologic Engineering Center (HEC) website.

## **Aids**

The original *WinWRAP* included optional file building aids that are now obsolete. The fifth pull-down menu accesses an optional editor for creating or modifying a *TABLES* input *TIN* file that is not necessary or recommended. The *TIN* file can be easily created and edited with Microsoft WordPad or other editors just like the other WRAP input and output files. This *TIN* file editing feature is the only editor actually constructed internally as a part of *WinWRAP* and has not been updated in recent years as new *TABLES* input records options were added or old records revised.

## **Exit**

The last pull-down menu on the *WinWRAP* desktop is labeled *Exit* and provides options for clearing the screen and for exiting *WinWRAP*. *WinWRAP* can also be exited by a mouse click of the X in the top right corner of the desktop.

Table 2.2  
WinWRAP Instructions from Information Menu

---

*Directories and Files*

WinWRAP must be placed in the same directory as the other WRAP executable files being used such as SIM.exe, SIMD.exe, TAB.exe, and HYD.exe.

The WRAP Programs menu allows input and output files to be selected either through the browse and click feature or by manually typing the filenames. Filenames have a root and extension, root.ext. When manually entering filenames, the user types only the root if the files are stored in the same directory as the WRAP executables. Otherwise, the entire pathname must be specified. The browse/click feature enters the full pathname automatically. After entering input filenames, a click of the output filename box will result in default output filenames being entered automatically.

Filenames including directory paths are limited to not exceed a length of 70 characters for DSS files and 116 characters for all other WRAP files. Filenames cannot contain more than two consecutive blank spaces.

*Program Execution*

Menu selections are made with a click of the mouse. Alternatively, without a mouse, the Alt key may be pressed concurrently with pressing the underlined first letter of the labels in the main menu and then scrolling choices in the pull-down menus. However, a mouse is required for the program execution windows.

The WRAP Programs menu in WinWRAP is used to select executable programs. To execute the WRAP programs, the user selects the dialog box for the program to be executed. The dialog boxes will save the last set of inputs.

When using the dialog boxes for executing the WRAP programs, clicking in the edit boxes for the output filenames will set the name to the input filenames. The user can change the output filenames manually if so desired.

*File Builders*

The file building aids accessed through the Aids menu date back to the original WinWRAP and are now obsolete. The TABLES TIN File builder accessed through the Aids menu is still functional but has not been updated as TABLES input records have been added and revised through evolving versions of WRAP.

---

## WinWRAP Example

A simulation example is presented in Chapters 3 and 4 and Appendices A and B of this manual. Execution of the programs *SIM* and *TABLES* within *WinWRAP* with the input files for the example is described in this last section of Chapter 2. Examples in the other manuals build upon and expand the *Fundamentals Manual* example. The electronic input files for the *Fundamentals Manual* example and all of the examples presented in the other manuals are available at the WRAP website along with the executable files for the computer programs and PDF files of all of the manuals.

The filename root *FundExam* is adopted for all of the input and output files for the example in the *Fundamentals Manual*. The example includes the following files.

|                 |   |
|-----------------|---|
| FundExam.DAT    | <i>SIM</i> input file containing water management input data  |
| FundExamHYD.DSS | <i>SIM</i> input file containing hydrology input data<br>(FLO and EVA files are also available as an optional alternative to the DSS hydrology file.) |
| FundExam.OUT    | <i>SIM</i> simulation results output file read by <i>TABLES</i>   |
| FundExam.DSS    | <i>SIM</i> simulation results output file read by <i>HEC-DSSVue</i>   |
| FundExam.MSS    | <i>SIM</i> output file containing messages tracking the simulation  |
| FundExam.TIN    | <i>TABLES</i> input file containing instructions for organizing simulation results  |
| FundExam.TMS    | <i>TABLES</i> output file containing messages tracking the table building   |
| FundExam.TOU    | <i>TABLES</i> output file containing organized <i>SIM</i> simulation results  |

The input files provided in the *Fundamentals Manual* example have already been created. Likewise, the Texas WAM System includes WRAP input files that have been developed and continue to be periodically updated for all of the river basins of Texas. Most applications of WRAP in Texas involve adding proposed new projects or water management strategies or new or modified water use requirements to existing datasets. Applications of WRAP outside of Texas require development of input datasets for the river basins of concern. Alternative water management plans are then analyzed based on simulations with various modified versions of the input dataset. The Chapter 2 example begins with a set of already-developed *SIM* and *TABLES* input files, which are described later in Chapters 3 and 4.

A *SIM* simulation is performed and simulation results are organized with *TABLES* within the framework of the *WinWRAP* interface. The computer programs *WinWRAP*, *SIM*, and *TABLES* (executable files *WinWRAP.exe*, *SIM.exe*, and *TAB.exe*) are stored in the same folder (directory) on a computer running some version of the Microsoft Windows operating system. *HEC-DSSVue* functions independently within its own set-up procedure. *WinWRAP* is activated like any executable program using one of the various options provided by MS Windows. Perhaps the easiest way to execute *WinWRAP* is a mouse click on the file *WinWRAP.exe*. The *WinWRAP* window that appears will contain the heading and menu bar at the top of the screen as shown in Table 2.1 and Figures 2.1, 2.3, and 2.4.

*SIM* and *TABLES* are executed within *WinWRAP* by clicking *WRAP Programs* on the *WinWRAP* menu bar shown in Figure 2.1. Selecting *SIM-TAB* results in the dialog box reproduced as Figure 2.2. *SIM* (or *SIMD*) and/or *TABLES* are selected for execution by checking the boxes labeled *Execute SIM* and *Execute TAB*. A button is used to select between the monthly *SIM* or daily *SIMD* (*D* for daily) simulation programs, with the default being *SIM*.

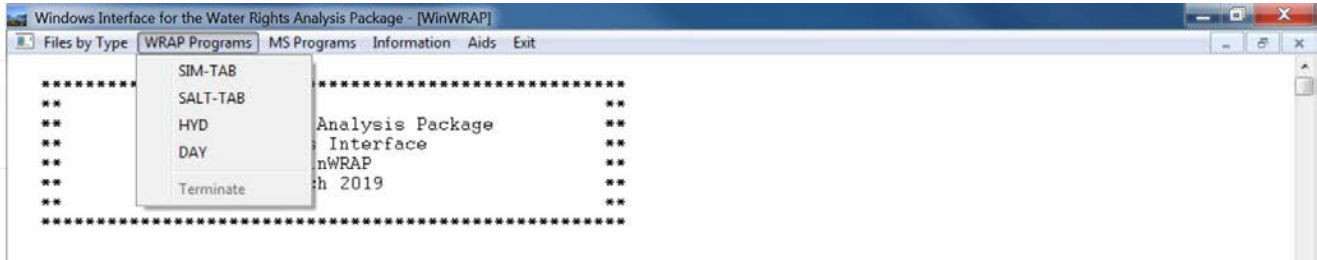


Figure 2.1 Selection of SIM-TAB activates the dialog box shown below in Figure 2.2.

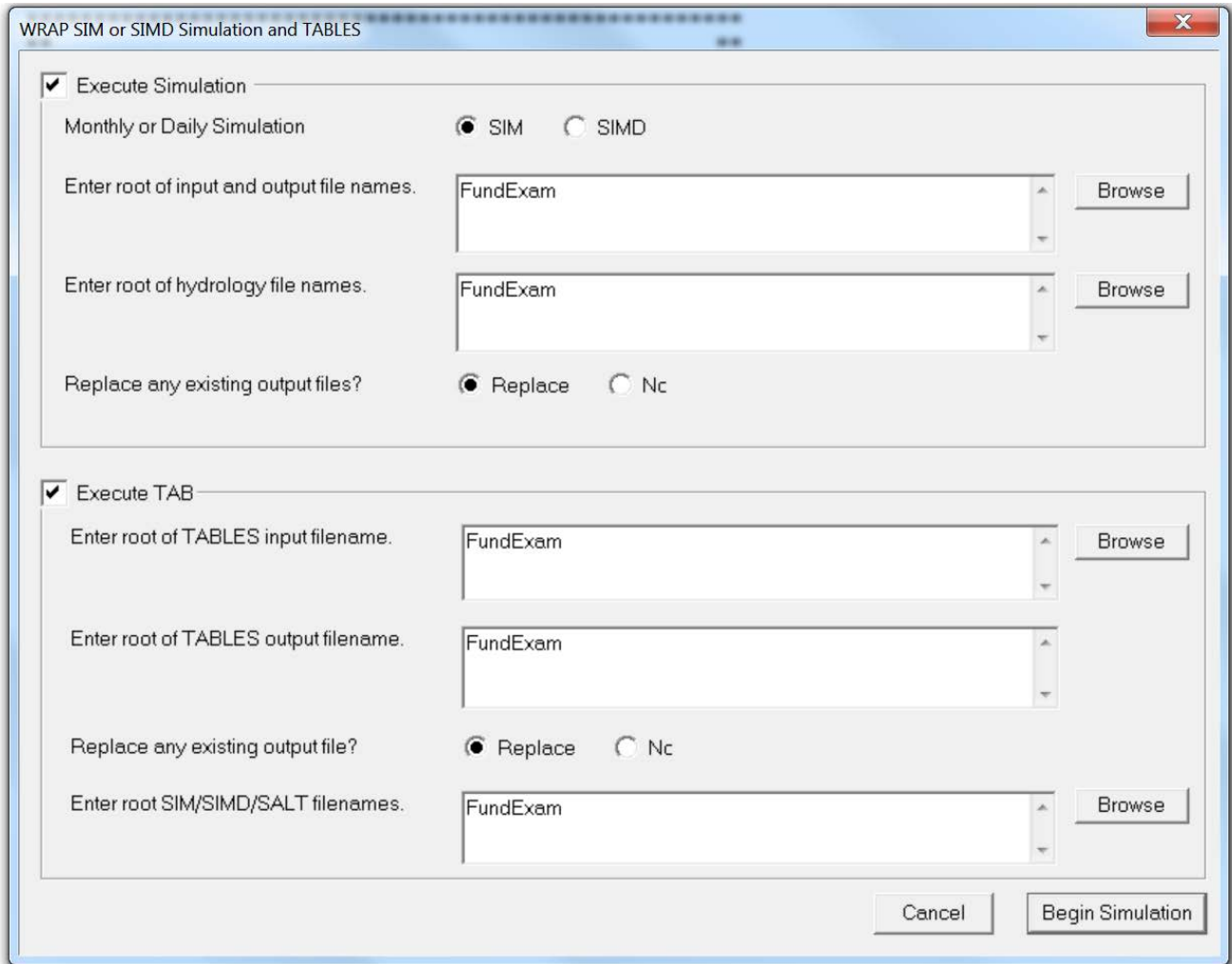


Figure 2.2 The filename root is specified for executing *SIM* and *TABLES*.

The filename root *FundExam* can be entered in the first box by either typing manually or browsing folders. The Browse feature allows the user to search through the folders on the computer to find and click on the file *FundExam.DAT*. The entire pathname will be displayed in the box if the data files are in a different folder than the executable programs. Only the filename root is displayed if the *DAT* file is in the same folder as the executable files. Since the same filename root and folder are used for all files, clicking the other boxes will automatically enter the same filename.

In this example, the same filename root is used for all files, and all input and output files are stored in the same directory. Therefore, a mouse click of each filename box after the first results in the same name repeated in all boxes shown in Figure 2.2. However, different filename roots and/or different folders may be entered in the different boxes. The executable files for all WRAP programs used, which in this example are *WinWRAP*, *SIM*, and *TABLES*, should be in the same folder, but the input and output data files can be in different folders.

After specifying the names of the input and output files, *SIM* and/or *TABLES* are executed by clicking the *Begin Simulation* button shown in the bottom right corner of Figure 2.2. The progress of the computations is displayed as shown in Figures 2.3 and 2.4.

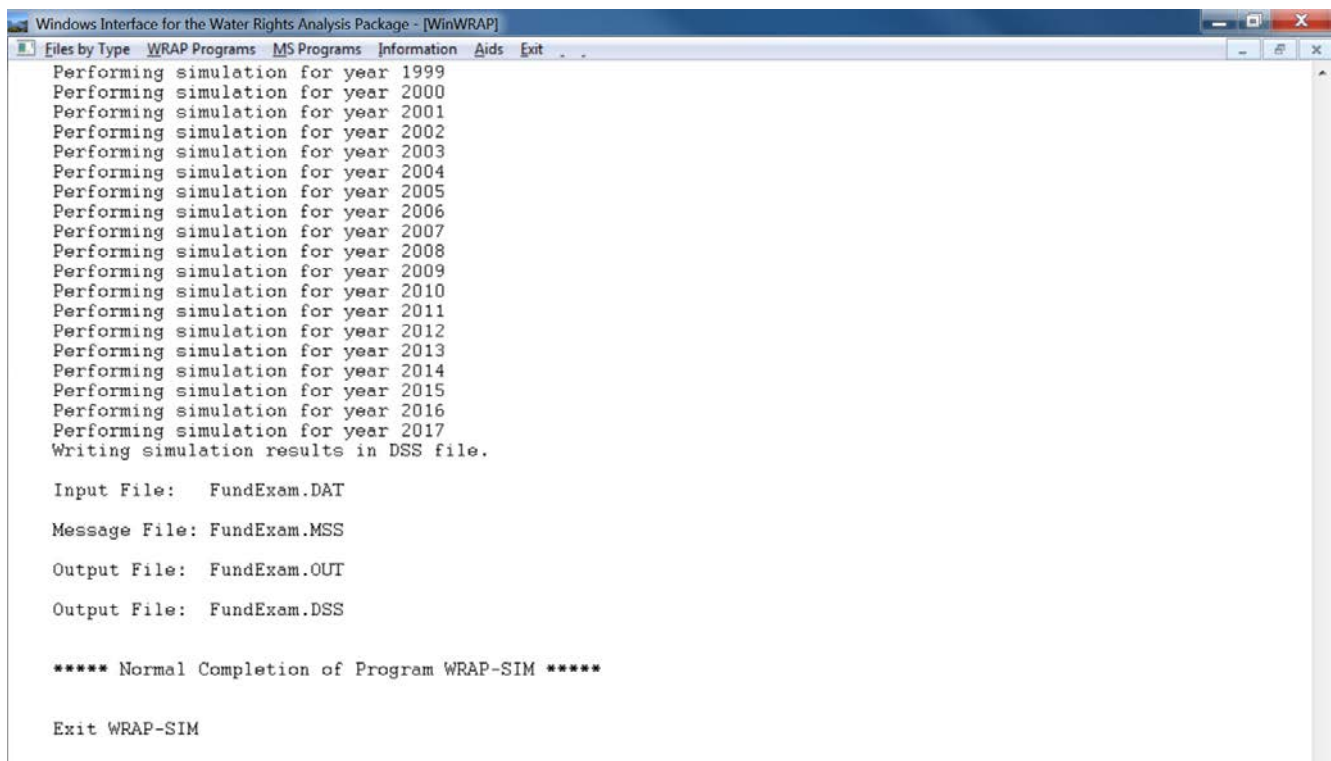


Figure 2.3 *WinWRAP* screen at completion of *SIM* simulation prior to *TABLES* execution.

The *SIM* simulation progresses through each year of a 1940-2017 hydrologic period-of-analysis. The *WinWRAP* screen upon completion of the 78-year simulation is shown in Figure 2.3. The tracking information for the file activation process and simulation years 1940 through 1998 has already scrolled off the screen at the time of completion captured in Figure 2.3. If an input data error results in termination of the *SIM* execution prior to completion of the simulation, a message is displayed on the screen that refers to the message (MSS) file. More detailed tracking information along with warning and error messages are stored in the MSS file.

The *WinWRAP* screen upon completion of execution of *TABLES* is reproduced as Figure 2.4. The records read by *TABLES* from its input TIN file are listed on the monitor as the table-creation operations are performed. *TABLES* organizes the simulation results as a set of tables stored in a file with the named FundExam.TOU which is reproduced as Appendix B of this manual and

discussed in Chapter 4. The TOU file can be read with WordPad, Word, Excel, or other editors. Program *TABLES* also creates a data storage system (DSS) file named FundExam.DSS which can be read with *HEC-DSSVue* for plotting or other purposes.

```

Y
The TABLES TIN input file contains 37 records.

A SIM input file is required.
Opening SIM DAT Input File: FundExam.DAT

One or more SIM/SIMD output files are required.
Opening SIM OUT Output File: FundExam.OUT

Tables are being developed as specified by a 1SUM record.
Tables are being developed as specified by a 2NAT record.
Tables are being developed as specified by a 2REG record.
Tables are being developed as specified by a 2UNA record.
Tables are being developed as specified by a 2STO record.

Tables are being developed as specified by a 2FRE record.
Tables are being developed as specified by a 2FRE record.
Tables are being developed as specified by a 2FRE record.
Tables are being developed as specified by a 2FRE record.
Tables are being developed as specified by a 2FRE record.
Tables are being developed as specified by a 2FRQ record.
Tables are being developed as specified by a 2REL record.
Tables are being developed as specified by a 2REL record.
Tables are being developed as specified by a 2REL record.
Tables are being developed as specified by a 2REL record.
Tables are being developed as specified by a 2SCP record.

Program TABLES output is in file FundExam.TOU

Program TABLES output is in DSS file FundExam.DSS

Normal Completion of Program TABLES

Exit TABLES

```

Figure 2.4 *WinWRAP* screen at completion of *TABLES* execution.

WRAP input and output files can be accessed from *WinWRAP* by clicking *Files by Type* which is the first item on the menu bar at the top of the screen. As shown in Table 2.1 at the beginning of this chapter, for convenience, the browsing feature limits the file listings to the group of files selected from the *WRAP Files* pull-down menu. Selection of *All Files* lists files with any of the WRAP extensions, such as DAT, DSS, MSS, OUT, TIN, TMS, or TOU. Selection of *TOU Files* lists only files with the extension TOU. As noted earlier in this chapter, Microsoft Windows provides easy-to-use mechanisms for connecting Microsoft Office programs or other programs to file extensions. WordPad or another editor of choice is automatically activated by clicking files with extensions assigned to the program. The DAT file or other input files can be modified using WordPad, and then *SIM* and *TABLES* executed again without leaving *WinWRAP*. *HEC-DSSVue* is activated by mouse clicking the DSS simulation results file within the *WinWRAP WRAP Files* pull-down menu window. Either *All WRAP Files*, *Main Output Files*, or *DSS Files* can be used for this.



## CHAPTER 3 SIM SIMULATION MODEL

Program *SIM* is a generalized river/reservoir system operations model that simulates the development, allocation, management, and use of the water resources of a river basin or region. Water is allocated among multiple users based on specified priorities. A monthly time-step accounting system tracks river flow sequences, subject to reservoir storage capacities and specified diversion, instream flow, and hydroelectric energy requirements. Stream flow and water in reservoir storage meet specified water right requirements subject to channel losses and losses or gains associated with evaporation from and precipitation onto reservoir water surfaces. Water balance computations are performed for each time step of the hydrologic simulation period. The model provides flexibility for adaptation to a broad range of modeling approaches. A conventional water availability modeling application of *SIM* is based on:

- simulating capabilities for fulfilling a specified scenario of water management and use requirements within the framework of constructed storage and conveyance infrastructure and institutional water allocation systems
- during an assumed hypothetical repetition of historical hydrology represented by sequences of monthly naturalized stream flows and reservoir net evaporation-precipitation rates covering the hydrologic period-of-analysis.

The component features of the *SIM* simulation model can be categorized as relating to either (1) natural river basin hydrology or (2) water resources development, management, allocation, and use along with associated river/reservoir system operations. From the perspective of WRAP, river basin hydrology includes naturalized stream flows, reservoir net evaporation-precipitation rates, and channel losses. Water rights include all aspects of water resources development and management including water supply diversions, return flows, environmental instream flow requirements, hydroelectric energy generation, river regulation for flood control, reservoir storage on major rivers, off-channel storage, multiple-reservoir system operations, and intrabasin and interbasin conveyance.

Water availability modeling studies are performed with WRAP to evaluate capabilities of reservoir/river systems to meet specified water management/regulation/use requirements for given sequences of naturalized stream flows and reservoir net evaporation rates. Water management is combined with natural hydrology. Water managers are concerned with future not past hydrologic conditions. However, since the future is unknown, historical hydrology is used to capture the hydrologic characteristics of a river basin. The water management/use scenario might be actual current water use, projected future conditions, the premise that all permit holders use their full authorized amounts, hypothetical yields, or some other scenario of interest.

### Units of Measure

Any consistent set of units may be used. Conversion factors are entered on the *XL* record if needed to achieve consistent units. Typical English units requiring no conversion factors are acre-feet for storage volume and volume/month and volume/year quantities, acres for reservoir surface area, and feet for net evaporation depth. Typical metric units are million cubic meters for volume, square kilometers for reservoir surface area, and meters for net evaporation depth.

## Input Records

The system for organizing *SIM* input datasets is based on files, record types, and fields in each record. Input files contain a set of required and optional records controlling various simulation options and representing the river/reservoir/use system being modeled. The record types are labeled by a two-character identifier that is placed at the beginning of each record in text-format input files and in pathname part C of DSS hydrology input file records. Many typical applications will require only basic *SIM* capabilities using less than a third of the 63 available record types. Twenty-five types of input records relevant to the modeling capabilities covered by this *Fundamentals Manual* are listed in Table 3.1 and described in Appendix C.

Table 3.1  
Types of SIM Input Records

---

*Basic Input File (filename root.DAT)*

|                |  |
|----------------|--|
| T1, T2, T3     | Titles or headings at the beginning of the file that are reproduced in the output            |
| **             | comments or notes not read by the computer that may be inserted throughout                   |
| JD             | Job control Data with basic simulation control parameters and option switches                |
| JO             | Job Options controlling various features of the simulation                                   |
| OF             | DSS File Options   |
| FY             | Firm Yield and yield-reliability table   |
| WO, GO, CO, RO | Water right, Group, Control point and Reservoir/hydropower Output                            |
| UC             | monthly water Use distribution Coefficients  |
| CP             | Control Point connectivity and naturalized flow, evaporation, and channel loss data          |
| WR             | Water Right requirements   |
| IF             | Instream Flow requirements   |
| WS             | Water right reservoir Storage  |
| HP             | Hydroelectric Power parameters   |
| SV/SA          | Storage Volume ( <i>SV</i> record) versus Surface Area ( <i>SA</i> record) table             |
| PV/PE          | Storage Volume ( <i>PV</i> record) versus Elevation ( <i>PE</i> record) table for hydropower |
| ED             | End of Data  |

*Hydrology Files (filename rootHYD.DSS or filenames root.FLO and root.EVA)*

|    |   |
|----|---|
| IN | INflows to the river/reservoir system (monthly naturalized stream flows)  |
| EV | EVaporation (monthly reservoir net evaporation less precipitation depths) |

---

One each of five types of records (*JD*, *ED*, *CP*, *WR* or *IF*, and *IN*) are required. The other records are optional. Various fields on most records are either optional or have default values and may be left blank in many applications. The *Users Manual* provides detailed explanations of input records which are reproduced in abbreviated form in Appendix C of this *Fundamentals Manual* for the records listed in Table 3.1. Most of the 38 other *SIM* input record types omitted from this manual activate options providing greater flexibility for modeling complex reservoir/river system operations and water management situations. Several of the record types omitted here are designed for transferring naturalized stream flows from gaged to ungaged sites. Ingenuity is applied in combining options activated by the different records to model unique situations. The system of

record types is designed to create comprehensible, documented datasets that can be conveniently analyzed and modified by model-users as well as efficiently executed by the computer.

Control points, water rights, and reservoirs (which may include hydropower plants) are the building blocks used to structure the model from the perspectives of both data management and computations. There are no limits on the number of control points (*CP* records), water rights (*WR* and *IF* records), and reservoirs (*WS* records) that may be included in a dataset.

### **Control Points**

The spatial configuration of a river system is defined by a set of control points. Each control point has a *CP* record in the DAT file, which includes identifiers of that control point and its next downstream control point. This defines the spatial connectivity of the system. Essentially any configuration of stream tributaries and conveyance systems may be modeled. All reservoirs, diversions, return flows, hydropower plants, instream flow requirements, and other system components are assigned control point locations. The control point assigned to a water right is the location at which the right has access to stream flow. Primary control points are the locations at which naturalized stream flows are provided in the input dataset. Secondary control points are locations at which naturalized flows are computed by *SIM* based on the flows at primary control points and watershed parameters.

### **River Basin Hydrology**

River basin hydrology is represented in *SIM* by sequences of naturalized stream flows and reservoir net evaporation less precipitation depths for each month of the hydrologic period-of-analysis at each pertinent location. Net reservoir surface evaporation-precipitation depths are input in an EVA or DSS file. Naturalized flows for primary control point locations are provided as input in a FLO or DSS file. Alternative methods for computing naturalized flows at ungaged locations (secondary control points) based on flows at primary control points (*IN* records) and watershed parameters read from a flow distribution (DIS) file are described in the *Reference and Users Manuals* but are not covered in this *Fundamentals Manual*. The *SIM* simulation model is based on total stream flows, rather than incremental inflows. However, methods outlined in the other manuals are provided to address the issue of negative incremental naturalized flows.

*SIM* simulates capabilities for meeting water management and use requirements during a hypothetical repetition of historical natural hydrology. For example, a simulation might be concerned with assessing reliabilities in meeting a specified set of annual water use requirements (with seasonal variations over the 12 months of the year) during a repeat of historical hydrology represented by sequences of naturalized stream flows and reservoir net evaporation rates for each month of the 936-month 1940-2017 hydrologic period-of-analysis.

The future is of concern, rather than the past. However, since future hydrology is unknown, historical natural river flows and reservoir evaporation-precipitation rates are adopted as being representative of the hydrologic characteristics of a river basin. A typical hydrologic period-of-analysis used for studies in Texas is 1940 to near the present. This period includes the 1950-1957 most severe drought-of-record for most of the state as well as a full range of fluctuating wet and dry periods. Water resources are highly variable and highly stochastic or random, subject to extremes of droughts and floods as well as continuous more normal

fluctuations. Major droughts typically involve long periods with sequences of many months of low flows. A basic premise of the conventional WRAP modeling approach is that historical naturalized stream flows and reservoir evaporation-precipitation rates for an adequately long period-of-analysis capture the essential statistical characteristics of river basin hydrology.

Channel loss adjustments are included in various aspects of the simulation computations, based on loss factors  $F_{CL}$  defined by Equation 3.1 and entered on the control point  $CP$  records.

$$\text{flow loss} = F_{CL} Q_{\text{upstream}} \quad (3.1)$$

The channel loss factor  $F_{CL}$  is defined above, where  $Q_{\text{upstream}}$  is the flow at the upstream control point of a river reach between two control points, and flow loss refers to the loss in the reach. Channel losses represent seepage, evapotranspiration, and other otherwise unaccounted losses.

### **Water Management**

In WRAP terminology, water resources development facilities, water use requirements, and river/reservoir system operating policies and practices are described in terms of water rights. *SIM* provides capabilities for modeling water management/use systems consisting of:

- reservoir projects operated to regulate and conserve river flow, off-channel storage reservoirs, pumping/conveyance facilities, and hydroelectric power plants
- international treaties, interstate compacts, water supply and hydropower contracts, contracts for nonfederal storage in federal reservoirs, and other agreements
- requirements specified in water right permits
- river/reservoir system operating policies and rules
- water use characteristics and practices

In WRAP, a water right is a set of water management and use requirements associated with either a water right  $WR$  record or an instream flow  $IF$  record. Water supply diversion and hydroelectric energy generation are specified as  $WR$  record rights. Instream flow requirements for environmental needs and other purposes are specified as  $IF$  record rights. The number of water rights counted by *SIM* is simply the number of  $WR$  and  $IF$  records included in the DAT input file.

Other types of input records describing various aspects of the river/reservoir/water use system follow the  $WR$  or  $IF$  record for a particular water right in the input file and are connected to the right in the simulation computations. The  $WS$  record describing reservoir storage and  $HP$  record providing hydropower data are covered in this *Fundamentals Manual*. Other record types connected to  $WR$  and  $IF$  records that are not covered by this manual include the environmental flow standard  $ES$ , target options  $TO$ , target series  $TS$ , supplemental options  $SO$ , flow switch  $FS$ , backup right  $BU$ , monthly limits  $ML$ , reservoir operating rules  $OR$ , priority circumvention  $PX$ , and drought index  $DI/IS/IP$  records. Ingenuity and creativity in combining  $WR$ ,  $IF$ , and supporting input records to model a particular water management situation are important in applying WRAP.

The set of information specifying the water management and use requirements defining a particular water right may include the following.

- identifiers of the control point locations of pertinent components
- priority number and other auxiliary information specifying priorities

- annual diversion target
- return flow specifications
- instream flow specifications
- annual hydroelectric energy generation target
- set of 12 monthly water use distribution coefficients
- set of rules for varying diversion, instream flow, and hydroelectric energy targets as a function of stream flow or storage subject to specified limits
- drought index for varying targets as a function of reservoir storage
- active and inactive reservoir storage capacity
- reservoir storage volume versus surface area relationship
- reservoir elevation versus storage volume relationship
- reservoir/river system operating rules
- interbasin or intrabasin conveyance
- annual and monthly limits on stream flow depletions
- annual limits on total diversions or diversions from storage
- identifiers for labeling rights and aggregating results for groups of rights

### Water Right Priorities

A fundamental concept of the simulation is that available stream flow is allocated to each water right in turn in ranked priority order. Priority numbers serve the important function of setting the order in which the rights are considered in the water rights computational sequence that allocates water. However, the priorities are used in no other way. Diversion, instream flow, hydropower, and storage refilling targets for each right are met to the extent allowed by available stream flow and storage prior to considering the requirements of more junior rights. The seniority of a right relative to other rights is expressed by their priority numbers. In comparing two rights, the senior right has a lower priority number than the junior right. *Junior* and *senior* are relative terms used in the context of comparing the priority of two water rights. The magnitude of the priority numbers for each of the rights relative to each other govern the order in which water is allocated among the rights.

Within the *SIM* computations, priority numbers have meaning only in a relative sense. In the Texas prior appropriation water rights permit system, priority numbers typically represent dates specified in the permits. For example, a priority date of March 12, 1982 specified in a water right permit is entered in the *WR* record as the integer 19820312, which is a larger number than the priority corresponding to any earlier date. With a little ingenuity, model-users can devise various other schemes for using the priority numbers to model relative priorities for allocating water.

Priorities are integer numbers normally specified on each *WR* and *IF* record. If two or more water rights have the same priority number, they are ranked in the same order as their *WR* or *IF* records are entered in the input file. Alternatively, the natural priority option assigns priorities internally in upstream-to-downstream order. Priorities may also be controlled for water use type groups using use priority *UP* records. With either of these options, each *WR* and *IF* record water right is assigned an integer number. Smaller numbers mean higher priority, rank, or seniority.

### Diversion, Instream Flow, and Hydropower Targets

The terms *target*, *requirement*, *demand*, *need*, and *authorized amount* are used essentially

interchangeably. A diversion target entered on a *WR* record represents water withdrawn from the river/reservoir system for water supply. An energy generation target is specified on a *WR* record for a hydroelectric power right. An instream flow requirement specified on an *IF* record is a target minimum regulated monthly flow at a control point location. Other *WR* record water rights with priorities junior to an instream flow requirement are not allowed to appropriate water that results in violating the minimum flow limit set by the *IF* record.

Water supply diversion, hydroelectric energy generation, and instream flow targets are specified in terms of an annual amount input on a *WR* or *IF* record combined with a set of 12 monthly use coefficients entered on *UC* records for distributing the annual amount over the 12 months of the year. Thus, water use requirements are expressed as monthly targets that may vary each month from January through December but are constant from year to year. Model options not covered in this manual allow diversion, instream flow, and hydropower targets to be also defined as a function of reservoir storage and/or stream flow and thus allowing variations between years.

### *WR Record Water Right Types*

Water right *WR* record field 6 provides a categorization scheme for specifying certain basic rules for meeting diversion or hydroelectric energy requirements from stream flow and reservoir storage and for refilling reservoir storage. The kinds of reservoir/river system operations associated with the water right type parameter are as follows.

|   |               |
|---|---------------|
| water supply diversion from stream flow       | types 1, 2    |
| diversions supplied from reservoir storage    | types 1, 2, 3 |
| inflows discharged into the river system      | type 4        |
| hydropower generation from stream flow        | type 5        |
| hydropower generation from reservoir releases | types 5, 6    |
| refilling of storage in one reservoir         | types 1, 5, 7 |

*Type 1 right.*- The default type 1 right allows a diversion to be met from stream flow depletions and/or storage in one or more reservoirs. A diversion requirement is met from stream flow, if available, and then from reservoir storage if stream flow is not available. One reservoir, called the primary reservoir, can be refilled from stream flow depletions or releases from other reservoirs. The primary reservoir that is refilled and the diversion must be located at the same control point. Any number of other secondary reservoirs in the system, from which releases are made, can be located at any of the control points. A storage-only right may simply refill storage in the one reservoir. A run-of-river diversion can be represented as a type 1 right with no reservoir.

*Type 2 right.*- A type 2 right is identical to a type 1 right except that reservoir storage is not refilled. Reservoirs may be used along with stream flow to meet diversion requirements, but other water rights (*WR/WS* records) are used to refill storage. Type 2 rights allow diversions to be supplied by releases from any number of reservoirs at locations other than the diversion site.

*Type 3 right.*- A type 3 right is identical to a type 2 right except the diversion target can be met only by releases or withdrawals from reservoir storage. A diversion can be met by releases from any number reservoirs without allowing diversion of unregulated stream flow entering the river below the dams. Unlike a type 3 right, a type 1 or 2 right makes reservoir releases only after the stream flow at the diversion location is depleted.

Type 4 right.- With a 4 entered in *WR* record field 6, the target amount is discharged into the stream. The target amount is computed for a type 4 right just like a diversion. The difference is that a type 4 right is not a diversion, but rather an inflow to the stream. The inflow is from external sources, not stream flow or reservoir storage included in the model. A type 4 right may model an interbasin transfer or other situations involving discharge of water into the river system within the water rights priority computation loop.

Type 5 right.- A 5 or 6 is entered in *WR* record field 6 for a hydroelectric power right. A type 5 hydropower right is identical to a type 1 right except a hydroelectric energy requirement is specified rather than a diversion. A run-of-river hydropower right can be represented as a type 5 right with one reservoir with inactive but no active storage capacity.

Type 6 right.- A type 6 right is identical to a type 5 right except the hydroelectric energy requirement can be met only by releases from reservoir storage. A type 6 hydropower right is analogous to a type 3 diversion right. Neither refill reservoir storage. Other rights are required to refill storage. Hydropower rights are not constrained by *IF* record instream flow requirements.

Type 7 right.- A type 7 right sets a storage target in the same manner as a diversion target. The storage capacity is the lesser of this target or the capacity defined in the conventional manner.

### **Reservoirs**

Each reservoir is associated with at least one *WR* record water right. Any number of *WR* record and *IF* record water rights may be connected to the same reservoir. The total storage capacity and inactive storage capacity from the *WS* record and operating rules from *OR* records may vary between water rights at the same reservoir. Any number of reservoirs may be connected to a single water right, with multiple-reservoir system operating rules governing release decisions each month. Each reservoir has one and only one control point location. Multiple rights and multiple reservoirs may be assigned to the same control point. Each water right has access, in priority order, to available stream flow at the control point.

A *WRAP-SIM* water right may include (1) maintaining or refilling storage in one reservoir and (2) meeting diversion, hydropower, or instream flow requirements by diverting or releasing from storage in any number of reservoirs. In constructing a model, these two aspects of reservoir operations can be viewed as essentially separate actions. A particular right may include either, neither, or both. Reservoir storage capacity is provided on the *WS* record associated with a water right. Any number of water rights can be associated with a single reservoir, with each right filling the reservoir to a different storage capacity and/or using the reservoir to meet its water use requirements. *SIM* allows releases from multiple reservoirs to meet the one diversion, hydropower, or instream flow target and maintain storage in the one reservoir specified by a single water right.

The *WR* and *WS* records are identical for either on-channel or off-channel storage. However, supplemental options *SO* and monthly limits *ML* records activate options that place monthly or annual limits on the amount of stream flow that may be appropriated to fill storage. These limits are designed for off-channel reservoirs to model the pumping and conveyance capacity of the facilities that convey water from the river to the off-channel reservoir. Stream flow is appropriated to refill storage the same for an off-channel reservoir as for a reservoir impounded by a dam on the river with the exception of the options to impose conveyance limits.

A storage volume versus water surface area relationship is assigned to each reservoir either as a table on *SV/SA* records or as Equation 3.2 with coefficients a, b, and c provided on a *WS* record.

$$A = aS^b + c \quad (3.2)$$

*S* and *A* denote storage volume and area. The storage/area relationship is used solely for determining net evaporation-precipitation volume, which for a given month is the product of the computed average water surface area during the month and a net evaporation rate from *EV* records. An elevation versus storage volume table is provided on *PE/PV* records for any reservoir associated with hydropower for use in determining head or for any reservoir for which water surface elevations are to be tabulated. The model uses linear interpolation with the *SV/SA* and *PE/PV* record tables.

By default, all reservoirs are assumed to be full to their maximum storage capacity at the beginning of the simulation. However, a less than capacity beginning storage content for any reservoir may be specified on its *WS* record. A set of beginning-ending storage (BES) options activated by the *JO* record sets beginning storage equal to estimated end-of-simulation storage.

The storage capacity associated with each *WR/WS* record set is the total cumulative capacity to which the reservoir can be refilled under that right's priority, assuming the reservoir has been drawn down in previous months and stream flow is now available for refilling. Multiple reservoirs may also be associated with a single water right. However, a right may include a storage capacity to be refilled in only one reservoir, called its *primary* reservoir. *Secondary* reservoirs supply water use requirements but are not refilled by the right. A secondary reservoir supplying water for a particular water right is the primary reservoir for another right which refills storage. Multiple water rights with different priorities may fill different storage capacities in the same reservoir. A junior right must have a storage capacity equaling or exceeding other senior rights at the same reservoir.

An inactive pool capacity may also be designated on the *WS* record. In the simulation computations, no releases are made from the inactive pool. The storage level is allowed to fall below the top of inactive pool only due to evaporation. The designated inactive pool storage capacity may vary with different water rights at the same reservoir.

### **Stream Flow**

The *SIM* simulation process consists of a series of adjustments to river flow sequences covering the hydrologic period-of-analysis, which involves three forms of stream flows at each control point: naturalized, regulated, and unappropriated. A *SIM* simulation begins with naturalized flows provided on *IN* records for primary control points. Naturalized flows may be distributed to secondary control points within the simulation. Regulated and unappropriated flows are computed for all control points. The computations are based on total cumulative flows, not incremental flows.

In general, the terms *naturalized*, *unregulated*, or *unimpaired* refer to sequences of past stream flows adjusted to represent a specified condition of river basin development that includes either no human impact or some defined level of development. Naturalized flows are ideally natural flows that would have occurred historically, in the absence of the water management activities reflected in the water rights input data, but with all other aspects of the river basin reflecting a prescribed fixed scenario.



Regulated and unappropriated flows computed by *SIM* reflect adjustments to naturalized flows for water right requirements representing a specified scenario of water resources development and use. Regulated flows are physical flows considering all water rights in the input dataset. Unappropriated flows are available for further appropriation after all the water rights receive their allocated share. Regulated flows may be greater than unappropriated flows due to instream flow requirements at the site or commitments to other rights at downstream control points.

The adjustments that convert naturalized flows to regulated flows include both stream flow depletions and return flows. Stream flow depletions are the quantities of water appropriated to meet water supply diversion requirements and refill reservoir storage. Return flows are added back to stream flows. Channel losses are considered as stream flow adjustments are cascaded downstream.

### **Simulation Algorithms**

The simulation tasks performed by *SIM* are outlined in Figure 3.1. After initial organization of the simulation, computations are performed in a water rights priority loop that is embedded within an annual and monthly time step loop.

Model execution begins with reading and organizing input data. Water rights are sorted into priority order. The simulation steps through time. At the beginning of each year, naturalized flows for primary control points and net reservoir evaporation rates are either read or activated from a previously read array. Flows are distributed from primary control points to all other secondary control points based on watershed parameters. Within each sequential month, water accounting computations are performed as each set of water management capabilities and use requirements (water right) is considered in priority order. Water allocation and regulation are modeled by accounting procedures within the water rights priority loop computational sequence. An array is maintained of stream flow available for appropriation at all control points. As each right is considered in priority order, the following tasks are performed.

1. The diversion, instream flow, or hydropower target is set starting with an annual amount and set of 12 monthly distribution factors provided as input. The target may be further modified as a function of the storage content in any number of specified reservoirs and naturalized, regulated, or unappropriated flow at any control point, and/or other considerations.
2. The amount of water available to the water right from stream flow is determined based on the available stream flow array considering the control point of the water right and all downstream control points. Channel losses are considered in checking flow availability.
3. Water use requirements are met subject to water availability following specified system operating rules. Water accounting computations determine the diversion, diversion shortage, end-of-month storage, and related quantities. Reservoirs and hydroelectric power plants necessitate an iterative algorithm since reservoir surface net evaporation-precipitation and hydropower releases are a function of both beginning-of-month and end-of-month storage.
4. The available stream flow array is adjusted for that location and all downstream sites to reflect the effects of the water right. Channel loss factors are applied in translating adjustments for stream flow depletions and return flows to flows at downstream control points. Within the priority loop, the available flow array is used to determine the amount of water available to each individual right. At the end of the water right computational sequence, the available flow array is used to determine regulated and unappropriated flows.

- Main input DAT file containing water rights data is read.
- Water rights are ranked in priority order.
- Various other data manipulations are performed.
- Flow distribution DIS file containing watershed parameters is read.
- Watershed parameters are determined for incremental watersheds.

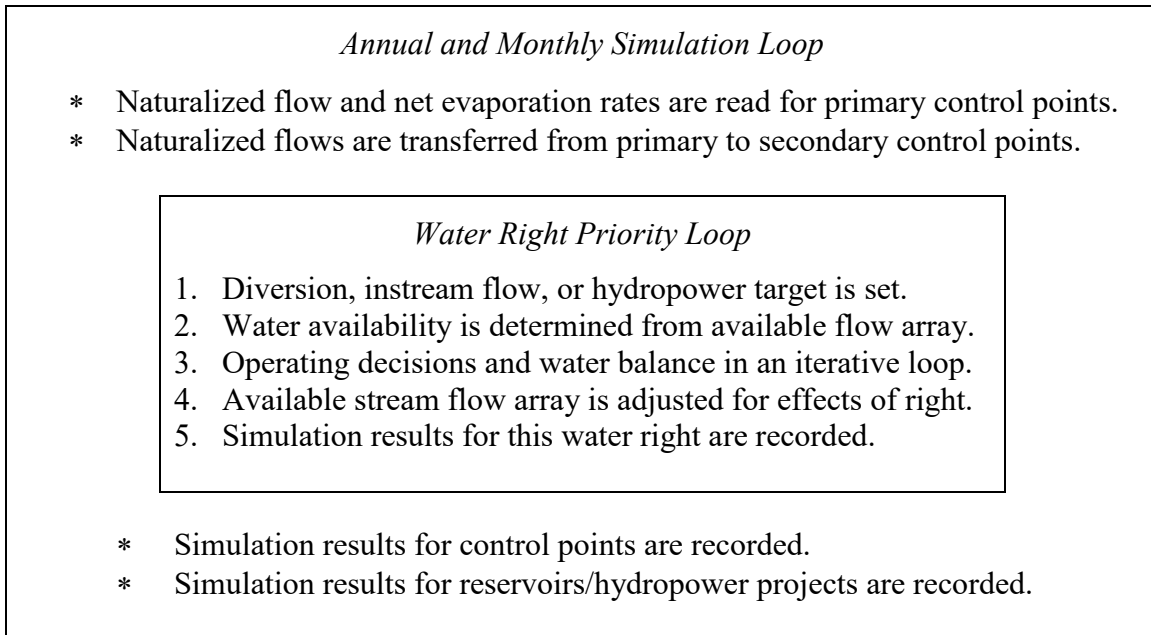


Figure 3.1 Outline of Simulation Performed by *SIM*

### **Water Availability in the Water Rights Priority Loop Computations**

The concept of water allocation computations being performed in a water rights loop is fundamental to the *SIM* simulation approach. The requirements of each individual right are met in priority order. Thus, in a particular month, senior rights affect the amount of water available to junior rights but basically are not adversely affected by the junior rights. However, fluctuating decreases and increases in water availability are a complexity in applying *SIM*. In reality, junior rights may increase the amount of water available to senior rights. Modeling complications may occur involving senior rights not getting access to water made available by junior rights through:

1. same-month return flows from diversions from storage
2. same-month hydroelectric power releases
3. contributions to meeting instream flow requirements at intermediate control points made by releases from upstream reservoirs to meet diversions at downstream locations

As each water right is considered in priority order in the water rights computational loop, regulated flows and the flows available to more-junior rights usually decrease but may also increase. Diversions and reservoir storage decrease flows at their control point and at

downstream control points. Conversely, flows are increased by hydropower releases and return flows from diversions from storage. Reservoir releases may increase flows at intermediate control points between the reservoir and downstream diversion site. A diversion and/or storage right may be unnecessarily curtailed (shorted) due to computationally not having access to water made available by more junior rights in the form of return flows or hydropower releases. Likewise, reservoir releases that increase flows at intermediate control points between the reservoir and downstream diversion site may not be properly credited as contributing to instream flows at the intermediate control points. Junior diversion and storage rights may be unnecessarily curtailed to maintain senior instream flow requirements.

Several *SIM* options have been adopted in practice to deal with the complexities of fluctuating decreases and increases in water availability in the water rights priority sequence. The next-month return flow option makes the return flows available in the next month at the beginning of the water rights loop. Thus, all rights have access to the return flows in priority order. Likewise, entering return flows as constant inflows on *CI* records makes the flows available at the beginning of the water right computations. The next-month hydropower option makes hydropower releases available to senior rights located downstream. The optional second-pass features associated with instream flow rights addresses this same complexity. These and other priority circumvention features are described in the *Reference* and *Users Manuals*.

### **Simulation Results**

The voluminous time series output for each month of a *WRAP-SIM* simulation includes:

- naturalized, regulated, and unappropriated flows for each control point
- return flows from diversions that are returned at each control point
- channel losses and loss credits for the stream reach below each control point
- diversions, diversion shortages, and return flows for each water right
- hydroelectric energy generated and energy shortages
- instream flow targets and shortages
- storage and net evaporation-precipitation for each reservoir, right, and control point
- amount of water available and stream flow depletions for each right

*SIM* simulation results are written to the output OUT file read by *TABLES* and/or DSS output file read by *HEC-DSSVue*. The program *TABLES* computes water supply and hydropower reliability indices and stream flow and storage frequency relationships and organizes the simulation results as tables of information in various user-specified optional formats described in Chapter 4.

For each month of a *SIM* simulation, output records are written for user-selected water rights (*WR* record right or instream flow *IF* right), control points, and reservoir/hydropower projects. The *WO*, *GO*, *CO*, and *RO* input records and *JD* record fields 5 and 6 control the selection of water rights, control points, and reservoir/hydropower projects to include in the simulation results output file. The output file records contain the data listed in Table 3.2.

Some data are unique to water right, control point, or reservoir/hydropower output records. Naturalized, regulated, and unappropriated flows, and channel losses are associated only with control points. Other data are repeated on two or three of the record types. With multiple water rights located at the same control point and associated with the same reservoir, certain water right

data may be aggregated for control points and reservoirs. Reservoir storage and net evaporation volumes are written to all three record types. The control point records contain the summation of storage and evaporation of all reservoirs assigned to the control point. If one water right with one reservoir is located at a control point, reservoir storage and evaporation will be identical on all three records. Likewise, diversion targets and shortages on a water right output record are associated with a single *WR* input record but may be summations for multiple rights for control point output.

Table 3.2  
Variables in the SIM Output File

| WR Record Rights           | Instream Flow Rights       | Control Points        | Reservoir/Hydropower     |
|----------------------------|----------------------------|-----------------------|--------------------------|
| diversion or energy target | instream flow target       | naturalized flow      | energy generated         |
| diversion/energy shortage  | flow shortage              | regulated flow        | energy shortage          |
| reservoir storage volume   | storage volume             | unappropriated flow   | secondary energy         |
| evap-precip volume         | evap-precip volume         | stream flow depletion | storage volume           |
| available stream flow      | available stream flow      | channel loss          | evap-precip volume       |
| stream flow depletion      | stream flow depletion      | channel loss credit   | evap-precip depth        |
| reservoir releases         | required reservoir release | reservoir releases    | adjusted evap-prec depth |
| return flow                | reservoir release          | return flow           | reservoir inflow         |
| available flow increase    | reservoir release shortage | diversion target      | reservoir release        |
| water right identifier     | water right identifier     | diversion shortage    | turbine flow             |
| first group identifier     |                            | storage volume        | water surface elevation  |
| second group identifier    |                            | evap-precip volume    | reservoir identifier     |
|                            |                            | cp identifier         |                          |

### **Simulation Example**

A hypothetical example was created by excerpting hydrology and reservoir data from the TCEQ WAM System dataset for the Brazos River Basin and adding other fabricated water rights data to develop a realistic but reasonably simple illustrative example. Water supply capabilities of the river/reservoir system presented in Figure 3.2 and Table 3.3 are assessed based on historical natural 1940-2017 hydrology. The river basin system has 11 control points, six reservoirs, and 30 water rights. The dams at Possum Kingdom, Whitney, Waco, Belton, Georgetown, and Granger Reservoirs at sites labeled control points PK, Whit, WacoL, Belton, George, and Grang are assumed to be located at the USGS gages listed in Table 1.2. In reality, the dams are located near but not exactly at these gage sites. The *SIM* input and output data files are presented in Appendix A. The *TABLES* input and output files are reproduced as Appendix B.

#### **SIM Input Files and Input Records for the Example**

Both control points and reservoirs are labeled in a *SIM* dataset with identifiers that are limited to not exceed six characters in length. The identifiers for the 11 control points adopted for the example are shown in the schematic of Figure 3.2. Normally reservoir identifiers are different than control point identifiers. However, for simplicity, for the six reservoirs, the identifiers for their control points are also adopted as the reservoir identifiers. Water rights have identifiers limited to not exceed 16 characters. Identifiers for the 30 water rights created for the

example are listed in Column 1 of Table 3.3. Water rights IF-1 and IF-2 are instream flow *IF* record rights. The 28 other water rights are defined by *WR* records.

Files for the example are listed in Table 3.4. The electronic input data files for this example are distributed along with the files for the other examples presented in the other manuals. The *SIM* hydrology input data (*IN* and *EV* records) are available both as a DSS file and as FLO and EVA files. Either alternative for storing *IN* and *EV* records yields the same simulation results. The filename for a *SIM* DSS hydrology input file always has the term HYD appended to the filename root to distinguish DSS input files from DSS output files. The choice of adopting the DSS input file versus FLO and EVA input files for a particular execution of *SIM* is controlled by the parameter INEV in *JO* record field 2.

Simulation results are recorded in an OUT file by default. Parameters on the *OF* record allow simulation results to be recorded in a DSS file either in addition to or in lieu of the OUT file. *SIM* can have one or no DSS input file and one or no DSS output file. The DSS input versus output files are distinguished by the "HYD" added to the filename root of the input file.

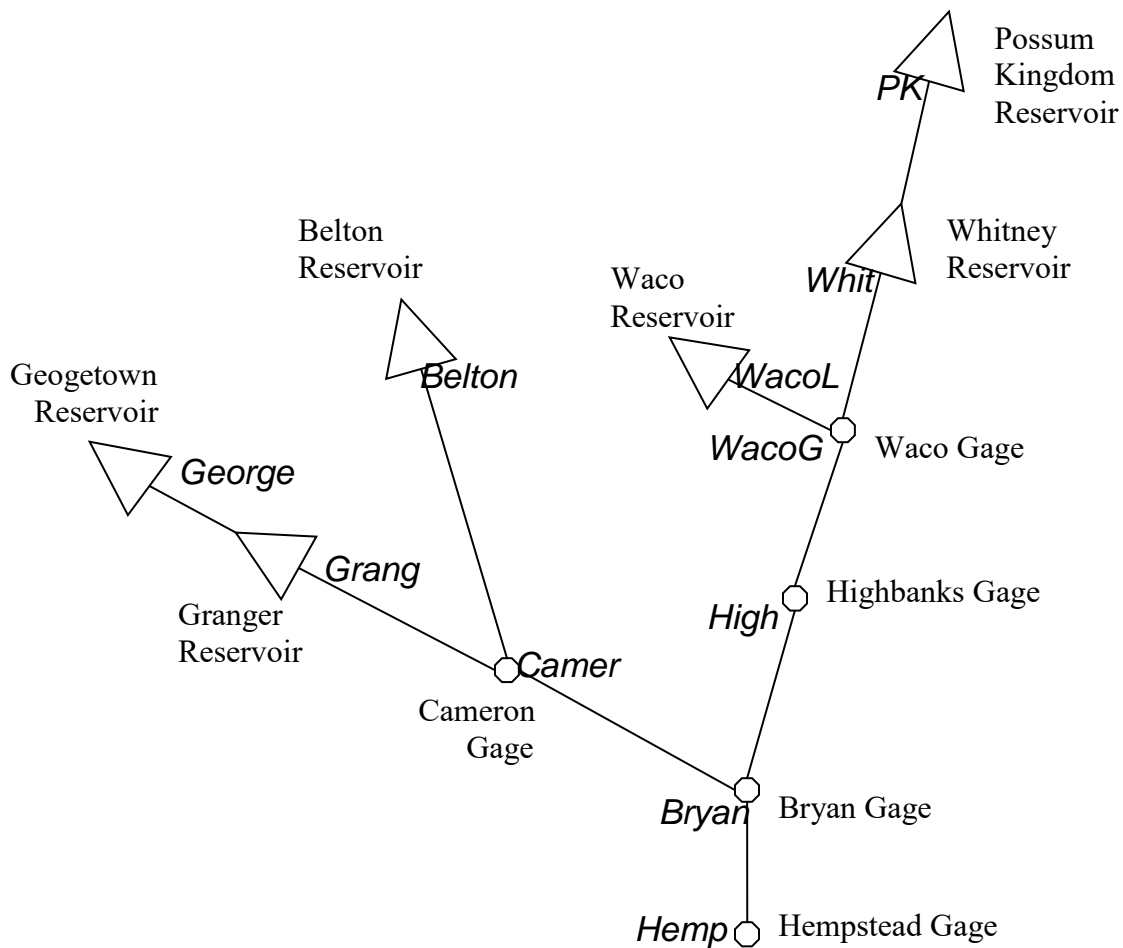


Figure 3.2 System Schematic for the Example

Table 3.3  
Water Rights in the Example

| 1                    | 2                      | 3               | 4                  | 5                                 | 6                               | 7                          | 8                              |
|----------------------|------------------------|-----------------|--------------------|-----------------------------------|---------------------------------|----------------------------|--------------------------------|
| Water<br>Right<br>ID | Control<br>Point<br>ID | Reservoir<br>ID | Priority<br>Number | Diversión<br>Target<br>(ac-ft/yr) | Energy<br>Target<br>(MW-hrs/yr) | IF<br>Target<br>(ac-ft/yr) | Storage<br>Capacity<br>(ac-ft) |
| IF-1                 | Camer                  |                 | 0                  |                                   |                                 | 3,600                      |                                |
| IF-2                 | Hemp                   |                 | 0                  |                                   |                                 | 120,000                    |                                |
| WR-1                 | PK                     | PK              | 193804             | 9,800                             |                                 |                            | 570,240                        |
| WR-2                 | PK                     | PK              | 193804             | 245,000                           |                                 |                            | 570,240                        |
| WR-3                 | Whit                   | Whit            | 198208             | 18,000                            |                                 |                            | 627,100                        |
| WR-4                 | Whit                   | Whit            | 888888             |                                   | 36,000                          |                            |                                |
| WR-5                 | Whit                   | Whit            | 990000             |                                   |                                 |                            | 627,100                        |
| WR-6                 | WacoL                  | WacoL           | 192901             | 60,000                            |                                 |                            | 104,100                        |
| WR-7                 | WacoL                  | WacoL           | 198609             | 20,800                            |                                 |                            | 192,100                        |
| WR-8                 | Belton                 | Belton          | 196312             | 82,760                            |                                 |                            | 457,600                        |
| WR-9                 | Belton                 | Belton          | 196312             | 97,500                            |                                 |                            | 457,600                        |
| WR-10                | George                 | George          | 196802             | 25,610                            |                                 |                            | 37,100                         |
| WR-11                | Grang                  | Grang           | 196802             | 42,000                            |                                 |                            | 65,500                         |
| WR-12                | Camer                  |                 | 198211             | 92,100                            |                                 |                            |                                |
| WR-13                | Camer                  |                 | 196105             | 18,200                            |                                 |                            |                                |
| WR-14                | Camer                  |                 | 194510             | 11,300                            |                                 |                            |                                |
| WR-15                | Camer                  |                 | 200601             | 88,000                            |                                 |                            |                                |
| WR-16                | WacoG                  |                 | 194607             | 32,300                            |                                 |                            |                                |
| WR-17                | High                   |                 | 195903             | 44,800                            |                                 |                            |                                |
| WR-18                | Bryan                  |                 | 198211             | 25,400                            |                                 |                            |                                |
| WR-19                | Bryan                  |                 | 196105             | 39,000                            |                                 |                            |                                |
| WR-20                | Bryan                  |                 | 194510             | 34,500                            |                                 |                            |                                |
| WR-21                | Hemp                   |                 | 196105             | 95,600                            |                                 |                            |                                |
| WR-22                | Hemp                   |                 | 194510             | 49,600                            |                                 |                            |                                |
| WR-23                | Hemp                   |                 | 201804             | 74,500                            |                                 |                            |                                |
| WR-24                | Hemp                   |                 | 201901             | 475,000                           |                                 |                            |                                |
| WR-25                | PK                     | PK              | 990000             |                                   |                                 |                            | 570,240                        |
| WR-26                | Belton                 | Belton          | 990000             |                                   |                                 |                            | 457,600                        |
| WR-27                | George                 | George          | 990000             |                                   |                                 |                            | 37,100                         |
| WR-28                | Grang                  | Grang           | 990000             |                                   |                                 |                            | 65,500                         |

*SIM* input DAT and output MSS, OUT, YRO files are presented in Appendix A. The DAT file reproduced on pages 57-59 contains all of the *SIM* input data except the *IN* and *EV* records. The MSS, OUT, and YRO files produced by *SIM* are also included in Appendix A on the pages listed in Table 3.4. The *TABLES* input TIN and output TMS and TOU files are presented in Appendix B. Program *TABLES* reads the *SIM* output OUT file as an input file.

The content and format of the *SIM* and *TABLES* input records are explained in Appendices C and D, respectively. Appendix C contains explanations describing the 25 types of *SIM* input records listed in Table 3.1 on page 18. The example uses 19 of them. The *Users*

*Manual* provides instructions for all 63 types of *SIM* input records. The descriptions of record content and format are essential for applying the model. In studying the example dataset, Appendix C should be referenced concurrently with the corresponding records in the input files.

Table 3.4  
Files for the Example

| Filename        | Pages | Description   |
|-----------------|-------|---|
| FundExam.DAT    | 57-59 | All <i>SIM</i> input except the <i>IN</i> and <i>EV</i> records.  |
| FundExamHYD.DSS | -     | <i>IN</i> and <i>EV</i> records for 11 and 6 cps for 1940-2017.   |
| FundExam.FLO    | -     | <i>IN</i> records for the 11 control points for 1940-2017.        |
| FundExam.EVA    | -     | <i>EV</i> records for the 6 control points with reservoirs.       |
| FundExam.MSS    | 59    | <i>SIM</i> message file.  |
| FundExam.DSS    | -     | <i>SIM</i> simulation results read by <i>HEC-DSSVue</i> .         |
| FundExam.YRO    | 38    | <i>SIM</i> yield-reliability table created with <i>FY</i> record. |
| FundExam.TIN    | 61    | <i>TABLES</i> specifications for building tables.                 |
| FundExam.TMS    | 61-62 | <i>TABLES</i> message file.                                       |
| FundExam.TOU    | 62-70 | Simulation results as organized by <i>TABLES</i> .                |

\*\*, *JD*, *JO*, *OF*, and *RO* Records in the *SIM DAT* File (pages 57 and 75-82)

Comment records starting with \*\* are used throughout the DAT file for the benefit of model users. The computer does not read records starting with \*\*. Comment records are used to organize and document input files. The \*\* notation is also used to deactivate records that are not to be used in the current execution of the model. For example, the 18<sup>th</sup> record of the DAT file on page 57 is a firm yield *FY* record which is not applicable for the first simulation discussed here but controls the yield-reliability analysis discussed later in this chapter. The *FY* record has been temporarily deactivated by adding the \*\* at the beginning.

The job data *JD* record is described on page 76. The 78 year hydrologic period-of-analysis extends from 1940 through 2017. ICHECK of 1 in *JD* record field 4 activates a standard level of error checks and trace messages. Negative incremental flow option 6 selected in *JD* record field 8 is the standard option that should be used in most applications.

The job options *JO*, optional files *OF*, and reservoir output *RO* records are described on pages 77, 79-80, and 81, respectively. Parameter INEV in *JO* record field 2 specifies options for reading the *IN* and *EV* records from a DSS file or FLO and EVA files. INEV options 1 (default) and 2 consist of reading *IN* and *EV* records from FLO and EVA files grouped either by year or by control point, respectively. Option 6 consists of reading *IN* and *EV* records from a DSS file. Other time series variables (*TS*, *HI*, *RU*, and *DF* records) described in the *Users* and *Daily Manuals* can also be stored in the hydrology DSS input file along with the *IN* and *EV* records.

*JD* record fields 5 and 6 and *CO*, *WO*, *GO*, and *RO* records are used to select the control points, water rights, and reservoirs for which simulation results are included in the OUT and DSS output files. The *CO*, *WO*, and *GO* records are included in Appendix C but are not used in

the example. A *RO* record is used. In this example, output records are written to the OUT file for all control points, all reservoirs, and all water rights except the hydropower right. For larger datasets with thousands of water rights and control points and hundreds of reservoirs, the time series of simulation results recorded in output files can be extremely large, increasing computer memory requirements and run times. Limiting the *SIM* output to only data that is actually of interest can also simplify the *TABLES* input TIN file by allowing *TABLES* to include all water rights, all control points, and/or all reservoirs from the *SIM* OUT file in its tables.

In this example, *SIM* simulation results are recorded in both an OUT file and DSS file as specified by parameters DSS(1) and DSS(3) in *OF* record fields 2 and 4 (page 79). Simulation results written to the OUT files consist of the 1940-2017 monthly time series variables for all 42 variables listed in Table C.1 on page 80. With the default DSS(4) option 1 activated by a blank *OF* record field 5, the default variables listed on page 81 are included in the DSS file. Parameter DSS(4) allows any or all of the 42 simulation results variables to be included in the DSS file. The OUT file choices are limited to either all or none of the variables. The selection of control points, water rights, and reservoirs for inclusion in the simulation results output described in the preceding paragraph applies the same to both the OUT and DSS files.

The OUT text file is designed to be read by *TABLES*. The binary DSS file is read by *HEC-DSSVue*. *TABLES* also includes options for reading *SIM* simulation results from an OUT file, manipulating the results, and writing the resulting data to a DSS file.

#### Use Coefficient UC Records in the SIM DAT File (pages 57 and 83)

The water use coefficient *UC* records contain a water use identifier corresponding to field 4 of the instream flow *IF* and water right *WR* records and a set of 12 coefficients for distributing the annual target in field 3 of the *IF* and *WR* records over the 12 months of the year. Fractions summing to 1.0 are computed by dividing each coefficient by the sum of all 12 coefficients. If *IF* or *WR* record field 4 is blank, 1/12 of the annual target is distributed to each month. If *IF* or *WR* record field 4 contains the entry *NDAYS*, the annual target is automatically distributed over the 12 months in proportion to the number of days in each month of either 28, 30, or 31. The entry *LDAYS* functions the same as *NDAYS* except February is assigned 29 days in leap years rather than 28 days.

In the example, monthly targets are set by simply multiplying the annual target from the *WR* or *IF* records by fractions computed from the use coefficients from *UC* records or from the *NDAYS* option. However, many other options on *ES/HC*, *SO*, *TO*, *FS*, *CV*, *TS*, *BU*, and *DI* records described in the *Reference* and *Users Manuals* may be adopted to compute targets as a function of hydrologic condition, stream flow, flow depletions, diversions, or reservoir storage.

#### Control Point CP Records in the SIM DAT File (pages 57 and 84-85)

Each control point has an identifier that can not exceed six characters in length. The control point identifiers shown in Figure 3.2 are entered in *CP* record field 2 followed in field 3 by the identifier of the next downstream control point. These pairs of control point identifiers define the spatial connectivity of the river system. Methods for inputting or computing naturalized stream flows and net evaporation rates are specified on the *CP* records, with blank fields indicating defaults. Channel loss factors defined by Equation 3.1 are entered in field 10.



Water Right WR, IF, WS, HP Records in the SIM DAT File (pages 57-59 and 86-91)

A water right consists of either an *IF* or *WR* record followed by a set of supporting records, which in this example includes one right with a *HP* record and several with *WS* records. The 30 water rights defined by two *IF* records and 28 *WR* records with associated *HP* and *WS* records are listed in Table 3.3. Several other types of optional records that may be combined with *IF* and *WR* records to define water right requirements are described in the *Reference and Users Manuals* and also in the *Daily Manual*. The *Daily Manual* also describes flood control operations which are treated as flood control *FC* record water rights.

The two water rights with identifiers IF-1 and IF-2 are instream flow requirements. Water right WR-4 generates hydroelectric power. WR-12, WR-13, WR-14, WR-16, WR-17, WR-18, WR-19, WR-20, WR-21, WR-22, and WR-23 are run-of-river diversion rights with no reservoir storage. WR-1, WR-2, WR-3, WR-6, WR-7, WR-8, WR-9, WR-10, and WR-11 are diversion rights that both refill and withdraw from reservoir storage. WR-15 and WR-24 are multiple-reservoir system diversion rights that do not refill storage. Reservoir storage is refilled by WR-25, WR-26, WR-27, and WR-28, which do nothing but refill storage in the system reservoirs that has been depleted by more senior diversion rights. WR-5 fills storage depleted by hydropower WR-4. WR-5 refilling of Whitney Reservoir is subject to the instream flow restrictions imposed by IF-1 and IF-2, but the WR-4 hydropower right is not. AMT in *WR* record field 3 is an annual water supply diversion target in acre-feet/year, with the exception of WR-4 with an annual hydroelectric energy generation target AMT of 36,000 megaWatt-hours/year.

Priorities serve the sole purpose of setting the order in which water rights are considered in the simulation computations. With priority numbers of zero in *IF* record field 5, IF-1 and IF-2 are the most senior rights in the river basin. In each month, the first action taken in the priority-sequenced simulation is to set the instream flow targets at first the Cameron gage control point and then the Hempstead gage control point. All of the other more junior rights are constrained from any water appropriations that would result in these minimum instream flow targets being violated. The WR-4 hydropower right with a priority of 888888 is junior to all of the diversion rights. With priority numbers of 990000 in *WR* record field 5, WR-5, WR-25, WR-26, WR-27, and WR-28, which serve the sole purpose of refilling reservoir storage, are the most junior rights in the river basin. All other rights have priority numbers that represent dates in permits reflecting the prior appropriation water rights system. For example, water right WR-1 has a priority of 193804 reflecting a right dating back to April 1938. With more than one right having the same priority number in *WR* or *IF* field 5, the right entered first in the DAT file is treated as having higher priority, meaning it is considered earlier in the simulation computations.

Water right WR-15 is a diversion at the Cameron gage control point (CP identifier Camer) supplied by available river flow at that control point supplemented by releases from Belton, Georgetown, and Granger Reservoirs which have reservoir identifiers of Belton, George, and Grang. The 88,000 acre-feet/year diversion target is distributed over the 12 months of the year using coefficients from the *UC* record with use identifier MUN2 representing municipal water use in that region. The priority number for WR-15 is 200601 representing a water right permit filing date of January 2006. Return flows are 35% (from *WR* field 8) of the diversion. Return flow method 2 in *WR* record field 7 means that return flows occur in the next month after the diversion. All rights may have access in priority order to the next-month return flow.

Since type 2 is entered in *WR* record field 6 for rights WR-15 and WR-24, the diversion target is met in each month first by available stream flow supplemented as necessary by reservoir releases. WR-24 is a type 2 diversion right at the Hempstead Gage control point (CP identifier Hemp) supplied by stream flow and releases from Possum Kingdom, Belton, Georgetown, and Granger Reservoirs. As type 2 rights, multiple-reservoir system water rights WR-15 and WR-24 do not refill reservoir storage. The reservoirs are refilled by the junior type 1 water rights WR-25, WR-26, WR-27, and WR-28.

For multiple-reservoir system rights WR-15 and WR-24, the release is made from the reservoir that is most full in terms of percentage of the active conservation pool capacity. The active conservation storage capacity is the total capacity from *WS* record field 3 less the inactive capacity from *WS* record field 7. In a particular month of the simulation, if the contents of the active conservation pool of Belton, Georgetown, and Granger Reservoirs is 82%, 91%, and 87% of capacity, releases are made from Georgetown since 91% indicates it is most full. The operation rules *OR* record described in the *Reference* and *Users Manuals* provides greater flexibility in modeling more complex system operating rules.

#### *SV/SA and PV/PE Record Tables in the SIM DAT File (pages 59 and 92)*

Storage volume versus water surface area tables are provided on *SV/SA* records for each of the reservoirs. These tables are linearly interpolated to determine water surface areas corresponding to computed storage volumes for use in computing net evaporation volumes. *SV/SA* records must be provided if fields 4, 5, and 6 of the *WS* record for the reservoir are blank.

Hydropower right WR-4 requires a storage volume versus water surface elevation table provided on *PV/PE* records for Whitney Reservoir with identifier Whit for use in determining head in the hydropower computations. *PV/PE* records must be provided for any reservoir associated with a hydropower right as defined by type of 5 or 6 being entered in *WR* field 6.

#### *Hydrology Input Files for Program SIM (page 93-94)*

Eleven 1940-2017 sequences of monthly naturalized stream flows in acre-feet are input as *IN* records in either a FLO file or hydrology DSS file. Six 1940-2017 sequences of monthly net reservoir surface evaporation less precipitation depths in feet are input as *EV* records in either an EVA file or the hydrology DSS file. The *IN* and *EV* records are read from the DSS file if *INEV* option 6 is specified in *JO* record field 2, which is the case in the DAT file reproduced in Appendix A. *INEV* option 2 consists of reading the *IN* and *EV* records from the FLO and EVA files. The DSS, FLO, and EVA files are not reproduced in this manual but are included in the electronic dataset that is available along with the WRAP manuals and software.

The parameter *INEV* in *JO* record field 2 specifies the file option and sequencing option used to compile the *IN* and *EV* records. Option 2 adopted for the FLO and EVA files included in the example dataset has the *IN* and *EV* records grouped by control point. The files begin with records for control point PK for all 78 years, followed by 78 records for control point Whit, followed by the 78 years of data for the next control point. The control points may be in any arbitrary order. The years 1940-2017 must be in chronological order.

The TCEQ WAM System datasets use the default *JO* field 2 *INEV* option 1 for sequencing records in the FLO and EVA files with grouping by year. The files begin with records for all control points for the first year. Since simulation computations are performed sequentially by month, the option of grouping by year allows storing only one year of naturalized flows and net evaporation depths in computer memory. Option 2 as well as option 6 (DSS file) requires reading of all *IN* and *EV* records at the beginning of the simulation. Thus, option 1 is more efficient in use of computer memory. Both programs *SIM* and *HYD* include routines for converting FLO and EVA files to a DSS file. Program *HYD* also includes routines for changing the sequencing of the *IN* and *EV* records in FLO and EVA input files.

Hydrologic period-of-analysis sequences of monthly naturalized flows are required for all control points in a WRAP input dataset. The term "primary control point" is applied to the sites at which sequences of monthly naturalized flows (*IN* records) are included in the input dataset. Secondary control points are sites at which naturalized flows are computed during the simulation based on flows at primary control points and watershed parameters provided in a flow distribution DIS file. Naturalized flows can also be repeated at multiple control points applying factors such as drainage area ratios entered on *CP* records in the DAT file. The example has 11 primary control points and no secondary control points and thus no DIS file.

#### MSS Message File for Program SIM (page 59-60)

Model users should routinely check the message file. For this example, the message file contains only trace messages tracking reading of input data and initiation of the simulation. Errors or irregularities in input data may result in either error or warning messages being written to the MSS file. Program execution is terminated along with an error message. A warning message indicates irregularities or possible problems without terminating execution. *SIM* contains a myriad of routines for checking input datasets. The *Reference and Users Manuals* provides guidance for detecting and correcting problems in voluminous input datasets. Various other options not used in the example dataset may result in other information being written to the message file that is not related to checking for errors or problems.

#### SIM Simulation Results

The example records simulation results in both OUT and DSS output files. With no *OF* record included in the DAT file, the OUT file will be created by default. The *OF* record allows OUT, DSS, and/or SOU output files to be either created or not created. The OUT file is designed to be efficiently accessed by program *TABLES*. The SOU file is structured in a much easier-to-read by people format than the OUT file allowing the simulation results to be conveniently viewed with Microsoft WordPad. The binary DSS file is designed to allow *SIM* simulation results to be accessed by *HEC-DSSVue* for plotting and other analyses. A DSS file can be created by either *SIM* or *TABLES*. *HEC-DSSVue* easily converts datasets between DSS and Microsoft Excel. *TABLES* also converts data to Excel readable columnar formats.

Variables included in the *SIM* simulation results are listed in Tables 3.2 and C.1 on pages 28 and 80. These variables are time series covering each month the 936 months of the 1940-2017 hydrologic period-of-analysis. The 42 simulation results variables are each associated with either control points, water rights, and/or reservoirs. *OF* record parameter DSS(4) allows inclusion of all 42 variables or any specified subset thereof in the DSS file for selected control

points, water rights, and/or reservoirs. The default DSS(4) selection defined in Table C.1 (page 81) is adopted in the example for the DSS file. The OUT file always includes all variables related to the selected control points, water rights, and/or reservoirs.

The selection of which control points, water rights, and/or reservoirs to include in the *SIM* output DSS and OUT files are controlled by parameters CPOUT and OUTWR in *JD* record fields 5 and 6 and the *RO*, *CO*, *WP*, and *GO* records. The example includes recording simulation results in the OUT and DSS output file for all water rights except the hydropower right (OUTWR=-1), all control points (CPOUT=-1), and all reservoirs (ALL=-1 on *RO* record). Simulation results for the hydropower right (WR-4) are included on the reservoir output records. Excluding WR-4 from the water right output records simplifies creation of water supply reliability tables with *TABLES* as explained in Chapter 4. *CO*, *WP*, and *GO* records are included in Appendix A but are not included in the example.

### **Yield-Reliability Analysis and Firm Yield**

A routinely employed WRAP modeling and analysis strategy consists of a hydrologic period-of-analysis simulation with results analyzed, summarized, and displayed using *TABLES* and *HEC-DSSVue* as discussed in Chapter 4. *SIM* also provides other optional simulation modes. The *SIM* yield-versus analysis feature is discussed below. Other *SIM* auxiliary special-purpose modeling and analysis capabilities are covered in the *Reference* and *Users Manuals*.

An iterative routine to develop a yield versus reliability relationship is controlled with the firm yield *FY* record. The firm yield is the last entry in the resulting *SIM* yield-reliability table, assuming a non-zero firm yield is possible. Firm yield is the maximum value of a diversion or hydropower target that has a reliability of 100 percent computed with Equations 4.1 and 4.2 presented in Chapter 4. In some situations, any non-zero target results in a reliability of less than 100 percent. The yield-reliability analysis computations are based on an automated repetition of the entire simulation. One or more selected water rights start with a user-specified annual diversion or hydropower target that is iteratively reduced until either the firm yield or a zero target is reached. Additional options for defining a "safe yield" are described in the *Reference* and *Users Manuals* but for brevity are not covered in this manual.

The annual water supply diversion target or hydroelectric energy generation target is entered in field 3 of the *SIM* water right *WR* record. The reliabilities associated with various yields, represented by the annual target amount, may be developed simply by running *SIM* and *TABLES* multiple times, manually changing the target entry in *WR* record field 3 for each run. The option activated by the *FY* record automates this procedure. In a single *SIM* execution, multiple simulations are repeated with the annual target amount being systematically changed. The resulting yield-reliability table is written as a *SIM* output YRO file.

The diversion or hydropower yield may be associated with a single water right or a set of any number of rights. If associated with multiple water rights, two options are available for allocating the annual yield amount between rights. With the first option, the yield is allocated between rights in proportion to target amounts entered in field 3 of the water right *WR* records. The second option is based on the priorities from *WR* record field 5. The yield is assigned to the most senior priority right up to the target amount specified by its *WR* record. Any yield remaining is assigned to the next most senior priority right up to its target amount, and so forth.

### Yield-Reliability Analysis Example

As previously discussed, the DAT file for the example is presented on pages 57-59. Activation of the iterative yield-reliability analysis option requires the addition of a *FY* record to the DAT file. The 18<sup>th</sup> record in the DAT file is a *FY* record that has been deactivated by conversion to a *\*\** record. Removal of the *\*\** activates the *FY* yield record and the iterative simulation algorithm that it controls. The results are written by *SIM* to the YRO file reproduced as Table 3.5 on page 38. The yield versus reliability table covers a range of diversion targets for water right WR-24. The estimated firm yield is 47,470 acre-feet/year.

Volume and period reliability are defined by Equations 4.1 and 4.2 presented in the next chapter. The firm yield is the maximum value for the target that has a volume reliability of one-hundred percent, with the one-hundred percent defined to a specified level of precision. The firm yield is the last target entry in the YRO file table if the iterations reach a volume reliability of one hundred percent. Otherwise, the firm yield is zero.

In the original dataset, the *WR* record for right WR-24 has an annual diversion target of 475,000 acre-feet/year. With the *FY* record added, this target is replaced with the 200,000 ac-ft/yr from *FY* field 3. All other aspects of the simulation reflected in the input dataset remain identically the same.

The results for the simulation with the 200,000 ac-ft/yr target is presented in the first line of the yield-reliability table shown as Table 3.5 on the next page. The mean actual annual diversion of 199,078 ac-ft/yr is 99.54% of the target. The target was met without shortage in 932 months or 99.57% of the 936 months in the simulation. Since the mean shortage over the 1940-2017 simulation is greater than the criterion of 0.05 acre-feet/year, the simulation is repeated with a reduced target diversion amount for right WR-24. The incremental reductions in the diversion target are set by *FY* record fields 4, 5, and 6. The target is reduced by 10,000 ac-ft/yr increments (*FY* field 4) until the mean diversion shortage drops to below 0.05 ac-ft/yr or the target reduces to zero. The iterative process is then repeated for 1,000 ac-ft/yr increments (*FY* field 5) and then 100 ac-ft/yr (*FY* field 6) and 10 acre-feet/year (10% of *FY* field 6) increments.

The parameter in *FY* record field 2 is the fraction (0.0 to 1.0) of the monthly target that must be met in order to not count the month as a failure in meeting the target in the period reliability computations. The blank *FY* field 2 in the example results in adoption of the default of 1.0. With an entry of 0.95 in field 2, the period reliability would be defined as the percentage of months during the simulation during which at least 95% of the diversion target was supplied. The *FY* record field 2 parameter affects only the last two columns of the yield-reliability table, consisting of the number of months without shortages and the corresponding period reliability.

Each of the 29 iterations reflected in the yield-reliability table is a complete 1940-2017 hydrologic period-of-analysis *SIM* simulation with all input the same except for the WR-24 diversion target. Iterations for each of the four levels of target increments stopped when the mean annual shortage dropped below 0.05 acre-feet/year. The increment for the 4th level of target reductions is 10 acre-feet/year, automatically set at 10 percent of the 100 acre-feet/year entered in *FY* record field 6. The simulation results shown in the YRO table indicate that a water right WR-24 diversion target of 47,480 ac-ft/yr results in a mean shortage of 0.11 ac-ft/yr which exceeds the criterion limit of 0.05 ac-ft/yr. However, the mean shortage for a target of 47,470

acre-feet/year is below this limit. The mean shortage is shown in the table to be 0.00 meaning it is less than 0.005 acre-feet/year, which is less than the limit of 0.05 acre-feet/year.

The firm yield is concluded to be 47,470 acre-feet/year. The YRO file table displays the diversion target versus reliability relationship for a range of diversion targets and reliabilities. This table, which is based on multiple *SIM* simulations with variations in the water supply diversion target, is different than the *TABLES* reliability table presented in the following Chapter 4 which is developed from the results of a single *SIM* simulation.

Table 3.5 Example SIM YRO File

Yield Versus Reliability Table for the Following Water Supply Diversion Right(s):

One right (100%): WR-24 SystemH

If more than one right, the target amount is distributed using the percentages shown above. The total number of periods is 936. The period reliability is the percentage of the periods for which at least 100.0 percent (FY record field 2; default=100%) of the target is supplied.

The table ends with the maximum target that results in a mean annual shortage of less than 0.05 units if such a firm yield is possible.

| Iteration | Level | Annual Target | Mean Shortage | Mean Actual | Volume Reliability (%) | Periods Without Shortage | Period Reliability (%) |
|-----------|-------|---------------|---------------|-------------|------------------------|--------------------------|------------------------|
| 1         | 0     | 200000.0      | 922.0         | 199078.0    | 99.54                  | 932                      | 99.57                  |
| 2         | 1     | 190000.0      | 805.8         | 189194.2    | 99.58                  | 932                      | 99.57                  |
| 3         | 1     | 180000.0      | 709.8         | 179290.2    | 99.61                  | 932                      | 99.57                  |
| 4         | 1     | 170000.0      | 551.8         | 169448.2    | 99.68                  | 933                      | 99.68                  |
| 5         | 1     | 160000.0      | 513.9         | 159486.1    | 99.68                  | 933                      | 99.68                  |
| 6         | 1     | 150000.0      | 476.1         | 149523.9    | 99.68                  | 933                      | 99.68                  |
| 7         | 1     | 140000.0      | 437.7         | 139562.2    | 99.69                  | 933                      | 99.68                  |
| 8         | 1     | 130000.0      | 399.9         | 129600.1    | 99.69                  | 933                      | 99.68                  |
| 9         | 1     | 120000.0      | 362.0         | 119638.0    | 99.70                  | 933                      | 99.68                  |
| 10        | 1     | 110000.0      | 324.2         | 109675.8    | 99.71                  | 933                      | 99.68                  |
| 11        | 1     | 100000.0      | 283.0         | 99717.0     | 99.72                  | 933                      | 99.68                  |
| 12        | 1     | 90000.0       | 215.0         | 89785.0     | 99.76                  | 934                      | 99.79                  |
| 13        | 1     | 80000.0       | 185.8         | 79814.2     | 99.77                  | 934                      | 99.79                  |
| 14        | 1     | 70000.0       | 104.2         | 69895.8     | 99.85                  | 934                      | 99.79                  |
| 15        | 1     | 60000.0       | 62.5          | 59937.5     | 99.90                  | 935                      | 99.89                  |
| 16        | 1     | 50000.0       | 30.3          | 49969.7     | 99.94                  | 935                      | 99.89                  |
| 17        | 1     | 40000.0       | 0.00          | 40000.0     | 100.00                 | 936                      | 100.00                 |
| ---       |       |               |               |             |                        |                          |                        |
| 18        | 2     | 49000.0       | 18.3          | 48981.7     | 99.96                  | 935                      | 99.89                  |
| 19        | 2     | 48000.0       | 6.34          | 47993.7     | 99.99                  | 935                      | 99.89                  |
| 20        | 2     | 47000.0       | 0.00          | 47000.0     | 100.00                 | 936                      | 100.00                 |
| ---       |       |               |               |             |                        |                          |                        |
| 21        | 3     | 47900.0       | 5.14          | 47894.9     | 99.99                  | 935                      | 99.89                  |
| 22        | 3     | 47800.0       | 3.94          | 47796.1     | 99.99                  | 935                      | 99.89                  |
| 23        | 3     | 47700.0       | 2.75          | 47697.3     | 99.99                  | 935                      | 99.89                  |
| 24        | 3     | 47600.0       | 1.55          | 47598.4     | 100.00                 | 935                      | 99.89                  |
| 25        | 3     | 47500.0       | 0.35          | 47499.6     | 100.00                 | 935                      | 99.89                  |
| 26        | 3     | 47400.0       | 0.00          | 47400.0     | 100.00                 | 936                      | 100.00                 |
| ---       |       |               |               |             |                        |                          |                        |
| 27        | 4     | 47490.0       | 0.23          | 47489.8     | 100.00                 | 935                      | 99.89                  |
| 28        | 4     | 47480.0       | 0.11          | 47479.9     | 100.00                 | 935                      | 99.89                  |
| 29        | 4     | 47470.0       | 0.00          | 47470.0     | 100.00                 | 936                      | 100.00                 |

## CHAPTER 4 ORGANIZATION AND ANALYSIS OF SIMULATION RESULTS WITH TABLES AND HEC-DSSVUE

The *SIM* simulation described in Chapter 3 combines historical natural river system hydrology during a 1940-2017 hydrologic period-of-analysis with a specified scenario of water resources development and use represented by 6 reservoirs and 30 water rights. A specified scenario of water resources development/allocation/management/use is simulated during a hypothetical repetition of 1940-2017 natural hydrology. The results of the simulation consist of 1940-2017 sequences of the 42 time series variables listed in Table C.1 for either each control point, reservoir, and/or water right.

The premise is that historical natural stream flow and reservoir evaporation-precipitation rates capture the statistical characteristics of unknown future hydrology. The future is always of interest, rather than the past. Plots and summaries of 1940-2017 monthly time series quantities of the various simulation result variables provide meaningful insight. However, the reliability and frequency metrics described in Chapter 4 are usually the key products of a simulation study.

### **Hydrologic Engineering Center Program HEC-DSSVue**

The HEC-DSS Visual Utility Engine (*HEC-DSSVue*) is a component of the HEC Data Storage System (DSS) which is based on DSS records stored in DSS files in a binary format accessible only to software with DSS features. The WRAP programs *SIM*, *SIMD*, *HYD*, *DAY*, and *TABLES* as well as *HEC-DSSVue* and HEC simulation models and certain other non-HEC modeling systems include routines for creating and reading DSS files. Files are easily converted between DSS and Microsoft Excel or text files. *HEC-DSSVue* is designed for managing, viewing, editing, plotting, mathematically manipulating, and statistically analyzing data in DSS files.

The *HEC-DSSVue* software and user's manual can be downloaded free-of-charge from the U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center (HEC) website: <http://www.hec.usace.army.mil/>. The myriad of optional capabilities and variations of methods provided by *HEC-DSSVue* are explained in detail in its 490 page user's manual. Chapter 6 of the *WRAP Users Manual* outlines WRAP applications of HEC-DSS and *HEC-DSSVue* and summaries features that are particularly relevant to WRAP. HEC-DSS and *HEC-DSSVue* are also discussed in the *WRAP Reference, Hydrology, and Daily Manuals*.

The WRAP post-simulation program *TABLES* reads simulation results from the OUT file created by *SIM*. *HEC-DSSVue* reads any DSS file including the DSS file of simulation results created by *SIM* or a DSS file created by *TABLES*. *HEC-DSSVue* and *TABLES* provide extensive arrays of options for organizing, analyzing, summarizing, and displaying *SIM* simulation results. Capabilities provided by *HEC-DSSVue* versus *TABLES* are compared as follows.

- *HEC-DSSVue* provides comprehensive, flexible plotting capabilities that includes primarily time series plots but also other types of graphs. *TABLES* has no plotting capability.
- *TABLES* provide water supply reliability analysis capabilities that are very important in water availability modeling. These WAM reliability metrics are not included in *HEC-DSSVue*.

- Both *TABLES* and *HEC-DSSVue* provide similar frequency analyses capabilities that can be applied to stream flow, reservoir storage, and the other simulation results variables. Some basic frequency analysis capabilities are the same in both programs. Each program provides certain analysis options not provided by the other. Both create frequency tables. *HEC-DSSVue* also creates frequency plots.
- *TABLES* provides a broad array of options for organizing, analyzing, and summarizing simulation results and input data that are designed specifically for WRAP. *HEC-DSSVue* provides an array of generic options for performing mathematical operations and statistical analysis of time series data that are not included in *TABLES* but are applicable to WRAP.
- *TABLES* can read a DSS input file and/or create a DSS output file. *SIM* simulation results from an OUT or DSS file can be manipulated with *TABLES* with the resulting modified dataset converted to DSS records in a DSS file accessible to *HEC-DSSVue*.
- *HEC-DSSVue* can conveniently both read Microsoft Excel files or text files and convert DSS datasets to Excel or text files. *TABLES* can convert time series data to columnar format to be read by Excel but cannot read Excel files or any text files not in OUT file format.
- *TABLES* provides an array of optional capabilities designed specifically for working with *SIM*, *SIMD*, and *SALT* input and output datasets. *HEC-DSSVue* is a comprehensive data management program that greatly simplifies storing, organizing, cataloging, accessing, displaying, and analyzing large time series datasets.

### **WRAP Program TABLES**

The post-simulation program *TABLES* provides an array of tables and data tabulations in user-specified formats for organizing, summarizing, analyzing, and displaying *SIM* simulation results. *TABLES* reads the time series of monthly values of the simulation result variables listed in Table 3.2 and creates tables and data listings. *TABLES* also creates tables organizing and summarizing water right and control point data read from a *SIM* input file.

Some of the *TABLES* routines simply rearrange, organize, summarize, and tabulate, with appropriate table headings, selected data read from *SIM* input or output files. Water rights, reservoir, and control point data read from the *SIM* input DAT file can be sorted, organized, and summarized in a variety of formats. The various options provided by *TABLES* include rearranging time series of simulation results as: tables with annual rows and monthly columns in a text file for reports; columnar tabulations in a text file to be read by Microsoft Excel; records in a binary DSS file to be read by *HEC-DSSVue*.

Program *TABLES* also includes computational algorithms, which may range from simple summations or statistics to more complex arithmetic operations. A reliability table for water supply diversion or hydroelectric energy targets includes volume reliabilities and period reliabilities for meeting various percentages of the target demands. Frequency tables are developed for naturalized flows, regulated flows, unappropriated flows, reservoir storage, instream flow shortages, and other simulation results quantities. Reservoir storage may be also displayed as comparative tabulations of storage contents as a percentage of capacity and drawdown-duration and storage-reliability tables. Water budgets, control point summaries, and basin summaries may be developed. Program *TABLES* capabilities are covered in *Reference Manual* Chapter 7 and *Users Manual* Chapter 5.



## TABLES Files and Input Records

The *TABLES* input TIN file specifies the tables and/or other types of information to be developed and stored in the *TABLES* output TOU file. The data from which the tables and data listings are compiled are read from *SIM* input and/or output files. Most applications involve *TABLES* reading simulation results from a *SIM* OUT file. However, various *TABLES* options activated by the records in the TIN file may involve reading *SIM* input data from the DAT file.

*TABLES* consists of a main program and a number of subroutines. The main program opens files, checks the identifier on each record of the TIN file, and calls the appropriate subroutines. The *SIM* input and output files are read and the specified tables and data listings are developed and written to the *TABLES* output TOU file by the subroutines. Each subroutine is associated with specific types of tables or data listings and is activated by one or more types of input records read from the TIN file. *TABLES* input records are listed in Table 4.1 with the four-character identifiers that are placed at the beginning of each record. Explanations of most of these input records are provided as Appendix D. A number of other types of *TABLES* input TIN file records not included in this *Fundamentals Manual* are covered in the *Users, Daily, and Salinity Manuals*.

*TABLES* creates tables for user-specified water rights, groups of water rights, control points, or reservoir/hydropower projects. Selections may be specified by listing identifiers on the *TABLES* IDEN records. Alternatively, the default often adopted is to include all water rights, control points, or reservoir/hydropower records in the *SIM* output OUT file, as controlled by *SIM* input records.

Table 4.1  
Types of *TABLES* Input Records

---

| <u>Miscellaneous Records</u> |                                 |
|------------------------------|---------------------------------|
| TITL – titles or headings    | UNIT – units for table headings |
| COMM or **** – comments      | ENDF – end of input data        |
| PAGE – title page            | IDEN – identifiers              |

Type 1 Records – Tables Developed from *SIM* Input DAT File

1SUM – water rights summary by control point or type of use  
1SRT – listing of water rights sorted by priority, type of use, control point, or water right type  
1RES – listing of information regarding reservoirs  
1CPT – listing of control point information in upstream-to-downstream order

Type 2 Records – Tables Developed from *SIM* Output OUT File

*Time Series Tables in Optional TOU File Formats or HEC-DSS File*

2NAT – naturalized stream flow (control points)  
2REG – regulated stream flow (control points)  
2UNA – unappropriated stream flow (control points)  
2CLO – channel loss (control points)  
2RFR – return flow entering at this control point (control points)

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Table 4.1 (Continued)  
Types of *TABLES* Input Records

---

|      |   |
|------|---|
| 2CLC | – channel loss credits (control points)   |
| 2URR | – upstream reservoir releases (control points)  |
| 2CPI | – control point inflows excluding secondary reservoir releases (control points)         |
| 2STO | – reservoir storage (control points, water rights, reservoirs)                          |
| 2EVA | – reservoir evaporation-precipitation volume (control points, water rights, reservoirs) |
| 2DEP | – stream flow depletion (control points, water rights)                                  |
| 2TAR | – diversion target (control points, water rights)                                       |
| 2SHT | – diversion shortage (control points, water rights)                                     |
| 2DIV | – diversion (control points, water rights)  |
| 2RFL | – return flow (water rights)  |
| 2XAV | – increase in available stream flow (water rights)                                      |
| 2ASF | – available stream flow (water rights)  |
| 2ROR | – releases from other reservoirs (water rights)   |
| 2IFT | – instream flow target (instream flow rights, control points)                           |
| 2IFS | – instream flow shortage (instream flow rights, control points)                         |
| 2FSV | – flow switch volume (instream flow rights)   |
| 2FSC | – flow switch count (instream flow rights)  |
| 2HPS | – hydropower shortage (+) or Secondary Energy (–) (reservoir/hydropower)                |
| 2HPE | – energy generated (reservoir/hydropower)   |
| 2RID | – inflows to reservoir from stream flow depletions (reservoir/hydropower)               |
| 2RIR | – inflows from releases from other reservoirs (reservoir/hydropower)                    |
| 2RAH | – releases accessible to hydropower (reservoir/hydropower)                              |
| 2RNA | – releases not accessible to hydropower (reservoir/hydropower)                          |
| 2EPD | – adjusted evaporation-precipitation depths (reservoir/hydropower)                      |
| 2EVR | – evaporation-precipitation depths from <i>EV</i> records (reservoir/hydropower)        |
| 2WSE | – reservoir water surface elevation (reservoir/hydropower)                              |
| 2RSC | – reservoir storage capacity (reservoir/hydropower)                                     |
| 2RSD | – reservoir storage drawdown (reservoir/hydropower)                                     |

*Reliability and Frequency Tables*

|      |  |
|------|--|
| 2REL | – reliability summary by control point, water right, water right group, or reservoir         |
| 2FRE | – frequency table for stream flow, reservoir storage or elevation, or instream flow shortage |
| 2FRQ | – frequency for specified stream flow, storage or elevation, or instream flow shortage       |
| 2RES | – reservoir percentage of storage capacity, draw-down duration, and storage reliability      |

*Summary and Water Budget Tables*

|      |   |
|------|---|
| 2SCP | – monthly or annual summary table for a control point           |
| 2SWR | – monthly or annual summary table for a water right             |
| 2SRE | – monthly or annual summary table for a reservoir               |
| 2SGP | – monthly or annual summary table for a water right group       |
| 2SBA | – monthly or annual summary table for the entire river basin    |
| 2BUD | – water budget for control points and/or the entire river basin |

---

## Reliability and Frequency Metrics

Simulation results are used in a variety of ways to develop an understanding of a river basin hydrology and water management and use. Alternative model runs demonstrate the effects of alternative water use scenarios and management strategies. *SIM* simulation results may be organized with *TABLES* in various formats including: the entire time sequences of monthly values of various variables; annual or monthly summaries; water budgets; reliability indices; and frequency relationships. These forms of information may all be useful in analyzing, interpreting, and applying the results of a simulation study to support decision-making processes.

Concise measures of likelihood, probability, frequency, or reliability are particularly useful in displaying simulation results and analyzing water availability. Program *TABLES* options include the following probability statistics for concisely summarizing *SIM* results.

- volume and period reliability tables for water supply diversion and hydroelectric energy generation targets (2REL record)
- frequency tables for naturalized, regulated, and unappropriated flows, reservoir storage volumes and water surface elevations, instream flow targets and shortages, and other time series variables (2FREQ and 2FRQ records)

### Volume and Period Reliability

The reliability summary created with a 2REL record may be for either water supply diversion or hydroelectric energy generation targets for individual water rights, the aggregation of all diversion rights at specified control points, groups of selected diversion or hydropower rights, or the aggregation of all rights in the model. The reliabilities or frequencies may be for an individual month of the year such as July or August or may reflect all months. *TABLES* computes both period reliabilities based on percent-of-time and volume reliabilities based on diversion volumes or hydroelectric energy production amounts.

Volume reliability is the percentage of the total target demand amount that is actually supplied. For water supply diversions, the amounts are volumes. For hydroelectric power, the amounts are kilowatt-hours of energy generated. Volume reliability ( $R_V$ ) is the ratio of volume supplied or energy supplied ( $v$ ) to the volume or energy target ( $V$ ), converted to a percentage.

$$R_V = \frac{v}{V} (100\%) \quad (4.1)$$

Equivalently, for water supply,  $R_V$  is the mean actual diversion rate as a percentage of the mean target diversion rate. For hydropower,  $R_V$  is the mean actual rate of energy production as a percentage of the mean target energy production rate.

Period reliability is based on counting the number of periods of the simulation during which the specified demand target is either fully supplied or a specified percentage of the target is equaled or exceeded. A reliability summary includes tabulations of period reliabilities expressed both as the percentage of months and the percentage of years during the simulation during which water supply diversions or hydroelectric energy production equaled or exceeded

specified magnitudes expressed as a percentage of the target demand. The various variations of period reliability ( $R_P$ ) are computed by *TABLES* from the results of a *SIM* simulation as:

$$R_P = \frac{n}{N} (100\%) \quad (4.2)$$

where  $n$  denotes the number of periods during the simulation for which the specified percentage of the demand target is met, and  $N$  is the total number of periods considered. The 2REL record allows  $N$  and  $n$  to be defined optionally either considering all months or only months with non-zero demand targets.

A *TABLES* reliability summary includes tabulations of period reliabilities expressed both as the percentage of months and the percentage of years during the simulation during which water supply diversions or hydroelectric energy production equaled or exceeded specified magnitudes expressed as a percentage of the target demand. For example, the standard reliability table shows the percentage of months in the simulation for which the computed diversion equals or exceeds 75% of the monthly diversion target. It also shows the percentage of years for which the total diversions during the year equal or exceed 75% of the annual permitted amount. The table also shows the percentage of months for which the demand is fully 100% met, without shortage, as well as reliabilities for several other percentages of the target.

Period reliability  $R_P$  is an expression of the percentage of time that the full demand target or a specified portion of the demand target can be supplied. Equivalently,  $R_P$  represents the likelihood or probability of the target being met in any randomly selected month or year.

#### Flow-Frequency and Storage-Frequency Relationships

Frequency tables created with *TABLES* 2FRE and 2FRQ records may be developed for:

- naturalized flow, regulated flow, unappropriated flow, and end-of-month reservoir storage for specified control points
- instream flow shortage and end-of-month storage for specified water rights
- end-of-month storage and water surface elevation for specified reservoirs
- instream flow targets and shortages for *IF* record water rights or control points
- related variables such as storage draw-downs or flow deviations derived by arithmetic manipulations of the above variables

Frequency tables may be for a specified month of the year such as November or for all months. The analyses may be applied to monthly amounts or moving averages or moving totals over any user-specified number of months.

Exceedance frequency is expressed in terms of relative frequency as:

$$\text{Exceedance Frequency} = \frac{n}{N} (100\%) \quad (4.3)$$

where  $n$  is the number of months during the simulation that a particular flow or storage amount is equaled or exceeded, and  $N$  is the total number of months in the simulation. The exceedance

frequency is an expression of the percentage of time that particular flow or storage amounts can be expected to be equaled or exceeded. Equivalently, the exceedance frequency represents the likelihood or probability of a certain amount of water being available.

The 2FRE table includes the mean and standard deviation, minimum and maximum, and the flow or storage amounts that are equaled or exceeded specified percentages of the time. In applying Eq. 4.3 for the specified fixed frequencies, *TABLES* sorts and searches the flow or storage data from the *SIM* simulation results to find a value that is equaled or exceeded during the specified percentage of the months of the simulation. If a single flow value does not precisely match that frequency, linear interpolation is applied to the two flow values that bracket the specified frequency.

In addition to the default relative frequency option based on Eq. 4.3, the 2FRE record also provides options based on Eq. 4.4 and the log-normal or normal probability distributions.

The 2FRQ table also develops a flow-frequency, storage-frequency, or instream flow shortage-frequency relationship. However, the model-user enters selected flow or storage amounts of interest. *TABLES* simply counts the number of months for which a specified amount was equaled or exceeded and applies Equation 4.3 or Equation 4.4 to assign a frequency.

*HEC-DSSVue* includes a frequency analysis routine that computes exceedance frequency with the Weibull formula.

$$\text{Exceedance Frequency} = \frac{n}{N+1} (100\%) \quad (4.4)$$

Whereas Equation 4.3 assigns the smallest value in the dataset exceedance frequency of 100%, Equation 4.4 always assigns exceedance frequencies of less than 100%. For large sample size *N*, these two common versions of relative frequency formulas yield essentially the same results.

### **Simulation Example**

An example is presented in Chapters 1, 2, 3, and 4 of this manual. *SIM* input and output are reproduced as Appendix A. Program *TABLES* reads the *SIM* output file and constructs the tables presented in Appendix B. Numerous tables could be generated for the 30 water rights, 11 control points, and 6 reservoirs. A few tables are created for illustrative purposes with specifications defined by the TIN file presented in Appendix B on page 61.

### **HEC-DSSVue Plots**

*HEC-DSSVue* is used to plot simulation results stored in the *SIM* and *TABLES* output DSS file. Examples of plots created with *HEC-DSSVue* are presented in Figures 4.1, 4.2, 4.3, and 4.4 on the next two pages. Figures 4.1, 4.2, and 4.3 are derived from DSS records of monthly flow and storage recorded in the DSS file by *SIM*. Annual flow volumes are computed within *HEC-DSSVue* by summing monthly volumes. Figure 4.4 is a plot of monthly storage from DSS records recorded in the same DSS file by *TABLES*. End-of-month storage volumes for the six reservoirs are summed by *TABLES*. These plots were created, edited, and pasted to the clipboard within *HEC-DSSVue* and copied from the clipboard to this document within Microsoft Word.

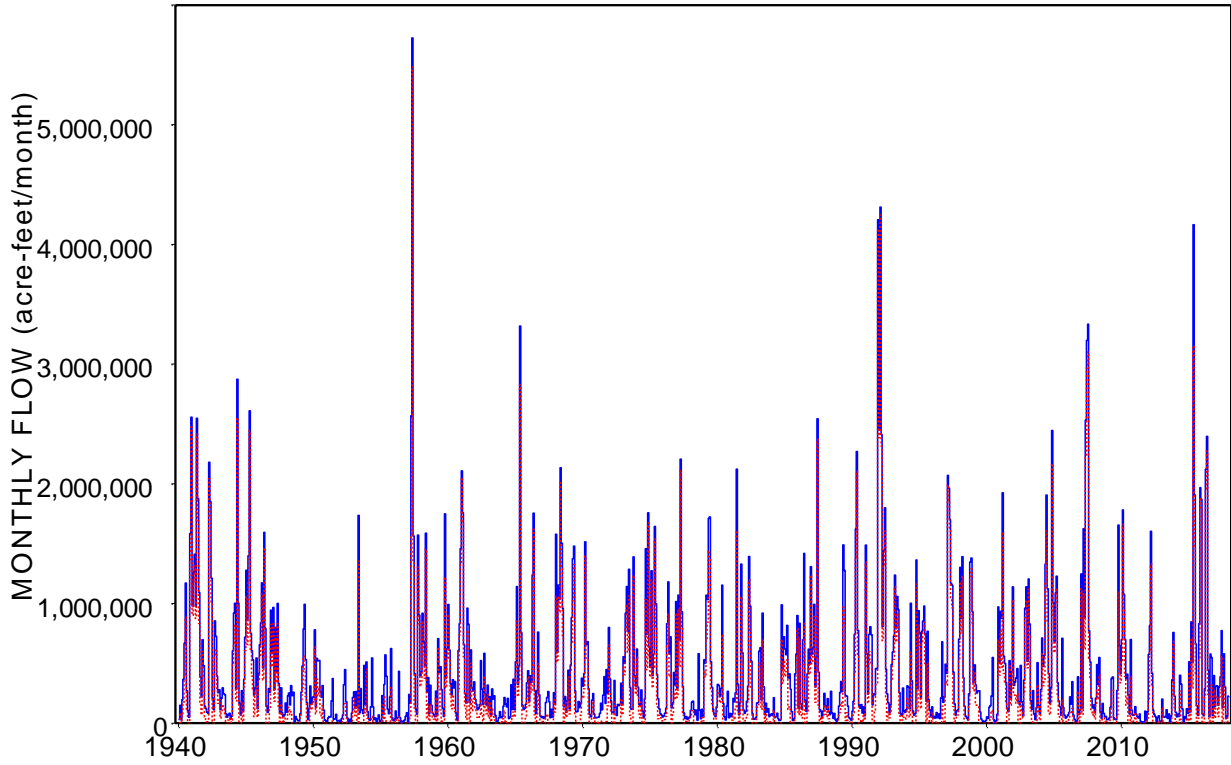


Figure 4.1 Naturalized (blue solid line) and Unappropriated (red dotted line) Monthly Flow Volumes at Control Point HEMP

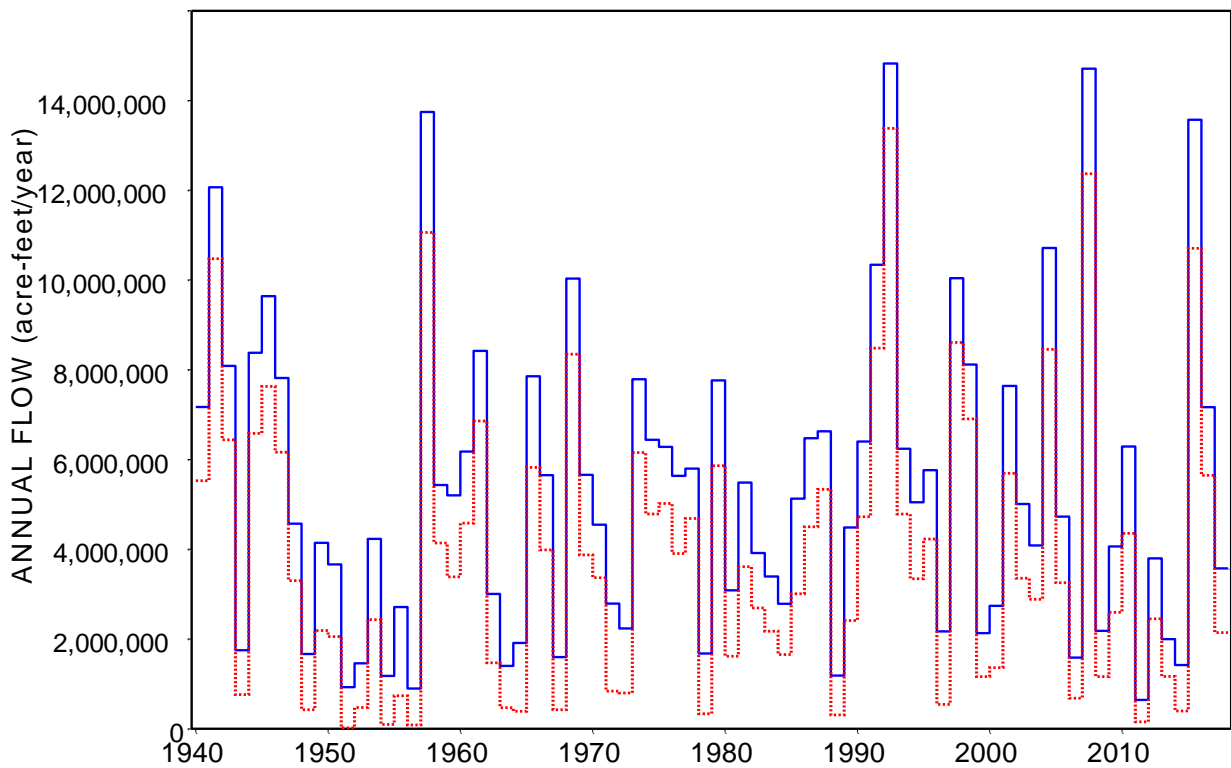


Figure 4.2 Naturalized (blue solid) and Unappropriated (red dotted) Annual Flows at HEMP

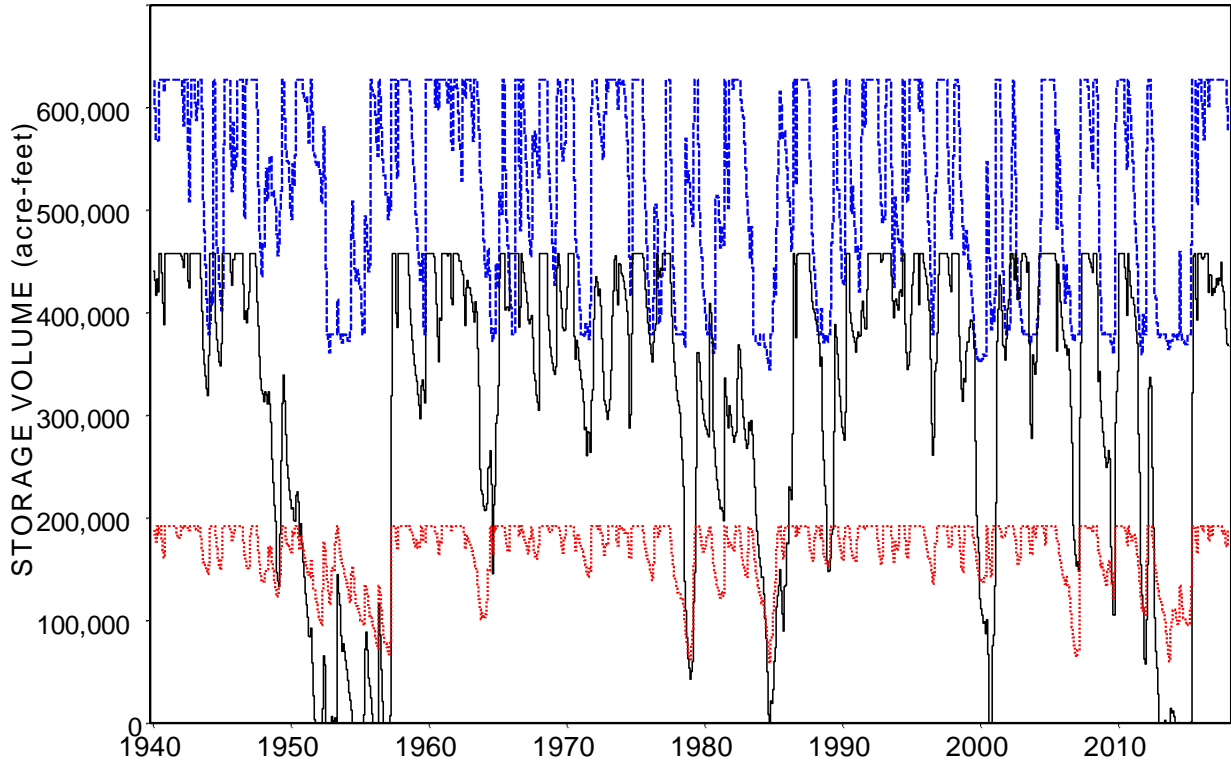


Figure 4.3 End-of-Month Storage Contents of Lakes Whitney (blue, capacity 627,100 acre-feet), Belton (black solid, 457,600 acre-feet), and Waco (red dotted, 104,100 acre-feet)

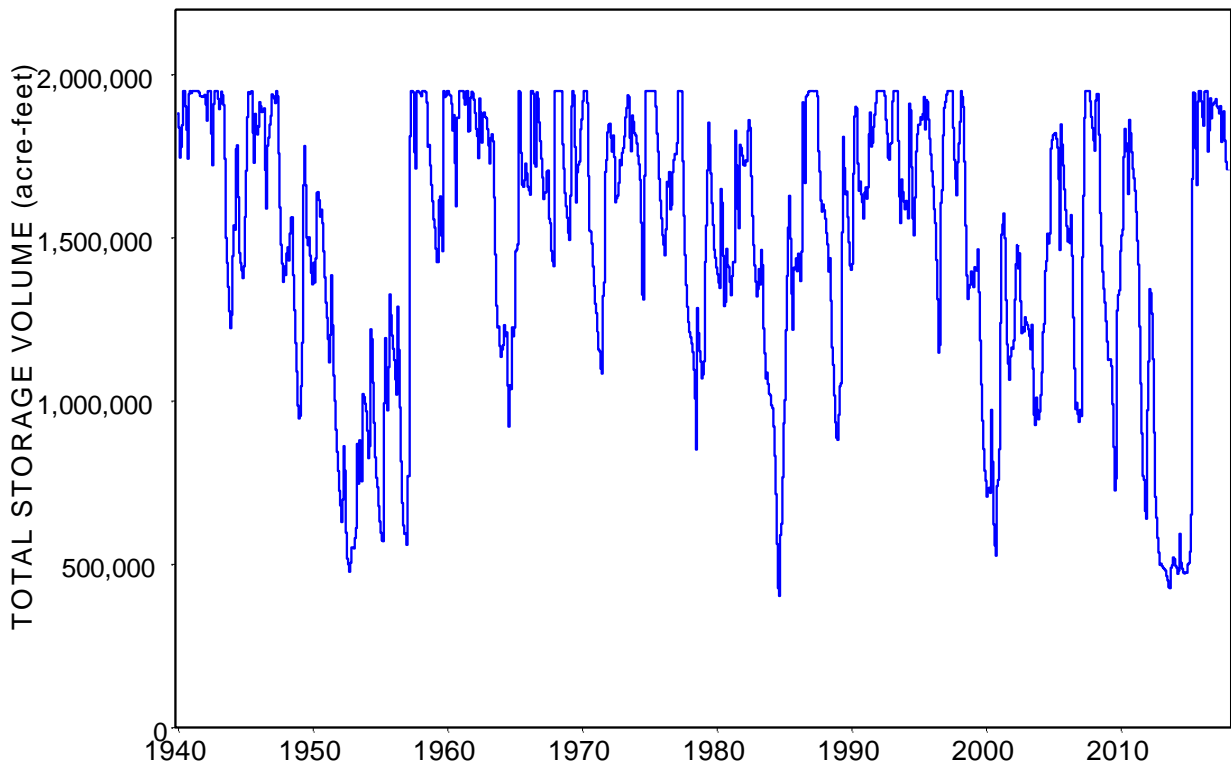


Figure 4.4 Summation of End-of-Month Storage Contents of the Six Reservoirs

*SIM* creates a DSS output file as specified by DSS(3) and DSS(4) on the *OF* record (pages 57 and 79-80). *TABLES* writes to this same DSS file as specified by PT on the 2STO record (pages 61 and 100). If *SIM* had not created a DSS file, *TABLES* would create its own DSS output file. *SIM* and *TABLES* over-write existing OUT and TOU output files but add to an existing DSS file.

Monthly naturalized flows and unappropriated flow volumes in acre-feet at control point HEMP for the 1940-2017 hydrologic period-of-analysis are plotted in Figure 4.1. Annual naturalized stream flow volumes, computed within *HEC-DSSVue* by summing monthly flows, are plotted in Figure 4.2. Annual totals or moving averages can be computed by either *TABLES* or *HEC-DSSVue*. The monthly flows in Figure 4.1 were aggregated to the annual flows in Figure 4.2 within *HEC-DSSVue* through the following menu selection path: Tools/Math Functions/Time Functions/Year. However, the parameter PT on the *TABLES* time series record also allows monthly flow volumes to be summed to annual volumes.

End-of-month storage volumes for three individual reservoirs are plotted in Figure 4.3 using *HEC-DSSVue*. These storage volumes were recorded in the DSS file by *SIM*. The summation of end-of-month storage contents of all six reservoirs are plotted in Figure 4.4. The storage volumes of each of the six reservoirs were read by *TABLES* from the *SIM* output OUT file and summed as specified by the parameter TOTAL on the 2STO record (pages 61 and 98-101). The totals were then recorded in the DSS file as specified by the parameter PT on the 2STO record. *HEC-DSSVue* also has a feature for adding any number of time series records which is employed through the menu selection path: Tools/Math Functions/Arithmetic/Add.

### *TABLES Input and Output Files*

The input records found in the *TABLES* input TIN file are described in Appendix D. Other types of *TABLES* input records not covered in Appendix D can be found in the *Users Manual*. All *TABLES* TIN file input records are optional. Most contain a variety of options. The TIN file may be created and modified with any editor such as *Microsoft WordPad*. Program *TABLES* creates the message TMS file on page 61-62 and TOU file with simulation results reproduced on pages 62-70.

The TMS message file on page 61-62 contains only the trace of the *TABLES* execution. The absence of warning or error messages indicates that no irregularities or input errors were detected.

Comment records beginning with COMM, \*\*\*\*, or \*\* are not read by the computer. Comment records simply provide a means to document the TIN file. Records can also be temporarily deactivated by adding a \*\*\*\*. Records following the ENDF record also are not read by the computer. Model users may store alternative sets of records behind an ENDF record.

### *Type 1 Summaries of Data from the SIM Input DAT File (Pages 62 and 97)*

The 1REC, 1RCT, 1SRT, 1SUM, 1RES, and 1CPT records described in the *Users Manual* create listings and tabulations that organize and summarize water right, reservoir, or control point data read from the *SIM* input DAT file. The four-character identifiers for type 1 records begin with the numeral one signifying that the source of data is a *SIM* input DAT file. The 1SUM record (page 62) results in a summary table of water rights data by control point, type of use, water right type, or water right group that includes water right and reservoir quantities and priority ranges.



### Time Series Tables (pages 63-66 and 98-101)

The 2NAT, 2REG, and 2UNA records in the TIN file on page 61 are examples of the types of time series records listed on page 98 with fields defined on page 99-101. The time series of simulation results for the variables listed in Table 3.2 on page 28 and in Appendix D on page 98 may be tabulated in the following alternative formats.

1. Tables with annual rows and monthly columns as illustrated by the 2NAT, 2REG, and 2UNA record tables shown on pages 62-65.
2. Each time series variable may be tabulated as a column as illustrated by the 2NAT, 2REG, and 2UNA record results on page 65-66. This format is designed for convenient conversion to a Microsoft Excel spreadsheet for plotting or further computations. Either monthly or annual values may be tabulated. A monthly tabulation would be 12 times as long as the annual tabulation shown on page 65-66.

### Frequency Tables (pages 66-68 and 105-106)

2FRE or 2FRQ record field 2 is a selection of variables for which frequency tables are created. The frequency tables for the example for naturalized, regulated, and unappropriated flows presented on page 66-68 are based on time series data including those tabulated on pages 63-66. The frequency tables may reflect all 936 months of the 1940-2017 hydrologic simulation period or alternatively be limited to a particular month, such as the month of August, during each of the 78 years. The frequency tables included in the example reflect all 12 months of the year, since an individual month such as May or July is not specified.

As an example of reading the frequency tables, referring to the first line of the first storage frequency table on page 67, the end-of-month storage contents of Possum Kingdom (PK) Reservoir equaled or exceeded 563,419 acre-feet during 25 percent of the 936 months of the simulation. This can be interpreted as an estimated 0.25 probability that storage in Possum Kingdom Reservoir will be at or above 563,419 acre-feet at any randomly selected point in time based on all the premises reflected in the model. Alternatively, from a duration perspective, the storage contents of Possum Kingdom Reservoir can be expected to be at or above 563,419 acre-feet 25 percent of the time. The second storage frequency table on page 67 shows the optional format with only frequencies associated with the total storage for all six reservoirs.

The first six frequency tables on pages 66-68 were created with the 2FRE records shown on page 61. The values of the selected variable associated with fixed exceedance frequencies are tabulated. The column format of the 2FRE table shown on page 67 includes more frequencies than the preceding row version. The last frequency table on page 68 shows the alternative format of a frequency table created with a 2FRQ record.

The last frequency table at the top of page 68 is a 2FRQ record water surface elevation frequency relationships for Whitney Reservoir (reservoir identifier Whit). Exceedance frequencies of 100.00%, 98.18%, 75.21%, 60.15%, 50.43%, 39.64%, and 30.88% are computed for elevations of 518.0 feet, 520.0, 524.0, 528.0, 530.0, 532.0, and 533.7 feet, respectively, specified on the 2FRQ record. Unlike the 2FRE with variable quantities computed for set given exceedance frequencies, the 2FRQ record computes exceedance frequencies for specified values of the variable of interest.

Reliability Tables (pages 67-68 and 103-104)

An array of variations of reliability tables may be created. Reliability tables may be for either water supply diversions or hydroelectric energy generation. Reliability tables for water supply diversions may be for either individual water rights, water right groups, or totals of all water rights at each control point. Hydropower production reliability tables are typically connected to selected reservoirs but can also be for individual water rights. Reliabilities may be computed considering all 12 months of the year or a selected individual month.

The 2REL records of the example *TABLES* input TIN file are shown on page 61. The content and format of each field of the 2REL record are explained on pages 104-105. The resulting tables written to the TOU file are on pages 67-68.

The first reliability table on page 68 is for aggregated water supply diversions at each control point. The diversion targets at the PK control point sum to a total of 254,800 ac-ft/yr. The mean shortage is 8,910 ac-ft/yr resulting in a volume reliability of 96.50 percent. The reliability table also shows the percentage of months and percentage of years during which specified percentages of the diversion target are equaled or exceeded. Diversion targets at the PK control point are fully met during 94.87 percent of the 936 months and 85.9 percent of the 78 years of the simulation. At least 75% of the total monthly target is supplied during 95.1 percent of the 936 months. At least 75% of the annual target is supplied during 96.2 percent of the 78 years.

The second reliability table on page 68 is for individual water rights. The first and second reliability tables have the same format and reflect the same counting computations. The difference is that the diversion data is for individual water rights in the second table and for the sum of all diversion rights at each control point for the first table. If only one water right was assigned to each control point, both tables would be the same. However, the two tables are different since 22 diversion rights are assigned to 11 control points.

The reliability summary table for individual water rights found in the lower portion of page 68 can be compared with the yield-reliability table (YRO file) replicated as Table 3.5 on page 38. Water right WR-24 is a diversion right at control point Hemp supplied by unregulated flows and releases from four upstream reservoirs. The WR-24 diversion target of 475,000 acre-feet/year is supplied with a volume reliability of 98.16% and 97.76% as shown in the reliability table on page 68. In the *FY* record reliability analysis of Table 3.5 (page 38), the diversion target of 475,000 acre-feet/year for water right WR-24 is replaced in an iterative search for the firm field, which is defined as the maximum annual diversion target with volume and period reliabilities of 100.0%. The volume and period reliabilities for WR-24 in Table 3.5 are defined and computed in the same manner as those in the 4<sup>th</sup> and 5<sup>th</sup> columns of the reliability summary table on page 68. The difference is that the YRO file table (Table 3.5) represents multiple simulations with varying values for the diversion target rather than the fixed target of 475,000 acre-feet/year. Water right WR-24 illustrates a typical situation where reliabilities vary very little with changes in diversion targets. In other cases, reliabilities may be more sensitive to changes in diversion targets. In some cases, the firm yield may be zero.

The reliability table at the top of page 69 is for hydroelectric power generation. The 2REL record creating this record has the reservoir/hydropower option selected in field 4. This means that

reservoir/hydropower output records were read by *TABLES* from the *SIM* OUT file. Hydropower production may also be included on water right output records. However, the -1 entered for the OUTWR parameter in *JD* record field 6 in the *SIM* DAT file excludes hydropower rights in the selection of rights to be included in the *SIM* OUT file. Reservoir/hydropower output records are included in the *SIM* OUT file in accordance with the *RO* record. Although the hydropower right WR-4 could be included in the water right reliability tables on pages 69-70, mixing hydropower production in kilowatt-hours and diversions in acre-feet in the same table is awkward and potentially confusing.

The hydroelectric power plant at Whitney Reservoir has an annual energy generation target of 36,000 kilowatt-hours/year specified on the *WR* record for water right WR-4, distributed over the 12 months of the year with the *UC* record coefficients from the DAT file. The reliability table at the top of page 69 shows a mean annual shortage of 3,525 kilowatt-hours/year for a reliability of 94.80% [ $R_V = ((3,600 - 3,525.04) / 3,600) 100\% = 90.21\%$ ]. The monthly energy targets are fully supplied in 84.51% of the 936 months of the simulation.

Optional water right group identifiers entered in *WR* record fields 13 and 14 in the DAT file (pages 58-59, 87-88) may be used for various purposes. One use of these group identifiers is to group water rights in reliability tables. The last reliability table on page 69 is for water right groups. The diversions amounts are the totals for all water rights included in a particular group. The reliability metrics are computed by *TABLES* based on the summations of the targets for all water rights in the group the summation of the corresponding shortage in each month of the simulation.

Summary Tables (pages 69-70 and 107-108)

2SCP, 2SWR, 2SGP, 2SRE, and 2SBA records generate monthly or annual summary tables for control points, water rights, water right groups, or the entire river basin. An annual summary table for the Belton control point is presented on pages 69-70. Monthly tables would be 12 times as long with a line for each of 936 months rather than each of 78 years.

With no other control points located upstream, the Belton control point summary table contains all of the information needed for a complete water budget of inflows, outflows, and change in storage. However, summary tables for other control points or the entire river basin do not contain enough information for a complete basin water budget. Information is recorded elsewhere regarding regulated flow inflows, incremental naturalized flow inflows, negative incremental flow adjustments, channel losses, and channel loss credits. The 2BUD record described in the *Reference and Users Manuals* activates detailed water budgets for control points and the entire river basin.

For an upstream control point such as the Belton control point, a water balance for a particular month, year, or entire 1940-2017 simulation can be expressed as follows:

$$\begin{aligned} \text{change in storage} &= \text{naturalized stream flow} - \text{regulated stream flow} \\ &\quad - \text{diversions} - \text{net evaporation} + \text{return flow} \end{aligned}$$

Mean 1940-2017 and annual 1956 and 1957 values of these quantities from the Belton control point summary table on pages 69-70 are reproduced in Table 4.2. The 1950-1957 drought was ended by one of the greatest floods on record in April-May 1957. These naturalized stream flow data illustrate the dramatic fluctuations in stream flow that may occur.

Since no other control points are located upstream of the Belton control point, naturalized flows represent inflows to the control point. Regulated flows are the stream flows leaving the control point and flowing downstream. There are no return flows entering the river at this control point. Water is removed through net evaporation and diversions. The change in reservoir storage in 1956 and 1957 is the difference in end-of-period storage for the year and the previous year. For the 1940-2017 mean, the storage change of 489 acre-feet is the storage at the end of 2017 of 419,869 acre-feet minus the beginning of simulation storage contents which is the capacity of 457,600 acre-feet, divided by 78 years. The simulated storage contents at the end of 1956 and 1957 are 0.0 and 457,600 acre-feet. The storage capacity of Belton Reservoir is 457,600 acre-feet.

Table 4.2  
Water Budget for an Upstream Control Point (Belton)

| Quantity                           | Time Period |         |           |
|------------------------------------|-------------|---------|-----------|
|                                    | 1940-2017   | 1956    | 1957      |
| naturalized flows (acre-feet/year) | 500,113     | 156,828 | 1,379,758 |
| regulated flows (acre-feet/year)   | 311,916     | 39,493  | 752,499   |
| net evaporation (acre-feet/year)   | 16,674      | 8,648   | 8,710     |
| diversions (acre-feet/year)        | 172,670     | 108,688 | 160,948   |
| storage change (acre-feet/year)    | -1,147      | -0-     | 457,600   |

The diversion shortages in the last column of the 2SCP summary table on pages 69-70 are the diversion targets less the actual diversions. Shortages occur if water availability is inadequate to supply the full target demand. Stream flow depletions in the fourth column of the tables are the amounts of water appropriated to supply diversions and refill reservoir storage capacity that has been drawn-down over time by diversions, releases, and evaporation.

Unappropriated stream flow is the portion of the naturalized flow still remaining after considering all of the water rights in the dataset. For the Belton control point, the unappropriated flow is less than the regulated flow because a portion of the stream flow at the Belton control point is committed to meet water right requirements at other control points located further downstream.

An annual summary table for the entire river basin is created by *TABLES* as specified with a 2SBA record. The naturalized and unappropriated stream flows in the 2SBA table are the annual totals of the maximum naturalized and unappropriated flows at any control point in each month. The other quantities are the summation of the amounts at all control points.

## CHAPTER 5 DEALING WITH ERRORS IN WRAP INPUT DATA FILES

*SIM* and *TABLES* execute to completion for the example datasets presented in this manual. The tracking messages on the monitor screen end with "*Normal Completion of Program SIM*" and "*Normal Completion of Program TABLES*". This is because all of the blunders introduced during creation of the input data files have been corrected. Users will naturally make blunders in editing the existing input files or when creating new input files. This chapter addresses the question of how to deal with the common situation of the programs terminating before completion of their intended tasks.

### Trace, Error, and Warning Messages

*SIM*, *TABLES*, and the other WRAP programs all contain similar features for detecting missing and erroneous records in the input files. Of course, many errors such as entering incorrect numbers in the correct format are not automatically detected. Routines in the programs check for errors that violate format rules or result in detectable inconsistencies. Trace, warning, and error messages are recorded on the monitor screen and/or in the message file.

- Trace messages help locate errors by tracking progress in reading input, performing computations, and creating output files.
- Error messages are accompanied by termination of program execution.
- Warning messages alert users to peculiarities without stopping program execution.

Programs *SIM*, *TABLES*, *SIMD*, *HYD*, *DAY*, and *SALT* automatically create message files with the filename extension MSS, TMS, SMM, HMS, DMS, and SMS, respectively, that contain trace, error, and warning messages, along with other information. The messages in the message files are in a different format for errors in DSS input files versus errors in the other input files. A new message file is created with each execution of a program.

*SIM*, *TABLES*, and *HYD* routines for detecting input data inconsistencies and irregularities and associated warning and error messages are described in Chapter 9 of the *Reference Manual*. Numerous examples of error and warning messages are presented. Error messages are written to the monitor and message file and program execution is terminated if detectable problems are encountered in reading input data or performing the simulation.

Warning messages are recorded in the message file without terminating program execution to alert the model-user to possible irregularities in the input data. Warning messages signal potential concerns that may or may not actually be problems. Message files generated by *SIM* and the other WRAP programs should be routinely reviewed to trace the simulation and view warning messages even if the program executes normally without premature termination.

Numerous different error and warning messages are possible. Most of the messages are generated by problems detected by the program while reading input data files, though various checks incorporated in the simulation computation routines also may generate error and warning messages. The messages are usually self-explanatory, but *Reference Manual* Chapter 9 may be consulted as needed to better understand and respond to the messages.

## Text Files with No Tabs or Formatting Characters

DSS files are in binary format, and the other input files are text files. Microsoft programs and other programs use the default filename extension *txt* for the initial creation of unformatted text files. The extension *txt* is easily changed to the filename extensions used by WRAP. WRAP input files must be text files with no formatting characters including no tabs. WordPad and other programs allow unformatted text files to include tabs and indents, but the WRAP programs do not.

The WRAP programs cannot read tabs, indents, and other formatting characters. Tabs and other characters inserted into documents by word processing or spreadsheet programs to control spacing or formatting may be either hidden or visible to the human user of the software. Either way, such characters will prevent the WRAP programs from executing. Blank spaces must be entered with the space bar on the keyboard or created by software without inserting tabs.

As an example, in editing the DAT file using WordPad, the tab key is erroneously used rather than the space bar in entering four spaces before the entry 78 for NYRS on the *JD* record. Execution of *SIM* with this DAT input file results in the execution being terminated with the following information written in the MSS message file.

```
WRAP-SIM MESSAGE FILE

*** Starting to read file FundExam.DAT

ERROR: Fortran IOSTAT error occurred reading an
       input record with CD identifier of JD
       IOSTAT status variable =    64
       Stopped from Subroutine READDAT due to error.

The first 82 characters of each of the last two records read are as follows:
** NYRS   YRST  ICHECK  CPOUT  OUTWR  OUTFILE  ADJINC
JD 78     1940      1      -1     -1           4

*** Execution of SIM terminated due to an input error.
*** IOSTAT status variable (error code) =    64
*** JD record contains data in wrong format.
```

The first trace message in the MSS file indicates that *SIM* started to read the file FundExam.DAT. An error message indicates that an error was encountered in reading the *JD* record. The *JD* record contains data in an unacceptable format. The last two records read by *SIM* before execution was terminated are reproduced along with the error message.

Unlike Microsoft Word which allows the tabs and indents in a document to be shown, WordPad does not. Since in WordPad the tab character cannot be seen in the MSS and DAT files, the user may not immediately recognize why the data on the *JD* record has the wrong format. The hidden tab character between JD and 78 must be deleted, and blank spaces inserted using the space bar on the keyboard.

## Variable Formats and Fixed Field Widths

The data in the WRAP input files can be either comma-delimited or in a fixed field width format. With the comma-delimited format, the data on each record are separated by commas. In

the fixed field width format, the data are organized in fields as outlined in Appendices C and D. Though the computer reads either format, the fixed field width option is recommended because the resulting datasets are easier for people to read and edit. The TCEQ WAM System datasets are all in the fixed field width format. Without commas inserted to separate the data, the fixed field width option is automatically applied. Each value must be entered in the columns assigned to its field. The fields are defined in Appendices C and D.

Commas are not allowed within either a number or a character variable entry in either the fixed-width or comma-delimited formats. With the fixed-width format, a comma will result in termination of program execution accompanied by a wrong-format error message.

Data entered on the input records for the WRAP programs are values of integer, real, or character variables. Integer variables (I format) must be integer numbers with no decimal. Integers must be right-justified in their fields since trailing blanks are read as zeros. Real numbers (F format) must either have a decimal or be right justified again because trailing blanks in the field are read as zeros. Values of character variables (A format) can contain letters and/or numbers and can be placed anywhere in their assigned fields.

Input values for Fortran character variables (alphanumeric (A) specification) can be right-justified in the appropriate field to preclude the problem of reading unwanted trailing blanks to the right of the identifiers. However, the WRAP code automatically removes trailing blanks for most of the alphanumeric character input variables such as control point, water right, and reservoir identifiers. Thus, as long as the alphanumeric identifiers are in the correct field, right-justification is not required.

Control point, water right, and reservoir identifiers and other alphanumeric input entries can include lower and/or upper case letters and/or numbers. The WRAP programs generally differentiate between lower and upper case letters for alphanumeric variables. However, DSS pathnames are an exception in that all letters whether lower or upper case are read as upper case.

The fixed-field format provides a well-defined structure for organizing data. Failure to adhere to this structure results in errors. However, the errors may or may not be detected as the programs read the input files. If detected, the program stops execution, with messages that the data is in the wrong format. For example, a real number with a decimal entered in a field defined for an integer variable will always result in program termination with an error. However, a real number placed in the wrong field, which happens to be a field for another real variable, may not be detected as the program reads the data but will cause incorrect simulation results. Likewise, an integer or real number or alphanumeric character variable encroaching into an adjacent field may or may be detected by the error checking routines, but if not detected will produce erroneous results.

### **Sequential Progression of Program Tasks**

Most *SIM* error messages are generated during reading of input files. However, some error checks are performed during computations. If *SIM* terminates prior to completion, the OUT file contains all results computed up to program termination. The point of termination is useful in locating the source of the error. Essentially all numbers generated by *SIM* can be

written to the OUT file and scrutinized. The content and format of the records in the OUT file are outlined in Chapter 5 of the *Reference Manual*. With a completed simulation, *SIM* simulation results organized with *TABLES* can be examined in great detail with the output data organized in a variety of tabulations. Checks and analyses can be performed based on the ingenuity and judgment of the model user to verify the validity of the simulation results.

Errors in the input records in the *TABLES* input TIN file are easy to find. The program is very modular. *TABLES* reads one record of the TIN input file, performs the specified operations, records the results, and then proceeds to the next record in the TIN file. Trace messages are written to the message TMS file as each TIN file input record is read. Error and warning messages are inserted in the trace messages. Thus, if an input problem occurs, the input record causing the problem is evident.

### **ICHECK Options**

Optional levels of information recorded in the *SIM* message MSS file for checking input data are specified by variable *ICHECK* in field 4 of the *JD* record. Similar *ICHECK* options are included in *SIMD* and *HYD*. An *ICHECK* of 0 or 1 is usually adopted. *ICHECK* of 1 activates all error and warning checks. Most warning checks and several of the error checking routines requiring the most computer time are in effect only if *ICHECK* is 1. A blank or zero *JD* record field 4 deactivating the checking routines will reduce execution times slightly and may reduce the size of the message file.

If program execution is terminated prior to normal completion, the error message will usually provide sufficient information to identify the problem without needing to resort to the *ICHECK* options 2 through 12 activated by *JD* record field 4. However, *ICHECK* options are sometimes useful in locating an erroneous input record as well as otherwise providing general information. The *ICHECK* options are explained in *Reference Manual* Chapter 9 and *Users Manual* Chapter 2 along with general discussions of dealing with errors.

### **DSS Error Messages**

DSS routines write error messages to the *SIM* MSS file, *TABLES* TMS file, and the message files of the other WRAP programs as discussed in Chapter 9 of the *WRAP Reference Manual* and Chapter 6 of the *Users Manual*. Optional levels of error messages are controlled by input parameters *DSS(6)* on the *SIM OF* record and *DSSMES* on the *TABLES FILE* record.

The DSS-related errors that are most likely to occur in applying the WRAP programs are a missing DSS file, one or more missing records in a DSS file, or missing data in a DSS record. If a WRAP program attempts to read a DSS input file that does not exist, the program will create an empty DSS file and then terminate execution with an error message stating that data was not found. A similar error message is generated by one or more missing records in an existing file or gaps of one or more periods of missing data in a DSS record. As explained in Chapter 9 of the *Reference Manual*, the DSS message level 4 is useful in finding missing DSS records and *HEC-DSSVue* option path */Display/Tabulate/Edit/Show Missing/Find/* can be employed to find periods of missing data in DSS records.



# APPENDIX A SIM FILES FOR THE EXAMPLE

## SIM Input DAT File

```

** File FundExam.DAT
** SIM Input File for the Example in the Fundamentals Manual
** May 2019
**
**          1          2          3          4          5
**345678901234567890123456789012345678901234567890123456
**-----!-----!-----!-----!-----!-----!-----!
** JD Record Fields
** NYRS    YRST    ICHECK    OUTCP    OUTWR          ADJINC
JD      78     1940         1         1         1             6
JO       6
RO      -1
OF       1     0     1
**
** Activation of the FY record results in a yield-reliability table being
** developed and written to a file with the name FundExam.YRO.
**
**FY      1200000. 100000. 10000. 1000.  WR-24
**
UC IND1  0.054  0.060  0.070  0.083  0.094  0.105  0.113  0.106  0.096  0.083  0.072  0.062
UC IND2  0.058  0.077  0.087  0.097  0.107  0.124  0.128  0.124  0.078  0.041  0.038  0.041
UC IRR2  0.005  0.008  0.018  0.032  0.075  0.189  0.304  0.253  0.079  0.022  0.008  0.007
UC MUN1  0.065  0.063  0.068  0.072  0.085  0.093  0.118  0.114  0.095  0.087  0.071  0.069
UC MUN2  0.065  0.063  0.066  0.069  0.082  0.105  0.111  0.106  0.100  0.089  0.074  0.069
UC POWER 2250.  2250.  2250.  2250.  2250.  3000.  6000.  6000.  3000.  2250.  2250.  2250.
**
**          1          2          3          4          5          6          7
**345678901234567890123456789012345678901234567890123456789012
**-----!-----!-----!-----!-----!-----!-----!-----!
CP   PK      Whit
CP   Whit    WacoG
CP   WacoL   WacoG
CP   WacoG   High
CP   High    Bryan
CPBelton    Camer
CPGeorge    Grang
CP   Grang   Camer
CP   Camer   Bryan
CP   Bryan   Hemp
CP   Hemp
**
**-----!-----!-----!-----!-----!-----!-----!-----!
**          1          2          3          4          5          6          7          8
**34567890123456789012345678901234567890123456789012345678901234567890
**-----!-----!-----!-----!-----!-----!-----!-----!-----!
**
** Instream Flow Requirements at Cameron and Hempstead Gages **!*****!*****!
**
IF Camer  3600.  NDAYS      0          IF-1
IF Hemp  120000. NDAYS      0          IF-2
**
** Possum Kingdom Lake at Control Point PK ***!*****!*****!*****!*****!
**
WR   PK      9800.  MUN1  193804      2      0.35          WR-1          PK
WS   PK      570240.
WR   PK      245000.  IND1  193804          WR-2          PK
WS   PK      570240.

```

```

**      1      2      3      4      5      6      7      8
**34567890123456789012345678901234567890123456789012345678901234567890123456789012345678
**-----!-----!-----!-----!-----!-----!-----!-----!-----!-----!-----!
**
** Whitney Lake at CP Whit      !*****!*****!*****!*****!*****!*****!*****!*****!
**
WR Whit 18000.    MUN1 198208      2    0.40                      WR-3      Whitney
WS Whit 627100.                      379000.
WR Whit 36000.    POWER 888888    6    2                      WR-4      Whit HP
WS Whit 627100.                      379000.
HP 0.86    440.
WR Whit                      990000                      WR-5      Refill
WS Whit 627100.                      379000.
**
** Waco Lake at CP WacoL    *****!*****!*****!*****!*****!*****!*****!*****!
**
WR WacoL 60000.    MUN1 192901      2    0.35                      WR-6      WacoLake
WS WacoL 104100.
WR WacoL 20800.    MUN1 198609      2    0.40                      WR-7      WacoLake
WS WacoL 192100.
**
** Belton Lake at CP Belton  *!*****!*****!*****!*****!*****!*****!*****!*****!
**
WRBelton 82760.    MUN1 196312      2    0.45                      WR-8      Belton
WSBelton 457600.
WRBelton 97500.    IND1 196312      2    0.20                      WR-9      Belton
WSBelton 457600.
**
** Georgetown Lake at CP George  *****!*****!*****!*****!*****!*****!*****!*****!
**
WRGeorge 25610.    MUN2 196802      0    0.48                      WR-10     George
WSGeorge 37100.
**
** Granger Lake at CP Grang  *!*****!*****!*****!*****!*****!*****!*****!*****!
**
WR Grang 42000.    MUN2 196802      0    0.40                      WR-11     Granger
WS Grang 65500.
**
** Cameron Gage - Run-of-River Diversion Rights *****!*****!*****!*****!*****!*****!
**
WR Camer 92100.    IRR2 198211      2    0.35                      WR-12     Cameron
WR Camer 18200.    IND2 196105      2    0.50                      WR-13     Cameron
WR Camer 11300.    IRR2 194510      2    0.10                      WR-14     Cameron
**
** Cameron Gage - Multiple-Reservoir System Diversion Right *!*****!*****!*****!*****!
**
WR Camer 88000.    MUN2 200601    2    2    0.35                      WR-15     SystemC
WSBelton 457600.
WSGeorge 37100.
WS Grang 65500.
**
** Waco Gage - Run-of-River Diversion Right  **!*****!*****!*****!*****!*****!*****!
**
WR WacoG 32300.    IRR2 194607                      WR-16     WacoGage
**
** Highbank Gage - Run-of-River Diversion Right *****!*****!*****!*****!*****!*****!
**
WR High 44800.    IRR2 195903                      WR-17     Highbank
**
** Bryan Gage - Run-of-River Diversion Rights *****!*****!*****!*****!*****!*****!
**
WR Bryan 25400.    MUN2 198211      2    0.40                      WR-18     Bryan
WR Bryan 39000.    IND2 196105      2    0.65                      WR-19     Bryan
WR Bryan 34500.    IRR2 194510      2    0.05                      WR-20     Bryan

```

## SIM Input DAT File (Continued)

```

**
** Hempstead Gage - Run-of-River Diversion Rights  ***!*****!*****!*****!*****!
**
WR Hemp 49600.   IRR2 194510                               WR-22           Hemp
WR Hemp 95600.   IND2 196105                               WR-21           Hemp
WR Hemp 74500.   IRR2 201804                               WR-23           Hemp
**
** Hempstead Gage - Multiple-Reservoir System Diversion Right  *****!*****!*****!
**
WR Hemp 475000.  MUN2 201901  2                               WR-24           SystemH
WS   PK 570240.
WSBelton 457600.
WSGeorge 37100.
WS Grang 65500.
**
** Refilling Storage in Multiple-Reservoir System Reservoirs  !*****!*****!*****!
**
WR   PK                               990000                               WR-25           Refill
WS   PK 570240.
WRBelton                               990000                               WR-26           Refill
WSBelton 457600.
WRGeorge                               990000                               WR-27           Refill
WSGeorge 37100.
WR Grang                               990000                               WR-28           Refill
WS Grang 65500.
**
** Reservoir Storage Volume (acre-feet) versus Surface Area (acres) Tables
**
SVBelton  0.   40.  160.  650.  1100.  1800.  20900.  58700.  123500.  218100.  304170.  457600.
SA         0.   17.   32.   63.   110.   200.   1760.   3270.   5290.   7580.   9261.  12258.
**
SVGeorge  0.   3.   97.  280.  640.  1250.  2610.  4170.  6310.  11500.  22900.  37100.
SA         0.   2.   19.   45.   77.   130.   237.   323.   410.   620.   958.   1310.
**
SV Grang  0.   76.  272.  960.  2200.  3460.  5310.  7030.  10310.  23950.  46600.  65500.
SA         0.   16.   52.  180.  344.   500.   750.   980.  1230.  1828.  3280.  4400.
**
SV   PK   0.  236.  865.  3579. 10447. 22038. 25810. 147410. 298092. 504100. 547414. 570240.
SA         0.   60.  216.  525.  962.  1403.  1500.  5675.  9875. 14440. 15803. 17700.
**
SV WacoL  0.   8.   36.  1438. 3509. 4804. 17091. 29704. 105675. 152500. 207106. 304510.
SA         0.   4.   12.  160.  338.  562.  2741.  3524.  5986.  7270.  8465. 11049.
**
SV Whit   0.   9.  1145. 4843. 51240. 157245. 379108. 427400. 559219. 627100. 807330. 1120975.
SA         0.  22.  237.  507.  3210.  7500. 15760. 16450. 21740. 23560. 28070. 34920.
**
** Reservoir Storage Volume (acre-feet) versus Elevation (feet) Table for Hydropower at Lake Whitney
**
PV Whit  2630. 19600. 41710. 79990. 143200. 229400. 363600. 473100. 601800. 782000. 1095000 1473000
PE       448.8 470.0 480.0 490.0 500.0 510.0 520.0 527.0 533.0 540.0 550.0 560.0
ED

```

## SIM Message MSS File

WRAP-SIM MESSAGE FILE

```

*** Starting to read file FundExam.DAT
*** JD record was read.
*** JO record was read.
*** Reading RO records.
*** OF record was read.
*** Starting to read UC records.
*** Finished reading UC records.
*** Starting to read CP records.

```

```

*** Finished reading CP records.
*** Starting to read IF/WR records.
*** Finished reading IF/WR records.
*** Starting to read SV/SA records.
*** Finished reading SV/SA records.
*** Starting to read PV/PE records.
*** Finished reading PV/PE records.
*** Following input to be read later from DSS file: FundExamHYD.DSS
      IN and EV records (JO record INEV option 6)
*** Finished reading file FundExam.DAT
*** Starting to open remaining files.
*** Opened file FundExam.OUT
*** Finished opening text (non-DSS) files.
      -----DSS---ZOPEN: Existing File Opened, File: FundExamHYD.dss
                          Unit: 25; DSS Versions - Software: 6-WA, File: 6-QF
*** Starting to read flows from DSS file.
      Number of control points = 11
*** Finished reading flows from DSS file.
*** Starting to read evaporation from DSS file.
      Number of control points = 6
*** Finished reading evaporation from DSS file.
      -----DSS---ZCLOSE Unit: 25, File: FundExamHYD.dss
                          Pointer Utilization: 0.09
                          Number of Records: 675
                          File Size: 3424.2 Kbytes
                          Percent Inactive: 25.4

*** Finished ranking water rights in priority order.

*****
System components counted from input file:
  11 control points (CP records)
  11 primary control points (INMETHOD=1)
  6 control points with evap input (CPEV=blank)
  6 reservoirs
  2 instream flow rights (IF records)
  28 all water rights except IF rights (WR records)
  3 system water rights
  1 hydropower rights
  6 sets of water use coefficients (UC records)
  6 storage-area tables (SV/SA records)
  1 storage-elevation tables (PV/PE records)
*****

*** Beginning annual loop.
*** End of input data trace.
*** Negative incremental flow adjustments are performed for the first year.
*** Beginning to write simulation results to DSS file.
      -----DSS---ZOPEN: Existing File Opened, File: FundExam.dss
                          Unit: 26; DSS Versions - Software: 6-WA, File: 6-WA
*** Beginning control point output to DSS file.
*** Beginning water right output to DSS file.
*** Beginning reservoir output to DSS file.
*** Finished writing simulation results to DSS file.
      -----DSS---ZCLOSE Unit: 26, File: FundExam.dss
                          Pointer Utilization: 0.40
                          Number of Records: 1832
                          File Size: 1952.2 Kbytes
                          Percent Inactive: 0.0

Date: 02/14/2019
Beginning Time: 16:23:04
Ending Time: 16:23:05

***** Normal Completion of Program WRAP-SIM *****

```

**APPENDIX B  
TABLES FILES FOR THE EXAMPLE**

**TABLES Input TIN File**

```

** File FundExam.TIN
** TABLES Input File for the Example in the Fundamentals Manual
**      1      2      3      4      5      6
** 567890123456789012345678901234567890123456789012345678901234
****----!----!----!----!----!----!----!----!----!----!----!----!
** Water rights summary table.
1SUM  2
** Time series tables of naturalized, regulated, and unappropriated flows.
2NAT  1  2  1  0  1
IDEN  Hemp
2REG  1  2  1  0 -1
2UNA  0  2  0  0  3
IDEN  Hemp  Whit  High  Camer
****----!----!----!----!----!----!----!----!----!----!----!----!
** Time series output records of total storage in DSS file.
2STO  0  4  0  0  0  0  1
****----!----!----!----!----!----!----!----!----!----!----!----!
** Frequency tables for flow, storage, and reservoir surface elevation.
2FRE  1
2FRE  3
2FRE  2  0  0  2
2FRE  4
2FRE -4
2FRQ  7  0  7  Whit  518.0  520.0  524.0  528.0  530.0  532.0  533.7
****----!----!----!----!----!----!----!----!----!----!----!----!
** Reliability for water supply diversions and hydroelectric energy.
2REL
2REL  0  0  1
2REL  0  0  2  1
IDEN  Whit
2REL  0  0  3  11
IDEN  PK WhitneyWacoLake Belton George Granger CameronWacoGage
IDENHighbank Bryan Hemp
****----!----!----!----!----!----!----!----!----!----!----!----!
** Summary table for the entire river basin.
2SBA
ENDF

```

**TABLES Message TMS File**

TABLES MESSAGE FILE

```

*** File was opened: FundExam.TIN
*** File was opened: FundExam.TOU
*** Identifiers for the 37 records in the TIN file were checked.
*** File was opened: FundExam.DAT
*** File was opened: FundExam.OUT

```

```

*** Tables are being developed as specified by a 1SUM record.
*** Tables are being developed as specified by a 2NAT record.
*** Tables are being developed as specified by a 2REG record.
*** Tables are being developed as specified by a 2UNA record.
*** Tables are being developed as specified by a 2STO record.
-----DSS---ZOPEN: Existing File Opened, File: FundExam.dss
                   Unit: 25; DSS Versions - Software: 6-WA, File: 6-WA
*** Tables are being developed as specified by a 2FRE record.
*** Tables are being developed as specified by a 2FRE record.
*** Tables are being developed as specified by a 2FRE record.
*** Tables are being developed as specified by a 2FRE record.
*** Tables are being developed as specified by a 2FRE record.
*** Tables are being developed as specified by a 2FRQ record.
*** Tables are being developed as specified by a 2REL record.
*** Tables are being developed as specified by a 2REL record.
*** Tables are being developed as specified by a 2REL record.
*** Tables are being developed as specified by a 2REL record.
*** Tables are being developed as specified by a 2REL record.
*** Tables are being developed as specified by a 2SBA record.

```

Program TABLES output is in file FundExam.TOU

Program TABLES output is in DSS file FundExam.DSS

Date: 02/14/2019

Time: 16:23:06

\*\*\*\*\* Normal Completion of Program TABLES \*\*\*\*\*

### TABLES Output TOU File

#### WATER RIGHTS INPUT DATA SUMMARY BY CONTROL POINT

The DAT file contains 28 WR records and 2 IF records. Only water rights meeting the criteria on the 1SUM record are included in the following table.

| CONTROL POINT | NUMBER OF RIGHTS | ANNUAL AMOUNT (AC-FT/YR) | NUMBER OF RESERVOIRS | RESERVOIR STORAGE (AC-FT) | PRIORITIES RANGE |        |
|---------------|------------------|--------------------------|----------------------|---------------------------|------------------|--------|
|               |                  |                          |                      |                           | FROM             | TO     |
| PK            | 3                | 254800.                  | 1                    | 570240.                   | 193804           | 990000 |
| Whit          | 3                | 18000.                   | 1                    | 627100.                   | 198208           | 990000 |
| WacoL         | 2                | 80800.                   | 1                    | 192100.                   | 192901           | 198609 |
| WacoG         | 1                | 32300.                   | 0                    | 0.                        | 194607           | 194607 |
| High          | 1                | 44800.                   | 0                    | 0.                        | 195903           | 195903 |
| Belton        | 3                | 180260.                  | 1                    | 457600.                   | 196312           | 990000 |
| George        | 2                | 25610.                   | 1                    | 37100.                    | 196802           | 990000 |
| Grang         | 2                | 42000.                   | 1                    | 65500.                    | 196802           | 990000 |
| Camer         | 5                | 213200.                  | 0                    | 0.                        | 0                | 200601 |
| Bryan         | 3                | 98900.                   | 0                    | 0.                        | 194510           | 198211 |
| Hemp          | 5                | 814700.                  | 0                    | 0.                        | 0                | 201901 |
| TOTALS        | 30               | 1805370.                 | 6                    | 1949640.                  | 0                | 990000 |

NATURALIZED STREAMFLOWS (AC-FT) AT CONTROL POINT Hemp

| YEAR | JAN      | FEB      | MAR      | APR      | MAY      | JUN      | JUL      | AUG     | SEP      | OCT      | NOV      | DEC      | TOTAL     |          |
|------|----------|----------|----------|----------|----------|----------|----------|---------|----------|----------|----------|----------|-----------|----------|
| 1940 | 31649.   | 149252.  | 27694.   | 196281.  | 365199.  | 666230.  | 1169485. | 270114. | 104996.  | 50294.   | 1583495. | 2555544. | 7170233.  |          |
| 1941 | 979247.  | 1259427. | 1410847. | 975471.  | 2546960. | 1875875. | 1090393. | 388552. | 218959.  | 696832.  | 480542.  | 141057.  | 12064162. |          |
| 1942 | 121393.  | 91784.   | 81192.   | 2179373. | 1850680. | 1212631. | 208756.  | 113331. | 854651.  | 724460.  | 391230.  | 254386.  | 8083867.  |          |
| 1943 | 279553.  | 113166.  | 206330.  | 295215.  | 245965.  | 237666.  | 79147.   | 49935.  | 69435.   | 82923.   | 34604.   | 57692.   | 1751631.  |          |
| 1944 | 603979.  | 918534.  | 1001116. | 285473.  | 2873795. | 1001501. | 164638.  | 69061.  | 271158.  | 102042.  | 365180.  | 719386.  | 8375863.  |          |
| 1945 | 1276690. | 864125.  | 1398516. | 2609293. | 749770.  | 602668.  | 528786.  | 235449. | 293928.  | 544513.  | 120164.  | 413930.  | 9637832.  |          |
| 1946 | 653822.  | 838506.  | 1171931. | 460553.  | 1593598. | 791866.  | 143677.  | 90000.  | 288791.  | 258801.  | 943605.  | 581967.  | 7817117.  |          |
| 1947 | 967053.  | 277791.  | 799363.  | 432631.  | 1000378. | 330427.  | 89097.   | 294902. | 86479.   | 56045.   | 68392.   | 167786.  | 4570344.  |          |
| 1948 | 90927.   | 228448.  | 251690.  | 151638.  | 313734.  | 230557.  | 258432.  | 10550.  | 56222.   | 33461.   | 21356.   | 20060.   | 1667075.  |          |
| 1949 | 78886.   | 260970.  | 476036.  | 786000.  | 992585.  | 531890.  | 172158.  | 30151.  | 123286.  | 310062.  | 165043.  | 214943.  | 4142010.  |          |
| 1950 | 219523.  | 778975.  | 131746.  | 541309.  | 521444.  | 523810.  | 263838.  | 216515. | 313183.  | 108910.  | 26170.   | 16962.   | 3662385.  |          |
| 1951 | 15206.   | 44123.   | 55948.   | 51714.   | 186876.  | 373286.  | 31795.   | 35109.  | 74308.   | 18347.   | 17408.   | 23601.   | 927721.   |          |
| 1952 | 14518.   | 38079.   | 66357.   | 320688.  | 447993.  | 177529.  | 43689.   | 11596.  | 32333.   | 9639.    | 82694.   | 213923.  | 1459038.  |          |
| 1953 | 262333.  | 122826.  | 264572.  | 128560.  | 1734822. | 85529.   | 289575.  | 111500. | 81149.   | 482956.  | 155644.  | 150874.  | 4230340.  |          |
| 1954 | 96913.   | 38216.   | 23137.   | 135825.  | 543755.  | 136769.  | 29167.   | 43685.  | 12194.   | 36126.   | 68414.   | 14457.   | 1178658.  |          |
| 1955 | 23614.   | 229326.  | 71595.   | 323653.  | 569671.  | 391921.  | 115774.  | 78914.  | 218878.  | 623465.  | 43545.   | 21180.   | 2711536.  |          |
| 1956 | 30693.   | 102177.  | 37886.   | 47356.   | 433944.  | 44872.   | 1643.    | 16270.  | 12699.   | 24657.   | 57089.   | 87282.   | 896568.   |          |
| 1957 | 4982.    | 240688.  | 167145.  | 2568225. | 5723474. | 1563512. | 412584.  | 118377. | 75232.   | 1571000. | 902597.  | 393682.  | 13741498. |          |
| 1958 | 428231.  | 917726.  | 681004.  | 474522.  | 1586392. | 258629.  | 381396.  | 79567.  | 316635.  | 149946.  | 84245.   | 72058.   | 5430351.  |          |
| 1959 | 54250.   | 267825.  | 65306.   | 705367.  | 426649.  | 471742.  | 282046.  | 124275. | 55041.   | 1749062. | 375424.  | 622514.  | 5199501.  |          |
| 1960 | 991604.  | 610903.  | 330544.  | 235044.  | 362810.  | 294985.  | 348178.  | 82947.  | 25569.   | 606888.  | 831487.  | 1458006. | 6178965.  |          |
| 1961 | 2107635. | 1757539. | 657012.  | 245124.  | 167689.  | 960449.  | 98409.   | 825934. | 172883.  | 612469.  | 296899.  | 268213.  | 346045.   | 8417891. |
| 1962 | 198945.  | 157239.  | 111573.  | 125395.  | 155134.  | 523288.  | 283191.  | 156254. | 582902.  | 241861.  | 152600.  | 317686.  | 3006068.  |          |
| 1963 | 112454.  | 220821.  | 72283.   | 285536.  | 200949.  | 228459.  | 63972.   | 13527.  | 17473.   | 44087.   | 96124.   | 45405.   | 1401090.  |          |
| 1964 | 55001.   | 140689.  | 214174.  | 161308.  | 135622.  | 206354.  | 37636.   | 51309.  | 320405.  | 114096.  | 366469.  | 111808.  | 1914871.  |          |
| 1965 | 512568.  | 1141895. | 325565.  | 481274.  | 3317694. | 756083.  | 149762.  | 113577. | 123718.  | 156591.  | 336735.  | 437176.  | 7852638.  |          |
| 1966 | 186484.  | 395879.  | 341249.  | 1239937. | 1753522. | 271484.  | 81552.   | 272210. | 761195.  | 237360.  | 61597.   | 46777.   | 5649246.  |          |
| 1967 | 54807.   | 39497.   | 49537.   | 172097.  | 214180.  | 265066.  | 178049.  | 46134.  | 115640.  | 50472.   | 255095.  | 157998.  | 1598572.  |          |
| 1968 | 1578515. | 591144.  | 1152980. | 1033861. | 2133563. | 1503288. | 957940.  | 135899. | 222105.  | 90886.   | 187854.  | 441579.  | 10029614. |          |
| 1969 | 121712.  | 485213.  | 881813.  | 1373146. | 1478281. | 268482.  | 95014.   | 97265.  | 181244.  | 131152.  | 166832.  | 376345.  | 5656499.  |          |
| 1970 | 309194.  | 412966.  | 1514064. | 656221.  | 681790.  | 287769.  | 72635.   | 52023.  | 192542.  | 247962.  | 76147.   | 44227.   | 4547540.  |          |
| 1971 | 46220.   | 48059.   | 53272.   | 80867.   | 167192.  | 111208.  | 234626.  | 388154. | 165210.  | 447284.  | 248300.  | 799588.  | 2789980.  |          |
| 1972 | 367806.  | 185893.  | 90377.   | 87477.   | 356981.  | 133043.  | 64212.   | 156439. | 145667.  | 156562.  | 333165.  | 159528.  | 2237150.  |          |
| 1973 | 553860.  | 499162.  | 918266.  | 1141694. | 765145.  | 1285945. | 296387.  | 116051. | 115417.  | 1389280. | 396121.  | 311456.  | 7788784.  |          |
| 1974 | 619076.  | 299839.  | 157616.  | 145717.  | 277372.  | 99726.   | 43788.   | 202959. | 1456569. | 744166.  | 1757427. | 635072.  | 6439327.  |          |
| 1975 | 468062.  | 1272999. | 396948.  | 572999.  | 1643212. | 996601.  | 405697.  | 203418. | 120815.  | 77972.   | 70387.   | 51322.   | 6280432.  |          |
| 1976 | 59769.   | 82360.   | 124748.  | 831759.  | 1179533. | 580132.  | 722099.  | 127069. | 169287.  | 423344.  | 319978.  | 1015165. | 5635333.  |          |
| 1977 | 290226.  | 1069119. | 693595.  | 2205217. | 930935.  | 306174.  | 83919.   | 38203.  | 55117.   | 32064.   | 40542.   | 51691.   | 5796800.  |          |
| 1978 | 106545.  | 175301.  | 183733.  | 112008.  | 69873.   | 109343.  | 24609.   | 580831. | 106833.  | 36615.   | 115966.  | 57370.   | 1679027.  |          |
| 1979 | 529210.  | 502141.  | 1069192. | 1032908. | 1709100. | 1723142. | 512949.  | 298116. | 114692.  | 80443.   | 55539.   | 135203.  | 7762635.  |          |
| 1980 | 324015.  | 315415.  | 222890.  | 290801.  | 1152527. | 164906.  | 54636.   | 26983.  | 141864.  | 266415.  | 44865.   | 81303.   | 3086620.  |          |
| 1981 | 53638.   | 77368.   | 206786.  | 178577.  | 251009.  | 2122164. | 325257.  | 69492.  | 171949.  | 1329083. | 588130.  | 110134.  | 5483587.  |          |
| 1982 | 81252.   | 97429.   | 181921.  | 307147.  | 1391769. | 976557.  | 517114.  | 80017.  | 32759.   | 33183.   | 48431.   | 167523.  | 3915102.  |          |
| 1983 | 172341.  | 602204.  | 630218.  | 194478.  | 918831.  | 304859.  | 69396.   | 166134. | 92650.   | 121401.  | 53552.   | 68057.   | 3394121.  |          |
| 1984 | 78164.   | 63006.   | 213330.  | 46059.   | 54859.   | 82786.   | 36488.   | 21855.  | 28734.   | 987868.  | 452494.  | 722077.  | 2787720.  |          |
| 1985 | 620550.  | 572389.  | 816672.  | 376713.  | 412317.  | 282707.  | 97237.   | 22499.  | 36491.   | 412176.  | 577582.  | 899053.  | 5126386.  |          |
| 1986 | 123096.  | 833621.  | 162461.  | 116222.  | 696243.  | 1418480. | 189964.  | 98505.  | 411127.  | 618584.  | 499366.  | 1306844. | 6474513.  |          |
| 1987 | 576826.  | 629392.  | 992301.  | 302690.  | 554487.  | 2542750. | 424470.  | 111061. | 98226.   | 45879.   | 101556.  | 248335.  | 6627973.  |          |
| 1988 | 144989.  | 115153.  | 204897.  | 95939.   | 69725.   | 265518.  | 84484.   | 40188.  | 80989.   | 28888.   | 16973.   | 38140.   | 1185883.  |          |
| 1989 | 143940.  | 255567.  | 348473.  | 264450.  | 1488986. | 1275320. | 231947.  | 225722. | 141761.  | 46319.   | 36454.   | 25468.   | 4484407.  |          |
| 1990 | 100487.  | 182522.  | 742057.  | 1621966. | 2269407. | 773362.  | 149582.  | 124595. | 155126.  | 84231.   | 136657.  | 61992.   | 6401984.  |          |
| 1991 | 1486745. | 575450.  | 242527.  | 741269.  | 805098.  | 739273.  | 152036.  | 243981. | 236140.  | 456992.  | 455184.  | 4205115. | 10339810. |          |
| 1992 | 2451846. | 4310347. | 2411111. | 808865.  | 1443301. | 1798333. | 449601.  | 244907. | 171433.  | 89178.   | 153234.  | 489900.  | 14822056. |          |
| 1993 | 593854.  | 726762.  | 1236991. | 789723.  | 1058926. | 949845.  | 255186.  | 80715.  | 65611.   | 292922.  | 100431.  | 89763.   | 6240729.  |          |
| 1994 | 112563.  | 311862.  | 300283.  | 120815.  | 1002066. | 353977.  | 101911.  | 67122.  | 81990.   | 1363836. | 289928.  | 939900.  | 5046253.  |          |
| 1995 | 754753.  | 214615.  | 767486.  | 853516.  | 977812.  | 744099.  | 183764.  | 767377. | 196341.  | 110553.  | 56118.   | 136461.  | 5762895.  |          |
| 1996 | 44471.   | 56570.   | 41931.   | 89042.   | 45748.   | 76705.   | 38424.   | 210755. | 679660.  | 173469.  | 220157.  | 492996.  | 2169928.  |          |
| 1997 | 416222.  | 2069258. | 1961994. | 1701186. | 1167022. | 1151842. | 426245.  | 160646. | 66858.   | 101895.  | 111753.  | 701908.  | 10036829. |          |
| 1998 | 1301512. | 875780.  | 1390736. | 379394.  | 142234.  | 58406.   | 41982.   | 27070.  | 243922.  | 1345635. | 1379469. | 931054.  | 8117194.  |          |
| 1999 | 339452.  | 487002.  | 319618.  | 251143.  | 269856.  | 270736.  | 91913.   | 34293.  | 19044.   | 12042.   | 12782.   | 22713.   | 2130594.  |          |
| 2000 | 52541.   | 39388.   | 133346.  | 145661.  | 227436.  | 548314.  | 29430.   | 107.    | 18006.   | 74274.   | 970577.  | 499033.  | 2738113.  |          |
| 2001 | 933159.  | 875374.  | 1923731. | 558560.  | 497891.  | 338103.  | 123187.  | 95311.  | 522050.  | 201971.  | 430379.  | 1137969. | 7637685.  |          |
| 2002 | 314398.  | 343726.  | 379209.  | 455796.  | 180354.  | 154151.  | 482200.  | 176919. | 61548.   | 359259.  | 960879.  | 1138297. | 5006739.  |          |
| 2003 | 516954.  | 1204562. | 827897.  | 187022.  | 115768.  | 271945.  | 74992.   | 29760.  | 129735.  | 504773.  | 146202.  | 77390.   | 4087000.  |          |
| 2004 | 280485.  | 711322.  | 472965.  | 564312.  | 1328699. | 1906031. | 1122164. | 413466. | 163704.  | 297736.  | 2444548. | 1005149. | 10710581. |          |
| 2005 | 682614.  | 1087686. | 1227855. | 338217.  | 185436.  | 137124.  | 66230.   | 709125. | 130924.  | 67420.   | 43092.   | 52441.   | 4728164.  |          |
| 2006 | 67813.   | 89317.   | 220363.  | 159638.  | 347349.  | 66534.   | 31920.   | 11846.  | 21084.   | 387212.  | 73034.   | 111716.  | 1587826.  |          |

|      |          |          |          |          |          |          |          |         |         |          |          |          |           |
|------|----------|----------|----------|----------|----------|----------|----------|---------|---------|----------|----------|----------|-----------|
| 2007 | 1246376. | 124282.  | 1624969. | 880714.  | 2530686. | 3198214. | 3332536. | 770922. | 511223. | 208420.  | 127999.  | 151606.  | 14707947. |
| 2008 | 88187.   | 208481.  | 488886.  | 325659.  | 547968.  | 96364.   | 40682.   | 165011. | 81272.  | 52766.   | 57559.   | 30100.   | 2182935.  |
| 2009 | 31363.   | 44486.   | 131529.  | 373286.  | 386109.  | 43801.   | 32023.   | 30134.  | 273377. | 1654384. | 646484.  | 417229.  | 4064205.  |
| 2010 | 697424.  | 1781291. | 1075769. | 698616.  | 371417.  | 409214.  | 236530.  | 76763.  | 699212. | 107847.  | 66308.   | 69381.   | 6289772.  |
| 2011 | 137747.  | 73688.   | 53548.   | 42889.   | 77824.   | 17069.   | 9642.    | 4515.   | 9614.   | 100807.  | 22876.   | 94924.   | 645143.   |
| 2012 | 574950.  | 815768.  | 1602292. | 416151.  | 108327.  | 74891.   | 54990.   | 15110.  | 45546.  | 60733.   | 12887.   | 17142.   | 3798787.  |
| 2013 | 200802.  | 50760.   | 55425.   | 51515.   | 111457.  | 39531.   | 76531.   | 7284.   | 57756.  | 361414.  | 757395.  | 226338.  | 1996208.  |
| 2014 | 91576.   | 52676.   | 75333.   | 55476.   | 399870.  | 325529.  | 118622.  | 4680.   | 56048.  | 37505.   | 120655.  | 82394.   | 1420364.  |
| 2015 | 512282.  | 92805.   | 845422.  | 507933.  | 4164012. | 1907139. | 660570.  | 145934. | 63865.  | 830923.  | 1968222. | 1870107. | 13569214. |
| 2016 | 77125.   | 60584.   | 286943.  | 2120006. | 2395610. | 440948.  | 55851.   | 577767. | 548588. | 65168.   | 397319.  | 140827.  | 7166736.  |
| 2017 | 308167.  | 311535.  | 149668.  | 305032.  | 387825.  | 773078.  | 131604.  | 579499. | 302670. | 39406.   | 60107.   | 225782.  | 3574373.  |
| MEAN | 413306.  | 502693.  | 547407.  | 559041.  | 935186.  | 634878.  | 279994.  | 158092. | 205299. | 340669.  | 343142.  | 425504.  | 5345212.  |

REGULATED STREAMFLOWS (AC-FT) AT CONTROL POINT Hemp

| YEAR | JAN      | FEB      | MAR      | APR      | MAY      | JUN      | JUL     | AUG     | SEP      | OCT      | NOV      | DEC      | TOTAL     |
|------|----------|----------|----------|----------|----------|----------|---------|---------|----------|----------|----------|----------|-----------|
| 1940 | 10192.   | 93144.   | 10192.   | 71769.   | 172948.  | 417470.  | 895234. | 121352. | 9863.    | 10192.   | 1354564. | 2481989. | 5648907.  |
| 1941 | 910896.  | 1189890. | 1325472. | 883799.  | 2422796. | 1698409. | 843273. | 173505. | 80009.   | 609985.  | 390997.  | 63750.   | 10592781. |
| 1942 | 28507.   | 21061.   | 22841.   | 2050878. | 1722588. | 1019005. | 10192.  | 10192.  | 569623.  | 628929.  | 300080.  | 175693.  | 6559588.  |
| 1943 | 204645.  | 50899.   | 102473.  | 164500.  | 135053.  | 66940.   | 10192.  | 10192.  | 34517.   | 51761.   | 16736.   | 35934.   | 833842.   |
| 1944 | 510747.  | 678073.  | 828887.  | 194435.  | 2561010. | 765150.  | 10192.  | 10192.  | 189053.  | 22260.   | 313239.  | 616896.  | 6700134.  |
| 1945 | 1068341. | 666620.  | 1202366. | 2452802. | 607877.  | 404244.  | 285047. | 65574.  | 261253.  | 313987.  | 60329.   | 358958.  | 7747396.  |
| 1946 | 568017.  | 718625.  | 1094370. | 371348.  | 1474264. | 580597.  | 10192.  | 10192.  | 9863.    | 129236.  | 833833.  | 481858.  | 6282394.  |
| 1947 | 839296.  | 192088.  | 724897.  | 347830.  | 839453.  | 136741.  | 10192.  | 169811. | 68066.   | 10192.   | 29097.   | 54673.   | 3422335.  |
| 1948 | 44485.   | 97575.   | 142941.  | 80996.   | 106691.  | 9863.    | 10192.  | 10192.  | 9863.    | 10192.   | 9863.    | 10192.   | 543044.   |
| 1949 | 53705.   | 182994.  | 306608.  | 570709.  | 455983.  | 232325.  | 10192.  | 10192.  | 9863.    | 165113.  | 120653.  | 189939.  | 2308278.  |
| 1950 | 182398.  | 647454.  | 87803.   | 377810.  | 237928.  | 313902.  | 82684.  | 49681.  | 155737.  | 19305.   | 9863.    | 10192.   | 2174757.  |
| 1951 | 10192.   | 9205.    | 10192.   | 9863.    | 10192.   | 29412.   | 10192.  | 10192.  | 9863.    | 10192.   | 9863.    | 10192.   | 139549.   |
| 1952 | 10192.   | 9205.    | 23462.   | 164326.  | 174487.  | 51166.   | 10192.  | 10192.  | 9863.    | 10192.   | 9863.    | 111670.  | 594810.   |
| 1953 | 217444.  | 73892.   | 152024.  | 15271.   | 1363887. | 9863.    | 10192.  | 10192.  | 9863.    | 132561.  | 97354.   | 460717.  | 2553260.  |
| 1954 | 49924.   | 9205.    | 10192.   | 9863.    | 66729.   | 9863.    | 10192.  | 10192.  | 9863.    | 10192.   | 9863.    | 10192.   | 216269.   |
| 1955 | 10192.   | 161969.  | 26153.   | 239532.  | 41498.   | 19445.   | 10192.  | 10192.  | 9863.    | 306892.  | 9863.    | 10192.   | 852882.   |
| 1956 | 10192.   | 41847.   | 12370.   | 9863.    | 62321.   | 9863.    | 10192.  | 10192.  | 9863.    | 10192.   | 9863.    | 11365.   | 208123.   |
| 1957 | 10192.   | 9205.    | 63812.   | 1582127. | 5492297. | 1369686. | 137896. | 10192.  | 28795.   | 1313080. | 840701.  | 317160.  | 11175144. |
| 1958 | 363081.  | 860181.  | 581725.  | 384210.  | 1463017. | 47399.   | 170421. | 10192.  | 163900.  | 116211.  | 55812.   | 44390.   | 4260539.  |
| 1959 | 31627.   | 221750.  | 23355.   | 641957.  | 303517.  | 120172.  | 10192.  | 30836.  | 31948.   | 1227920. | 304093.  | 557149.  | 3504516.  |
| 1960 | 916431.  | 536635.  | 249647.  | 130422.  | 245433.  | 142211.  | 107885. | 10192.  | 9863.    | 273410.  | 748299.  | 1332011. | 4702440.  |
| 1961 | 2059622. | 1692344. | 564113.  | 132980.  | 40732.   | 783985.  | 592263. | 10192.  | 510750.  | 115230.  | 197243.  | 279185.  | 6978638.  |
| 1962 | 127882.  | 104825.  | 59153.   | 49464.   | 76584.   | 207751.  | 82755.  | 10192.  | 401294.  | 132561.  | 88908.   | 248196.  | 1589566.  |
| 1963 | 51404.   | 178680.  | 22917.   | 127888.  | 71087.   | 59647.   | 10192.  | 10192.  | 9863.    | 10192.   | 9863.    | 27965.   | 589890.   |
| 1964 | 21141.   | 47596.   | 115907.  | 9863.    | 27614.   | 9863.    | 10192.  | 10192.  | 38808.   | 54671.   | 103554.  | 61974.   | 511377.   |
| 1965 | 421690.  | 859857.  | 233030.  | 362000.  | 2835395. | 538110.  | 10192.  | 10192.  | 10442.   | 50564.   | 214553.  | 396785.  | 5942810.  |
| 1966 | 156532.  | 345190.  | 265518.  | 867394.  | 1628783. | 79129.   | 10192.  | 74270.  | 506423.  | 142003.  | 9863.    | 19971.   | 4105266.  |
| 1967 | 24366.   | 9205.    | 10192.   | 54273.   | 85590.   | 10428.   | 10192.  | 10192.  | 9863.    | 10192.   | 206853.  | 102498.  | 543844.   |
| 1968 | 1069124. | 518414.  | 1072830. | 937541.  | 2029650. | 1319826. | 718092. | 10192.  | 181749.  | 59329.   | 151117.  | 397458.  | 8465323.  |
| 1969 | 87986.   | 434746.  | 677790.  | 1033321. | 1334020. | 68203.   | 10192.  | 10192.  | 17022.   | 10192.   | 76828.   | 233512.  | 3994004.  |
| 1970 | 218287.  | 296966.  | 1405693. | 552464.  | 553198.  | 86399.   | 10192.  | 10192.  | 87970.   | 197218.  | 50517.   | 18533.   | 3487630.  |
| 1971 | 19252.   | 16017.   | 10192.   | 9863.    | 26654.   | 9863.    | 10192.  | 10192.  | 9863.    | 24145.   | 154913.  | 660683.  | 961829.   |
| 1972 | 277372.  | 93420.   | 10192.   | 9863.    | 185166.  | 9863.    | 10192.  | 10192.  | 9863.    | 10192.   | 211887.  | 80331.   | 918532.   |
| 1973 | 475471.  | 413997.  | 795404.  | 1001437. | 603828.  | 1071876. | 75706.  | 10192.  | 9863.    | 1243938. | 320652.  | 251574.  | 6273940.  |
| 1974 | 561177.  | 231632.  | 87369.   | 53209.   | 185974.  | 9863.    | 10192.  | 22099.  | 1041028. | 457108.  | 1682850. | 563271.  | 4905772.  |
| 1975 | 396172.  | 1204914. | 304740.  | 476159.  | 1547627. | 800983.  | 159232. | 47121.  | 75060.   | 55913.   | 44142.   | 27667.   | 5139730.  |
| 1976 | 27323.   | 40087.   | 67591.   | 654924.  | 922791.  | 396577.  | 428863. | 14320.  | 80012.   | 261013.  | 204537.  | 927501.  | 4025540.  |
| 1977 | 225553.  | 962613.  | 485439.  | 2121611. | 803130.  | 84641.   | 10192.  | 10192.  | 25511.   | 20340.   | 22820.   | 35186.   | 4807228.  |
| 1978 | 67037.   | 114296.  | 118537.  | 9863.    | 10192.   | 9863.    | 10192.  | 10192.  | 13766.   | 10192.   | 54058.   | 29354.   | 457543.   |
| 1979 | 450898.  | 393627.  | 709719.  | 853770.  | 1449402. | 1398240. | 278806. | 172134. | 98087.   | 44239.   | 40061.   | 92210.   | 5981195.  |
| 1980 | 284139.  | 257811.  | 179611.  | 194278.  | 750866.  | 9863.    | 10192.  | 10192.  | 9863.    | 10192.   | 9863.    | 10192.   | 1737062.  |
| 1981 | 10192.   | 34622.   | 72135.   | 39835.   | 126974.  | 1616667. | 114221. | 10192.  | 93625.   | 1062424. | 513929.  | 38644.   | 3733459.  |
| 1982 | 29459.   | 39373.   | 80690.   | 201855.  | 1206434. | 766234.  | 304949. | 10192.  | 9863.    | 10192.   | 9863.    | 143150.  | 2812254.  |
| 1983 | 146546.  | 511569.  | 491512.  | 126425.  | 706089.  | 149160.  | 10192.  | 82900.  | 29031.   | 10192.   | 9863.    | 22583.   | 2296060.  |
| 1984 | 10820.   | 9205.    | 117474.  | 11517.   | 10192.   | 9863.    | 10192.  | 10192.  | 9863.    | 710153.  | 341677.  | 525820.  | 1776969.  |
| 1985 | 400413.  | 439592.  | 539282.  | 124319.  | 148465.  | 10243.   | 10192.  | 10192.  | 9863.    | 128585.  | 507145.  | 800733.  | 3129024.  |
| 1986 | 82458.   | 713642.  | 100715.  | 52091.   | 499877.  | 839019.  | 10192.  | 10192.  | 103747.  | 545059.  | 416722.  | 1246791. | 4620505.  |
| 1987 | 506575.  | 565047.  | 901124.  | 185346.  | 442619.  | 2379247. | 155157. | 10192.  | 62422.   | 23653.   | 62827.   | 162247.  | 5456457.  |
| 1988 | 85161.   | 63367.   | 155718.  | 46332.   | 10192.   | 9863.    | 10192.  | 10192.  | 9863.    | 10192.   | 9863.    | 10192.   | 431126.   |
| 1989 | 74370.   | 98244.   | 184131.  | 151449.  | 979792.  | 839352.  | 32011.  | 97699.  | 31926.   | 16753.   | 18544.   | 10192.   | 2534462.  |
| 1990 | 44446.   | 98007.   | 420863.  | 1397484. | 2116314. | 565571.  | 10192.  | 10192.  | 40143.   | 17285.   | 88343.   | 35950.   | 4844790.  |
| 1991 | 1355093. | 482629.  | 175665.  | 606214.  | 536550.  | 513467.  | 10192.  | 10192.  | 101043.  | 331861.  | 339151.  | 4136876. | 8598933.  |



|      |          |          |          |          |          |          |          |         |         |          |          |          |           |
|------|----------|----------|----------|----------|----------|----------|----------|---------|---------|----------|----------|----------|-----------|
| 1992 | 2396456. | 4254050. | 2325488. | 699155.  | 1332709. | 1612134. | 211561.  | 36510.  | 103988. | 53451.   | 91238.   | 379000.  | 13495740. |
| 1993 | 527743.  | 542331.  | 1150855. | 688857.  | 928498.  | 758130.  | 70765.   | 10192.  | 35376.  | 93692.   | 56120.   | 42712.   | 4905272.  |
| 1994 | 62325.   | 217660.  | 218052.  | 60724.   | 600238.  | 159852.  | 10192.   | 10192.  | 9863.   | 1172237. | 113681.  | 830114.  | 3465130.  |
| 1995 | 660036.  | 131564.  | 675018.  | 771462.  | 853254.  | 508089.  | 10192.   | 513621. | 74616.  | 19230.   | 26056.   | 103023.  | 4346160.  |
| 1996 | 14475.   | 12584.   | 10192.   | 21389.   | 10192.   | 9863.    | 10192.   | 10192.  | 151235. | 47445.   | 9863.    | 355557.  | 663177.   |
| 1997 | 328238.  | 1999229. | 1868915. | 1617703. | 1041399. | 973095.  | 149751.  | 10192.  | 40648.  | 69126.   | 78030.   | 550682.  | 8727008.  |
| 1998 | 1189690. | 757956.  | 1237368. | 277733.  | 11373.   | 9863.    | 10192.   | 10192.  | 156080. | 1236007. | 1297208. | 829178.  | 7022839.  |
| 1999 | 281241.  | 437984.  | 181776.  | 159219.  | 147240.  | 14217.   | 10192.   | 10192.  | 9863.   | 10192.   | 9863.    | 10192.   | 1282170.  |
| 2000 | 10192.   | 9205.    | 25580.   | 45094.   | 116194.  | 104868.  | 10192.   | 10192.  | 9863.   | 23230.   | 705739.  | 411860.  | 1482209.  |
| 2001 | 780144.  | 476681.  | 1604252. | 425076.  | 338908.  | 179319.  | 10192.   | 10192.  | 486918. | 160155.  | 299110.  | 1040615. | 5811562.  |
| 2002 | 245807.  | 242477.  | 177968.  | 253727.  | 10192.   | 9863.    | 182750.  | 98405.  | 54540.  | 271073.  | 890652.  | 1036689. | 3474144.  |
| 2003 | 472781.  | 1127689. | 750446.  | 113518.  | 27406.   | 16992.   | 10192.   | 10192.  | 23650.  | 329059.  | 91594.   | 33948.   | 3007466.  |
| 2004 | 193154.  | 588558.  | 323282.  | 369602.  | 1177033. | 1617796. | 858176.  | 106324. | 80088.  | 179437.  | 2175945. | 902658.  | 8572053.  |
| 2005 | 600626.  | 1013734. | 1135612. | 233368.  | 70319.   | 9863.    | 10192.   | 205352. | 24989.  | 24192.   | 18976.   | 26245.   | 3373468.  |
| 2006 | 36097.   | 54361.   | 99174.   | 90969.   | 134007.  | 9863.    | 10192.   | 10192.  | 9863.   | 273109.  | 9863.    | 63390.   | 801079.   |
| 2007 | 1132071. | 81882.   | 1090750. | 629722.  | 2230198. | 2973242. | 3110912. | 552024. | 390673. | 109911.  | 77413.   | 104710.  | 12483507. |
| 2008 | 46187.   | 153747.  | 285660.  | 209335.  | 414466.  | 9863.    | 10192.   | 51363.  | 53491.  | 10715.   | 26071.   | 10192.   | 1281282.  |
| 2009 | 10192.   | 9205.    | 36239.   | 277559.  | 285178.  | 9863.    | 10192.   | 10192.  | 81585.  | 1107059. | 530105.  | 347106.  | 2714476.  |
| 2010 | 528813.  | 1670104. | 974511.  | 399338.  | 161175.  | 244396.  | 10192.   | 10192.  | 402348. | 11712.   | 24526.   | 37390.   | 4474698.  |
| 2011 | 97254.   | 33299.   | 10192.   | 9863.    | 10192.   | 9863.    | 10192.   | 10192.  | 9863.   | 10192.   | 9863.    | 53334.   | 274298.   |
| 2012 | 191714.  | 614753.  | 1340576. | 316278.  | 13975.   | 9863.    | 10192.   | 10192.  | 9863.   | 33099.   | 9863.    | 10192.   | 2570560.  |
| 2013 | 137364.  | 15983.   | 10192.   | 9863.    | 14651.   | 9863.    | 10192.   | 10192.  | 9863.   | 226274.  | 692131.  | 141051.  | 1287618.  |
| 2014 | 42037.   | 9205.    | 15213.   | 9863.    | 277066.  | 40997.   | 10192.   | 10192.  | 9863.   | 10192.   | 54279.   | 28925.   | 518024.   |
| 2015 | 434263.  | 29902.   | 718343.  | 302669.  | 3163253. | 1484755. | 405478.  | 10192.  | 49212.  | 537777.  | 1892065. | 1795685. | 10823594. |
| 2016 | 10192.   | 17711.   | 224148.  | 1967351. | 2282092. | 250612.  | 10192.   | 329678. | 328533. | 10192.   | 283282.  | 51470.   | 5765452.  |
| 2017 | 241409.  | 226708.  | 65694.   | 211664.  | 280574.  | 572105.  | 10192.   | 317713. | 142593. | 10192.   | 11085.   | 174544.  | 2264474.  |
| MEAN | 339605.  | 416303.  | 435802.  | 427954.  | 741584.  | 432393.  | 140949.  | 50039.  | 103838. | 220599.  | 271698.  | 362985.  | 3943747.  |

|      | 2NAT<br>Hemp | 2REG<br>Hemp | 2UNA<br>Hemp | 2UNA<br>Whit | 2UNA<br>High | 2UNA<br>Camer |
|------|--------------|--------------|--------------|--------------|--------------|---------------|
| 1940 | 7170233.     | 5648907.     | 5528907.     | 775698.      | 1826617.     | 1651163.      |
| 1941 | 12064162.    | 10592781.    | 10472783.    | 4039777.     | 5879754.     | 2890108.      |
| 1942 | 8083867.     | 6559588.     | 6439588.     | 2074348.     | 3856642.     | 1741354.      |
| 1943 | 1751631.     | 883842.      | 763842.      | 84676.       | 455194.      | 176415.       |
| 1944 | 8375863.     | 6700134.     | 6580134.     | 58584.       | 1798467.     | 1996258.      |
| 1945 | 9637832.     | 7747396.     | 7627398.     | 834621.      | 2957776.     | 1942864.      |
| 1946 | 7817117.     | 6282394.     | 6162394.     | 697018.      | 1765208.     | 1282417.      |
| 1947 | 4570344.     | 3422335.     | 3302335.     | 634537.      | 1272495.     | 748202.       |
| 1948 | 1667075.     | 543044.      | 423044.      | 0.           | 241535.      | 33370.        |
| 1949 | 4142010.     | 2308278.     | 2188278.     | 361415.      | 874169.      | 293264.       |
| 1950 | 3662385.     | 2174757.     | 2054757.     | 330080.      | 624732.      | 104240.       |
| 1951 | 927721.      | 139549.      | 19549.       | 20727.       | 20335.       | 0.            |
| 1952 | 1459038.     | 594810.      | 474810.      | 0.           | 250277.      | 66567.        |
| 1953 | 4230340.     | 2553260.     | 2433260.     | 0.           | 578296.      | 427865.       |
| 1954 | 1178658.     | 216269.      | 96269.       | 0.           | 37568.       | 19141.        |
| 1955 | 2711536.     | 855982.      | 735983.      | 254258.      | 399803.      | 85642.        |
| 1956 | 896568.      | 208123.      | 88123.       | 23531.       | 62980.       | 2959.         |
| 1957 | 13741498.    | 11175144.    | 11055144.    | 4242048.     | 6266360.     | 2423407.      |
| 1958 | 5430351.     | 4260539.     | 4140539.     | 957424.      | 1950320.     | 1336064.      |
| 1959 | 5199501.     | 3504516.     | 3384516.     | 452304.      | 1410748.     | 998092.       |
| 1960 | 6178965.     | 4702440.     | 4582440.     | 551646.      | 1514032.     | 1398207.      |
| 1961 | 8417891.     | 6978638.     | 6858638.     | 1006112.     | 2893396.     | 1980667.      |
| 1962 | 3006068.     | 1589566.     | 1469566.     | 801337.      | 1154008.     | 263545.       |
| 1963 | 1401090.     | 589890.      | 469890.      | 125693.      | 240351.      | 62200.        |
| 1964 | 1914871.     | 511377.      | 391377.      | 0.           | 328858.      | 117579.       |
| 1965 | 7852638.     | 5942810.     | 5822811.     | 243920.      | 1995571.     | 2259248.      |
| 1966 | 5649246.     | 4105266.     | 3985266.     | 908097.      | 2216099.     | 956896.       |
| 1967 | 1598572.     | 543844.      | 423844.      | 0.           | 308730.      | 137691.       |
| 1968 | 10029614.    | 8465323.     | 8345322.     | 1381320.     | 3328071.     | 2073928.      |
| 1969 | 5656499.     | 3994004.     | 3874004.     | 829845.      | 1745697.     | 657178.       |
| 1970 | 4547540.     | 3487630.     | 3367630.     | 700888.      | 1487493.     | 1078545.      |
| 1971 | 2789980.     | 961829.      | 841829.      | 263583.      | 599960.      | 102681.       |
| 1972 | 2237150.     | 918532.      | 798532.      | 173996.      | 436302.      | 117976.       |
| 1973 | 7788784.     | 6273940.     | 6153940.     | 920798.      | 2525282.     | 782059.       |

|      |           |           |           |          |          |          |
|------|-----------|-----------|-----------|----------|----------|----------|
| 1974 | 6439327.  | 4905772.  | 4785772.  | 520343.  | 1828914. | 942852.  |
| 1975 | 6280432.  | 5139730.  | 5019730.  | 847045.  | 2113578. | 1596164. |
| 1976 | 5635333.  | 4025540.  | 3905540.  | 0.       | 1360379. | 807750.  |
| 1977 | 5796802.  | 4807228.  | 4687228.  | 593068.  | 1911443. | 1314145. |
| 1978 | 1679027.  | 457543.   | 337543.   | 0.       | 122388.  | 25769.   |
| 1979 | 7762635.  | 5981195.  | 5861195.  | 520218.  | 1918322. | 1073535. |
| 1980 | 3086620.  | 1737062.  | 1617062.  | 0.       | 556588.  | 259225.  |
| 1981 | 5483587.  | 3733459.  | 3613460.  | 1104725. | 1914891. | 873687.  |
| 1982 | 3915102.  | 2812254.  | 2692254.  | 1885726. | 2112573. | 242258.  |
| 1983 | 3394121.  | 2296060.  | 2176060.  | 0.       | 458932.  | 358210.  |
| 1984 | 2787720.  | 1776969.  | 1656969.  | 0.       | 429386.  | 152831.  |
| 1985 | 5126386.  | 3129024.  | 3009025.  | 0.       | 795335.  | 573150.  |
| 1986 | 6474513.  | 4620505.  | 4500505.  | 598008.  | 1939340. | 1116932. |
| 1987 | 6627973.  | 5456457.  | 5336456.  | 1351772. | 2207285. | 1666329. |
| 1988 | 1185883.  | 431126.   | 311126.   | 0.       | 193018.  | 35973.   |
| 1989 | 4484407.  | 2534462.  | 2414462.  | 851988.  | 1965978. | 116401.  |
| 1990 | 6401984.  | 4844790.  | 4724790.  | 2516907. | 3547923. | 620492.  |
| 1991 | 10339810. | 8598933.  | 8478933.  | 2235693. | 4135798. | 1826913. |
| 1992 | 14822056. | 13495740. | 13375741. | 2720330. | 5241312. | 3960284. |
| 1993 | 6240729.  | 4905272.  | 4785272.  | 285663.  | 1336932. | 1183922. |
| 1994 | 5046253.  | 3465130.  | 3345130.  | 258897.  | 1141075. | 415589.  |
| 1995 | 5762895.  | 4346160.  | 4226160.  | 1088794. | 2586660. | 894119.  |
| 1996 | 2169928.  | 663177.   | 543177.   | 79745.   | 389800.  | 101004.  |
| 1997 | 10036829. | 8727008.  | 8607008.  | 1856318. | 4318639. | 3176304. |
| 1998 | 8117194.  | 7022839.  | 6902839.  | 422428.  | 1906538. | 1811953. |
| 1999 | 2130594.  | 1282170.  | 1162170.  | 0.       | 385136.  | 271020.  |
| 2000 | 2738113.  | 1482209.  | 1362209.  | 0.       | 414779.  | 348131.  |
| 2001 | 7637685.  | 5811562.  | 5691563.  | 560837.  | 2297974. | 1191768. |
| 2002 | 5006736.  | 3474144.  | 3354144.  | 0.       | 867964.  | 647408.  |
| 2003 | 4087000.  | 3007466.  | 2887466.  | 0.       | 628699.  | 570131.  |
| 2004 | 10710581. | 8572053.  | 8452052.  | 487301.  | 2606457. | 2123079. |
| 2005 | 4728164.  | 3373468.  | 3253468.  | 256898.  | 1092322. | 1177892. |
| 2006 | 1587826.  | 801079.   | 681079.   | 0.       | 260154.  | 129626.  |
| 2007 | 14707947. | 12483507. | 12363508. | 2514994. | 5157479. | 4016636. |
| 2008 | 2182935.  | 1281282.  | 1161282.  | 244452.  | 701690.  | 260929.  |
| 2009 | 4064205.  | 2714476.  | 2594476.  | 26339.   | 1030259. | 583736.  |
| 2010 | 6289772.  | 4474698.  | 4354698.  | 786463.  | 2097049. | 1533078. |
| 2011 | 645143.   | 274298.   | 154298.   | 0.       | 138693.  | 35407.   |
| 2012 | 3798787.  | 2570560.  | 2450560.  | 257189.  | 985455.  | 340756.  |
| 2013 | 1996208.  | 1287618.  | 1167618.  | 0.       | 338041.  | 186349.  |
| 2014 | 1420364.  | 518024.   | 398024.   | 0.       | 105049.  | 73006.   |
| 2015 | 13569214. | 10823594. | 10703593. | 2199553. | 4644394. | 2036399. |
| 2016 | 7166736.  | 5765452.  | 5645452.  | 1373418. | 2754183. | 1367821. |
| 2017 | 3574373.  | 2264474.  | 2144474.  | 445170.  | 870578.  | 629977.  |

FLOW-FREQUENCY FOR NATURALIZED STREAMFLOWS

| CONTROL POINT | STANDARD MEAN DEVIATION | PERCENTAGE OF MONTHS WITH FLOWS EQUALING OR EXCEEDING VALUES SHOWN IN THE TABLE |         |         |         |         |         |         |         |         |         |          | MAXIMUM  |
|---------------|-------------------------|---|---------|---------|---------|---------|---------|---------|---------|---------|---------|----------|----------|
|               |                         | 100%  | 99%     | 98%     | 95%     | 90%     | 75%     | 60%     | 50%     | 40%     | 25%     | 10%      |          |
| PK            | 57843.2 123894.         | 0.0   | 0.0     | 0.0     | 0.0     | 1384.4  | 5866.0  | 10695.  | 15700.  | 24830.  | 54063.  | 143746.  | 1794495. |
| Whit          | 107505.2 194568.        | 0.0   | 0.0     | 1138.3  | 3263.4  | 6206.6  | 15341.0 | 25966.  | 39379.  | 60919.  | 115994. | 269125.  | 2981239. |
| WacoL         | 29848.8 53414.          | 0.0   | 0.0     | 0.0     | 0.0     | 245.4   | 2301.0  | 5536.   | 9088.   | 14595.  | 34506.  | 81659.   | 526506.  |
| WacoG         | 155102.4 258754.        | 0.0   | 526.8   | 1833.4  | 5110.8  | 9745.8  | 22309.0 | 40522.  | 63432.  | 97423.  | 175996. | 408190.  | 3376485. |
| High          | 188086.6 294671.        | 0.0   | 1988.0  | 3555.4  | 8162.6  | 13905.4 | 28093.0 | 53733.  | 78796.  | 120185. | 219665. | 471562.  | 3599267. |
| Belton        | 41676.1 74102.          | 0.0   | 0.0     | 0.0     | 183.8   | 923.0   | 3929.0  | 8236.   | 13046.  | 21749.  | 44896.  | 111761.  | 629875.  |
| George        | 4715.3 8748.            | 0.0   | 0.0     | 0.0     | 0.0     | 58.6    | 260.0   | 692.    | 1187.   | 1983.   | 5179.   | 13983.   | 76105.   |
| Grang         | 16074.9 25765.          | 0.0   | 0.0     | 0.0     | 62.8    | 456.8   | 1752.0  | 3711.   | 5454.   | 8659.   | 20102.  | 45868.   | 212283.  |
| Camer         | 111137.1 173050.        | 0.0   | 208.6   | 930.6   | 2610.2  | 5008.0  | 14985.0 | 29186.  | 44782.  | 65285.  | 131624. | 296162.  | 1403134. |
| Bryan         | 330468.1 485044.        | 0.0   | 5076.2  | 8044.3  | 15700.2 | 26182.8 | 55094.0 | 102384. | 150473. | 227305. | 401884. | 787075.  | 4704304. |
| Hemp          | 445434.5 595319.        | 107.0   | 10926.5 | 14500.9 | 26049.8 | 41961.6 | 81990.0 | 149836. | 222890. | 311503. | 572999. | 1152708. | 5723474. |

FLOW-FREQUENCY FOR UNAPPROPRIATED STREAMFLOWS

| CONTROL POINT | STANDARD MEAN DEVIATION | PERCENTAGE OF MONTHS WITH FLOWS EQUALING OR EXCEEDING VALUES SHOWN IN THE TABLE |     |     |     |     |     |        |        |         |         |         |          |          |
|---------------|-------------------------|---|-----|-----|-----|-----|-----|--------|--------|---------|---------|---------|----------|----------|
|               |                         | 100%  | 99% | 98% | 95% | 90% | 75% | 60%    | 50%    | 40%     | 25%     | 10%     | MAXIMUM  |          |
| PK            | 24654.9 105885.         | 0.0   | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.     | 0.      | 0.      | 0.      | 52787.   | 1783135. |
| Whit          | 56237.8 176449.         | 0.0   | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.     | 0.      | 0.      | 26317.  | 173390.  | 2971574. |
| WacoL         | 21590.1 51632.          | 0.0   | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.     | 0.      | 0.      | 15628.  | 70962.   | 524844.  |
| WacoG         | 106725.6 236555.        | 0.0   | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 17335. | 33281. | 43922.  | 84831.  | 297379. | 3363118. |          |
| High          | 135804.0 271905.        | 0.0   | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 24972. | 42577. | 63154.  | 129702. | 371865. | 3582674. |          |
| Belton        | 22075.5 66089.          | 0.0   | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.     | 0.     | 0.      | 0.      | 72996.  | 552013.  |          |
| George        | 2453.7 7143.            | 0.0   | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.     | 0.     | 0.      | 0.      | 8169.   | 73808.   |          |
| Grang         | 9928.9 22775.           | 0.0   | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.     | 0.     | 0.      | 8551.   | 34650.  | 200139.  |          |
| Camer         | 77859.8 158433.         | 0.0   | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3897.  | 10962. | 26289.  | 85790.  | 223803. | 1392319. |          |
| Bryan         | 239274.3 448918.        | 0.0   | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 34696. | 65967. | 112337. | 275502. | 656112. | 4523928. |          |
| Hemp          | 318645.9 552273.        | 0.0   | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 37878. | 82019. | 159985. | 404274. | 963667. | 5482105. |          |

FLOW-FREQUENCY FOR REGULATED STREAMFLOWS

| CP      | FK         | Whit       | WacoL     | WacoG      | High       | Belton    | George   | Grang     | Camer      | Bryan      | Hemp       |
|---------|------------|------------|-----------|------------|------------|-----------|----------|-----------|------------|------------|------------|
| Mean    | 34636.34   | 63973.88   | 21773.80  | 121648.99  | 151589.95  | 25993.00  | 2780.60  | 11382.29  | 82452.66   | 264061.00  | 328642.34  |
| Std Dev | 108900.59  | 175850.83  | 51597.56  | 232488.81  | 266901.44  | 65967.44  | 7462.23  | 23129.21  | 156926.16  | 439612.41  | 552265.00  |
| Minimum | 0.00       | 0.00       | 0.00      | 0.00       | 0.00       | 0.00      | 0.00     | 0.00      | 0.00       | 0.00       | 9205.48    |
| 99.5%   | 0.00       | 0.00       | 0.00      | 0.00       | 0.00       | 0.00      | 0.00     | 0.00      | 276.16     | 4278.47    | 9205.48    |
| 99%     | 0.00       | 0.00       | 0.00      | 0.00       | 0.00       | 0.00      | 0.00     | 0.00      | 295.89     | 10210.74   | 9863.00    |
| 98%     | 0.00       | 0.00       | 0.00      | 983.84     | 857.36     | 0.00      | 0.00     | 0.00      | 295.89     | 17160.69   | 9863.01    |
| 95%     | 0.00       | 0.00       | 0.00      | 5922.81    | 7066.87    | 0.00      | 0.00     | 0.00      | 295.89     | 27039.04   | 9863.01    |
| 90%     | 0.00       | 0.00       | 0.00      | 12276.08   | 16958.64   | 0.00      | 0.00     | 0.00      | 305.75     | 36655.40   | 10191.78   |
| 85%     | 0.00       | 0.00       | 0.00      | 19062.36   | 25394.47   | 0.00      | 0.00     | 0.00      | 305.75     | 42141.98   | 10191.78   |
| 80%     | 0.00       | 0.00       | 0.00      | 25226.75   | 31153.97   | 0.00      | 0.00     | 0.00      | 1949.61    | 48809.81   | 10191.78   |
| 75%     | 0.00       | 0.00       | 0.00      | 29773.20   | 35121.22   | 0.00      | 0.00     | 0.00      | 3902.65    | 54517.21   | 10191.78   |
| 70%     | 0.00       | 0.00       | 0.00      | 32821.61   | 39671.35   | 0.00      | 0.00     | 0.00      | 6366.40    | 58945.04   | 17232.20   |
| 60%     | 0.00       | 0.00       | 0.00      | 39114.92   | 49071.03   | 0.00      | 0.00     | 0.00      | 11116.47   | 70806.62   | 47505.39   |
| 50%     | 0.00       | 0.00       | 0.00      | 47768.53   | 59178.02   | 0.00      | 0.00     | 0.00      | 20151.04   | 87841.74   | 92210.49   |
| 40%     | 0.00       | 18374.49   | 0.00      | 64706.23   | 77944.01   | 2664.95   | 0.00     | 2481.44   | 39477.36   | 121603.63  | 170176.91  |
| 30%     | 18981.27   | 41465.81   | 8453.52   | 79765.54   | 109017.78  | 10059.44  | 0.00     | 9450.27   | 63027.98   | 207966.80  | 304222.28  |
| 25%     | 29340.66   | 53437.19   | 16009.90  | 95011.06   | 134277.52  | 15457.19  | 260.00   | 11255.58  | 86065.99   | 285932.06  | 413997.06  |
| 20%     | 45053.14   | 64011.85   | 30953.28  | 127052.32  | 189532.19  | 33716.60  | 2897.15  | 17629.11  | 117443.84  | 377628.78  | 541721.06  |
| 15%     | 56908.62   | 95319.14   | 44268.99  | 187459.61  | 254532.44  | 52882.22  | 5755.95  | 25126.00  | 164552.14  | 498738.94  | 716312.00  |
| 10%     | 78962.93   | 177289.41  | 70962.08  | 297903.69  | 381052.28  | 73961.51  | 9600.50  | 38537.19  | 224108.41  | 668371.38  | 973661.69  |
| 5%      | 166127.38  | 336957.66  | 126230.95 | 554376.06  | 686392.62  | 141653.08 | 18278.58 | 60167.34  | 385609.44  | 1108598.62 | 1397635.50 |
| 2%      | 408854.03  | 670201.19  | 212007.28 | 814163.31  | 981440.81  | 241334.81 | 28034.03 | 85773.74  | 591658.06  | 1756610.12 | 2117796.75 |
| 1%      | 513265.78  | 845458.31  | 269009.84 | 1142404.88 | 1294697.88 | 382446.81 | 35370.34 | 110916.23 | 744026.88  | 2191469.25 | 2471481.50 |
| 0.5%    | 696401.94  | 1092618.38 | 300005.69 | 1428372.62 | 1650678.25 | 495287.16 | 52599.12 | 144253.72 | 1073530.88 | 2658072.25 | 3127660.75 |
| Maximum | 1783135.12 | 2971574.25 | 524844.50 | 3363118.50 | 3582674.00 | 552012.56 | 73807.57 | 200139.30 | 1392594.88 | 4523927.50 | 5492297.00 |

STORAGE-FREQUENCY FOR SPECIFIED CONTROL POINTS

| CONTROL POINT | STANDARD MEAN DEVIATION | PERCENTAGE OF MONTHS WITH STORAGE EQUALING OR EXCEEDING VALUES SHOWN IN THE TABLE |         |         |         |         |          |          |          |          |          |          |          |
|---------------|-------------------------|---|---------|---------|---------|---------|----------|----------|----------|----------|----------|----------|----------|
|               |                         | 100%  | 99%     | 98%     | 95%     | 90%     | 75%      | 60%      | 50%      | 40%      | 25%      | 10%      | MAXIMUM  |
| PK            | 411555. 180319.         | 0.  | 0.      | 0.      | 0.      | 91270.  | 328890.  | 437374.  | 484596.  | 518051.  | 563419.  | 570240.  | 570240.  |
| Whit          | 521587. 97498.          | 344632.   | 358676. | 365797. | 372806. | 379000. | 427755.  | 495137.  | 539644.  | 578884.  | 627100.  | 627100.  | 627100.  |
| WacoL         | 167829. 31435.          | 58481.  | 68551.  | 77653.  | 98994.  | 119427. | 153546.  | 172472.  | 181408.  | 189138.  | 192100.  | 192100.  | 192100.  |
| Belton        | 321113. 149123.         | 0.  | 0.      | 0.      | 0.      | 53058.  | 238718.  | 336073.  | 376237.  | 407884.  | 452700.  | 457600.  | 457600.  |
| George        | 21317. 14579.           | 0.  | 0.      | 0.      | 0.      | 0.      | 6124.    | 17477.   | 25345.   | 31537.   | 36208.   | 37100.   | 37100.   |
| Grang         | 44488. 23455.           | 0.  | 0.      | 0.      | 0.      | 385.    | 26841.   | 43219.   | 53591.   | 63311.   | 65500.   | 65500.   | 65500.   |
| Total         | 1487887. 418842.        | 403113.   | 474952. | 493152. | 593416. | 831806. | 1220172. | 1455229. | 1593436. | 1712082. | 1846296. | 1947934. | 1949640. |

STORAGE-FREQUENCY FOR SPECIFIED CONTROL POINTS

| CONTROL POINT | STANDARD MEAN DEVIATION | PERCENTAGE OF MONTHS WITH STORAGE EQUALING OR EXCEEDING VALUES SHOWN IN THE TABLE |         |         |         |         |          |          |          |          |          |          |          |
|---------------|-------------------------|---|---------|---------|---------|---------|----------|----------|----------|----------|----------|----------|----------|
|               |                         | 100%  | 99%     | 98%     | 95%     | 90%     | 75%      | 60%      | 50%      | 40%      | 25%      | 10%      | MAXIMUM  |
| Total         | 1487887. 418842.        | 403113.   | 474952. | 493152. | 593416. | 831806. | 1220172. | 1455229. | 1593436. | 1712082. | 1846296. | 1947934. | 1949640. |

WATER SURFACE ELEVATION-FREQUENCY FOR RESERVOIR Whit

| ELEVATION FREQ(%) | ELEVATION FREQ(%) | ELEVATION FREQ(%) | ELEVATION FREQ(%) | ELEVATION FREQ(%) | ELEVATION FREQ(%) | ELEVATION FREQ(%) |       |       |       |       |       |       |       |
|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------|-------|-------|-------|-------|-------|-------|
| 518.0             | 100.00            | 520.0             | 98.18             | 524.0             | 75.21             | 528.0             | 60.15 | 530.0 | 50.43 | 532.0 | 39.64 | 533.7 | 30.88 |

RELIABILITY SUMMARY FOR SELECTED CONTROL POINTS

| NAME   | TARGET     | MEAN       | *RELIABILITY* | PERIOD VOLUME | PERCENTAGE OF MONTHS                  |       |       |       |       |       |       |       | PERCENTAGE OF YEARS                   |       |       |       |       |       |  |  |
|--------|------------|------------|---------------|---------------|---------------------------------------|-------|-------|-------|-------|-------|-------|-------|---------------------------------------|-------|-------|-------|-------|-------|--|--|
|        | DIVERSION  | SHORTAGE   | (%)           |               | WITH DIVERSIONS EQUALING OR EXCEEDING |       |       |       |       |       |       |       | PERCENTAGE OF TARGET DIVERSION AMOUNT |       |       |       |       |       |  |  |
|        | (AC-FT/YR) | (AC-FT/YR) | (%)           |               | 100%                                  | 95%   | 90%   | 75%   | 50%   | 25%   | 1%    | 100%  | 98%                                   | 95%   | 90%   | 75%   | 50%   | 1%    |  |  |
| PK     | 254800.0   | 8910.30    | 94.87         | 96.50         | 94.9                                  | 94.9  | 95.0  | 95.1  | 95.8  | 97.0  | 99.5  | 85.9  | 85.9                                  | 88.5  | 92.3  | 96.2  | 97.4  | 100.0 |  |  |
| Whit   | 18000.0    | 1515.04    | 91.88         | 91.58         | 91.9                                  | 91.9  | 91.9  | 91.9  | 92.0  | 92.3  | 92.4  | 74.4  | 74.4                                  | 74.4  | 76.9  | 85.9  | 94.9  | 100.0 |  |  |
| WacoL  | 80800.0    | 0.00       | 100.00        | 100.00        | 100.0                                 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0                                 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |  |  |
| WacoG  | 32300.0    | 1957.95    | 96.69         | 93.94         | 96.7                                  | 96.8  | 96.9  | 97.0  | 97.5  | 98.2  | 98.6  | 75.6  | 78.2                                  | 78.2  | 79.5  | 88.5  | 98.7  | 100.0 |  |  |
| High   | 44800.0    | 4095.52    | 95.51         | 90.86         | 95.5                                  | 95.7  | 95.8  | 96.2  | 96.9  | 97.2  | 97.6  | 62.8  | 66.7                                  | 67.9  | 73.1  | 82.1  | 93.6  | 100.0 |  |  |
| Belton | 180260.0   | 7589.74    | 94.34         | 95.79         | 94.3                                  | 94.4  | 94.4  | 94.7  | 95.2  | 96.6  | 98.7  | 84.6  | 84.6                                  | 87.2  | 88.5  | 93.6  | 96.2  | 100.0 |  |  |
| George | 25610.0    | 3438.62    | 83.44         | 86.57         | 83.4                                  | 83.8  | 84.0  | 84.9  | 86.2  | 88.1  | 95.0  | 67.9  | 67.9                                  | 69.2  | 73.1  | 80.8  | 87.2  | 100.0 |  |  |
| Grang  | 42000.0    | 2598.82    | 91.24         | 93.81         | 91.2                                  | 91.5  | 91.7  | 92.3  | 93.5  | 95.9  | 97.9  | 79.5  | 80.8                                  | 82.1  | 85.9  | 89.7  | 94.9  | 100.0 |  |  |
| Camer  | 209600.0   | 33523.84   | 80.24         | 84.01         | 80.2                                  | 81.5  | 82.5  | 84.7  | 91.8  | 97.9  | 99.6  | 15.4  | 17.9                                  | 25.6  | 41.0  | 76.9  | 94.9  | 100.0 |  |  |
| Bryan  | 98900.0    | 4489.08    | 90.71         | 95.46         | 90.7                                  | 90.9  | 91.2  | 95.3  | 99.3  | 99.8  | 99.9  | 48.7  | 52.6                                  | 67.9  | 80.8  | 96.2  | 100.0 | 100.0 |  |  |
| Hemp   | 694700.0   | 35096.32   | 85.58         | 94.95         | 85.6                                  | 87.9  | 90.2  | 94.8  | 98.6  | 99.1  | 99.9  | 33.3  | 44.9                                  | 64.1  | 85.9  | 97.4  | 100.0 | 100.0 |  |  |
| Total  | 1681770.0  | 103215.23  |               | 93.86         |                                       |       |       |       |       |       |       |       |                                       |       |       |       |       |       |  |  |

RELIABILITY SUMMARY FOR SELECTED WATER RIGHTS

| NAME  | TARGET     | MEAN       | *RELIABILITY* | PERIOD VOLUME | PERCENTAGE OF MONTHS                  |       |       |       |       |       |       |       | PERCENTAGE OF YEARS                   |       |       |       |       |       |  |  |
|-------|------------|------------|---------------|---------------|---------------------------------------|-------|-------|-------|-------|-------|-------|-------|---------------------------------------|-------|-------|-------|-------|-------|--|--|
|       | DIVERSION  | SHORTAGE   | (%)           |               | WITH DIVERSIONS EQUALING OR EXCEEDING |       |       |       |       |       |       |       | PERCENTAGE OF TARGET DIVERSION AMOUNT |       |       |       |       |       |  |  |
|       | (AC-FT/YR) | (AC-FT/YR) | (%)           |               | 100%                                  | 95%   | 90%   | 75%   | 50%   | 25%   | 1%    | 100%  | 98%                                   | 95%   | 90%   | 75%   | 50%   |       |  |  |
| WR-6  | 60000.0    | 0.00       | 100.00        | 100.00        | 100.0                                 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0                                 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |  |  |
| WR-1  | 9800.0     | 60.10      | 99.04         | 99.39         | 99.0                                  | 99.0  | 99.1  | 99.1  | 99.3  | 99.5  | 99.5  | 93.6  | 94.9                                  | 94.9  | 96.2  | 100.0 | 100.0 | 100.0 |  |  |
| WR-2  | 245000.0   | 8850.20    | 94.87         | 96.39         | 94.9                                  | 94.9  | 95.0  | 95.1  | 95.8  | 96.9  | 98.9  | 85.9  | 85.9                                  | 88.5  | 92.3  | 96.2  | 97.4  | 100.0 |  |  |
| WR-14 | 11300.0    | 97.07      | 99.36         | 99.14         | 99.4                                  | 99.4  | 99.4  | 99.5  | 99.6  | 99.6  | 99.7  | 94.9  | 94.9                                  | 96.2  | 97.4  | 97.4  | 100.0 | 100.0 |  |  |
| WR-20 | 34500.0    | 254.23     | 99.57         | 99.26         | 99.6                                  | 99.6  | 99.6  | 99.7  | 99.8  | 99.9  | 99.9  | 94.9  | 94.9                                  | 96.2  | 96.2  | 98.7  | 100.0 | 100.0 |  |  |
| WR-22 | 49600.0    | 888.54     | 99.04         | 98.21         | 99.0                                  | 99.0  | 99.1  | 99.3  | 99.6  | 99.7  | 99.7  | 89.7  | 89.7                                  | 91.0  | 92.3  | 96.2  | 100.0 | 100.0 |  |  |
| WR-16 | 32300.0    | 1957.95    | 96.69         | 93.94         | 96.7                                  | 96.8  | 96.9  | 97.0  | 97.5  | 98.2  | 98.6  | 75.6  | 78.2                                  | 78.2  | 79.5  | 88.5  | 98.7  | 100.0 |  |  |
| WR-17 | 44800.0    | 4095.52    | 95.51         | 90.86         | 95.5                                  | 95.7  | 95.8  | 96.2  | 96.9  | 97.2  | 97.6  | 62.8  | 66.7                                  | 67.9  | 73.1  | 82.1  | 93.6  | 100.0 |  |  |
| WR-13 | 18200.0    | 775.86     | 96.79         | 95.74         | 96.8                                  | 96.8  | 96.8  | 97.0  | 97.0  | 97.0  | 97.0  | 75.6  | 75.6                                  | 75.6  | 75.6  | 92.3  | 100.0 | 100.0 |  |  |
| WR-19 | 39000.0    | 1502.53    | 97.22         | 96.15         | 97.2                                  | 97.3  | 97.3  | 97.3  | 97.3  | 97.3  | 97.3  | 76.9  | 76.9                                  | 78.2  | 78.2  | 93.6  | 100.0 | 100.0 |  |  |
| WR-21 | 95600.0    | 4963.05    | 95.83         | 94.81         | 95.8                                  | 95.8  | 95.9  | 96.4  | 96.8  | 97.2  | 97.2  | 71.8  | 71.8                                  | 71.8  | 76.9  | 91.0  | 100.0 | 100.0 |  |  |
| WR-8  | 82760.0    | 2703.77    | 95.30         | 96.73         | 95.3                                  | 95.5  | 95.5  | 95.8  | 96.9  | 97.5  | 98.8  | 85.9  | 85.9                                  | 88.5  | 92.3  | 93.6  | 100.0 | 100.0 |  |  |
| WR-9  | 97500.0    | 4885.96    | 94.34         | 94.99         | 94.3                                  | 94.3  | 94.4  | 94.4  | 94.7  | 94.9  | 95.3  | 84.6  | 84.6                                  | 84.6  | 87.2  | 93.6  | 94.9  | 100.0 |  |  |
| WR-10 | 25610.0    | 3438.62    | 83.44         | 86.57         | 83.4                                  | 83.8  | 84.0  | 84.9  | 86.2  | 88.1  | 95.0  | 67.9  | 67.9                                  | 69.2  | 73.1  | 80.8  | 87.2  | 100.0 |  |  |
| WR-11 | 42000.0    | 2598.82    | 91.24         | 93.81         | 91.2                                  | 91.5  | 91.7  | 92.3  | 93.5  | 95.9  | 97.9  | 79.5  | 80.8                                  | 82.1  | 85.9  | 89.7  | 94.9  | 100.0 |  |  |
| WR-3  | 18000.0    | 1515.04    | 91.88         | 91.58         | 91.9                                  | 91.9  | 91.9  | 91.9  | 92.0  | 92.3  | 92.4  | 74.4  | 74.4                                  | 74.4  | 76.9  | 85.9  | 94.9  | 100.0 |  |  |
| WR-12 | 92100.0    | 29411.93   | 81.73         | 68.07         | 81.7                                  | 82.4  | 83.0  | 84.7  | 87.1  | 91.2  | 94.9  | 16.7  | 17.9                                  | 19.2  | 25.6  | 43.6  | 75.6  | 100.0 |  |  |
| WR-18 | 25400.0    | 2732.32    | 90.71         | 89.24         | 90.7                                  | 90.9  | 90.9  | 91.0  | 91.5  | 91.5  | 91.8  | 48.7  | 50.0                                  | 50.0  | 53.8  | 84.6  | 98.7  | 100.0 |  |  |
| WR-7  | 20800.0    | 0.00       | 100.00        | 100.00        | 100.0                                 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0                                 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |  |  |
| WR-15 | 88000.0    | 3238.98    | 95.83         | 96.32         | 95.8                                  | 95.8  | 95.8  | 96.2  | 96.3  | 96.9  | 97.5  | 87.2  | 87.2                                  | 87.2  | 89.7  | 93.6  | 98.7  | 100.0 |  |  |
| WR-23 | 74500.0    | 20507.71   | 86.65         | 72.47         | 86.6                                  | 86.8  | 86.9  | 87.6  | 88.5  | 89.2  | 90.0  | 34.6  | 35.9                                  | 38.5  | 42.3  | 50.0  | 75.6  | 100.0 |  |  |
| WR-24 | 475000.0   | 8737.01    | 97.76         | 98.16         | 97.8                                  | 97.8  | 97.9  | 98.0  | 98.2  | 98.7  | 99.0  | 89.7  | 89.7                                  | 92.3  | 94.9  | 96.2  | 100.0 | 100.0 |  |  |
| Total | 1681770.0  | 103215.23  |               | 93.86         |                                       |       |       |       |       |       |       |       |                                       |       |       |       |       |       |  |  |

RELIABILITY SUMMARY FOR SELECTED HYDROELECTRIC POWER PROJECTS

| NAME  | ENERGY TARGET | MEAN SHORTAGE | *RELIABILITY* |       | PERCENTAGE OF MONTHS  |      |      |      |      |      |      |      | PERCENTAGE OF YEARS  |      |      |      |      |       |  |  |
|-------|---------------|---------------|---------------|-------|---|------|------|------|------|------|------|------|----------------------|------|------|------|------|-------|--|--|
|       |               |               | PERIOD AMOUNT |       | WITH ENERGY GENERATION EQUALING OR EXCEEDING PERCENTAGE OF TARGET |      |      |      |      |      |      |      | PERCENTAGE OF TARGET |      |      |      |      |       |  |  |
|       |               |               | (%)           | (%)   | 100%  | 95%  | 90%  | 75%  | 50%  | 25%  | 1%   | 100% | 98%                  | 95%  | 90%  | 75%  | 50%  | 1%    |  |  |
| Whit  | 36000.0       | 3525.04       | 84.51         | 90.21 | 84.5  | 85.1 | 85.9 | 87.4 | 90.4 | 93.1 | 97.2 | 59.0 | 62.8                 | 66.7 | 75.6 | 83.3 | 96.2 | 100.0 |  |  |
| Total | 36000.0       | 3525.04       |               | 90.21 |   |      |      |      |      |      |      |      |                      |      |      |      |      |       |  |  |

RELIABILITY SUMMARY FOR SELECTED WATER RIGHT GROUPS

| NAME     | TARGET DIVERSION (AC-FT/YR) | MEAN SHORTAGE (AC-FT/YR) | *RELIABILITY* |        | PERCENTAGE OF MONTHS  |       |       |       |       |       |       |       | PERCENTAGE OF YEARS                   |       |       |       |       |       |  |  |
|----------|-----------------------------|--------------------------|---------------|--------|---|-------|-------|-------|-------|-------|-------|-------|---------------------------------------|-------|-------|-------|-------|-------|--|--|
|          |                             |                          | PERIOD VOLUME |        | WITH DIVERSIONS EQUALING OR EXCEEDING PERCENTAGE OF TARGET DIVERSION AMOUNT |       |       |       |       |       |       |       | PERCENTAGE OF TARGET DIVERSION AMOUNT |       |       |       |       |       |  |  |
|          |                             |                          | (%)           | (%)    | 100%  | 95%   | 90%   | 75%   | 50%   | 25%   | 1%    | 100%  | 98%                                   | 95%   | 90%   | 75%   | 50%   | 1%    |  |  |
| PK       | 254800.0                    | 8910.30                  | 94.87         | 96.50  | 94.9  | 94.9  | 95.0  | 95.1  | 95.8  | 97.0  | 99.5  | 85.9  | 85.9                                  | 88.5  | 92.3  | 96.2  | 97.4  | 100.0 |  |  |
| Whitney  | 18000.0                     | 1515.04                  | 91.88         | 91.58  | 91.9  | 91.9  | 91.9  | 91.9  | 92.0  | 92.3  | 92.4  | 74.4  | 74.4                                  | 74.4  | 76.9  | 85.9  | 94.9  | 100.0 |  |  |
| WacoLake | 80800.0                     | 0.00                     | 100.00        | 100.00 | 100.0   | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0                                 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |  |  |
| Belton   | 180260.0                    | 7589.74                  | 94.34         | 95.79  | 94.3  | 94.4  | 94.4  | 94.7  | 95.2  | 96.6  | 98.7  | 84.6  | 84.6                                  | 87.2  | 88.5  | 93.6  | 96.2  | 100.0 |  |  |
| George   | 25610.0                     | 3438.62                  | 83.44         | 86.57  | 83.4  | 83.8  | 84.0  | 84.9  | 86.2  | 88.1  | 95.0  | 67.9  | 67.9                                  | 69.2  | 73.1  | 80.8  | 87.2  | 100.0 |  |  |
| Granger  | 42000.0                     | 2598.82                  | 91.24         | 93.81  | 91.2  | 91.5  | 91.7  | 92.3  | 93.5  | 95.9  | 97.9  | 79.5  | 80.8                                  | 82.1  | 85.9  | 89.7  | 94.9  | 100.0 |  |  |
| Cameron  | 121600.0                    | 30284.86                 | 81.73         | 75.09  | 81.7  | 82.7  | 83.3  | 85.3  | 89.9  | 93.9  | 99.6  | 16.7  | 17.9                                  | 24.4  | 25.6  | 56.4  | 88.5  | 100.0 |  |  |
| WacoGage | 32300.0                     | 1957.95                  | 96.69         | 93.94  | 96.7  | 96.8  | 96.9  | 97.0  | 97.5  | 98.2  | 98.6  | 75.6  | 78.2                                  | 78.2  | 79.5  | 88.5  | 98.7  | 100.0 |  |  |
| Highbank | 44800.0                     | 4095.52                  | 95.51         | 90.86  | 95.5  | 95.7  | 95.8  | 96.2  | 96.9  | 97.2  | 97.6  | 62.8  | 66.7                                  | 67.9  | 73.1  | 82.1  | 93.6  | 100.0 |  |  |
| Bryan    | 98900.0                     | 4489.08                  | 90.71         | 95.46  | 90.7  | 90.9  | 91.2  | 95.3  | 99.3  | 99.8  | 99.9  | 48.7  | 52.6                                  | 67.9  | 80.8  | 96.2  | 100.0 | 100.0 |  |  |
| Hemp     | 219700.0                    | 26359.30                 | 86.65         | 88.00  | 86.6  | 87.0  | 87.9  | 90.7  | 96.2  | 99.0  | 99.7  | 34.6  | 39.7                                  | 44.9  | 55.1  | 79.5  | 97.4  | 100.0 |  |  |
| Total    | 1118770.0                   | 91239.24                 |               | 91.84  |   |       |       |       |       |       |       |       |                                       |       |       |       |       |       |  |  |

ANNUAL SUMMARY TABLE FOR CONTROL POINT Belton

| YEAR | NATURALIZED SIREAMFLOW (AC-FT) | REGULATED SIREAMFLOW (AC-FT) | UNAPPROPRIATED SIREAMFLOW (AC-FT) | RETURN FLOW (AC-FT) | SIREAMFLOW DEPLETION (AC-FT) | EOP STORAGE (AC-FT) | NET EVAPORATION (AC-FT) | ACTUAL DIVERSION (AC-FT) | DIVERSION SHORTAGE (AC-FT) |
|------|--------------------------------|------------------------------|-----------------------------------|---------------------|------------------------------|---------------------|-------------------------|--------------------------|----------------------------|
| 1940 | 597161.0                       | 390975.7                     | 370275.1                          | 0.0                 | 226885.9                     | 457600.0            | 25925.4                 | 180260.0                 | 0.0                        |
| 1941 | 1531522.0                      | 1328523.4                    | 1305181.6                         | 0.0                 | 202998.6                     | 457600.0            | 22738.6                 | 180260.0                 | 0.0                        |
| 1942 | 1235396.0                      | 1029231.1                    | 997437.2                          | 0.0                 | 237958.7                     | 457600.0            | 25904.9                 | 180260.0                 | 0.0                        |
| 1943 | 149279.0                       | 66064.1                      | 33120.6                           | 0.0                 | 116158.4                     | 319224.8            | 41330.1                 | 180260.0                 | 0.0                        |
| 1944 | 1082585.0                      | 825832.2                     | 766139.2                          | 0.0                 | 316445.8                     | 369775.1            | 25942.4                 | 180260.0                 | 0.0                        |
| 1945 | 1118878.0                      | 820711.1                     | 819209.6                          | 0.0                 | 298166.9                     | 457600.0            | 30082.0                 | 180260.0                 | 0.0                        |
| 1946 | 630915.0                       | 456876.2                     | 437210.5                          | 0.0                 | 193704.6                     | 420078.6            | 31300.2                 | 180260.0                 | 0.0                        |
| 1947 | 315570.0                       | 192240.8                     | 174226.8                          | 0.0                 | 141343.2                     | 320931.6            | 42216.3                 | 180260.0                 | 0.0                        |
| 1948 | 113104.0                       | 70965.4                      | 0.0                               | 0.0                 | 111484.0                     | 146733.6            | 36076.5                 | 180260.0                 | 0.0                        |
| 1949 | 315257.0                       | 38884.4                      | 0.0                               | 0.0                 | 315257.0                     | 217766.2            | 25080.1                 | 180260.0                 | 0.0                        |
| 1950 | 156271.0                       | 24942.7                      | 0.0                               | 0.0                 | 156271.0                     | 142338.9            | 26495.6                 | 180260.0                 | 0.0                        |
| 1951 | 53954.0                        | 39817.2                      | 0.0                               | 0.0                 | 52938.0                      | 0.0                 | 12098.4                 | 144377.2                 | 35882.8                    |
| 1952 | 138526.0                       | 39096.7                      | 0.0                               | 0.0                 | 137638.0                     | 6549.8              | 2605.6                  | 90273.9                  | 89986.1                    |
| 1953 | 249849.0                       | 14847.3                      | 0.0                               | 0.0                 | 246608.0                     | 61162.2             | 7807.1                  | 172582.2                 | 7677.8                     |
| 1954 | 25834.0                        | 179.6                        | 0.0                               | 0.0                 | 25654.3                      | 0.0                 | 2473.1                  | 84343.4                  | 95916.6                    |
| 1955 | 184671.0                       | 24682.2                      | 0.0                               | 0.0                 | 184671.0                     | 0.0                 | 4488.2                  | 155500.6                 | 24759.4                    |
| 1956 | 156828.0                       | 39492.6                      | 0.0                               | 0.0                 | 149760.4                     | 0.0                 | 8647.7                  | 108687.7                 | 71572.3                    |
| 1957 | 1379758.0                      | 752499.3                     | 694103.4                          | 0.0                 | 667323.4                     | 457600.0            | 8710.2                  | 160948.4                 | 19311.6                    |
| 1958 | 159684.0                       | 428972.5                     | 419366.2                          | 0.0                 | 100317.8                     | 348849.0            | 19202.5                 | 180260.0                 | 0.0                        |
| 1959 | 608820.0                       | 311777.4                     | 311777.4                          | 0.0                 | 297042.6                     | 457600.0            | 8031.6                  | 180260.0                 | 0.0                        |
| 1960 | 522063.0                       | 324499.7                     | 300781.1                          | 0.0                 | 221281.9                     | 457600.0            | 17303.3                 | 180260.0                 | 0.0                        |
| 1961 | 1001937.0                      | 804940.9                     | 769386.0                          | 0.0                 | 232551.0                     | 457600.0            | 16736.0                 | 180260.0                 | 0.0                        |
| 1962 | 189096.0                       | 11891.3                      | 2285.0                            | 0.0                 | 186811.0                     | 424209.5            | 30335.2                 | 180260.0                 | 0.0                        |
| 1963 | 103856.0                       | 101389.5                     | 0.0                               | 0.0                 | 97139.7                      | 211531.4            | 34884.7                 | 180260.0                 | 0.0                        |
| 1964 | 425909.0                       | 150969.3                     | 0.0                               | 0.0                 | 405730.0                     | 300168.4            | 6042.6                  | 180260.0                 | 0.0                        |
| 1965 | 1095355.0                      | 751436.9                     | 682781.0                          | 0.0                 | 399234.2                     | 457600.0            | 6226.6                  | 180260.0                 | 0.0                        |
| 1966 | 465427.0                       | 287756.9                     | 224694.8                          | 0.0                 | 240732.2                     | 429433.0            | 25577.0                 | 180260.0                 | 0.0                        |

|      |           |           |           |     |          |          |         |          |          |
|------|-----------|-----------|-----------|-----|----------|----------|---------|----------|----------|
| 1967 | 108517.0  | 27543.0   | 0.0       | 0.0 | 107456.0 | 304852.4 | 25294.6 | 180260.0 | 0.0      |
| 1968 | 1001569.0 | 774897.6  | 732103.8  | 0.0 | 269465.2 | 350867.2 | 396.6   | 180260.0 | 0.0      |
| 1969 | 343004.0  | 85892.9   | 85892.9   | 0.0 | 257111.1 | 403694.8 | 24023.5 | 180260.0 | 0.0      |
| 1970 | 558768.0  | 420453.2  | 362683.1  | 0.0 | 196085.0 | 344011.2 | 17738.5 | 180260.0 | 0.0      |
| 1971 | 354499.0  | 109725.0  | 0.0       | 0.0 | 354499.0 | 393752.6 | 14772.6 | 180260.0 | 0.0      |
| 1972 | 145254.0  | 42751.7   | 0.0       | 0.0 | 138972.2 | 295945.1 | 20049.7 | 180260.0 | 0.0      |
| 1973 | 341533.0  | 9606.3    | 0.0       | 0.0 | 341533.0 | 438244.4 | 9367.4  | 180260.0 | 0.0      |
| 1974 | 456180.0  | 243231.6  | 175402.1  | 0.0 | 280778.0 | 457600.0 | 13332.8 | 180260.0 | 0.0      |
| 1975 | 532990.0  | 417049.0  | 417049.0  | 0.0 | 115941.0 | 379933.2 | 13347.8 | 180260.0 | 0.0      |
| 1976 | 314128.0  | 52440.7   | 52440.7   | 0.0 | 261687.3 | 457600.0 | 3760.6  | 180260.0 | 0.0      |
| 1977 | 617618.0  | 543320.2  | 516959.8  | 0.0 | 100658.2 | 324286.1 | 27351.7 | 180260.0 | 0.0      |
| 1978 | 33262.0   | 121519.9  | 0.0       | 0.0 | 31483.0  | 42896.6  | 12871.6 | 180260.0 | 0.0      |
| 1979 | 435436.0  | 0.0       | 0.0       | 0.0 | 435436.0 | 295151.7 | 2920.8  | 180260.0 | 0.0      |
| 1980 | 203807.0  | 66951.2   | 0.0       | 0.0 | 201630.0 | 227762.7 | 23984.8 | 180260.0 | 0.0      |
| 1981 | 244551.0  | 0.0       | 0.0       | 0.0 | 244551.0 | 288971.8 | 3081.9  | 180260.0 | 0.0      |
| 1982 | 196030.0  | 9062.6    | 0.0       | 0.0 | 196030.0 | 275985.5 | 19693.7 | 180260.0 | 0.0      |
| 1983 | 93979.0   | 18748.1   | 0.0       | 0.0 | 93979.0  | 161219.4 | 9737.1  | 180260.0 | 0.0      |
| 1984 | 105513.0  | 54962.8   | 0.0       | 0.0 | 101600.9 | 32647.7  | 7717.3  | 171404.6 | 8855.4   |
| 1985 | 331912.0  | 3107.0    | 0.0       | 0.0 | 328805.0 | 175561.9 | 5630.8  | 180260.0 | 0.0      |
| 1986 | 717091.0  | 255643.1  | 175988.1  | 0.0 | 536281.6 | 457600.0 | -850.2  | 180260.0 | 0.0      |
| 1987 | 659678.0  | 514933.4  | 514933.4  | 0.0 | 144744.6 | 400259.4 | 21825.2 | 180260.0 | 0.0      |
| 1988 | 136411.0  | 184991.1  | 0.0       | 0.0 | 136167.2 | 147832.2 | 23587.2 | 180260.0 | 0.0      |
| 1989 | 375489.0  | 36761.3   | 0.0       | 0.0 | 375489.0 | 288484.0 | 17815.8 | 180260.0 | 0.0      |
| 1990 | 798613.0  | 527909.3  | 448864.6  | 0.0 | 339906.5 | 361680.5 | 17247.2 | 180260.0 | 0.0      |
| 1991 | 857139.0  | 581302.2  | 571695.9  | 0.0 | 285443.0 | 457600.0 | -342.7  | 180260.0 | 0.0      |
| 1992 | 1672776.0 | 1492543.0 | 1492543.0 | 0.0 | 180232.9 | 457600.0 | -27.1   | 180260.0 | 0.0      |
| 1993 | 570773.0  | 412751.8  | 410277.1  | 0.0 | 160495.9 | 407368.5 | 27992.7 | 180260.0 | 0.0      |
| 1994 | 450862.0  | 260808.2  | 179848.8  | 0.0 | 271013.2 | 398236.7 | 18925.6 | 180260.0 | 0.0      |
| 1995 | 750420.0  | 509828.1  | 435982.1  | 0.0 | 290500.6 | 442870.1 | 15698.5 | 180260.0 | 0.0      |
| 1996 | 320005.0  | 123335.1  | 0.0       | 0.0 | 320005.0 | 437066.2 | 22213.9 | 180260.0 | 0.0      |
| 1997 | 1633351.0 | 1424163.0 | 1422684.1 | 0.0 | 210667.0 | 457600.0 | 8394.3  | 180260.0 | 0.0      |
| 1998 | 605704.0  | 503141.6  | 429372.2  | 0.0 | 176331.8 | 362466.6 | 17435.8 | 180260.0 | 0.0      |
| 1999 | 120400.0  | 154394.4  | 0.0       | 0.0 | 120400.0 | 121182.7 | 27029.7 | 180260.0 | 0.0      |
| 2000 | 195989.0  | 66285.7   | 0.0       | 0.0 | 195354.0 | 85821.5  | 7091.2  | 157973.2 | 22286.8  |
| 2001 | 551003.0  | 37934.1   | 0.0       | 0.0 | 551003.0 | 403503.5 | 15127.0 | 180260.0 | 0.0      |
| 2002 | 313435.0  | 68313.9   | 58798.2   | 0.0 | 254636.8 | 450341.5 | 18023.1 | 180260.0 | 0.0      |
| 2003 | 288127.0  | 194310.8  | 80409.9   | 0.0 | 206754.2 | 339990.5 | 23907.2 | 180260.0 | 0.0      |
| 2004 | 973196.0  | 676939.8  | 676939.8  | 0.0 | 296256.2 | 457600.0 | -1613.1 | 180260.0 | 0.0      |
| 2005 | 600672.0  | 464112.8  | 396283.2  | 0.0 | 204388.8 | 382857.2 | 31042.0 | 180260.0 | 0.0      |
| 2006 | 58264.0   | 80975.5   | 0.0       | 0.0 | 58062.0  | 153206.4 | 26679.5 | 180260.0 | 0.0      |
| 2007 | 1748425.0 | 1272554.4 | 1272554.4 | 0.0 | 475870.6 | 448877.3 | -60.5   | 180260.0 | 0.0      |
| 2008 | 185857.0  | 151425.4  | 64313.5   | 0.0 | 121543.5 | 269446.0 | 33603.0 | 180260.0 | 0.0      |
| 2009 | 368535.0  | 102655.7  | 0.0       | 0.0 | 350463.0 | 343066.6 | 11998.6 | 180260.0 | 0.0      |
| 2010 | 718576.0  | 444379.2  | 434772.9  | 0.0 | 283803.2 | 414627.9 | 22375.5 | 180260.0 | 0.0      |
| 2011 | 68587.0   | 209613.0  | 0.0       | 0.0 | 61597.0  | 57682.3  | 35659.6 | 180260.0 | 0.0      |
| 2012 | 343314.0  | 208438.8  | 0.0       | 0.0 | 343314.0 | 0.0      | 12297.5 | 180260.0 | 0.0      |
| 2013 | 113009.0  | 18450.2   | 0.0       | 0.0 | 96695.0  | 11887.4  | -31.4   | 82702.8  | 97557.2  |
| 2014 | 64896.0   | 108.0     | 0.0       | 0.0 | 64788.0  | 0.0      | 196.3   | 76479.0  | 103781.0 |
| 2015 | 1102787.0 | 467546.7  | 423855.3  | 0.0 | 678931.6 | 457600.0 | 11792.9 | 165847.4 | 14412.6  |
| 2016 | 701044.0  | 542064.8  | 522069.4  | 0.0 | 169038.7 | 419869.3 | 16450.0 | 180260.0 | 0.0      |
| 2017 | 158366.0  | 10059.4   | 0.0       | 0.0 | 158366.0 | 368148.9 | 19766.9 | 180260.0 | 0.0      |
| MEAN | 500113.4  | 311915.8  | 264906.3  | 0.0 | 232517.3 | 304493.7 | 16674.2 | 172670.2 | 7589.7   |

## APPENDIX C SIM INPUT RECORDS

All of the *SIM* and *TABLES* input record types are explained in detail in Chapters 3 and 5 of the *Users Manual* from the perspective of text files. A select group of these records are included in Appendices C and D, respectively, of this *Fundamentals Manual*. For some of the input records, some of the fields that are outside the scope of this manual are omitted in the following abbreviated presentation. DSS hydrology input file records are described in Chapter 6 of the *Users Manual*. The system for organizing *SIM* input datasets is based on file types, record types, and fields in each record. *SIM* input record types are labeled by a two-character identifier that is placed at the beginning of each record. *TABLES* input record types are labeled by four-character identifiers.

### Input Record Format

The sets of required and optional records in the *SIM* input files contain information organizing the simulation and representing the river/reservoir/use system being modeled. Input files are prepared using Microsoft WordPad, Notepad++, or another editor in unformatted text file format. Microsoft programs use the default filename extension txt for unformatted text files. The extension txt is changed to the filename extensions used by WRAP.

Only those records and those fields of a particular record are used as needed for the particular modeling application. Fields not needed are simply left blank. For fields with numeric entries, leaving the field blank is equivalent to entering a zero. The 2-character record identifiers are required. Records with the first two characters blank are not allowed in a data set; this includes totally blank records. An error message is generated by a blank record identifier.

Tabs, indents, and other formatting characters, whether hidden or visible, cannot be read by the WRAP programs. Blank spaces must be entered with the space bar on the keyboard. Commas are not allowed within either numbers or alphanumeric entries.

Variables with integer specifications (I format) must be right-justified in the appropriate field with no decimal. Trailing blanks are read as zeros. Real number variables (F format) must be either right justified or include the decimal. Input values for character variables (alphanumeric (A) specification) must be contained in the appropriate field, but left or right justification is not required. Format specifications found in the 4th column of the record description tables of Appendices C and D are illustrated by the following examples.

- F8.0 – Real number in field of 8 characters with any number of digits to the right of the decimal. Either include the decimal or right justify the number.
- 5F8.0– Five real numbers, each having a F8.0 specification.
- I8 – Integer number with maximum of 8 digits. Right justified, no decimal.
- 3I8 – Three integers with each right justified in field of 8 characters.
- A2 – Alphanumeric label (character variable) in a field that is 2 characters wide.
- 2x – Two spaces are skipped. Fields with the spacing descriptor x are not read.
- 2x,A6 – Two blank spaces followed by an alphanumeric variable with maximum of six characters.

### Types of *SIM* Input Records

Title *T1*, *T2*, and *T3* Records.- The DAT input file begins with optional *T1*, *T2* and *T3* records. The titles or headings provided on the title records are reproduced at the beginning of the main output file created by *SIM* and on the cover page created by *TABLES*. The title records may contain any descriptive information. Title records serve no other purpose than optional headings. (page 75)

Comment *\*\** Record.- Comment records beginning with a double asterisk may be entered almost anywhere within the input data. The comments are notes written by the model-user for information only and are not read (other than the *\*\** identifier) or used in any way by the program. Notes are very useful in documenting a dataset. The *\*\** is also routinely used to deactivate records without actually deleting them. Various records may be activated or deactivated in alternative simulation runs by adding or deleting the *\*\**. (page 75)

Job Control Data *JD* and Job Options *JO* Records.- General information controlling the simulation includes the hydrologic period-of-analysis and parameters for several *SIM* computational features including options associated with negative incremental flows, system reservoir release decisions, beginning-ending storage, priority system, input and output, and input error checking. (pages 76-77)

Firm Yield and Yield-Reliability Table *FY* Record.- The *FY* record activates an iterative simulation routine for creating a YRO output file yield-reliability table that includes the firm yield. (page 78)

DSS File Options *OF* record.- Specifications for *SIM* input and out DSS files. (page 79)

Output Specification *CO*, *RO*, *WO*, *GO* Records.- *SIM* output records are for either a control point, water right, or reservoir/hydropower project. The *JD* record and *CO*, *WO*, *GO*, and *RO* records control selection of control points, water rights, groups of water rights, and reservoir/hydropower projects to include in the output. Simulation results may be extremely voluminous. The output selection options allow the size of the output file to be controlled. (pages 81-82)

Use Coefficient *UC* Record.- Sets of 12 factors associated with water use types are used to distribute annual diversion, energy generation, or instream flow requirements over the 12 months of the year. The types of water use may be associated with particular uses, such as irrigation, municipal, and industrial water supply, or hydroelectric energy, or otherwise represent different distributions of annual requirements over the year. *SIM* sums the 12 factors and divides each by the total to transform them to decimal fractions summing to unity. (page 83)

Control Point *CP* Record.- A *CP* record is required for each control point. This record contains the six-character alpha-numeric identifier of the control point, the identifier of the next control point located immediately downstream, information related to sources of naturalized stream flow and net evaporation-precipitation rate data for the control point, and the channel loss factor for the river reach below the control point. The location of all system components is based on entering control point identifiers on various records that reference back to the spatial configuration defined by the control points and next downstream control points listed on the *CP* records. (pages 84-85)

Water Right *WR* Record.- In *SIM*, a water right is defined as a *WR* or *IF* record with associated attached records with supplemental information. Although an actual water right permit may be represented by a set of several *WR* records, in *WRAP* nomenclature, each *WR* or *IF* record is a water right and each right has one *WR* record or *IF* record. The *WR* record contains the water right



identification, control point location, annual permitted diversion or energy generation amount, use type (connection to *UC* records) for distributing the annual target over 12 months, priority number, type of right (connection to rules for meeting targets), drought index identifier (connection to *DI* record), and return flow specifications. *WS*, *HP*, and other records attached to a *WR* or *IF* record provide optional additional information regarding the right. (pages 86-87)

*Instream Flow IF Record.*- The *IF* record is similar to the *WR* record, except an instream flow target is entered rather than a diversion target, and several of the *WR* record fields are not applicable. The minimum instream flow target restricts the stream flow available to junior rights. Any number of *IF* records may be assigned to a control point, changing the flow target and priority. (page 88)

*Water Right Reservoir Storage WS Record.*- Reservoir data on a *WS* record include active and inactive storage capacity and storage-area information. *WS* records are associated with specific water right *WR* records. One primary and multiple secondary reservoirs can be associated with a water right, with a *WS* record for each reservoir following the *WR* record. The right refills storage in the one primary reservoir as well as using it to supply water. Secondary reservoirs associated with a right meet water use requirements but are not refilled by that particular water right. (pages 89-90)

*Hydroelectric Power HP Record.*- Hydroelectric power parameters include tailwater elevation information, efficiency factor, turbine capacity, and limits constraining energy generation. *HP* record hydropower parameters are associated with the reservoir described by a particular *WS* record and water right *WR* record. (page 91)

*Storage SV versus Area SA Records.*- A pair of *SV* and *SA* records provides a table of storage volume versus surface area for a reservoir. Each volume on the *SV* record corresponds to a surface area on the *SA* record. The *SV/SA* records represent one of two optional methods for providing reservoir storage versus area relationships. The alternative option involves use of a regression equation with coefficients entered on a *WS* record. Reservoir storage-area relationships are used within *SIM* for computing net evaporation-precipitation amounts. For a simulated storage volume, the reservoir surface area is determined by linear interpolation of the *SV/SA* table. (page 92)

*Storage PV versus Elevation PE Records.*- Each reservoir associated with a hydroelectric power right requires a pair of *PV* and *PE* records defining the volume-elevation relationship. Storage volumes are entered on the *PV* record, and the corresponding water surface elevations are entered on the *PE* record. The storage-elevation relationship is used for computing the head term in the power equation. For a simulated storage volume, the reservoir water surface elevation is determined by linear interpolation of the *PV/PE* table. (page 92)

*End-of-Data ED Record.*- The *ED* record is placed at the end of the series of records discussed above in the *DAT* input file, has no input fields, and simply indicates the end of the data. (page 75)

*Inflow IN and Evaporation EV Records.*- Naturalized stream flow sequences for the hydrologic period-of-analysis for each control point are either entered on inflow *IN* records or computed from naturalized flows entered on *IN* records at one or more other control points. Reservoir net evaporation-precipitation depths for each control point with a reservoir are entered on *EV* records in the same format as *IN* records. *IN* and *EV* records are stored as binary *DSS* records in a *DSS* file or in alternative file organization formats in *FLO* and *EVA* files. *DSS* records are discussed in Chapter 5 of the *WRAP Users Manual*. (pages 93-94)

### Sequential Order of Input Records

One each of five types of *SIM* input records (*JD*, *ED*, *CP*, *WR* or *IF*, and *IN*) are required. The other records are optional. *IN* and *EV* records are contained in the FLO and EVA files or DSS file. All other *SIM* input records included in this *Fundamentals Manual* are stored in the DAT file.

#### Basic Input File (filename root.DAT)

|          |                                  |  |
|----------|----------------------------------|--|
| T1,T2,T3 | Titles or Headings               | Optional T1 is first record. Optional T2 and T3 records follow.  |
| **       | Comments                         | Comments may be inserted throughout.   |
| JD       | Job Control Data                 | JD record is required. JO, OF, CO, RO, WO, GO records are optional.  |
| JO       | Job Options                      | They are placed in any order between the T1/T2/T3 and UC records.  |
| FY       | Firm Yield                       |  |
| OF       | Optional DSS and SOU Files       |  |
| CO       | Control Point Output             | CO, RO, WO, GO records are optional and are inserted in any order between the T1/T2/T3 records and the UC records.   |
| RO       | Reservoir Output                 |  |
| WO       | Water Rights Output              | All CO records grouped together; WO records together, etc.   |
| GO       | Groups of Water Rights to Output |  |
| UC       | Use Distribution                 | Set of all UC records precede CP records.  |
| CP       | Control Point                    | All CP records grouped together in any order; at least one required.   |
| IF       | Instream Flow                    | IF and WR records are grouped together in any order, followed by a set of optional SO, WS/HP/OR, ML, BU, TO, LO, CV, FS, TS, and PX records which are described in the <i>Users Manual</i> . |
| WR       | Water Right                      |  |
| WS       | Reservoir Storage                | WS records are included in set of records that follow a WR or IF record.   |
| HP       | Hydroelectric Power              | HP and OR records follow a WS record.  |
| SV       | Storage Volume                   | Set of all SV-SA tables grouped together in any order, with each SA record immediately following corresponding SV record.  |
| SA       | Surface Area                     |  |
| PV       | Storage Volume                   | Set of all PV-PE tables grouped together in any order, with each PE record immediately following corresponding PV record.  |
| PE       | Surface Elevation                |  |
| ED       | End of Data                      | Last record in DAT file.   |

#### Stream Flow (root.FLO) File or Hydrology DSS (rootHYD.DSS) File

|    |         |  |
|----|---------|--|
| IN | Inflows | Parameter INEV in JO record field 2 provides options for storing and organizing IN records and EV records. |
|----|---------|--|

#### Evaporation-Precipitation (root.EVA) File or Hydrology DSS (rootHYD.DSS) File

|    |             |   |
|----|-------------|---|
| EV | Evaporation | EV records in the EVA file are organized the same as the FLO file IN records. |
|----|-------------|---|

**T1, T2, and T3 Records – Titles or Headings**

| field | columns | variable | format | value    | description       |
|-------|---------|----------|--------|----------|-------------------|
| 1     | 1-2     | CD       | A2     | T1,T2,T3 | Record identifier |
| 2     | 3-78    | TITLE    | A78    | AN       | Title or heading  |

Optional title records, if used, are placed at the beginning of the *SIM* DAT file preceded only by comment **\*\*** records. The headings provided by the one to three title records are printed at the beginning of the *SIM* output file and on the *TABLES* cover page.

**\*\* Record – Comments**

| field | columns    | Variable | format | value | description                                |
|-------|------------|----------|--------|-------|--|
| 1     | 1-2        | CD       | A2     | **    | Record identifier                          |
| 2     | 3-no limit |          |        | AN    | Comments which are not read by the program |

A record beginning with two asterisks **\*\*** is not read by the program, except for the **\*\*** identifier. Comment **\*\*** records are used to insert notes in the input dataset or to temporarily deactivate selected records.

**ED Record – End of Data**

| field | columns | variable | format | value | description       |
|-------|---------|----------|--------|-------|-------------------|
| 1     | 1-2     | CD       | A2     | ED    | Record identifier |

The *ED* record ends the DAT file.

**Explanation of Table Columns**

- field      The first column of the tables refers to the field of the input record.
- columns    The columns or characters of the input record assigned to the field.
- variable    The program variable for which a value is entered in the field.
- format      The type and format of the variable is either integer (I), real (F), or character (A).
- value       Possible values of the variable are specified with + referring to a positive number, – referring to a negative number, and AN referring to an alphanumeric identifier.
- description A brief description of the variable is provided in the last column of the tables.

## JD Record – Simulation Job Control Data

| field  | columns   | variable | format | value               | description   |
|--|---|----------|--------|---------------------|---|
| 1  | 1-2   | CD       | A2     | JD                  | Record identifier   |
| 2  | 3-8   | NYRS     | I6     | +                   | Number of years in the simulation period-of-analysis.   |
| 3  | 9-16  | YRST     | I8     | +                   | First year of simulation. All <i>IN</i> and <i>EV</i> records before year YRST will be skipped.                           |
| <u>Level of Error Checks and Traces</u>              |   |          |        |                     |   |
| 4  | 24  | ICHECK   | I8     | blank,0             | Normal trace, reduced error, and no warning checks.   |
|  |   |          |        | 1                   | Normal trace and complete error and warning checks.   |
|  |   |          |        | 2-12                | Additional ICHECK options.  |
| <u>Simulation Results Output</u>                     |   |          |        |                     |   |
| 5  | 25-32   | OUTCP    | I8     | blank,0             | Control point output is specified only by <i>CO</i> records.  |
|  |   |          |        | 1                   | Control point data is output for all control points.  |
|  |   |          |        | 2                   | Control point data is output only for cps with <i>IN</i> records plus those cps listed on <i>CO</i> records.              |
|  |   |          |        | 3                   | Artificial control points explained in <i>Users Manual</i> .  |
|  |   |          |        | 4                   | All control points are included in the output files.  |
| ≥5   | Control point output is limited to first CPOUT control points plus those cps listed on <i>CO</i> records.               |          |        |                     |   |
| 6  | 33-40   | OUTWR    | I8     | blank,0             | WR output is specified only by <i>WO</i> and <i>GO</i> records.   |
|  |   |          |        | 1                   | Water rights data is output for all <i>WR</i> and <i>IF</i> record rights except hydropower rights and artificial rights. |
|  |   |          |        | 2                   | All <i>WR</i> and <i>IF</i> record rights with no exceptions.   |
|  |   |          |        | 3                   | Only non-hydropower <i>WR</i> record rights are output.   |
|  |   |          |        | 4                   | Only <i>IF</i> record instream flow rights.   |
|  |   |          |        | 5                   | Only hydroelectric power rights are output.   |
|  |   |          |        | 6                   | Only artificial water rights are output   |
| ≥7   | Water right output is limited to first OUTWR rights in input file plus those listed on <i>WO</i> and <i>GO</i> records. |          |        |                     |   |
| 7  | 44  | SOUF     | I4     | blank,1,2           | SOU file described in <i>Users Manual</i> is seldom used.   |
| 8  | 48  | OUTFILE  | I4     | blank, 2            | Binary file format option is seldom if ever used.   |
| <u>Negative Incremental Naturalized Flow Options</u> |   |          |        |                     |   |
| 9  | 56  | ADJINC   | I8     | blank,0,6           | Option 6 defined in <i>Reference Manual</i> is the default.   |
|  |   |          |        | 1,2,3,-3,4,-4,5,7,8 | Options described in <i>Reference Manual</i> Chapter 3.   |

JD record fields 10, 11, 12, and 13 activating other optional features are described in the *Users Manual*.

### Explanation of JD Record Fields

JD record fields 9-12 described in the *Users Manual* are omitted here. The omitted fields either have defaults or control optional features. Fields 1, 2, and 3 (*CD*, *NYRS*, *YRST*) are the only absolutely required entries. All other fields are left blank unless the options activated by the field are needed.

**Fields 2 and 3:** The hydrologic period-of-analysis is specified in JD record fields 2 and 3.

**Field 4:** Parameter ICHECK in *JD* record field 4 controls the level of error checks. Option 1 activating all error and warning message checks should normally be selected unless specific needs arise for other options. Error and warning messages are written to the MSS file. Program execution terminates with error messages but continues with warning messages.

**Fields 5 and 6:** Output selection is controlled by *JD* fields 5 and 6 and the *CO*, *RO*, *WO*, and *GO* records. Simulation results are included in the output file for all control points and all water rights with entries of 1 in *JD* fields 5 and 6.

**Fields 7:** The OUT file can optionally be created in binary machine language read only by *TABLES* rather than the default text file. The standard option 1 text file is recommended.

**Field 8:** Negative incremental refers to the naturalized flow in the particular month at a control point being less than naturalized flow at upstream control points. Options for addressing this situation are described in the *Reference Manual*. Option 4 or 6 is recommended in most cases.

## JO Record – Simulation Job Options

| field                                    | columns | variable | format | value  | description  |
|--|---------|----------|--------|--|--|
| 1  | 1-2     | CD       | A2     | JO   | Record identifier  |
| <i>Organization of IN and EV Records</i> |         |          |        |  |  |
| 2  | 8       | INEV     | I6     | blank,0,1<br>-1<br>2<br>-2<br>3<br>4<br>5<br>6 | Grouped by years in FLO and EVA files.<br>Grouped by years in FLO file. No EVA file.<br>Grouped by control points in FLO and EVA files.<br>Grouped by control points in FLO file. No EVA file.<br>Grouped by years in DAT file.<br>Grouped by control points in DAT file.<br>Grouped by years in HYD file in HYD file format.<br>HEC-DSS hydrology input file. |

The 16 other optional *JO* record fields are described in the *Users Manual*.

## Sequencing of JD, JO, FY, OF, CO, RO, WO, and GO records in the DAT File

The optional *T1*, *T2*, and/or *T3* records, if used, must be placed at the beginning of the DAT file. *SIM* reads the *JD*, *JO*, *FY*, *OF*, *CO*, *RO*, *WO*, and *GO* records as the section of the DAT file that follows the *T1/T2/T3* records (or beginning of file if no title records) and precedes the *UC* records. These records must all be inserted before the *UC* records but can otherwise be in any order, except multiple *CO*, *RO*, *WO*, and *GO* records should be grouped together. For example, all *CO* records must be grouped together, and all *RO* records must be grouped together. All of these records are optional except the required *JD* record.

## *SIM*

### FY Record – Yield-Reliability Table in YRO Output File

| field | columns | variable | format | value          | description   |
|-------|---------|----------|--------|----------------|---|
| 1     | 1-2     | CD       | A2     | FY             | Record identifier   |
| 2     | 3-8     | FYIN(1)  | F6.0   | +<br>blank,0   | Fraction (0.0-1.0) of monthly target that must be met. Applied as specified by FYC(1) in field 10.<br>Default = 1.0<br><br><u>Specification of Increments for Iterative Algorithm</u> |
| 3     | 9-16    | FYIN(2)  | F8.0   | +              | Initial value for the annual target amount. (Must be greater than zero.)  |
| 4     | 10-24   | FYIN(3)  | F8.0   | +              | Incremental decrease for first level of decreases for iterative simulations. (Must be greater than zero.)   |
| 5     | 25-32   | FYIN(4)  | F8.0   | +<br>blank,0   | Incremental decrease for second level of decreases. Optional second level is not used.  |
| 6     | 33-40   | FYIN(5)  | F8.0   | +<br>blank,0   | Incremental decrease for third level of decreases. Optional third and fourth levels are not used.<br><br><u>Water Right or Water Right Group</u>                                      |
| 7     | 41-56   | FYWRID   | A16    | AN             | Water right identifier for <i>FY</i> record rights.   |
| 8     | 57-64   | FYGROUP  | A8     | AN             | Water right group identifier for <i>FY</i> record rights.   |
| 9     | 68      | MFY      | I4     | blank,0,1<br>2 | Proportional to amounts in <i>WR</i> record field 3.<br>Based on priorities in <i>WR</i> record field 5.  |

Fields 10, 11, 12, 13, and 14 options activate safe yield criteria explained in the *Users Manual*.

The *FY* record activates the yield-reliability analysis described in Chapter 6 of the *Reference Manual* and on pages 36-37 of this *Fundamentals Manual*. The *FY* record is inserted any place between the *T1/T2/T3* records and *UC* records in the DAT file. The resulting yield-reliability table is recorded in an YRO file which is automatically created with the *FY* record.

The firm yield is the maximum value of a water supply diversion or hydroelectric energy target that does not incur a shortage in any month of a hydrologic period-of-analysis simulation. An automated repetitive procedure to develop a yield versus reliability table is controlled with the firm yield *FY* record. The firm yield is the last entry in the resulting *SIM* yield-reliability table, assuming a non-zero firm yield is possible.

Parameters entered in *FY* record fields 10, 11, 12, 13, and 14 define criteria for a safe yield alternative to firm yield which are omitted in this manual. Whereas firm yield is a maximum demand that just depletes reservoir storage capacity, the safe yield criteria allows computation of a maximum diversion demand that preserves a storage reserve.

## OF Record – DSS File Options

| field | columns | variable | format | value                                   | description  |
|-------|---------|----------|--------|---|--|
| 1     | 1-2     | CD       | A2     | OF                                      | Record identifier  |
| 2     | 8       | DSS(1)   | I6     | 1<br>2                                  | Conventional OUT or CRM output file is activated.<br>OUT file listing water rights, control pts, reservoirs.   |
| 3     | 12      | DSS(2)   | I4     | 1                                       | Multi-reservoir system operation tracking option.  |
| 4     | 16      | DSS(3)   | I4     | 1<br>2<br>3                             | DSS output file with <i>SIM/SIMD</i> monthly results.<br>Both daily and monthly results in <i>SIMD</i> DSS file.<br>DSS output file contains only <i>SIMD</i> daily results.   |
| 5     | 17-20   | DSS(4)   | I4     | blank,0<br>-1                           | Default set of variables in DSS output file.<br>All variables are included in DSS output file.   |
| 6     | 24      | DSS(5)   | I4     | 1<br>blank,0                            | FLO and EVA files converted to DSS.<br>Option is not activated.  |
|       |         |          |        |   | <u><i>DSS Message MSS File Options</i></u>   |
| 7     | 28      | DSS(6)   | I4     | 1<br>blank,0,2<br>3<br>4<br>7<br>8<br>9 | Messages that DSS files are opened or closed.<br>Error and warning messages (default).<br>Pathnames to MSS file as DSS records are written.<br>Pathnames to MSS file as DSS records are read.<br>Beginning level of DSS debugging messages.<br>Intermediate level of DSS debugging messages.<br>Maximum level of DSS debugging messages. |

The optional fields 8-12 and auxiliary *OF* record are described in the *Users Manual*.

Without the optional *OF* record or with blank fields in a *OF* record, defaults are activated. The defaults for DSS(2), DSS(3), and DSS(5) is to not activate the optional feature.

Most of the file activation parameters are on the job options *JO* record. The *OF* record activates and provides information for DSS input and output files. Without an *OF* record, *SIM* simulation results are written to an OUT file for a conventional simulation or CRM file for short-term conditional reliability modeling. The *OF* record activates a DSS output file for the *SIM* simulation results. An OUT file is read by *TABLES*. A DSS file is read by *HEC-DSSVue*.

With DSS(3) options 1 or 2 activated, if DSS(4) *OF* record field 5 is blank, the default set of variables listed in Table C.1 on the following page is included in the DSS file. With a -1 entered for DSS(4) in field 5, the DSS file contains all of the variables. The list can be in any order but only the first DSS(4) integer numbers are read. The labels shown in parenthesis on page 80 are identifiers in DSS pathnames and correspond to the record identifiers for the *TABLES* time series records. An optional auxiliary *OF* record described in the *Users Manual* allows listing of selected variables from Table C.1 for inclusion in the simulation results output.

**Table C.1 Simulation Results Variables Recorded in the DSS Output File**Control Point Output RecordsDefault List for DSS(4) = 0

naturalized stream flow (NAT)  
 regulated stream flow (REG)  
 unappropriated stream flow (UNA)  
 end-of-month reservoir storage (STO)  
 diversion target (TAR)  
 diversion shortage (SHT)

Complete List for DSS(4) Not Equal to Zero

1. naturalized stream flow (NAT)
2. regulated stream flow (REG)
3. unappropriated stream flow (UNA)
4. channel loss credits (CLC)
5. channel losses (CLO)
6. return flows returned here (RFR)
7. upstream reservoir releases (URR)
8. control point inflows (CPI)
9. end-of-month reservoir storage (STO)
10. reservoir net evaporation volume (EVA)
11. stream flow depletions (DEP)
12. diversion target (TAR)
13. diversion shortage (SHT)
14. diversion amount (DIV)
15. instream flow target (IFT)
16. instream flow shortage (IFS)

Water Right Output RecordsDefault for WR Record Water Rights

diversion target (TAR)  
 diversion shortage (SHT)  
 diversion or energy amount (DIV)  
 end-of-month reservoir storage (STO)  
 stream flow depletion (DEP)

Complete List for DSS(4) Not Equal to ZeroDefault for Instream Flow IF Record Water Rights

instream flow target (IFT)  
 instream flow shortage (IFS)

17. reservoir storage volume (STO)
18. reservoir net evaporation volume (EVA)
19. stream flow depletion (DEP)
20. diversion or hydropower target (TAR)
21. diversion or energy shortage (SHT)
22. diversion or energy amount (DIV)
23. available stream flow (ASF)
24. releases from secondary reservoirs (ROR)
25. return flow (RFL)
26. available increase (XAV)
27. instream flow IF record target (TIF)
28. Instream flow IF right target (IFT)
29. Instream flow IF right shortage (IFS)
30. Instream flow IF right FS record flow (FSV)
31. Instream flow IF right FS record count (FSC)

Variables 1 – 24 apply to both *WR* and *IF* record rights.

Variables 25 and 26 apply only to *WR* record rights.

Variables 27, 28, 29, 30, 31 apply only to *IF* record rights.

Reservoir Output RecordsDefault List for DSS(4) = 0

end-of-month reservoir storage (STO)  
 net evaporation-precipitation volume (EVA)  
 net evaporation-precipitation depth (EPD)  
 reservoir water surface elevation (WSE)

Complete List for DSS(4) Not Equal to Zero

32. end-of-month reservoir storage (STO)
33. net evaporation-precipitation volume (EVA)
34. power shortage or secondary energy (HPS)
35. hydroelectric energy generated (HPE)
36. inflows from stream flow depletions (RID)
37. inflows from reservoir releases (RIR)
38. releases accessible to hydropower (RAH)
39. releases not accessible to hydro (RNA)
40. adjusted evaporation-precipitation depth (EPD)
41. net evaporation depths (EVR)
42. reservoir water surface elevation (WSE)
43. reservoir storage capacity (RSC)



**CO** Record – Control Point Output Records to be Included in Output File

| field | columns | variable            | format | value | description   |
|-------|---------|---------------------|--------|-------|---|
| 1     | 1-2     | CD                  | A2     | CO    | Record identifier   |
| 2     | 7-8     | ARTIF               | A6     | ARTIF | Artificial control points as defined in <i>Users Manual</i> .   |
| 3-14  | 9-104   | CPOUID(J)<br>J=1,12 | 12A8   | AN    | Identifiers of control points for which <i>SIM</i> simulation results will be included in output files. |

**RO** Record – Reservoir/Hydropower Output Records to be Included in Output File

| field | columns | variable            | format | value                     | description   |
|-------|---------|---------------------|--------|---------------------------|---|
| 1     | 1-2     | CD                  | A2     | RO                        | record identifier   |
| 2     | 7-8     | NREOUT              | I6     | blank,0<br>-1<br>-2<br>-3 | Only the reservoirs listed on <i>RO</i> records are included.<br>All except artificial reservoirs are in output files.<br>All reservoirs are included in output files.<br>Only artificial reservoirs explained in <i>Users Manual</i> . |
| 3-14  | 9-104   | REOUID(J)<br>J=1,12 | 12A8   | AN                        | Identifiers of reservoirs for which simulation results will be included in output files.  |

**WO** Record – Water Right Output Records to be Included in Output File

| field | columns | variable           | format | value | description  |
|-------|---------|--------------------|--------|-------|--|
| 1     | 1-2     | CD                 | A2     | WO    | Record identifier  |
| 2     | 7-8     | ARTIF              | A6     | ARTIF | Artificial water rights as defined in <i>Users Manual</i> .                                |
| 3-14  | 9-200   | WROUT(J)<br>J=1,12 | 12A16  | AN    | Identifiers of water rights for which simulation results will be included in output files. |

**GO** Record – Groups of Water Rights Output Records to be Included in Output File

| field | columns | variable           | format | value                            | description   |
|-------|---------|--------------------|--------|----------------------------------|---|
| 1     | 1-2     | CD                 | A2     | GO                               | Record identifier   |
| 2     | 3-8     | GOUC               | I6     | blank,0<br>1<br>2<br>3<br>4<br>5 | Water right use type identifier option is not used.<br>UC identifiers assigned as first group identifiers.<br>UC identifiers assigned as 2nd group identifiers.<br>Output all rights with non-blank first identifiers.<br>Output all rights with non-blank 2nd identifiers.<br>Either 1st or 2nd group identifiers are not blank. |
| 3-14  | 9-104   | GROUP(J)<br>J=1,12 | 12A16  | AN                               | Identifiers of water right groups for which water right simulation results will be included in the output files.  |

### **Explanation of CO, RO, WO, and GO Record Fields**

Any number of *CO*, *RO*, *WO*, and *GO* records are used along with *JD* record fields 5 and 6 to select data to include in the simulation results written to the OUT, CRM, SOU, and/or DSS files. The optional *CO*, *RO*, *WO*, and *GO* records are placed as a group between the title records and *UC* records. All *CO* records are grouped together. All *RO* records are grouped as a set. Likewise, all *WO* are grouped together, and all *GO* records are grouped together. It does not matter which of the four sets of records precede or follow the others. All are optional.

Any number of control points, reservoirs, water rights, and water right groups may be listed on any number of *CP*, *RO*, *WO*, and *GO* records with any number up to 12 of identifiers on each record. For example, any number of control point identifiers may be provided on any number of *CO* records, with zero to 12 identifiers on each record. For example, 42 control point identifiers could be listed on 9 *CO* records with five identifiers on each of eight records and two on the ninth record. Alternatively, the 42 control point identifiers could be listed on four *CO* records with 12 identifiers on any three of the *CO* records and six identifiers on the other *CO* record. Any of the identifiers can occupy any of the columns of their 8-column or 16-column fields, without being either left-justified or right-justified.

The *RO* record provides the parameter NREOUT options of including all reservoirs, either with or without artificial reservoirs, or only artificial reservoirs in the simulation results. Parameters CPOUT and OUTWR in *JD* record fields 5 and 6 provide similar options for control points and water rights.

Water right output records are selected by matching identifiers WROUT(J) on *WO* records with the identifier WRID(wr) on the *WR* or *IF* records or alternatively by matching *GO* record group identifiers GROUP(J) with either of the two group identifiers [WRIDS(wr,1) and WRIDS(wr,2)] on the *WR* or *IF* records. Output records are included in the output files for all *WR* or *IF* record rights for which *GO* record group identifiers GROUP(J) are matched with either of the two group identifiers [WRIDS(wr,1) and WRIDS(wr,2)] on either the *WR* or *IF* records.

The identifiers WRIDS(wr,1) and WRIDS(wr,2) are included on the OUT file records read by *TABLES* for *WR* record rights but not on *IF* water right output records. Both *WR* and *IF* rights record the water right identifier WRID(wr) on the OUT file output records.

The water right use type option is activated by entering the integer 1 or 2 for GOUC in *GO* record field 2. This option treats water use type identifiers connecting *UC* and *WR* or *IF* records as *WR* record first (GOUC=1) or second (GOUC=2) group identifiers WRIDS(wr,1) and WRIDS(wr,2). The *GO* record identifiers GROUP(J) are matched with USEID in *UC* record field 2 and *WR* or *IF* record field 4. The specified either first or second group identifiers on the *WR* and *IF* records are ignored. Thus, all water rights with the same monthly water use coefficients are in a specified group for which simulation results are included in the output files if the *UC* record USE identifiers are included as in the GROUP(J) list on the *GO* records. Use identifiers and regular group identifiers can be included on the same *GO* records.

If GOUC option 3 is selected in *GO* record field 2, output records for all *WR* or *IF* record water rights that have a non-blank WRIDS(wr,1) are included in the output file. Likewise, GOUC of 4 selects all rights with non-blank WRIDS(wr,2), and GOUC of 5 includes both group identifiers.

## UC Record – Monthly Water Use Coefficients

| field | Columns | variable   | format | value | description   |
|-------|---------|------------|--------|-------|---|
| 1     | 1-2     | CD         | A2     | UC    | Record identifier   |
| 2     | 3-8     | USEID      | A6     | AN    | Identifier relates sets of use factors to the use type in field 4 of <i>WR</i> and <i>IF</i> records. |
| 3     | 9-16    | PDUSCF(1)  | F8.0   | +     | Water use coefficient for month 1   |
| 4     | 17-24   | PDUSCF(2)  | F8.0   | +     | Water use coefficient for month 2   |
| 5     | 25-32   | PDUSCF(3)  | F8.0   | +     | Water use coefficient for month 3   |
| 6     | 33-40   | PDUSCF(4)  | F8.0   | +     | Water use coefficient for month 4   |
| 7     | 41-48   | PDUSCF(5)  | F8.0   | +     | Water use coefficient for month 5   |
| 8     | 49-56   | PDUSCF(6)  | F8.0   | +     | Water use coefficient for month 6   |
| 9     | 57-64   | PDUSCF(7)  | F8.0   | +     | Water use coefficient for month 7   |
| 10    | 65-72   | PDUSCF(8)  | F8.0   | +     | Water use coefficient for month 8   |
| 11    | 73-80   | PDUSCF(9)  | F8.0   | +     | Water use coefficient for month 9   |
| 12    | 81-88   | PDUSCF(10) | F8.0   | +     | Water use coefficient for month 10  |
| 13    | 89-96   | PDUSCF(11) | F8.0   | +     | Water use coefficient for month 11  |
| 14    | 97-104  | PDUSCF(12) | F8.0   | +     | Water use coefficient for month 12  |

A *UC* record with 12 coefficients or a pair of *UC* records with six coefficients each is provided for each water use type. The two alternative forms of *UC* records are the same except for the number of coefficients included on each record.

The use type identifier in field 2 of the *UC* record corresponds to the use type identifier in field 4 of the *WR* and *IF* records. The set of 12 monthly factors is used to distribute an annual diversion, instream flow, or hydroelectric energy requirement over the 12 months of the year. *SIM* divides each monthly coefficient by the sum of the 12 coefficients to obtain a set of 12 monthly multipliers.

## SIM

### CP Record – Control Point Information

| field   | columns | variable         | format | value   | description   |
|---|---------|------------------|--------|---|---|
| 1   | 1-2     | CD               | A2     | CP  | Record identifier   |
| 2   | 3-8     | CPID(cp,1)       | A6     | AN  | Control point identifier [cp = 1,NCPTS]   |
| 3   | 11-16   | CPID(cp,2)       | 2x,A6  | AN  | Identifier of next downstream control point.<br>blank,OUT Outlet. There is no control point downstream.   |
| 4   | 17-24   | CPDT(cp,1)       | F8.0   | +   | Factor by which inflows are multiplied. Default = 1.0   |
| 5   | 25-32   | CPDT(cp,2)       | F8.0   | +   | Factor by which evaporation rates are multiplied<br>blank,0 Default factor = 1.0  |
| <u>Method for Obtaining Naturalized Flows</u>             |         |                  |        |   |   |
| 6   | 40      | INMETHOD<br>(cp) | I4     | blank,0,1<br>2<br>3<br>4<br>5<br>6<br>7<br>8<br>9<br>10 | <i>IN</i> records are input for this control point.<br>2 Specifications are provided by <i>CPIN(cp)</i> in field 8.<br>3 Distribution equation with <i>FC</i> record coefficients.<br>4 NRCS CN with synthesized flow limited to source.<br>5 NRCS CN method without above noted flow limit<br>6 Channel loss coefficient with DAR method<br>7 Drainage area ratio method (areas from <i>WP</i> records)<br>8 NRCS CN method with channel losses<br>9 Control point flow does not limit available flow.<br>10 Equation proportioning flows at other control points. |
| 7   | 43-48   | CPIN(cp)         | 2x,A6  | AN<br>NONE<br>ZERO                                      | Control point from which flows are repeated.<br>The words <i>none</i> , <i>zero</i> , <i>NONE</i> , or <i>ZERO</i> entered in field indicate zero stream flows at this control point.   |
| <u>Method for Obtaining Net Evaporation-Precipitation</u> |         |                  |        |   |   |
| 8   | 51-56   | CPEV(cp)         | 2x,A6  | blank<br>AN<br>NEXT<br>NONE<br>ZERO                     | <i>EV</i> records are read as input.<br>Control point from which <i>EV</i> records are repeated.<br><i>EV</i> records for next downstream cp are repeated.<br>The words <i>none</i> , <i>zero</i> , <i>NONE</i> , or <i>ZERO</i> in this field indicate zero net evaporation at this control point.   |
| <u>Evaporation-Precipitation Adjustment</u>               |         |                  |        |   |   |
| 9   | 57-64   | EWA(cp)          | F8.0   | blank,0<br>-1.0<br>-2.0<br>-3.0, <-3.0<br>+             | Default set by <i>JD</i> record field 10 is used.<br>Ungaged CP from <i>FD</i> record field 2 is used.<br>Gaged CP from <i>FD</i> record field 3 is used.<br>No adjustment. (Overrides non-blank <i>JD</i> field 10)<br>Watershed area in acres for E-P adjustment.   |
| <u>Channel Loss Factor</u>                                |         |                  |        |   |   |
| 10  | 65-72   | CL(cp)           | F8.0   | +   | Channel loss factor for reach below CP. Default = 0.0<br>blank The default channel loss factor is 0.0.  |

Optional fields 11, 12, and 13 of the *CP* record are described in the *Users Manual*.

### Explanation of CP Record Fields

A *CP* record is required for each and every control point. The control points may be entered in any order, but all *CP* records must be grouped together separated by nothing except \*\* records.

**Field 2:** The six alphanumeric character identifier of the control point is entered on various other types of records to designate location.

**Field 3:** The control point located immediately downstream of each control point is designated in order for the model to delineate the spatial configuration of the river system.

**Field 4, 5:** The naturalized flows from the *IN* records and net evaporation depths from *EV* records are multiplied by factors in fields 4 and 5 that could be unit conversions, drainage area ratios, or other factors.

**Field 6:** Naturalized flows at a control point may be provided as input on *IN* records or synthesized within the model by optional methods selected by field 7.

**Field 7:** The naturalized streamflows at a control point may be repeated from those provided at another control point or set at zero.

**Field 8:** The net evaporation-precipitation depths at a control point may be repeated from those provided at another control point or set at zero.

**Field 9:** A methodology described in Chapter 3 of the *Reference Manual* adjusts the evaporation-precipitation depths from the *EV* records for runoff from the land area covered by a reservoir that is reflected in the naturalized stream flows to prevent double-counting. The default is to apply no adjustment. *EPADJ* in *JD* record field 10 sets the default used to correct the evaporation-precipitation depths. The default for this default is to apply no adjustment. The option specified in the *JD* record field 10 is used for all control points for which the *CP* record field 9 is blank [ $EWA(cp)=0$ ].  $EWA(cp)$  entered in field 9 of a *CP* record supersedes the default set in field 10 of the *JD* record.

**Field 10:** The channel loss in a river reach is defined as the flow at the upstream control point multiplied by the channel loss factor entered in *CP* record field 10 for the upstream control point.

# SIM

## WR Record – Water Right

| field   | columns | variable        | format | value        | description  |
|---|---------|-----------------|--------|--------------|--|
| 1   | 1-2     | CD              | A2     | WR           | Record identifier  |
| 2   | 3-8     | CP              | A6     | AN           | Control point identifier   |
| 3   | 9-16    | AMT             | F8.0   | 0,+          | Diversion (types 1-3 in field 6), inflow (type 4), hydropower (types 5-6), or storage (type 7) target. |
| 4   | 19-24   | USE             | 2x,A6  | blank        | Monthly target is 1/12 of annual target from field 3.  |
|   |         |                 |        | LDAYS, NDAYS | Distribution based on number of days in each month.  |
|   |         |                 |        | AN           | Use type identifier to connect to <i>UC</i> and <i>UP</i> records.                                     |
|   |         |                 |        | XMONTH       | Monthly rather than annual target in field 3.  |
| 5   | 25-32   | WRNUM(wr,7)     | I8     | –,0,+        | Priority number.   |
| <u>Water Right Type</u>                       |         |                 |        |              |  |
| 6   | 36      | WRNUM<br>(wr,5) | I4     | blank,0,1    | Type 1 water right (refills reservoir storage).  |
|   |         |                 |        | 2            | Type 2 water right (no refilling storage).   |
|   |         |                 |        | 3            | Type 3 water right (no streamflow depletions).   |
|   |         |                 |        | 4            | Type 4 water right (inflow to river system).   |
|   |         |                 |        | 5, –1        | Type 5 water right (hydroelectric power).  |
|   |         |                 |        | 6, –3        | Type 6 water right (hydroelectric power).  |
|   |         |                 |        | 7            | Type 7 water right (target sets storage capacity).   |
|   |         |                 |        | 8            | Target is computed for use with <i>FS</i> and <i>TO</i> records.                                       |
| <u>Return Flow Specifications</u>             |         |                 |        |              |  |
| 7   | 40      | RFMETH<br>(wr)  | I4     | blank,0,1    | Constant factor, flows returned same month.  |
|   |         |                 |        | 2            | Constant factor, flows returned next month.  |
|   |         |                 |        | 3            | Monthly factors, flows returned same month.  |
|   |         |                 |        | 4            | Monthly factors, flows returned next month.  |
| 8   | 41-48   | RFAC            | F8.0   | +            | Constant return flow factor.   |
|   |         | RFIDWR          | 2x,A6  | AN           | Identifier on RF record for monthly factors.   |
| 9   | 51-56   | RCP             | 2x,A6  | blank        | Flow returned to next downstream control point.  |
|   |         |                 |        | AN           | Identifier of control point to return flow.  |
| <u>Optional Flow Switch and Drought Index</u> |         |                 |        |              |  |
| 10  | 57-62   | FSCV(wr)        | I4     | +            | Flow switch identifier described in <i>Users Manual</i> .  |
| 11  | 63-64   | DINDEX(wr)      | 2x,I2  | +            | Optional drought index described in <i>Users Manual</i> .  |
| <u>Identifiers</u>                            |         |                 |        |              |  |
| 12  | 65-80   | WRID(wr)        | A16    | AN           | Water right identifier.  |
| 13  | 81-88   | WRIDS(,1)       | A8     | AN           | Optional water right group identifier.   |
| 14  | 89-96   | WRIDS(,2)       | A8     | AN           | Optional water right group identifier.   |

An optional alternative set of identifiers can be provided in fields 15-17.

*WR* and *IF* records may be in any order. The set of all *WR* and *IF* records, along with their supporting records, follow the set of all *CP* records. *WS*, *HP*, and other auxiliary records defining a *WR* or *IF* record water right are inserted directly after the *WR* or *IF* record.

### Explanation of WR Record Fields

**Field 2:** The water right has access to available streamflow at this control point. Streamflow depletions for diversions and maintaining storage for the right occur at this control point.

**Field 3:** *AMT* is an annual diversion volume (type 1, 2 or 3), inflow volume (type 4), hydroelectric energy (type 5 or 6), or storage volume (type 7) target which is converted within *SIM* to monthly targets by multiplying by monthly distribution factors. These monthly targets may be further adjusted by options controlled by entries on other auxiliary records. With *XMONTH* entered in field 4, the target in field 3 is a monthly rather than annual amount.

**Field 4:** The water use identifier serves the sole purpose of connecting *WR* and *IF* records to *UC* and *UP* records. Any alphanumeric identifier of 6 characters or less may be used along with the two following special cases. If *WR* or *IF* record field 4 is blank, the 12 monthly water use factors default to a uniform 1/12. If the term *NDAYS* is entered in *WR* or *IF* record field 4, the 12 factors otherwise read on the *UC* records are set at the number of days in each month starting with January (31, 28, 31, 30, 31, 30, 31, 31, 30, 31, 30, 31). *LDAYS* is identical to *NDAYS* except *LDAYS* assigns 29 days to February in leap year rather than 28. *SIM* divides these factors by their sum of 365 (or 366) to obtain the monthly multiplier factors.

*XMONTH* or *xmonth* in field 4 indicates that the target in field 3 is already a monthly amount.

**Field 5:** The priority number is an integer reflecting relative priorities that governs the order in which water rights are considered in the simulation. A blank field 5 assigns a priority of zero, which is treated like any other integer number. The priority in field 5 may be over-ridden or adjusted by factors entered on the *UP* record. Priorities may also be replaced by the upstream-to-downstream natural priority option activated by *JO* record field 9.

**Field 6:** The water right types defined in *Reference Manual* Chapter 4 specify rules for meeting water right requirements. The default type 1 right allows a diversion target to be supplied from streamflow depletions and/or storage in one or more reservoirs. The diversion is met from streamflow to the extent that streamflow is available and then from storage. One primary reservoir can be refilled from streamflow depletions and releases from other system reservoirs. The diversion and primary reservoir must be at the control point (field 2) with both having access to available streamflow at that control point. Types 2 and 3 rights do not refill storage and thus do not have to be at the same control point as the reservoir. A type 2 right is supplied by streamflow depletions at the *WR* record field 2 control point and releases from storage in one or more reservoirs. A type 3 right is supplied only by releases from reservoir storage.

Types 5 and 6 rights are similar to types 1 and 3 rights except hydroelectric power generation replaces the diversion target. A type 4 right discharges water into the stream. Type 7 rights refill a reservoir to a monthly target storage capacity determined the same way as a diversion target.

**Field 7, 8, 9:** All or a portion of the diversion may be returned to the river system at the same control point as the diversion or at any other control point. Hydropower releases are also treated as return flows. The optional methods are outlined in Chapter 4 of the *Reference Manual*.

**Field 10 and 11:** The identifier in field 10 connects a flow switch *FS* record to the right. The drought index in field 11 assigns a set of *DI/IS/IP* records to the water right.

**Field 12-17:** Water right identifiers are described in Chapter 2 of the *Users Manual*.

## IF Record – Instream Flow Requirement

| field   | columns | variable        | format | value                                | description   |
|---|---------|-----------------|--------|--------------------------------------|---|
| 1   | 1-2     | CD              | A2     | IF                                   | Record identifier   |
| 2   | 3-8     | CP              | A6     | AN                                   | Control point identifier  |
| 3   | 9-16    | AMT             | F8.0   | +                                    | Annual minimum instream flow target   |
| 4   | 19-24   | USE             | 2x,A6  | AN<br>NDAYS<br>LDAYS<br>blank        | Use type identifier to connect to <i>UC</i> and <i>UP</i> records<br>Distribution based on number of days in each month<br>Same as NDAYS except February varies in leap year.<br>Monthly target is 1/12 of annual target from field 3.  |
| 5   | 25-32   | WRNUM<br>(wr,7) | I8     | –,0,+                                | Priority number   |
| <u>Parameters Defining Instream Flow Requirements</u> |         |                 |        |                                      |   |
| 6   | 34      | IFM<br>(if,1)   | I2     | blank,0<br>1,non-zero                | Instream flow limit is based on total regulated flow.<br>Reservoir releases for downstream use are excluded.  |
| 7   | 36      | IFM<br>(if,2)   | I2     | blank,0,1<br>2<br>3                  | Junior <i>IF</i> target at cp replaces preceding senior target.<br>Largest <i>IF</i> record target at control point is adopted.<br>Smallest <i>IF</i> record target at control point is adopted.  |
| 8   | 39-40   | IFM<br>(if,3)   | I4     | blank,0,1<br>2<br>–2<br>3<br>4<br>–4 | Constraints on water availability during first pass<br>Constraints on water availability during second pass<br>Constraints during both first and second passes<br>Constraints during first pass, reservoir storage used<br>Constraints during second pass, reservoir storage<br>Constraints during both first and second passes |
| <u>Connections to Other Optional Features</u>         |         |                 |        |                                      |   |
| 9   | 41-44   | FSCV(wr)        | I4     | +                                    | Identifier connecting to <i>FS</i> or <i>CV</i> record.   |
| 10  | 47-48   | DINDEX<br>(wr)  | I4     | blank,0<br>+,-                       | Drought index is not used for this water right.<br>Integer identifier of drought index. <i>DI</i> record field 2.   |
| <u>Water Right Identifier</u>                         |         |                 |        |                                      |   |
| 11  | 49-64   | WRID(wr)        | A16    | AN                                   | Water right identifier.   |
| 12  | 65-72   | WRIDS(wr,1)     | A8     | AN                                   | Optional first water right group identifier.  |
| 13  | 73-80   | WRIDS(wr,2)     | A8     | AN                                   | Optional second water right group identifier.   |
| <u>Option for Repeating at More than One CP</u>       |         |                 |        |                                      |   |
| 14  | 83-88   | CP2             | A6     | 12                                   | Control point defining downstream end of reach.   |

The data entered in fields 1, 2, 3, 4, 5, 8, 9, and 10 of the *IF* record are similar for both *IF* and *WR* record rights. These common variables are explained on the preceding page. Field 7 is relevant only if more than one *IF* record sets requirements at the same control point. Field 8 options 1 and 2 constrain streamflow depletions by all junior rights to protect instream flow targets but do not require releases from storage. Options 3 and 4 result in releases from storage in reservoirs identified by *WS* records associated with the *IF* record to mitigate instream flow shortages. Options 2 and 4 involve a repeat of the simulation, which is called a second pass through the water rights computation loop. These options are described in the *Reference Manual*.



## WS Record – Reservoir Storage Associated with a Water Right

| field | columns | variable    | format | value         | description   |
|-------|---------|-------------|--------|---------------|---|
| 1     | 1-2     | CD          | A2     | WS            | Record identifier   |
| 2     | 3-8     | RES         | A6     | AN            | Reservoir identifier  |
| 3     | 9-16    | WRSYS(sr,3) | F8.0   | +             | Total storage capacity at top of the conservation pool.<br><i>Storage-Area Relationship</i>   |
| 4     | 17-24   | EVCFA       | F8.0   | +             | Multiplier <i>A</i> for storage-area equation shown below.  |
| 5     | 25-32   | EVCFB       | F8.0   | +             | Exponent <i>B</i> for storage-area equation shown below.  |
| 6     | 33-40   | EVCFC       | F8.0   | +             | Constant <i>C</i> for storage-area equation shown below.<br>$\text{surface area} = A (\text{storage})^B + C$<br>If fields 4, 5 & 6 are all blank, a table on <i>SV</i> and <i>SA</i> records is required to define the storage-area relation.<br><i>Optional Storage Specifications</i> |
| 7     | 41-48   | INACT       | F8.0   | +             | Storage capacity at top of the inactive pool.   |
| 8     | 49-56   | BEGIN       | F8.0   | Blank,0<br>+  | Reservoir is full to capacity (field 3) at the beginning.<br>Storage volume at the beginning of the simulation.<br><i>Evaporation Allocation Reservoirs</i>   |
| 9     | 57-64   | IEAR        | I8     | Blank,0<br>+  | Option not used.<br><i>EA</i> record identifier (1, 2, 3, ...). 1 for first <i>EA</i> record.   |
| 10    | 71-72   | SA          | I8     | Blank,0<br>-1 | A separate storage-area relationship is provided.<br>Use <i>SV/SA</i> records for first reservoir on <i>EA</i> record.<br><i>Downstream Versus Lakeside Diversions</i>  |
| 11    | 79-80   | LAKESD      | I8     | Blank,0<br>-1 | Water supply diversions are accessible to hydropower.<br>Lakeside diversions do not generate hydropower.  |

A *WS* record follows its water right *WR* record. Multiple reservoirs may be associated with a single water right. A *WS* record is required for each reservoir associated with a right. The optional hydropower *HP* is connected to a particular *WS* record and follows directly after the *WS* record.

Multiple rights may be associated with a particular reservoir. The total storage capacity in *WS* field 3, inactive storage capacity in field 7, and turbine/lakeside diversion switch in field 11 are connected to a water right and may vary with different rights at the same reservoir. Other data entered on *WS* and *HP* records are connected to a particular reservoir and are constant for that reservoir with no variation between multiple rights. After being entered with one right, these data do not have to be repeated for other rights at the same reservoir. Fixed reservoir data include *WS* fields 4, 5, 6 and *HP* fields 4, 5, 6. *SV/SA*, *PV/PE*, and *TQ/TE* record tables are also fixed for a reservoir.

### Explanation of WS Record Fields

**Field 3:** A type 1 (*WR* field 6) right refills a reservoir to the storage capacity entered in *WS* field 3 subject to water availability. Multiple type 1 rights at the same reservoir may refill storage to various levels at different priorities. The field 3 storage capacity also limits the amount of water that may be withdrawn by a right. A diversion right has access to storage up to but not above the top of conservation pool. The conservation storage capacity for a junior right must equal or exceed the storage capacity associated with more senior rights at the same reservoir.

**Fields 4, 5, 6:** *WRAP-SIM* provides two options for inputting the storage volume versus surface area relationship for a reservoir: (1) a table provided on *SV* and *SA* records and (2) coefficients for the following equation provided in fields 4, 5, and 6 of the *WS* record:

$$\text{surface area} = A (\text{storage})^B + C$$

If *WS* record fields 4 and 6 are blank, a pair of *SV/SA* records must be provided for the reservoir. For multiple rights associated with the same reservoir, the storage-area input is provided only once, with the first right (*WR/IF* record) read. There is only one storage-area relationship for a reservoir even if the reservoir is associated with multiple water rights. Fields 4, 5, and 6 of the *WS* record are blank if the storage-area information is specified elsewhere.

**Field 7:** Releases or withdrawals are curtailed whenever storage contents fall below the top of the inactive pool.

**Field 8:** The reservoir is assumed full to capacity (field 3) at the beginning of the first month of the first year of the simulation unless an initial storage is entered in *WS* record field 8 or the beginning-ending-storage feature is activated by *JO* record field 5.

**Field 9:** The integer identifier connects this reservoir to an *EA* record, used to define options for allocating net evaporation between component reservoirs used to model a multiple-owner reservoir. An *EA* record is needed only if storage volumes accessed by the different owners are separate rather than shared in common. An *EA* record is not needed for multiple owners with access to the same storage pool. The integer 1 in *WS* record field 9 links this reservoir to the first *EA* record in the input file, a 2 links to the second *EA* record, a 3 links to the third *EA* record, and so forth. There is no limit on the number of *EA* records that may be included in a dataset.

**Field 10:** The reservoirs listed on an *EA* record may share the storage/area table provided by the *SV* and *SA* records for the first reservoir listed, or each reservoir may have its own storage-area relationship. A negative integer for *SA* in field 10 indicates that since this reservoir is adopting the same *SV* and *SA* records as the first reservoir on its *EA* record, a separate storage/area relationship is not entered in either *WS* record fields 4, 5, 6 or as *SV/SA* records.

**Field 11:** Field 11 is used for a diversion right to flag whether the diversion is available later in the priority loop for junior hydropower rights. *LAKESD* specifies whether a water supply diversion is released through the turbines, incidentally generating hydroelectric energy, or withdrawn lakeside without being accessible for hydropower production. *WS* record field 11 is relevant only for a senior water supply diversion met by releases from a reservoir at which a hydroelectric power plant for a more junior hydropower right is also located.

## HP Record – Hydroelectric Power

| field | columns | variable     | format | value        | description  |
|-------|---------|--------------|--------|--------------|--|
| 1     | 1-2     | CD           | A2     | HP           | Record identifier  |
| 2     | 3-8     | WRSYS(sr,9)  | F6.0   | Blank,0<br>+ | Default efficiency = 0.85<br>Energy efficiency for hydroelectric power plant.                      |
| 3     | 9-16    | WRSYS(sr,10) | F8.0   | Blank,0<br>+ | Tailwater discharge-elevation from TQ/TE records.<br>Constant tailwater elevation.                 |
| 4     | 17-24   | TELEV(res)   | F8.0   | Blank,0<br>+ | Bottom power pool defined by <i>INACT</i> in <i>WS</i> field 7.<br>Turbine inlet invert elevation. |
| 5     | 25-32   | TQCAP(res)   | F8.0   | Blank,0<br>+ | No limit on turbine discharge.<br>Turbine discharge capacity.                                      |
| 6     | 33-40   | TPCAP(res)   | F8.0   | Blank,0<br>+ | No limit on amount of secondary energy generated.<br>Maximum limit on energy production.           |

A hydroelectric power right is activated by a water right type of 5 or 6 in *WR* record field 6. A *HP* record is placed immediately behind the corresponding *WS* record to provide hydropower parameters. A *HP* record is not required for a hydropower right if the default values are adopted for all of the hydropower parameters.

### Explanation of HP Record Fields

**Field 2:** The efficiency is a fraction less than 1.0 representing the ratio of electrical energy to hydraulic energy used in the power equation. The default efficiency is 0.85.

**Field 3:** A constant tailwater elevation may be entered in *HP* record field 3 for computing the head used in the power equation. If a *HP* record is not used or field 3 is blank, a tailwater rating table is entered on a pair of *TE* and *TQ* records.

**Field 4:** Hydroelectric power is not generated if the average water surface elevation during the month falls below the limiting elevation specified in field 4.

**Field 5:** A maximum limit may be imposed on the flow volume/month that may be used to generate electric power. If field 5 is left blank, unlimited turbine discharge capacity is assumed.

**Field 6:** A maximum limit may be imposed on the electric energy/month that may be generated. If an energy production limit is specified, it must be greater than the monthly energy target developed based on adjusting the annual target entered in *WR* record field 3. Thus, the *HP* record field 6 limit affects only secondary energy generated in excess of the *WR* record field 3 firm energy target.

## ***SIM***

### **SV** Record – Storage Volumes for Reservoir Storage versus Area Table

| field | columns | variable          | format   | value | description   |
|-------|---------|-------------------|----------|-------|---|
| 1     | 1-2     | CD                | A2       | SV    | Record identifier   |
| 2     | 3-8     | RES               | A6       | AN    | Reservoir identifier  |
| 3-14  | 9-104   | TARA(I)<br>I=1,TL | TL(F8.0) | +     | Reservoir storage volumes corresponding to surface areas in same fields of the following <i>SA</i> record |

### **SA** Record – Surface Areas for Reservoir Storage versus Area Table

| field | columns | variable          | format   | value | description   |
|-------|---------|-------------------|----------|-------|---|
| 1     | 1-2     | CD                | A2       | SA    | Record identifier   |
| 2     | 3-8     | RES               | 6x       |       | Field not used  |
| 3-14  | 9-104   | TARB(I)<br>I=1,TL | TL(F8.0) | +     | Reservoir surface areas corresponding to storage volumes in same fields of the preceding <i>SV</i> record |

Storage volume (*SV* record) versus surface area (*SA* record) tables are used in the reservoir net evaporation-precipitation computations. A storage-area relationship may be defined optionally with a pair of *SV* and *SA* records or by equation coefficients provided on the *WS* record. Storage volume versus water surface elevation tables (*PV-PE* records) are used for computing head in hydroelectric power computations or for tabulating water surface elevations. A *SV* or *PV* record must be followed by the corresponding *SA* or *PE* record. A complete set of all *PV-PE* records grouped together follows the complete set of all *SV-SA* records.

### **PV** Record – Storage Volumes for Storage versus Elevation Table for Hydropower Right

| field | columns | variable          | format   | value | description  |
|-------|---------|-------------------|----------|-------|--|
| 1     | 1-2     | CD                | A2       | PV    | Record identifier  |
| 2     | 3-8     | RES               | A6       | AN    | Reservoir identifier   |
| 3-14  | 9-104   | TARA(I)<br>I=1,TL | TL(F8.0) | +     | Reservoir storage volumes corresponding to surface elevations in same fields of the following <i>PE</i> record |

### **PE** Record – Surface Elevations for Storage versus Elevation Table for Hydropower Right

| field | columns | variable          | format   | value | description  |
|-------|---------|-------------------|----------|-------|--|
| 1     | 1-2     | CD                | A2       | PE    | Record identifier  |
| 2     | 3-8     | RES               | 6x       |       | Field not used   |
| 3-14  | 9-104   | TARB(I)<br>I=1,TL | TL(F8.0) | +     | Reservoir surface elevations corresponding to storage volumes in same fields of the preceding <i>PV</i> record |

**IN** Record – Naturalized Stream Flows (Inflows) in FLO File

| field | Columns | variable      | format | value | description   |
|-------|---------|---------------|--------|-------|---|
| 1     | 1-2     | CD            | A2     | IN    | Record identifier   |
| 2     | 3-8     | ID            | A6     | AN    | Control point identifier  |
| 3     | 9-12    | NYR           | I4     | +     | First year for an <i>IN</i> record repeated for multiple years<br>blank,0 <i>IN</i> record is for one year only; it is not repeated |
| 4     | 13-16   | PYR           | I4     | +     | Year (last year to repeat if field 3 is not blank)  |
| 5     | 17-24   | INFLOW(cp,1)  | F8.0   | +     | Naturalized streamflow for Month 1  |
| 6     | 25-32   | INFLOW(cp,2)  | F8.0   | +     | Naturalized streamflow for Month 2  |
| 7     | 33-40   | INFLOW(cp,3)  | F8.0   | +     | Naturalized streamflow for Month 3  |
| 8     | 41-48   | INFLOW(cp,4)  | F8.0   | +     | Naturalized streamflow for Month 4  |
| 9     | 49-56   | INFLOW(cp,5)  | F8.0   | +     | Naturalized streamflow for Month 5  |
| 10    | 57-64   | INFLOW(cp,6)  | F8.0   | +     | Naturalized streamflow for Month 6  |
| 11    | 65-72   | INFLOW(cp,7)  | F8.0   | +     | Naturalized streamflow for Month 7  |
| 12    | 73-80   | INFLOW(cp,8)  | F8.0   | +     | Naturalized streamflow for Month 8  |
| 13    | 81-88   | INFLOW(cp,9)  | F8.0   | +     | Naturalized streamflow for Month 9  |
| 14    | 89-96   | INFLOW(cp,10) | F8.0   | +     | Naturalized streamflow for Month 10   |
| 15    | 97-104  | INFLOW(cp,11) | F8.0   | +     | Naturalized streamflow for Month 11   |
| 16    | 105-112 | INFLOW(cp,12) | F8.0   | +     | Naturalized streamflow for Month 12   |

**EV** Record – Net Reservoir Evaporation-Precipitation Rates in EVA File

| field | Columns | variable              | format | value | description  |
|-------|---------|-----------------------|--------|-------|--|
| 1     | 1-2     | CD                    | A2     | IN    | Record identifier  |
| 2     | 3-8     | ID                    | A6     | AN    | Control point identifier   |
| 3     | 9-12    | NYR                   | I4     | +     | First year for an <i>EV</i> repeated for multiple years<br>blank,0 <i>EV</i> record is for one year only; it is not repeated |
| 4     | 13-16   | PYR                   | I4     | +     | Year (last year to repeat if field 3 is not blank)   |
| 5     | 17-24   | EVAPR(cp,m)<br>m=1,12 | F8.0   | +     | Evaporation-precipitation for months 1 through 12.<br><i>EV</i> and <i>IN</i> records have identically the same format.      |

*IN* and *EV* records in FLO and EVA files are described on this page. *IN* and *EV* records stored as DSS records in the hydrology DSS file are described on the following page 94. Sequences of monthly stream flow volumes representing natural or some specified condition of river basin development are entered on inflow *IN* records. Sequences of monthly reservoir surface net evaporation less precipitation depths are entered on evaporation *EV* records.

*INEV* in *JO* record field 2 indicates the manner in which the *IN* and *EV* records are organized. *IN* and *EV* records stored in FLO and EVA files are organized based on alternative groupings by year or control point. For *JO* record field 2 *INEV* options 1, 3, and 5, the *IN* and *EV* records are grouped by year. A set of records for all control points for a particular year is followed by records for all control points for the next year. With *INEV* options 2 and 4, the *IN* and *EV* records for are grouped by control point, with a set of all annual records for a particular control point being grouped together. *INEV* option 6 means the *IN* and *EV* records are in a DSS file.

## ***SIM***

### **IN and EV Records – Naturalized Flows and Evaporation-Precipitation Rates in DSS File**

*SIM* can read one DSS hydrology input file and/or create one DSS simulation results output file. The *SIM* hydrology input file containing the *IN* and *EV* records has the filename rootHYD.DSS where "HYD" is appended to the "root" to differentiate from the DSS output file. The *SIM* simulation results output file has the filename root.DSS, with the same root as the DAT, MSS, and OUT files. *INEV* option 6 in *JO* record field activates the DSS hydrology input file. The contents of the *SIM* output OUT and DSS files are controlled by DAT file input parameters on the *JD*, *OF*, *CO*, *RO*, *WO*, and *GO* records.

#### **DSS Record Pathnames**

DSS files contain data records labeled with pathnames as explained in the *HEC-DSSVue User's Manual* and Chapter 6 of the *WRAP Users Manual*. All DSS pathnames are defined with six standard components called Parts A, B, C, D, E, and F. *HEC-DSSVue* automatically creates a catalog file with extension DSC listing all records in the DSS file by their pathnames. DSS records are identified, inventoried, and sorted in *HEC-DSSVue* by pathname and connected to WRAP programs by pathname. The pathname parts for *IN* and *EV* records in a *SIM* hydrology DSS input file are defined as follows.

- A – hydrology filename root
- B – control point identifier
- C – IN for naturalized flow or EV for evaporation-precipitation
- D – range of DSS record blocks that contain the data series
- E – 1MON for monthly data
- F – Part F is not used for the hydrology input file and is left empty.

For the output DSS file created by *SIM*, *SIMD* or *TABLES*, the pathnames are automatically defined within the programs. The programs create a new output file if a file with the pertinent filename (root.DSS) does not already exist. If a file with the appropriate output filename already exists, *SIM*, *SIMD* or *TABLES* writes over any individual DSS records that have exactly the same pathnames as those created by the programs. Individual data records with the same pathnames are over-written, but new records with new pathnames are added. The user can store output from multiple simulations in the same DSS file by renaming one or more of pathname parts within *HEC-DSSVue* for the alternative simulations. The pathname parts for the simulation results in a *SIM* output file that are automatically assigned by *SIM* are as follows.

- A – Filename root which is the same as the DAT and OUT or TOU filename root.
- B – Control point identifier.
- C – Type of data such as NAT, REG, UNA, STO, IFT, DIV, EVA, DEP, defined on page 80, combined with –CP, -WR, or –RE for control points, water rights, and reservoirs.
- D – Range of record blocks encompassing the hydrologic period-of-analysis.
- E – 1MON specifying a monthly time interval or 1DAY or 1YEAR.
- F – CP for control points Water right or reservoir identifier. Daily *SIMD* and *SIM* conditional reliability modeling results are labeled a little differently.

**APPENDIX D  
TABLES INPUT RECORDS**

All of the program *TABLES* input records are described in Chapter 5 of the *Users Manual*. Those types of records selected for inclusion in the *Fundamentals Manual* are described in this chapter. These records are placed in the *TABLES* input TIN file in any order. All are optional.

Format specifications found in the 4th column of the record description tables are defined as follows:

- A4 alphanumeric (AN) label right justified in a field that is 4 characters wide
- 8A8 up to 8 alphanumeric labels right justified in fields that are 8 characters wide
- 2x two blank spaces
- F8.0 real number in field of 8 characters (either include decimal or right justify)
- I8 integer number right justified in field of 8 characters

**TITL Record – Titles or Headings**

| field | columns | variable | format | value | description       |
|-------|---------|----------|--------|-------|-------------------|
| 1     | 1-4     | CD       | A4     | TITL  | Record identifier |
| 2     | 5-78    | TITLE    | A76    | AN    | Title or heading  |

From zero to five TITL records are entered as the first records of the input file. The alphanumeric information provided on the records is printed on the cover page and at the top of each table.

**COMM or \*\*\*\*\* Record – Comments**

| field | columns    | variable | format | value               | description       |
|-------|------------|----------|--------|---------------------|-------------------|
| 1     | 1-4        | CD       | A4     | ***** or ** or COMM | Record identifier |
| 2     | 5-no limit |          |        | AN                  | Comments or notes |

Any number of comment records can be inserted anyplace in the input file to provide notes or comments. The comment records are not read or used in any way by the program.

**PAGE Record – Title Page**

| field | columns | Variable | format | value | description       |
|-------|---------|----------|--------|-------|-------------------|
| 1     | 1-4     | CD       | A4     | PAGE  | Record identifier |

The PAGE record prints a title page.

## TABLES

### ENDF Record – End of Input File

| field | columns | Variable | format | value | description       |
|-------|---------|----------|--------|-------|-------------------|
| 1     | 1-4     | CD       | A4     | ENDF  | Record identifier |

Records placed after the ENDF record are not read, allowing multiple sets of table-building specifications to be stored in the same TIN file. The ENDF record serves no other purpose.

### UNIT Record – Information for Table Headings

| field | columns | variable | format | value           | description  |
|-------|---------|----------|--------|-----------------|--|
| 1     | 1-4     | CD       | A4     | UNIT            | Record identifier  |
| 2     | 5-9     | UNIT     | A5     | AN<br>blank     | Volume units printed in table headings. Without a <i>UNIT</i> record, the default is AC-FT.  |
| 3     | 10-14   | UNHP     | A5     | AN<br>blank     | Hydropower units printed in table headings. Without a <i>UNIT</i> record, the default is MW-HR.  |
| 4     | 15-19   | MONTH1   | A5     | blank<br>AN     | Default is to begin headings with the month JAN. First month in the table headings may be entered as either JAN (default), FEB, MAR, APR, MAY, JUN, JUL, AUG, SEP, OCT, NOV, or DEC. |
| 5     | 20-24   | NEWPAGE  | I5     | blank,0,+<br>-1 | Each table starts a new page.<br>No page breaks.   |

Several table headings include volume and/or energy units. If a *UNIT* record is not used, the defaults are:

$$\begin{aligned} \text{UNIT} &= \text{AC-FT} \\ \text{UNHP} &= \text{MW-HR} \end{aligned}$$

If a *UNIT* record is included in the data set with blank entries for *UNIT* and/or *UNHP*, their values are blanks. The units entered on the *UNIT* record are printed in the table headings but do not affect the data in the tables. Program *TABLES* organizes and manipulates data from *SIM* input and output files without considering units in its computations.

The listing of months in the table headings is controlled by field 4. If field 4 is left blank, the 12 monthly columns begin with January. The 12-month year may start in any other month as specified by an entry in field 4.

The variable *NEWPAGE* in field 5 is a switch specifying whether or not page breaks are inserted after each table. If *NEWPAGE* is zero (blank field 5) or positive, a page break is placed after each table causing the next table to begin a new page. A negative integer entered in field 5 results in omission of the page breaks.

A *UNIT* record is applicable to all subsequent records in the *TABLES* input data set.



**1SUM** Record – Water Rights Summary

| field | columns | variable | format | value                                     | description   |
|-------|---------|----------|--------|---|---|
| 1     | 1-4     | CD       | A4     | 1SUM                                      | Record identifier   |
| 2     | 8       | KK       | I4     | blank, 0, 1<br>2<br>3<br>4<br>5<br>6<br>7 | Summary by control point with only totals printed.<br>Summary by control point.<br>Summary by type of use.<br>Summary by water right type.<br>Summary by first water right group identifier.<br>Summary by second water right group identifier.<br>Summary by both water right group identifiers. |

Fields 3 through 10 are additional parameters for specifying water rights to include in table.

**1SRT** Record – Listing of Sorted Water Rights

| field | Columns | variable | format | value                                     | description   |
|-------|---------|----------|--------|---|---|
| 1     | 1-4     | CD       | A4     | 1SRT                                      | Record identifier   |
| 2     | 8       | KK       | I4     | blank, 0, 1<br>2<br>3<br>4<br>5<br>6<br>7 | Listing of rights in priority order.<br>Listing of rights by control point in priority order.<br>Listing of rights by type-of-use in priority order.<br>Listing of rights by water right type in priority order.<br>Listing of rights by first group in priority order<br>Listing of rights by second group in priority order<br>Listing of rights by both groups in priority order |

Fields 3 through 11 are additional parameters for specifying water rights to include in table.

**1RES** Record – Reservoir Information from *WS* Records in a DAT File

| field | columns | variable | format | value | description                         |
|-------|---------|----------|--------|-------|-------------------------------------|
| 1     | 1-4     | CD       | A4     | 1RES  | Record identifier                   |
| 2     | 8       | XLIMIT   | F12.0  | +     | Minimum reservoir storage capacity. |

Type 1 records (1SUM, 1SRT, 1RES, 1CPT, 1REC, 1CPT) read and organize data from the *SIM* input DAT file. The input records are described in Chapter 4 of the *Users Manual*. Examples are provided in Chapter 6 of the *Reference Manual*. A 1SUM table is included in the example in this *Fundamentals Manual*.

## **TABLES**

### **Time Series Records**

The following types of input records build tables in the same optional formats, with the only difference being the selection of variable to be tabulated. The items in parenthesis indicate whether the variable is associated with a control point, water right, and/or reservoir/hydropower.

|                    |  |
|--------------------|--|
| <b>2NAT</b> Record | – Naturalized Streamflow (control points)  |
| <b>2REG</b> Record | – Regulated Streamflow (control points)  |
| <b>2UNA</b> Record | – Unappropriated Streamflow (control points)   |
| <b>2CLO</b> Record | – Channel Loss (control points)  |
| <b>2CLC</b> Record | – Channel Loss Credits (control points)  |
| <b>2RFR</b> Record | – Return Flow Entering at this Control Point (control points)  |
| <b>2URR</b> Record | – Upstream Reservoir Releases (control points)   |
| <b>2CPI</b> Record | – Control Point Inflows excluding Secondary Reservoir Releases (control points)                      |
| <b>2STO</b> Record | – Reservoir Storage (control points, water rights, reservoirs)                                       |
| <b>2EVA</b> Record | – Reservoir Evaporation-Precipitation Volume (control points, water rights, reservoirs)              |
| <b>2DEP</b> Record | – Streamflow Depletion (control points, water rights)  |
| <b>2TAR</b> Record | – Diversion Target (control points, water rights)  |
| <b>2SHT</b> Record | – Diversion Shortage (control points, water rights)  |
| <b>2DIV</b> Record | – Diversion (control points, water rights)   |
| <b>2RFL</b> Record | – Return Flow (water rights)   |
| <b>2XAV</b> Record | – Increase in Available Streamflow Resulting from<br><i>PX</i> Record CP Limit Option (water rights) |
| <b>2ASF</b> Record | – Available Streamflow (water rights)  |
| <b>2ROR</b> Record | – Releases from Other Reservoirs (water rights)  |
| <b>2IFT</b> Record | – Instream Flow Target (instream flow rights, control points)  |
| <b>2IFS</b> Record | – Instream Flow Shortage (instream flow rights, control points)                                      |
| <b>2IFF</b> Record | – Instream Flow Target Supplied (instream flow rights, control points)                               |
| <b>2HPS</b> Record | – Hydropower Shortage (+) or Secondary Energy (–) (reservoir/hydropower)                             |
| <b>2HPE</b> Record | – Energy Generated (reservoir/hydropower)  |
| <b>2RID</b> Record | – Inflows to Reservoir from Streamflow Depletions (reservoir/hydropower)                             |
| <b>2RIR</b> Record | – Inflows from Releases from Other Reservoirs (reservoir/hydropower)                                 |
| <b>2RAH</b> Record | – Releases Accessible to Hydropower (reservoir/hydropower)   |
| <b>2RNA</b> Record | – Releases Not Accessible to Hydropower (reservoir/hydropower)                                       |
| <b>2EPD</b> Record | – Adjusted Evaporation-Precipitation Depths (reservoir/hydropower)                                   |
| <b>2EVR</b> Record | – Evaporation-Precipitation Depths from <i>EV</i> Records (reservoir/hydropower)                     |
| <b>2WSE</b> Record | – Reservoir Water Surface Elevation (reservoir/hydropower)   |
| <b>2RSC</b> Record | – Reservoir Storage Capacity (reservoir/hydropower)  |
| <b>2RSD</b> Record | – Reservoir Storage Drawdown (reservoir/hydropower)  |

**Time Series** Records – Record Types Listed on Preceding Page

| field | columns | variable | format | value                                      | description  |
|-------|---------|----------|--------|--|--|
| 1     | 1-4     | CD       | A4     | page 98                                    | Record identifier from the list of 34 identifiers.   |
| 2     | 8       | TA       | I4     | blank,0<br>1                               | Do not develop annual row/monthly column table.<br>Develop table with annual rows and monthly columns.   |
| 3     | 12      | PT       | I4     | blank,0<br>1<br>2<br>3<br>4<br>5<br>6<br>7 | Do not activate either HEC-DSS or text file option.<br>Develop columns of monthly data in TOU text file.<br>Develop columns of annual quantities in text file.<br>Develop columns of 12 monthly means in text file.<br>Develop HEC-DSS monthly time series records.<br>Develop HEC-DSS annual time series records.<br>The mean for the entire simulation in TOU text file.<br>Same as 6 but only summary total and mean written. |
| 4     | 16      | MORE     | I4     | 0<br>1                                     | Write columns; next record starts a new table.<br>Add more columns to existing table or start first table.   |
| 5     | 20      | ID       | I4     | 0<br>1<br>2<br>3                           | Develop tables for default ID or for control points.<br>Develop tables for water rights.<br>Develop tables for reservoirs.<br>Develop tables for water right groups.   |
| 6     | 24      | NUM      | I4     | blank,0<br>–<br>+                          | Tables for all control points (ID=0), rights (ID=1),<br>or reservoirs (ID=2). NUM cannot be zero if ID=3.<br>Develop tables for the NUM control points, rights,<br>reservoirs, or right groups listed on a previous record.<br>Number of control points, water rights, reservoirs,<br>or water right groups to follow on IDEN records.   |
| 7     | 28      | INPUT    | I4     | blank,0,1<br>2                             | Annual dataset from DATA record.<br>Monthly or daily dataset from DATA record.   |
| 8     | 32      | DECIMAL  | 3x,A1  | blank<br>0,1,2,3,4                         | Standard number of digits.<br>Number of digits to the right of the decimal.  |
| 9     | 36      | TOTALS   | I4     | Blank,0<br>1,+                             | Aggregated totals option is not activated.<br>Totals for all control points, water rights, or reservoirs.  |
| 10    | 40      | CFS      | I4     | 1, +                                       | Conversion from acre-feet/month to cfs.  |
| 11    | 40      | MAT      | I4     | blank,0<br>1<br>2                          | Moving average/total option is not adopted.<br>Moving averages are computed for TIME months.<br>Moving totals are computed for TIME months.  |
| 12    | 45-48   | TIME     | I4     | +  | Number of months for moving averages or totals.  |
| 13    | 49-56   | XF       | F8.0   | +, -, blank                                | Multiplier factor. Default multiplier factor = 1.0   |
| 14    | 57-64   | AF       | F8.0   | +, -, blank                                | Addition factor. Default addition factor = 0.0<br>$X2 = (XF)(X1) + AF$   |
| 15    | 65-72   | XUL      | F8.0   | +, -, blank                                | Upper limit defining selected range of values.   |
| 16    | 73-80   | XLL      | F8.0   | +, -, blank                                | Lower limit defining selected range of values.   |

## TABLES

### Explanation of Time Series Input Record Fields

**Field 1:** Variables are selected by this record identifier. One of the 34 alternative record identifiers, indicating variable selection, listed on page 98 may be entered in field 1. Alternatively, the data array developed by a DATA or DSSM record can be accessed by entering 2DAT or 2DSS for the field 1 *CD* as explained in the *Reference* and *Users Manuals*. In this case, a DATA or DSSM record is located ahead of the time series record in the input TIN file. The time series record will use the data array created by the DATA or DSSM record.

**Fields 2 and 3:** The types of tables or datasets to be created are selected in fields 2 and 3. Program *TABLES* creates no output if fields 2 and 3 are both blank. Parameter *TA* in field 2 deals only with monthly data. Field 3 must be activated to deal with annual or daily data. Options selected by *PT* in field 3 are applicable with either annual, monthly, or daily data.

**Field 2:** A set of one or more tables with rows for years and columns for months and annual totals or means is created by entering the integer 1 in field 2. The tables are written to the *TABLES* output file which has a default filename extension TOU.

**Field 3:** Either columns of data may be written to the TOU file or HEC-DSS records may be written to the DSS file. The data may include either monthly, daily, or annual amounts. Annual amounts may be accessed from a DATA record array or annual means or totals may be computed directly from monthly quantities read from the *SIM* output OUT file.

A TOU file table activated by entering a 1, 2, or 3 in field 3 consists of a single column for each variable with multiple variables being included as separate columns in the same table. This format is convenient for transport to a spreadsheet program. The column may contain either the entire time series of monthly data (*PT*=1), annual totals or means for each year (*PT*=2), or a set of 12 means for each of the 12 months of the year (*PT*=3). The parameter *MORE* in field 4 controls whether another column is added to the current table or a new table is started.

Options 4 and 5 in field 3 consist of storing the monthly or annual time series as binary records in a HEC-DSS file, accessible to graphing and other capabilities provided by HEC-DSSVue. HEC-DSS references data records by their pathnames, which consist of six parts in the format /A/B/C/D/E/F/. The pathname is assigned automatically by *TABLES* as indicated below.

- A – filename root of *TABLES* output files
- B – identifier of control point, water right, reservoir, or water right group
- C – record identifier for *TABLES* input record such as 2REG, 2DIV, 2WSE, etc.
- D – date of the beginning of the time series such as 01JAN1940
- E – time interval = MON or YEAR for *SIM* results (*SIMD* includes sub-monthly.)
- F – CP, WR, Res, or WRG (control point, water right, reservoir, water right group)

*PT* option 6 condenses the output to a single mean for the entire simulation for each specified control point, water right, or reservoir along with a total summation of the means.

**Field 4:** Field 4 is relevant only if a columnar tabulation is activated by entering a 1, 2, or 3 in field 3. Each variable is tabulated as a single column in a table. The parameter *MORE* in field 4 specifies whether to place another column in the current table or to create another new table. Each table can include any number of columns up to a limit of 100 columns. At least one record must have a *MORE* of zero in order to write the table.

**Field 5:** The time series variables are associated with either control points ( $ID=0$ ), water rights ( $ID=1$ ), reservoirs ( $ID=2$ ), and/or water right groups ( $ID=3$ ) as indicated in Table 4.9. For variables associated with only one ID, field 5 may be left blank. For variables that may be associated with more than one ID, an ID selection is entered in field 5. Summation of data for all water rights in a group ( $ID=3$ ) may be tabulated by 2STO, 2EVA, 2DEP, 2TAR, 2SHT, or 2DIV records by entering a 3 in field 5.

**Field 6:** The default is to include all of the control points ( $ID=0$ ), water rights ( $ID=1$ ), or reservoirs ( $ID=2$ ) found in the *SIM* OUT file. Optionally, *NUM* control points, water rights, reservoirs, or water right groups may be selected by listing identifiers on one to ten supplemental IDEN records. Water right groups may be selected only by listing them. A negative value for *NUM* may be entered in field 6 to indicate that the list read from a previous record is to be repeated. IDEN records are used if and only if *NUM* is a positive integer.

**Field 7:** A DATA record array is accessed by entering 2DAT in field 1. The DATA record manipulates monthly *SIM* or daily *SIMD* simulation results and may use these data to develop an annual dataset with one quantity per year. The field 7 default option 1 is to use the annual series.

**Field 8:** The data in the tables or tabulations created by *TABLES* may be recorded with either zero, 1, 2, 3, or 4 digits to the right of the decimal point. A blank field 7 results in a standard default number of digits that varies between variables and with the magnitude of the number.

The model-user will normally not want to record the simulation results in the *TABLES* output with more digits to the right of decimal than provided in the *SIM* output. *SIM* writes diversion targets and shortages in the OUT file with 3 digits to the right of the decimal (to nearest 0.001 unit). Net evaporation depths are recorded to the nearest 0.0001 unit. Reservoir water surface elevations in the *SIM* output file have three digits to the right of the decimal. Instream flow targets and shortages are recorded to the nearest 0.01 unit for instream flow rights and 0.1 unit for control points. The other variables in the OUT file have 2 digits to the right of the decimal (to nearest 0.01 unit) as described in Chapter 5 of the *Reference Manual*.

**Field 9:** The values for all the control points, rights, or reservoirs are summed in each month. The TOTALS option is valid for ID of 0, 1, or 2 and NUM of 0 in fields 5 and 6.

**Fields 11 and 12:** A non-zero *MAT* in field 8 results in the monthly time series data being converted to either moving averages or moving totals for *TIME* months, where the number of months *TIME* is entered in field 9. A moving total is the summation of amounts during the *TIME* most recent months including the current month. A moving average is the moving total divided by *TIME* months. The averages or totals are computed for the data in *TIME* months, including the current month and the *TIME*-1 preceding months. For the first *TIME* months of the time series, the moving totals or averages reach back to the beginning of the simulation. After totaling or averaging the data read from the OUT file, all other *TABLES* operations and the format of the output remain unchanged. A line is added to the heading for annual row/monthly column tables indicating that the data in the table are moving averages or totals.

**Fields 13 and 14:** The time series data are multiplied by *XF* (default  $XF=1.0$ ) and added to *AF* (default  $AF=0.0$ ) to serve various purposes. For example, *XF* may be a unit conversion factor. Reservoir storage may be converted to draw-down with  $XF = -1.0$  and *AF* = storage capacity.

**Fields 15 and 16:** The variable is changed to zero for all time periods in which the values falls outside of the range defined by the optional specified upper and lower limits.

## TABLES

### IDEN Records – Identifiers of Control Points, Water Rights, Water Right Groups, or Reservoirs

| field | columns | variable                        | format               | value | description  |
|-------|---------|---------------------------------|----------------------|-------|--|
| 1     | 1-4     | CD                              | A4                   | IDEN  | Record identifier  |
| 2-13  | 5-68    | IDCP(I)<br>IDRES(I)<br>IDEN8(I) | 12A8<br>12A8<br>12A8 | AN    | Identifiers of control points (ID=0), reservoirs (ID=2), water rights (ID=1), water right groups (ID=3). Used for non-zero positive NUM. |
| 2-13  | 5-132   | IDEN16(I)<br>I = 1, 12          | 12A16                |       | Twelve identifiers per record. Maximum of 100 identifiers. Blank fields are skipped over.  |

If the parameter *NUM* is greater than zero on the 34 time series listed on page 98, 2REL, or 2FRE records, a set of control point, reservoir, water right, or water right group identifiers are listed on one or more IDEN records following directly behind the referencing record. IDEN records contain only the *CD* of IDEN and the identifiers. IDEN records follow if and only if *NUM* is a positive non-zero integer. The actual value of the positive non-zero *NUM* is not relevant since the number of identifiers on the IDEN records is automatically counted. Any number of identifiers up to a maximum 100 may be included in each set of IDEN records. Any number of IDEN records with any number up to 12 identifiers or blank fields on each record may be included in each set of records. Only the non-blank fields of the IDEN records are read.

Any negative value for *NUM* adopts the last identifiers stored in memory in the IDCP, IDRES, IDEN8, or IDEN16 array. Identifiers entered once may be repeatedly used any number of times.

**2REL Record – Water Supply Diversion or Hydroelectric Energy Reliability Summary**

| field | columns | variable | format | value                            | description   |
|-------|---------|----------|--------|----------------------------------|---|
| 1     | 1-4     | CD       | A4     | 2REL                             | Record identifier   |
| 2     | 7-8     | MON      | I4     | blank,0<br>+                     | All months are included in the computations.<br>The month for which the analysis is performed.  |
| 3     | 12      | RFLAG    | I4     | blank,0<br>1,+                   | N = number of months with non-zero targets<br>$N = (\text{years})(12 \text{ months/year})$ for $R_p = (n/N) \times 100\%$   |
| 4     | 16      | ID       | I4     | blank,0<br>1<br>2<br>3<br>4<br>5 | <u>Control Points, Rights, Hydropower, WR Groups</u><br>Control points are selected in fields 5 and 6.<br>1 Water rights are selected in fields 5 and 6.<br>2 Hydropower reservoirs are selected in fields 5 and 6.<br>3 Summations for selected right groups or use types.<br>4 Water rights are selected by fields 6,7,8,9,10,11,12.<br>5 DSSM or DSSD record data array and identifiers. |
| 5     | 20      | NUM      | I4     | blank,0<br>1<br>-1               | Include all control points (ID=0), all water rights (ID=1), or all reservoirs (ID=2) or all up to 100 water right groups (ID=3) in reliability table.<br>1 Water right, reservoir, water right group, or control point identifiers follow on IDEN record(s).<br>-1 Identifiers assigned by last previous IDEN records.  |
| 6     | 21-28   | FAMT     | F8.0   | blank,0.0<br>-1.0<br>+           | <u>Minimum Limit on Annual Target for ID 1, 2, 3, 4</u><br>All water rights with non-zero target are included.<br>-1.0 All rights included even those with zero target.<br>+ Minimum limit on annual computed OUT file target.  |

Fields 7 through 14 are parameters for selecting water rights for inclusion in the table. Fields 13 and 14 activate additional auxiliary tables. These options are described in the *Users Manual*.

The 2REL record routine computes reliability metrics for *WR* record diversion targets and hydroelectric energy targets but do not include *IF* record instream flow rights. Reliability analysis methods and examples are found in the *Reference Manual* and pages 43-45 of this *Fundamentals Manuals*.

**Explanation of 2REL Record Fields**

**Field 2:** If a 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, or 12 is entered for *MON* in field 2, reliabilities are computed for the specified month. For example, reliabilities for meeting a diversion target in August (*MON* = 8) may be computed. The default is to include is all months in the computations.

**Field 3:** Period reliability computations may be based either on using simulation results from only the months with non-zero targets or using all months including those with zero target. The default *RFLAG* is to use only those months with zero targets. For example, for an agricultural irrigation diversion right, only months during the irrigation season with non-zero demands are considered.

## ***TABLES***

***Field 4:*** *TABLES* reads *SIM* simulation results output data for individual water rights (ID=1) from water right output records in the *SIM* output OUT file, simulation results for control points (ID=0) from the control point output records in the OUT file, or *SIM* output data for reservoir/hydropower projects (ID=2) from the reservoir records in the OUT file. ID=5 is described in *Users Manual*.

With ID options 1 and 4, reliabilities are tabulated for individual water rights. With default ID option 0, reliabilities are tabulated for the aggregation (summation) of all water rights at selected individual control points. For control points, reliabilities are for the summation of the diversions for all the rights located at each control point. Likewise, with the ID option 2, reliabilities are presented for the aggregated totals of all water rights at selected individual reservoirs/hydropower plants.

With ID option 3, reliabilities are tabulated for the total target amounts computed by summing the targets and shortages of all water rights identified with specified groups of water rights. Water right group identifiers are defined by fields 12 and 13 of the *WR* records in the *SIM* input DAT file and are included on the simulation output records written by *SIM* to the OUT file.

Reliabilities are for either water supply diversions or hydroelectric energy production. Control point (ID=0) output records include only diversions. For hydropower reservoirs (ID=2), reliabilities are computed only for electric energy generation for the most junior right at the reservoir. For water rights (ID = 1, 4) and water right groups (ID = 3), reliabilities may be computed for either water supply diversions or hydropower generation. However, inclusion of both diversions and hydropower in the same reliability table may be confusing and normally should be avoided.

*TABLES* works directly with data read from the *SIM* output OUT file. *SIM* parameters control the water rights, control points, and reservoir/hydropower projects for which simulation results are recorded in the OUT file. In discussing *TABLES*, all water rights or all control points or all reservoirs mean all of these output record types included by *SIM* in its OUT file. All water rights are assigned a control point in a *SIM* simulation. However, some or many water rights typically do not have reservoirs or water right group identifiers.

***Field 5:*** A blank or zero field 5 results in all of either the water rights (ID=1), control points (ID=0), reservoir/hydropower projects (ID=2), or water right groups (ID=3) in the *SIM* OUT file being included in the reliability table. *NUM* and *IDEN* records are not applicable for ID option 4.

Optionally, lists of control points, water rights, reservoir/ hydropower projects, or water right groups may be entered in *IDEN* records. Time series (page 98), *2REL*, and *2FRE* records employ *IDEN* records in identically the same way. With a 1 or any positive non-zero *NUM*, one or more *IDEN* records follow immediately behind the time series, *2REL*, or *2FRE* record. The number of identifiers on the *IDEN* records are automatically counted as the records are read.

A -1 or any negative integer in field 5 results in the identifiers assigned by the last previously read *IDEN* records being repeated. *IDEN* records enter identifiers into memory that may be then used repeatedly any number of times with negative entries for *NUM*.

***Field 6:*** Field 6 and fields 7-12 reduce the size of the reliability table. Control points (ID=0), water rights (ID=1,4), reservoir/hydropower projects (ID=2), or water right groups (ID=3) are omitted from the reliability table if the mean annual target is less than the final annual target limit *FAMT* entered in field 6.



## 2FRE Record – Flow-Frequency or Storage-Frequency Relationships

| field | columns | variable | format | value       | description  |
|-------|---------|----------|--------|-------------|--|
| 1     | 1-4     | CD       | A4     | 2FRE        | Record identifier  |
| 2     | 7-8     | Variable | I4     | 1           | Naturalized flows (ID=0)   |
|       |         |          |        | 2           | Regulated flows (ID=0)   |
|       |         |          |        | 3           | Unappropriated flows (ID=0)  |
|       |         |          |        | 4           | Reservoir storage associated with control points (ID=0)                                    |
|       |         |          |        | -4          | Reservoir storage associated with control points with only totals included in table (ID=0) |
|       |         |          |        | 5           | Reservoir storage associated with water rights (ID=1)                                      |
|       |         |          |        | -5          | Reservoir storage associated with a water rights with only totals included in table (ID=1) |
|       |         |          |        | 6           | Reservoir storage associated with reservoirs (ID=2)  |
|       |         |          |        | -6          | Reservoir storage associated with reservoirs with only totals included in table (ID=2)     |
|       |         |          |        | 7           | Reservoir water surface elevation (ID=2)   |
|       |         |          |        | 8           | Instream flow target for control points (ID=0)   |
|       |         |          |        | 9           | Instream flow shortage for control points (ID=0)   |
|       |         |          |        | 10          | IF shortage as % of target for control points (ID=0)                                       |
|       |         |          |        | 11          | Instream flow target for IF record rights (ID=1)   |
|       |         |          |        | 12          | Instream flow shortage for IF record rights (ID=1)   |
|       |         |          |        | 13          | IF shortage as % of target for IF record rights (ID=1)                                     |
|       |         |          |        | 14, 15      | DATA record array described in <i>Users Manual</i> .                                       |
|       |         |          |        | 16          | DSSM or DSSD array described in <i>Users Manual</i> .                                      |
| 3     | 11-12   | MON      | I4     | blank, 0    | All months are included in the computations.   |
|       |         |          |        | +           | The month for which the analysis is performed.   |
| 4     | 15-16   | NUM      | I4     | 0           | Include all control points, rights, or reservoirs in table.                                |
|       |         |          |        | +           | Control points, rights, or reservoirs on IDEN records.                                     |
|       |         |          |        | -           | Identifiers from previous IDEN records are repeated.                                       |
| 5     | 20      | TABLE    | I4     | blank, 0, 1 | Frequency table is created in standard row format.   |
|       |         |          |        | 2           | Frequency results are tabulated as columns.  |
|       |         |          |        | 3           | Abbreviated frequency results tabulated as columns.  |
|       |         |          |        | 4           | Quantities are expressed as a percentage of maximum.                                       |
| 6     | 24      | METHOD   | I4     | blank, 0, 1 | Relative frequency $P = (n/N) 100\%$   |
|       |         |          |        | 2           | Log-normal probability distribution.   |
|       |         |          |        | 3           | Normal probability distribution.   |
|       |         |          |        | 4           | Weibull relative frequency $P = [n/(N+1)] 100\%$   |
| 7     | 28      | MAT      | I4     | blank, 0    | Moving average/total option is not adopted.  |
|       |         |          |        | 1           | Moving averages are computed for TIME months.  |
|       |         |          |        | 2           | Moving totals are computed for TIME months.  |
| 8     | 32      | TIME     | I4     | +           | Number of months for moving averages or totals.  |
| 9     | 33-40   | XF       | F8.0   | +, -, blank | Multiplier factor. Default multiplier factor = 1.0   |
| 10    | 41-48   | AF       | F8.0   | +, -, blank | Addition factor. Default addition factor = 0.0   |
| 11    | 49-56   | XLIMIT   | F8.0   | +           | Minimum limit of monthly mean for inclusion in table.                                      |

## TABLES

### Explanation of 2FRE Record Fields

A 2FRE record develops probability statistics including mean, standard deviation, and quantities associated with specified exceedance frequencies for the variables listed in 2FRE field 2 or through use of a DATA record for any of the simulation results variables or transformations thereof.

**Field 2:** Any number of control points, water rights, or reservoirs may be included in a frequency table. Storage frequency tables also include the total storage associated with each frequency for all the control points, rights, or reservoir. A -4, -5, or -6 specifies that only the storage totals are included in the table without listing the individual control points or rights.

**Field 3:** If a 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, or 12 is entered for *MONTH* in field 2, frequencies are computed for only the specified month. The default is to include is all months in the analysis.

**Field 4:** The parameter *NUM* is identical in 2FRE record field 4, 2REL record field 5, and field 6 of the time series records.

**Field 5:** Alternative formats for displaying the results of the frequency computations.

**Field 6:** All four alternative methods for performing the frequency computations are explained in the *Users and Reference Manuals*. Option 1 is covered in the *Fundamentals Manual*.

**Fields 7, 8, 9 and 10:** Fields 7 through 10 of the 2FRE record are the same as fields 8 through 11 of the time series records described on pages 98-101.

### 2FRQ Record – Frequency for Specified Flow or Storage

| field | columns        | variable        | format       | value        | description  |
|-------|----------------|-----------------|--------------|--------------|--|
| 1     | 1-4            | CD              | A4           | 2FRQ         | Record identifier  |
| 2     | 8              | Variable        | I4           | +            | Variable selections in field 2 are the same for 2FRE and 2FRQ records except for -4, -6, and -5.                       |
| 3     | 12             | MONTH           | I4           | 0,blank<br>+ | All months are included in the computations.<br>The month for which the analysis is performed.                         |
| 4     | 16             | NM              | I4           | +            | Number of flows or storages entered for <i>TABLES</i> to determine frequencies (NM may range from 1 to 7)              |
| 5     | 17-24<br>17-32 | IDEN<br>IDEN16  | 2x,A6<br>A16 | AN           | Identifier of control point (field 2 variables 1-4), water water right (variables 5, 8), or reservoir (variables 6, 7) |
| 6-12  | 25-80<br>33-88 | QF(I)<br>I=1,NM | 7F8.0        | +            | Streamflow (variables 1,2,3), storage (variables 4,5,6), elevation (7), or instream flow shortage (variables 8,9)      |

A 2FRE record creates a frequency table with a set of pre-defined frequencies. The 2FRQ frequency table contains computed frequencies for up to 7 specified flow, storage, elevation, or instream flow target or shortage amounts specified in fields 6, 7, 8, 9, 10, 11, and 12 for a single control point, water right, or reservoir specified in field 5. Fields 2 and 3 are the same for the 2FRQ and 2FRE records, except the 2FRQ record does not include reservoir storage summations.

**2SCP Record – Summary Tables for Control Points**

| field | columns | variable             | format   | value             | description   |
|-------|---------|----------------------|----------|-------------------|---|
| 1     | 1-4     | CD                   | A4       | 2SCP              | Record identifier   |
| 2     | 8       | MNAN                 | I4       | 0<br>1<br>2       | Annual table<br>Monthly table<br>Both annual and monthly tables   |
| 3     | 9-12    | NUM                  | I4       | blank,0<br>+<br>– | Develop tables for all control points.<br>Number of control points to follow.<br>NUM identifiers from previous record are repeated. |
| 4-11  | 13-76   | IDCP(I)<br>I = 1,NUM | 8(2x,A6) | AN                | Identifiers of the selected control points for which to develop summary tables.   |

**2SWR Record – Summary Tables for Water Rights**

| field | columns | variable               | format | value             | description   |
|-------|---------|------------------------|--------|-------------------|---|
| 1     | 1-4     | CD                     | A4     | 2SWR              | Record identifier   |
| 2     | 5-8     | MNAN                   | I4     | 0<br>1<br>2       | Annual table<br>Monthly table<br>Both annual and monthly tables   |
| 3     | 9-12    | NUM                    | I4     | blank,0<br>+<br>– | Develop tables for all water rights.<br>Number of water rights to follow.<br>NUM identifiers from previous record are repeated. |
| 4-11  | 13-140  | IDEN16(I)<br>I = 1,NUM | 8A16   | AN<br>blank       | Identifiers of water rights for which to develop tables.<br>If NUM is zero or negative  |

2SCP, 2SWR, 2SGP, and 2SRE records are essentially the same except *IDCP* and *IDRES* denote control point and reservoir identifiers which may have a maximum of six characters, *IDEN8* denotes water right group identifiers which may consist of up to eight characters, and *IDEN16* is for water right identifiers which may be up to 16 characters long. Time series, 2REL, 2FREQ, 2SCP, 2SWR, and 2SRE records enter identifiers into memory that may be repeated with a negative NUM.

Water right groups must be listed explicitly on the 2SGP record. *NUM* cannot be zero for a water right group operation.

*TABLES* reads the data for 2SCP and 2SBA tables from the control point records in the *SIM* output file. The data for the 2SWR and 2SGP tables are from the water right records in the *SIM* output file. The data for the 2SRE table are from the reservoir/hydropower records in the *SIM* output file.

## **TABLES**

### **2SGP** Record – Summary Tables for Water Right Groups

| field | columns | variable               | format | value                  | description   |
|-------|---------|------------------------|--------|------------------------|---|
| 1     | 1-4     | CD                     | A4     | 2SGP                   | Record identifier   |
| 2     | 5-8     | MNAN                   | I4     | 0<br>1<br>2            | Annual table<br>Monthly table<br>Both annual and monthly tables   |
| 3     | 9-12    | NUM                    | I4     | 1,2,3,...,8<br>99<br>– | Water right groups are listed in fields 4 through 11.<br>Group identifiers on following IDEN records.<br>Identifiers from previous IDEN records are repeated. |
| 4-11  | 13-140  | IDEN8(I)<br>I = 1, NUM | 8A8    | AN                     | Identifiers of groups for which to develop tables.<br>Fields used only if NUM is 1, 2, 3, 4, 5, 6, 7, or 8.   |

### **2SRE** Record – Summary Tables for Reservoirs

| field | columns | variable | format   | value                             | description   |
|-------|---------|----------|----------|-----------------------------------|---|
| 1     | 1-4     | CD       | A4       | 2SRE                              | Record identifier   |
| 2     | 5-8     | MNAN     | I4       | 0<br>1<br>2                       | Annual table<br>Monthly table<br>Both annual and monthly tables   |
| 3     | 9-12    | NUM      | I4       | blank,0<br>1,2,3,...,8<br>99<br>– | Develop tables for all reservoirs.<br>Reservoirs are listed in fields 4 through 11.<br>Reservoir identifiers on following IDEN records.<br>Identifiers from previous IDEN records are repeated. |
| 4     | 13-76   | IDRES(I) | 8(2x,A6) | AN                                | Identifiers of reservoirs for which to develop tables.<br>Fields used only if NUM is 1, 2, 3, 4, 5, 6, 7, or 8.   |

### **2SBA** Record – Aggregate Summary Table for the Entire River Basin

| field | column | variable | format | value       | description   |
|-------|--------|----------|--------|-------------|---|
| 1     | 1-4    | CD       | A4     | 2SBA        | Record identifier   |
| 2     | 8      | MNAN     | I4     | 0<br>1<br>2 | Annual table<br>Monthly table<br>Both annual and monthly tables |