HSPEXP+ USER'S MANUAL
VERSION 3.0

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MARCH 2019

Project Number 2986
RSI-2770

DISCLAIMER

HSPEXP+ has been developed by RESPEC to support hydrology and water quality calibration of watershed models that are developed using Hydrologic Simulation Program-Fortran (HSPF) and conduct quality assurance and quality control of the models. This project is open source and released free of cost to support modelers who are using HSPF. This project is under active development, and as a result, we welcome any user comments, suggestions, and recommendations for implementation in future versions. However, no active support is available for HSPEXP+ by RESPEC or any other agency. RESPEC and the authors do not assume any responsibility for system operation, output, interpretation, or use.

ACKNOWLEDGEMENTS

HSPEXP+ is being developed by RESPEC to support watershed modeling projects. Version 3.0 has been developed by a RESPEC team including Mr. Paul Duda, Dr. Anurag Mishra, Mr. Paul Hummel, Mr. Tony Donigian, Mr. Seth Kenner, Mr. Chris Lupo, and Mr. Geoff Kramer. Dr. Anurag Mishra was the project manager and responsible for the project design, implementation, and testing prior to version 3.0. Technical and administrative guidance for earlier versions was provided by Mr. Paul Duda, Mr. Mark Gray, Mr. Brian Bicknell, and Mr. Tony Donigian. HSPEXP+ is under continuous development, and new capabilities are added to meet the priority needs of the user community, as additional resources are made available.

HSPEXP+ is an updated, refined, and expanded version of HSPEXP, originally developed by the USGS [Lumb et al., 1994]. It was developed as an 'expert system' for HSPF watershed model hydrologic calibration, hence the name "HSPEXP."

Dr. Rebecca Zeckoski from Virginia Tech assisted in developing the initial user interface and coding the expert guidance. Support for Dr. Zeckoski's contributions was made possible by the Center of Watershed Studies within Virginia Tech's Biological System Engineering Department.

The Clean Water Fund of Minnesota has supported the development of HSPEXP+ and the versions following the release of HSPEXP+1.0 in February 2015.

RESPEC thanks the modelers who provide valuable feedback to the HSPEXP+ project.

USER ASSISTANCE AND FEEDBACK

As indicated earlier, active support for HSPEXP+ is not available; however, feedback may be provided by email (hspexpplus@respec.com).

GLOSSARY OF TERMS

Term	Definition
HSPF	Hydrologic Simulation Program – Fortran
HSPEXP	EXPERT system for Calibration of HSPF
HSPEXP+	Enhanced Expert System for Calibration of HSPF
BASINS	Better Assessment Science Integrating point and Nonpoint Sources
UCI	User's Control Input
WINHSPF	Windows interface for HSPF
EXS	BASINS-Specification File
PERLND	Pervious land operation in UCI
PQUAL	Module for simulating Quality constituent on PERLND
IMPLND	Impervious Land operation in UCI
IQUAL	Module for simulating quality constituent on IMPLND
RCHRES	Operation to simuate rivers and lakes in UCI
ECH	ECHO file output from the HSPF model run.
EXT TARGETS	External Targets block in UCI file that directs the model data to output to different formats
WDM	Watershed Data Management. A binary format for saving time-series data.
SCHEMATIC	A block in UCI file that directs how the different operations connect to each other to pass different time series
MASS-LINK	A block in UCI file that directs how the time series are passed among operations
GEN-INFO	General Information block in UCI that describes the properties of land and RCHRES operations
CSV	Comma-Separated Values File Format
PNG	Portable Network Graphics File Format
EMF	Enhanced metafile format
JSON	Javascript Object Notation (JSON) format
DBF	dBase database file

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1.0 INTRODUCTION

The legacy version of Expert System for Calibration of HSPF (HSPEXP) [Bicknell et al., 2005] was developed by the US Geological Survey (USGS) [Lumb et al., 1994] as a tool to assist model users with hydrologic calibration of HSPF. HSPEXP+ is the next generation of HSPEXP.

HSPEXP+ has been completely redesigned and shares only some of the legacy input file format, mathematical formulae, and algorithms from HSPEXP. HSPEXP+ can perform several additional functions and has evolved into a comprehensive tool for hydrologic and water quality calibration, as well as quality assurance/quality control (QA/QC) for HSPF models.

HSPEXP (legacy version) interactively allows the user to edit the input UCI file for HSPF, run HSPF simulations, produce plots of HSPF hydrology outputs compared to observed values, compute error statistics for a simulation, and provide the user with expert advice on which parameters should be changed to improve the calibration. In general, using HSPEXP is an interactive process that requires repeating the cycle of simulation, computing statistics, reviewing plots, getting advice, and modifying parameters.

Artificial intelligence (AI) was first used with HSPF on a project at the Stanford Research Institute (SRI) in Menlo Park, California, to estimate initial values for model parameters. HSPEXP is the result of a USGS project to create an expert system to assist with calibrating a watershed model. The prototype was developed with AI software tools, and, when properly refined, was converted to ANSI standard Fortran using the Graphical Kernel System (GKS) for portability.

HSPEXP uses over 35 rules that involve over 80 conditions to recommend parameter adjustments. The rules are divided into four groups: annual volumes, low flows, storm flows, and seasonal flows. Rules in subsequent groups are not tested until all rules in the previous group pass. The rules are based on the experience of experts who have used HSPF in a variety of climates and physiographic regions.

Meteorological records of precipitation and estimates of potential evapotranspiration in a Watershed Data Management (WDM) file are required for watershed simulation using HSPF. Air temperature, dew point temperature, wind, and solar radiation are also required for simulating snow accumulation and melt. Air temperature, wind, solar radiation, humidity, cloud cover, tillage practices, point sources, and/or pesticide applications may be required for water quality simulation. Physical measurements and related parameters are required to describe the land area, channels, and reservoirs.

Output options include tables of statistics that compare observed data and simulated results, ten different types of graphical presentations, and tables of the expert advice. Time-series output data from the simulation is written to the WDM file. Output data may be viewed interactively or written to text files for printing or analysis in a spreadsheet program.

HSPEXP has been used to support HSPF applications in various watersheds including the Patuxent River (Maryland), the LeSueur River Basin (Minnesota), and the Truckee River Basin (California/Nevada).

HSPEXP was developed for older operating systems, and multiple users have reported that it is not suitable for current computers. The USGS has stopped active development of HSPEXP.
Building on the algorithms of HSPEXP, HSPEXP+ was developed by RESPEC to facilitate hydrologic and water quality calibration projects. The software is available free of cost through the RESPEC website, and its source code is available along with the BASINS source code.

2.0 CAPABILITIES OF HSPEXP+

HSPEXP+ is developed on the codebase of BASINS and can interact with the multiple data formats that are used in the HSPF model as described later. HSPEXP+ reads the UCI file for an HSPF watershed model as well as the output data generated by HSPF and then generates multiple reports, graphs, and guidance to assist in hydrologic and water quality calibration. HSPEXP+ also can be used for QA/QC.

Unlike its predecessor, HSPEXP+ cannot be used interactively to edit HSPF UCI files. HSPEXP+ also cannot generate the BASINS Specifications (EXS) file. However, HSPEXP+ users may prepare the EXS file using WinHSPF3.1, or in a text editor. The UCI file can be edited in WinHSPF or a text editor (based on the calibration results and advice generated by HSPEXP+).

2.1 HYDROLOGIC CALIBRATION

HSPEXP+ uses the EXS file (extension *.exs) to obtain information about the calibration site, observed flow time-series dataset, simulated time-series datasets, analysis period, drainage area, storm periods, and error criteria. The format of the EXS file is consistent with that used by HSPEXP. To read more about this file, please refer to the HSPEXP manual [Lumb et al., 1994]. The content and format of the EXS file has been described in the EXS File section of this manual. WinHSPF3.1 can be used to generate an EXS file interactively, which can be edited in a text editor later, if needed.

The following are HSPEXP+ capabilities for hydrologic calibration:

- Land use and watershed area reports are produced to provide a quick check of watershed segment connectivity.
- Expert Statistics [Lumb et al., 1994] are produced for hydrology calibration (using the algorithms from the original HSPEXP) at multiple sites in the watershed and in simple text files. The EXS file can list more than one site, or the folder that contains the model calibration files can have multiple EXS files for multiple locations.
- Advice for model calibration is produced for each calibration site in a text file.
- Additional statistics are produced including annual, monthly, and daily flow comparisons.
- Overall, annual, and monthly time-series graphs, flow frequency duration graphs, cumulative flow graphs, and time-series graphs of other components (e.g., potential evapotranspiration, lower zone storage, and upper zone storage) are produced.
- By default, HSPEXP+ (and its predecessor, HSPEXP) considers May, June, and July to be the summer months and December, January, and February to be the winter months for calculating seasonal statistics. In HSPEXP+, summer and winter months can be specified in the EXS file if changes to the default seasons are needed (i.e, northern and colder regions of the US or southern hemisphere). Please refer to the EXS file section for more details.
- All graphs produced by HSPEXP+ are high-quality PNG format that can be directly inserted into reports and presentations.
- All reports produced by HSPEXP+ can be directly opened in any spreadsheet program for quick viewing, formatting, and presentation.

- All graphs and reports are produced in a time-stamped folder with a copy of the UCI file for reference.
- HSPEXP+ can generate water balance reports in several layouts that include overall water balance, annual water balance, and water balance grouped by land use.

2.2 WATER QUALITY CALIBRATION

HSPEXP+ does not require the EXS file for water quality calibration tasks. HSPEXP+ can create simulated and observed data graphs as described in Section 2.3, and it can generate various constituent loading and reach budget reports as described below.

- HSPEXP+ generates nutrient balance reports in a variety of layouts for dissolved oxygen (DO), heat, sediment, total nitrogen (TN) and its components, and total phosphorus (TP) and its components.
- HSPEXP+ generates box-and-whisker plots of nutrient loading rates (i.e. lbs/ac/yr) for the entire watershed.
- HSPEXP+ produces Regan plots, which include a plot of simulated phytoplankton and benthic algae, along with multiple nutrients at all of the reaches, total suspended solids (TSS) at all of the reaches, maximum and minimum daily DO for all the reaches, and load duration curves for the reaches where River Eutrophication Standards (RES) are provided.
- HSPEXP+ does not calculate statistics that compare observed and simulated water quality data; however, it provides reports and graphs to better understand the water quality simulation and guide changes in the parameters accordingly. HSPEXP+ does not provide advice for water quality parameter adjustments.
- From HSPEXP+2.0 onwards, if GQUAL is simulated, HSPEXP+ will generate land loading and reach budget reports of the constituent, provided the GQUAL and related PQUAL are named exactly the same. This feature is still under testing, and users are advised extreme caution while analyzing the results from the GQUAL section.

2.3 AUTOMATED GRAPH GENERATION

Besides the typical graphs produced during hydrology calibration statistics generation, HSPEXP+ also generates graphs based on graph specification file(s), and a suite of QA/QC graphs called Regan plots. The automated graphs produced by HSPEXP+ are described below.

- HSPEXP+ produces Regan plots, which include a plot of simulated phytoplankton and benthic algae, along with multiple nutrients at all of the reaches, TSS at all of the reaches, Maximum and minimum daily DO concentration (if hourly DO is output in the binary file or WDM file), and load duration curves for the reaches where RES standards are provided.
- HSPEXP+ can generate additional graphs for water quality, snow depth, frequency duration, and scatter plots. The specifications for these graphs must be provided in one or more comma-separated file (*.csv format). From HSPEXP+2.0.0, HSPEXP+ can also produce graphs from files in JSON format generated by BASINS4.5 and later versions.

- The time series for these graphs can be obtained from a WDM file, HBN file, or a BASINS observed water quality (DBF format) file.
- HSPEXP+ also outputs the dataset used for generating the graphs in tab-delimited text files. Users can use the data in these text files for additional analysis outside of BASINS and HSPEXP+.

2.4 MULTI SIMULATION MANAGER

HSPEXP+ includes the capability to conduct multiple simulations based on a specification file provided by the user. The specification file is a CSV file that provides a list of WDM datasets for which HSPEXP+ will calculate statistics, a list of parameters that will be varied by HSPEXP+, and changes in the parameter value for each individual simulation. User can provide information about thousands of simulations in the specification file.

2.5 QA/QC REPORTING

HSPEXP+ produces a QA/QC report for the specified watershed model, providing a set of checks for HSPF hydrology and water quality models that are based on generalized professional judgment. HSPEXP+ uses the guidance from an existing body of watershed science knowledge and compares model parameters, pollutant loading rates, change in storages over the model simulation period etc. and presents them in the model QA/QC report.

The sequence of messages that are contained in the QA/QC Report for any UCI and its resulting output flag aspects of the model input and output that are considered nontypical, thereby providing the modeler with a checklist of items that warrant either re-affirmation or modification, either by refining aspects of the model input or undertaking additional calibration.

The sections of the QA/QC report include the following:

- Check of Watershed Area: HSPEXP+ reports areas of all operations contributing to the terminal reaches (with no outlets), as well as hydrology calibration reaches (determined through associated EXS files) . The resulting area table is designed to help the modeler understand if the model connectivity is working as expected.
- Parameter Values Analysis: Using a database of typical model parameter values for hydrology, sediment, temperature, dissolved oxygen, nitrogen, phosphorus, and biological oxygen demand as organics based on the modeling guidance developed for Minnesota Pollution Control Agency (MPCA) and BASINS technical notes, HSPEXP+ compares parameter values of each operation with this database and reports the parameters that are beyond the typical limits.
- Loading Rate Comparison to Target Rates: Using a database of typical-loading rates of total nitrogen (TN), total phosphorus (TP), biochemical oxygen demand (BOD), ammonia as nitrogen (NH4-N), nitrate as nitrogen (NO3-N), organic nitrogen (org-N), orthophosphorus as phosphorus (PO4-P), and organic phosphorus (org-P), based on modeling guidance developed for MPCA, HSPEXP+ compares the model-loading rates with the target-loading rates and reports the anomalies.
- Land Use Comparisons: Using the model output and a set of rules based on previous modeling guidance, HSPEXP+ reports anomalies in runoff and constituent loadings among the land use

categories in the model. For example, given that cropland typically has greater surface runoff than forest land, this section will compare the runoff rates for these land uses and report if it is different than expected.

- Constituent Storage Analysis: HSPEXP+ analyzes storage of select constituents in the model results, such as reach volume, bed sediment storage, nutrient storage etc., and evaluates if the storages show continuous increase or decrease for the period of simulation.
- Diurnal Pattern Analysis: HSPEXP+ checks a list of constituents that normally vary consistently by the time of the day, like water temperature and dissolved oxygen, and reports if these time series show anomalies.

Iterative use of the QA/QC module should result in decreasing the number of instances of nontypical specifications or results. The aspects that remain flagged in a model run that is considered a final calibration will document nuances of the model that should be explained in the modeling application report.

The user should be aware that unique settings and conditions can lead to hydrologic and water quality complexities that do not conform to the judgments that are embedded in this module. Furthermore, the set of aspects for which checks have been included is not all-inclusive. The QA/QC module assumes that the model is run in English Units and the units of nutrients are in lbs. This module also assumes that first four water quality constituents simulated on the land are ammonia (NH3+NH4), nitrate as nitrogen (NO3), orthophosphorus as phosphorus (ORTHO P), and biochemical oxygen demand (BOD) in the order that they are listed here with the QUALID as it is listed in the parenthesis.

Version 3.0 of HSPEXP+ is the first to have this QA/QC report feature.

2.6 RECEIVING WATER MODEL SETUP

HSPF models have traditionally been used to provide boundary conditions for more detailed lake models like WASP, EFDC etc., or simpler models like BATHTUB. However, developing input for these models requires significant expertise of HSPF software as well. Version 3.0 of HSPEXP+ has been enhanced to automatically generate model input files for BATHTUB and WASP for any HSPF reach of interest.

2.7 CAVEATS AND LIMITATIONS

Caveats for the HSPEXP+ program are listed below.

- HSPEXP+ is under continuous development. Although it has been tested on many computers and watersheds, HSPEXP+ may not work for a specific computer configuration or for a specific HSPF watershed model. For example, loading allocation reports may not be accurate when there are multiple diversions in a model that reroute back to the model. Some reports may not work for the operations with an active AGCHEM section.
- HSPEXP+ needs extensive testing with different projects.
- HSPEXP+ expects that the model is run with the units option flag set to English.
  - If automated graphs are requested, HSPEXP+ expects that the graph specification files in CSV format are present in the same folder as the other model files.

- HSPEXP+ assumes that the ammonia (NH3+NH4), nitrate (NO3), orthophosphate (ORTHO P), and biochemical oxygen demand (BOD) constituents that are simulated in PERLND PQUAL and IMPLND IQUAL have the exact same names as shown in parentheses here, and that they are simulated with the units of pounds. Although this requirement is now relaxed for most reports from version 2.0.0 onward, some reports may still have issues with names other than the default names. HSPEXP+ also assumes that nitrite (NO2) on the land is not simulated as a separate PQUAL, and all the nitrate from the land enters the reach as nitrate. However, in the RCHRES section, both nitrate and nitrite are simulated.
- For the Multi Simulation Manager, HSPEXP+ assumes that the WDM file specified in the EXT TARGETS sections of the UCI file has the same base name as the UCI file.

3.0 USING HSPEXP+

Using HSPEXP+ for an HSPF project requires some preparation by the user after setting up the model. The following instructions assume that the modeler has a properly functioning HSPF model.

3.1 USER INTERFACE

HSPEXP+ has a simple user interface. Basic explanations are provided in the user interface itself. The interface also shows useful tool tips to the user when the mouse hovers over certain sections. The user needs to find the UCI file for the project. The remaining options can be selected or deselected using check boxes. Any grayed-out features are unavailable for the current project based on the options selected. Setting up an HSPF project for analysis by using HSPEXP+ is described in the following sections.

3.1.1 SETTING UP THE PROJECT

The HSPEXP+ interface is shown in Figure 3-1.

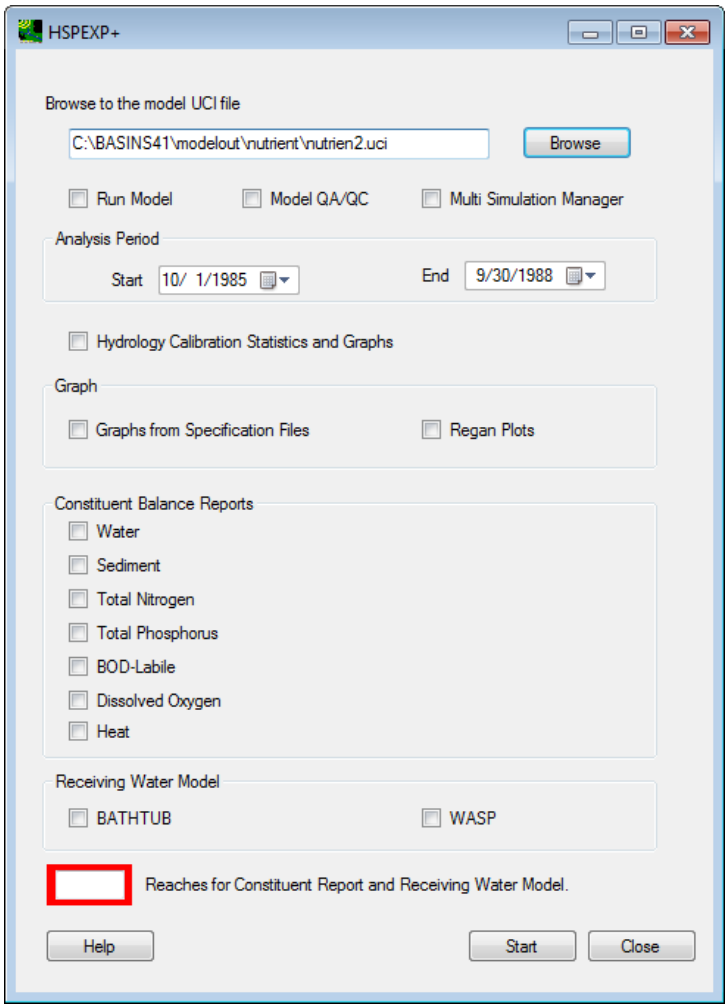


Figure 3-1. HSPEXP+ Interface.

3.1.2 SETTING UP USER'S CONTROL INPUT AND OTHER FILES

If a user wants to generate hydrology calibration statistics and graphs, HSPEXP+ requires that the name of the output WDM file be fewer than eight characters. The output file that contains the hydrology output (WDM file) from HSPF should be in the same folder as the UCI file. Although HSPF does not require separate WDM files for output and input (as many as four WDM files for each HSPF model), the output datasets should be saved in a different WDM file than the input datasets. When performing hydrologic calibration, the WDM file referred to in the EXS file is used to read the observed flow and simulated output. The echo (ECH) file from the HSPF run is used to obtain the time stamp of the most recent HSPF run.

The user must set up HSPF such that hydrologic calibration output is generated for each location of interest. To generate hydrologic calibration output at the location of interest, open the UCI file in WinHSPF3.1. Open the Output Manager, as shown in Figure 3-2.

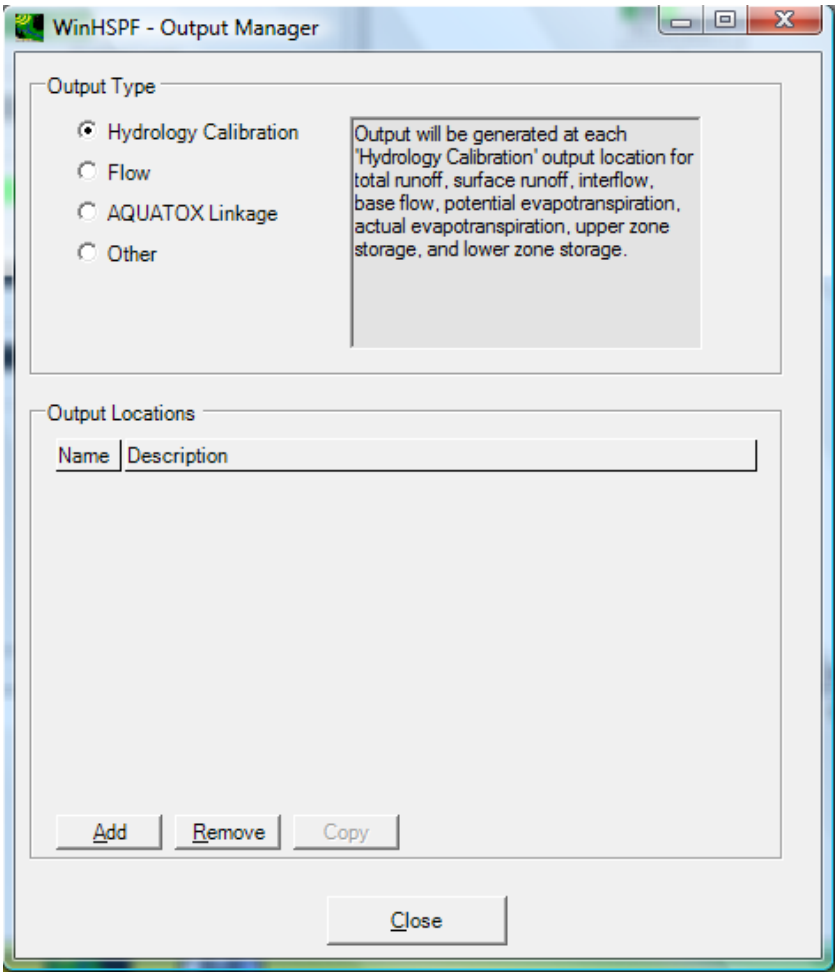


Figure 3-2. WinHSPF Output Manager.

Click the radio button beside Hydrology Calibration, and then click **Add**. In the WinHSPF- Add Output window, two separate frames show up. The left frame titled Operation: contains a list of available calibration locations (i.e., the reaches of the watershed). The right frame Observed Flow Time Series: lists the observed flow datasets in the project WDM file. The datasets listed in this frame have two

attributes: SCENARIO and CONSTITUENT specified as OBSERVED and FLOW, respectively in the model output WDM file. The window also contains two text fields. The user must choose one of the calibration locations, and that populates the WDM Location ID: field. This identifier is used as the location ID attribute on the WDM time-series datasets that will be created. The user must also select the corresponding observed dataset on the right frame that will be compared with the simulated data and used for hydrologic calibration. The user is also asked to enter a base dataset number for the datasets to be created. The new datasets will be numbered as the available datasets following that number, as shown in Figure 3-3.

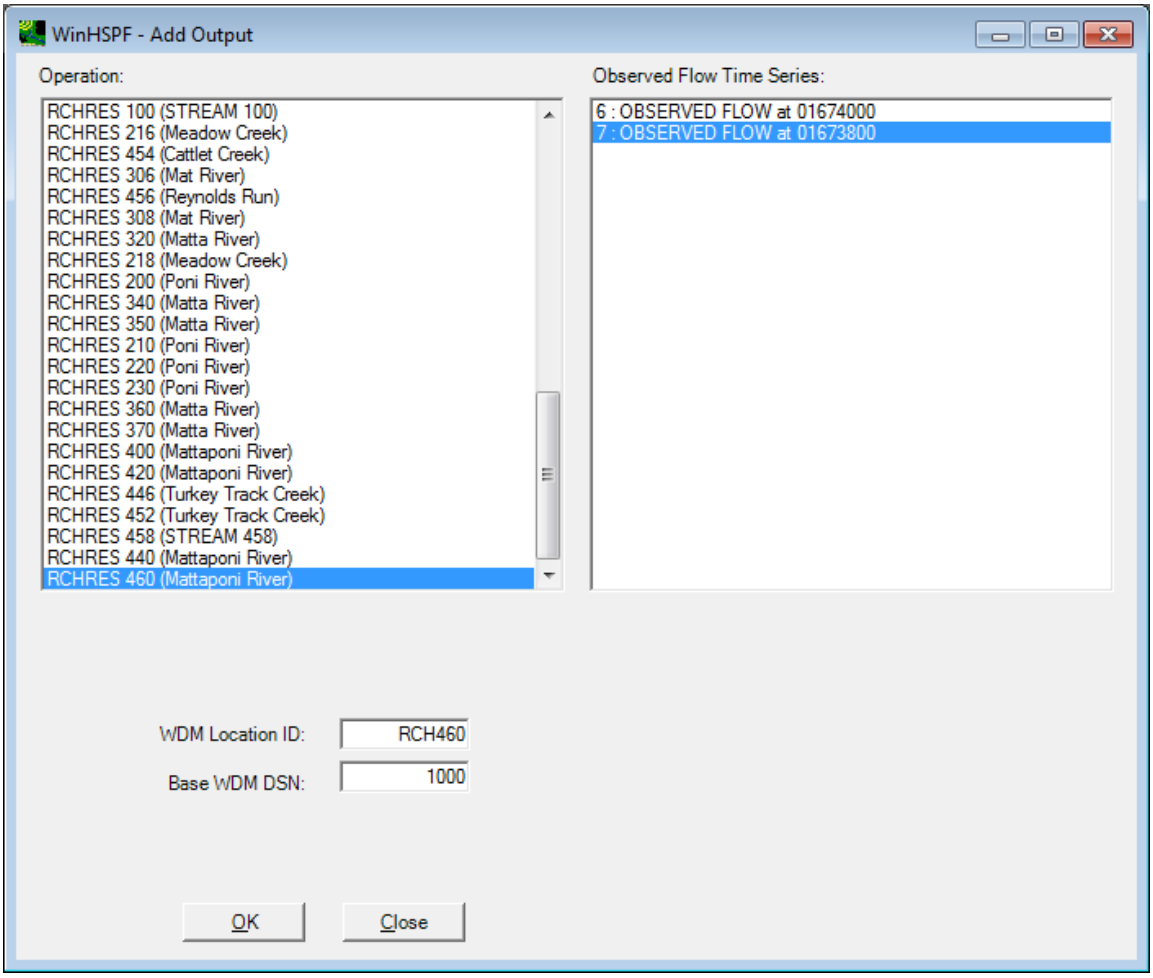


Figure 3-3. Interface to add Hydrologic Calibration Location(s) in WinHSPF3.1.

Clicking **OK** from this window brings the user back to the Output Manager window. As the user returns to the Output Manager window, eight new time-series datasets are created in the project WDM file, as required by HSPEXP+. The user can click **Add** to insert more than one hydrology calibration location.

The UCI in memory is modified to include the appropriate COPY operation as well as the appropriate EXT TARGETS, SCHEMATIC, and MASS-LINK Blocks. At the same time, WinHSPF creates an EXS file. The observed flow data are also used to identify the storm dates, and those dates are listed in the EXS file. WinHSPF uses the HySEPLocMin method [Sloto and Crouse, 1996] in the USGS Groundwater Toolbox to separate storm flow and baseflows. A stormflow time series is then used to select major

storms within the simulation period. The user is advised to check these storm dates before using them for hydrology calibration.

If nutrient balance reports are being generated, HSPEXP+ requires that the GEN-INFO table should have names for each PERLND, IMPLND, and RCHRES. HSPEXP+ uses this information from the GEN-INFO table to group the output. If the GEN-INFO table does not have a proper land-use description or the names of RCHRES operations, the output in some of the reports will not be grouped in a user-friendly fashion.

If nutrient balance reports are being generated, the user must name the nutrient constituents for PQUAL and IQUAL in the QUALID section as shown below and list the unit in pounds.

- Ammonia should be named NH3+NH4.
- Nitrate should be named NO3. HSPEXP+ assumes that Nitrite (NO2) is not simulated separately on the land surface.
- Orthophosphorus should be named ORTHO P.
- Biochemical Oxygen Demand should be named BOD.

Although this requirement is relaxed in versions following 2.0.0 for most reports, some reports may still have issues, and the user is recommended to follow the naming scheme specified above. If Regan plots are being generated, the user must ensure that the appropriate sections are active and that the outputs are written to an HBN file at monthly or shorter intervals.

If GQUAL constituents are being simulated, the name and units of the GQUAL constituent must match the corresponding PQUAL and IQUAL constituent.

3.1.3 BASINS-SPECIFICATION FILE CONTENT AND FORMAT

The format of the EXS file is consistent with that used in the predecessor program HSPEXP. To read more about this file, please refer to the HSPEXP manual or refer to the EXS file information at the end of this section. HSPEXP+ is unable to produce the EXS file. However, WinHSPF 3.1 and newer versions can generate the EXS file for the hydrology calibration locations as described in Section 3.1.2. A single EXS file can be used for calibration at one to ten separate locations. If a user wants to calibrate at more than ten locations, or if the storm dates are different for different locations, users can provide multiple EXS files. The number of EXS files is unlimited.

When used with HSPEXP+, the EXS file can include comment lines, following the same format of a UCI file. Any line with three asterisks (***) is treated as a comment by HSPEXP+ (unlike its predecessor).

HSPEXP+ considers June, July, and August to be the summer months and December, January, and February to be the winter months for calculating seasonal statistics. EXS files generated using WinHSPF3.1 list these months at the end of the file by using the keyword Seasons. The user can specify different summer and winter months in the EXS file, if needed.

Descriptions of all the parts of an EXS file are provided in Tables 3-1 and 3-2. Most of the information in these tables is reproduced from the original HSPEXP manual (Lumb et al, 1994, page 34), with some changes that are relevant for HSPEXP+. The specification file content and format are shown in Table 3-1, and definitions of input types are shown in Table 3-2.

Table 3-1. BASINS-Specification File Content and Format

Line Type/Content	Number of Lines	Line Format	Description
General Information	1	A8, 2I5, 4F8, 2X, I4, 2I2, 2X, I4, 2I2	Name (prefix) of WDM file
			Number of sites
			Current site number
			Latitude and longitude limits of the basin
			Start and end dates for calibration statistics, if different from simulation period.
WDM Dataset ID Nos.	# of sites	10I4, 1X, I2, 2X, A20	DSN for simulated runoff (inches)
			DSN for observed flow (cfs)
			DSN for simulated surface runoff (inches)
			DSN for simulated interflow (inches)
			DSN for simulated baseflow (inches)
			DSN for precipitation (inches)
			DSN for potential evapotranspiration (inches)
			DSN for actual evapotranspiration (inches)
			DSN for upper zone storage (inches)
			DSN for lower zone storage (inches)
			Flag indicating whether statistics have been calculated for the site (not used)
			Site name
Number of Storms	# of storms	I4	Number of storm periods
Storm Periods	# of storms	I5, 5I3, I5, 5I3	Storm start and end dates/times (yr, mo, dy, hr, min, sec)
Drainage Areas	1	10F8	Drainage area (acres) for each site
Error Criteria	# of sites	10F8	Values for error terms and criteria
			Acceptable error in total volume (%)
			Acceptable error in low-flow recession (-)
			Acceptable error in 50% lowest flows (%)
			Acceptable error in 10% highest flows (%)
			Ratio of interflow to surface runoff
			Acceptable error in seasonal volumes (%)
			Acceptable error in summer storm volumes (%)
			Multiplier on third and fourth error terms
			Percent of flows to use on low-flow recession error
Seasons Keyword	1	A7	Enter Seasons
Summer Months	1	csv	Enter the months for summer in csv format
Winter Months	1	csv	Enter the months for winter in csv format

Table 3-2. Definitions of Inputs

A *n* - character input with column width = n columns
I *n* - integer input with column width = n columns
F *n* - real number input with column width = n columns
n X - n blank spaces
csv - comma-separated values

The last five line types in an EXS file that were used with the original HSPEXP program are not used in HSPEXP+; these are three lines of computed statistics and two lines of flags for ancillary data.

An example EXS file is shown in Figure 3-4. Please refer to the HSPEXP manual (Lumb et al., 1994) for additional details about the format.

```
***This Basins Specification file (EXS) file has been generated from WinHSPF.
<WDMNAME><Ste><cSt><LatMin><LatMax><LngMin><LngMax><yyyymmdd><yyyymmdd>***
BMRW         1     1        0        0        0        0  2003 1 1  20151231
SIMQFLOWSUROIFOWAGWOSUPYPETXSAETUZSXLZSX     LOCATION***
1001    610021003100410091005100610071008  0  RCH460
***The following Storm dates (100 or less) are generated by subtracting the baseflow time series from the observed flow time series.
***The baseflow time series was generated using the HysepLocMin method that is available with the USGS Surface Water Toolbox.
***The storm date generation process is under development; users should verify these dates independently.
<St>***
  21
 2003  1  1  0  0  0 2003  1 27  0  0  0
 2003  2 15  0  0  0 2003  3  2  0  0  0
 2003  3  3  0  0  0 2003  3 11  0  0  0
 2003  3 20  0  0  0 2003  3 29  0  0  0
 2003  3 30  0  0  0 2003  4  6  0  0  0
 2003  5 16  0  0  0 2003  6  4  0  0  0
 2003  6 15  0  0  0 2003  7  2  0  0  0
 2003  9 12  0  0  0 2003 10 14  0  0  0
 2003 11  6  0  0  0 2003 11 19  0  0  0
 2003 11 20  0  0  0 2003 12  4  0  0  0
 2003 12  6  0  0  0 2004  1  2  0  0  0
 2004  2  3  0  0  0 2004  3  4  0  0  0
 2004  4 12  0  0  0 2004  5  2  0  0  0
 2004  7 26  0  0  0 2004  8  1  0  0  0
 2004  9 15  0  0  0 2004  9 27  0  0  0
 2004 11 12  0  0  0 2004 11 24  0  0  0
 2004 12  7  0  0  0 2004 12 21  0  0  0
 2005  1 14  0  0  0 2005  1 26  0  0  0
 2005  3 23  0  0  0 2005  4 22  0  0  0
 2005  5 20  0  0  0 2005  6  2  0  0  0
 2005 12 16  0  0  0 2005 12 24  0  0  0
*** This area was computed by WinHSPF as the total area of PERLNDs and IMPLNDs contributing to the calibration reach.
***It does Not include the area Of water bodies. It Is Not based On the published (e.g., USGS) streamgage drainage area.
<Area  >***
155045.8
   10.00     .03   10.00   15.00   15.00    2.50   20.00   15.00    1.50   30.00   15.00   20.00   15.00   10.00   10.00   15.00   20.00   15.00   15.00
***If you want to specify seasons for your Expert Statistics Calculation, specify them here.
***Seasons Is a keyword, that tells HSPEXP+ that user will provide it's own seasons
Seasons:
***Months selected for Summers, comma separated
6,7,8
***Months selected for Winters, comma separated
12,1,2,3
```

Figure 3-4. Example EXS File.

3.1.4 SETTING UP GRAPH SPECIFICATION FILE(S) TO GENERATE ADDITIONAL GRAPHS

Graph specification files can be used for producing additional graphs, if needed. The graph specification files should be in the same folder as the UCI file. The graph specification file format is a CSV format, where the user can provide specifications for as many graphs as necessary. In this file, blank lines, lines that start with a comma (,) or lines that contain asterisks (***) are not read by HSPEXP+ (i.e., these lines are comments).

In the graph specification file, two types of input are required. The first is the general specification of the graph. For this type of input, the user specifies the graph type (time series, scatter, or frequency duration), output file name (in *.png or *.emf format), number of data series (curves) to be plotted on each graph, and axes labels. In the second type of input, the user provides information about each dataset that will be plotted. HSPEXP+ expects one line of input for each dataset that will be plotted.

Each input line provides information about the source data file, WDM DSN of the dataset, or location and constituent of the dataset, curve type (point or line), curve color, curve legend, and transformations. Once the information about each curve is provided, the specification for the next graph may be provided.

The first two lines of the graph specification file are header lines. The first header line has headings for general specifications of a graph, and the second line has headings for specifications of individual datasets.

General Specification of the Graph

The list below explains the headings for the general specifications of the graph. Each graph should have one line for general specifications.

- Graph Type: The type of graph can be time series, frequency, or scatter. These are the only types currently available.
- Destination File Name: A unique output file name must be provided with an extension of *.png or *.emf.
- Number of Data Series: An integer value indicates the number of datasets in the graph.
- *Y*-Axis Label: Label for the *Y* axis (if one writes deg-, or mu-, it is converted to º or µ, respectively). This value may be blank.
- *X*-Axis Label: Label for the *X*-axis. This value may be blank.
- Aux-Axis Label: Label for the auxiliary axis. This value may be blank.
- Right-Axis Label: Label for the right axis. This value may be blank.
- Start Date: The start date in mm/dd/yyyy[1] format. This date will be used to subset the input dataset. If the start and end dates are blank, the dates are read from the simulation time span in the main HSPEXP+ interface. This value may be blank.
- End Date: The end date in mm/dd/yyyy format. This date will be used to subset the input dataset. This value may be blank.
- Y-Axis Limit (Min): Minimum value for *Y*-axis. This value may be blank.
- Y-Axis Limit (Max): Maximum value for *Y*-axis. This value may be blank.
- Aux-Axis Limit (Min): Minimum value for aux-axis. This value may be blank.
- Aux-Axis Limit (Max): Maximum value for aux-axis. This value may be blank.
- Right-Axis Limit (Min): Minimum value for right axis. This value may be blank.
- Right-Axis Limit (Max): Maximum value for right axis. This value may be blank.
- Y-Axis Log?: Should the *Y*-axis be a log scale? Write yes. This value may be blank.
- Aux-Axis Log?: Should the aux-axis be a log scale? Write yes. This value may be blank.
- Right-Axis Log?: Should the right axis be a log scale? Write yes. This value may be blank.

[1] Some spreadsheet program can change the dates, depending on the local system setting. The user must also verify that the dates are correct in a text editing program.

- Season Start Month/Day: To plot only seasonal data (for example, only winter months for snow depth frequency duration), provide the start day of the season (e.g., 10/1).[2] This value may be blank.
- Season End Month/Day: To plot only seasonal data (for example, only winter months for snow depth frequency duration), provide the end day of the season (for example, 4/30). This value may be blank.

Specification for Curve

All the headings for the specifications of each individual curve in the graph are explained below.

- Axis for the curve (or optional curve definition): If this entry is specifying the axis for a curve, enter left, right, or aux-axis. Note: for a frequency graph, only a left axis option is available. For scatter graphs, provide the names of axes as *X*-axis or *Y*-axis to differentiate between dependent and independent variables. Optional curve definitions: For scatter graphs, a Regression line and/or a 45-deg line may be generated, so this entry would be a regression or 45-deg line (these two lines do not need a source time series). For combining (i.e., adding, multiplying, subtracting, or dividing) a time series with another time series provided to the graph, this entry must include add, multiply, subtract, or divide. The time series is then combined with the previous time series. Make sure that the two time series that are combined have the same time step.
- Data Source: The data source can be a WDM file (absolute path or relative path must be provided), a BASINS Observed WQ file (DBF), a HBN file, a USGS RDB water quality file, or a WQX filtered file.
  - If the data source is a WDM file, provide the DSN number. If the data source is a DBF file, HBN file, USGS RDB water quality file, or WQX filtered file, provide the location and the constituent name.
- Blank, if WDM file. Constituent, if DBF, HBN File, USGS RDB water quality file, or WQX filtered file: Leave it blank if the data source is a WDM file, or else provide the constituent name.
- Plot Type (Line or Point): line or point indicating the type of the plot.
- Color of Plot: Write the color of the plot (line or points). This value may be blank.
- StepType: Write nonstep for continuous line, and either forwardstep or rearwardstep for the step type plots.
- Symbol Type, if Point Graph: The available options are circle, square, plus, diamond, star, hdash, vdash, triangle, triangledown, and xcross. Leave this specification blank for line graphs. Circle is default type for point data. This value may be blank.
- Size of Line or Point: Size of line or points can be provided as an integer value. This value may be blank.
- Label for the Curve: Users can provide a label for the curve or leave it blank for HSPEXP+ to generate a default label. Users can also write *don't show* to not show the label and symbol for the curve in the legend. This value may be blank.
- Aggregation: Before plotting, users can aggregate the data from the existing time step to hourly, daily, monthly, or yearly. This value may be blank.

[2] Some spreadsheet program can change the dates, depending upon the local system setting. The user must also verify that the dates are correct in a text editing program.

- Aggregation Type: Users can select the type of aggregation as average, min, max, or sum. Users can also aggregate by percentiles. For example, %50 will extract the 50th percentile while aggregating. This value may be blank.
- Transformation: Users can transform the aggregated dataset by using four key words. *C to F* will transform Celsius temperature data to Fahrenheit and *F to C* will do the reverse. *Sum c* will add a constant c to every time step, and *product c* will multiply by c for every time step. This value may be blank. An example graph specification file, when opened in a spreadsheet program, is shown in Figure 3-5.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	***This is a graph specification file. The lines with "******" or blank lines are ignored by program.																			
2	***The first two rows are heading rows to help a user fill in the column values and are not read by the program.																			
3	***To make a new graph the user first specifies the type of graph (timeseries scatter or frequency duration) then the name of the graph number of curves in the																			
4	***graph axes labels axes limits (user cannot limit the x-axis width). In the lines following the specification of graph user provides the specifications																			
5	***of each curve																			
6	Type of Graph	Destination File Name	Number of Data Series	Y-Axis Label	X-Axis Label	Aux-Axis Label	Right Axis Label	Start Date (mm/dd/yyyy) format	End Date (mm/dd/yyyy) format	Y-Axis Limit (Min)	Y-Axis Limit (Max)	Aux-Axis Limit (Min)	Aux-Axis Limit (Max)	Right-Axis Limit (Min)	Right-Axis Limit (Max)	Y-Axis Log?	Aux Axis Log	Right Axis Log	Season Start Month /day	Season End Month /day
7	Axis for the Curve	Data Source	DSN Number if WDM File. Location if DBF or HBN File	Blank if WDM File. Constituent if DBF or HBN File.	Plot Type (line or point)	Color of Plot	StepType	Symbol Type if Point Graph	Size of Line or Point	Label for the Curve	Aggregation	Aggregation Type	Transformation							
8	***																			
9	Timeseries	RCH238_LakeLevel.png	3	Lake Level (m)							925	945	0							
10	Left	Lakes\lake_level.dbf	058014200	Elevation (ft)	point	blue		circle	5	Observed Lake Level at Pokegama Lake			prod 0.308							
11	Left	Snake.wdm	2389		line	red	nonstep		1	Simulated Lake Level at RCH 238	Daily	Average	prod 0.308							
12	Aux	Snake.wdm	2380		line	red	nonstep		1	Daily Average Simulated Flow at RCH 238	Daily	Average								
13	***																			
14	Timeseries	Temp\RCH230_WT.png	3	Water Temperature (deg-C)							0	100								
15	Left	STC_WQ_OBS.dbf	07030004-503	TW-degF	point	blue		circle	5	Observed Water Temperature at Snake R	2 MI E of Grasston		f to c							
16	Left	Snake.wdm	2301		line	red	nonstep		1	Daily Average Simulated Water Temperature at RCH 230	Daily	Average	f to c							
17	***Left	Snake.wdm	2301		line	Purple	nonstep		1	75% Quartile of Simulated Water Temperature at RCH 230	Daily	75%	f to c							
18	Aux	Snake.wdm	2300		line	red	nonstep		1	Daily Average Simulated Flow at RCH 230	Daily	Average								
19	***																			

Figure 3-5. Example Graph Specification File.

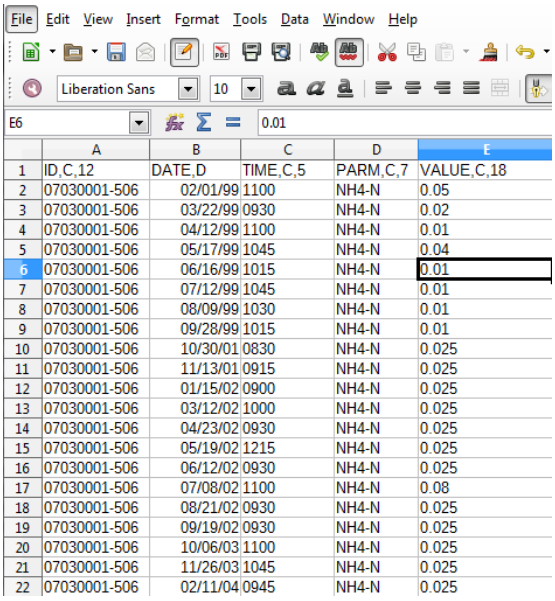
If using HSPEXP+2.0.0 or later, the user is able to provide graph specification file(s) that were generated in the BASINS interface. BASINS 4.5 and later can be used to generate a graph using the interactive interface and then save the specification file in the JavaScript Object Notation (JSON) format. HSPEXP+ will generate graphs for all the JSON files in the project folder.

3.1.5 SETTING UP BASINS OBSERVED WATER QUALITY DATA FILE

The observed water quality data can be provided in a DBF file for BASINS or HSPEXP+ to read. This format is useful when the data is non-continuous. The DBF file can be edited or created in LibreOffice or OpenOffice (note: MS Excel 2007 and newer versions can open this file format but do not support saving this format). This file format has five columns that should be named exactly as shown below. Any additional columns are not read by BASINS or HSPEXP+.

- ID: This column should identify the location of the collected data
- DATE: This column should identify the date in text format (mm/dd/yyyy).
- TIME: This column should identify the time in text format (HHMM).
- PARM: This column should identify the name of the constituent.
- VALUE: This column should identify the value recorded at the respective date and time for the respective location and constituent.

The user can use unlimited locations, parameters, and values. These aspects are limited by the capacity of the software used to create it. Large DBF files may result in longer times to open, close, and read the file. A portion of a sample DBF file is shown in Figure 3-6.



	A	B	C	D	E
1	ID,C,12	DATE,D	TIME,C,5	PARM,C,7	VALUE,C,18
2	07030001-506	02/01/99	1100	NH4-N	0.05
3	07030001-506	03/22/99	0930	NH4-N	0.02
4	07030001-506	04/12/99	1100	NH4-N	0.01
5	07030001-506	05/17/99	1045	NH4-N	0.04
6	07030001-506	06/16/99	1015	NH4-N	0.01
7	07030001-506	07/12/99	1045	NH4-N	0.01
8	07030001-506	08/09/99	1030	NH4-N	0.01
9	07030001-506	09/28/99	1015	NH4-N	0.01
10	07030001-506	10/30/01	0830	NH4-N	0.025
11	07030001-506	11/13/01	0915	NH4-N	0.025
12	07030001-506	01/15/02	0900	NH4-N	0.025
13	07030001-506	03/12/02	1000	NH4-N	0.025
14	07030001-506	04/23/02	0930	NH4-N	0.025
15	07030001-506	05/19/02	1215	NH4-N	0.025
16	07030001-506	06/12/02	0930	NH4-N	0.025
17	07030001-506	07/08/02	1100	NH4-N	0.08
18	07030001-506	08/21/02	0930	NH4-N	0.025
19	07030001-506	09/19/02	0930	NH4-N	0.025
20	07030001-506	10/06/03	1100	NH4-N	0.025
21	07030001-506	11/26/03	1045	NH4-N	0.025
22	07030001-506	02/11/04	0945	NH4-N	0.025

Figure 3-6. Portion of Sample Water Quality Data DBF File.

3.1.6 SETTING UP MULTI SIMULATION SPECIFICATION FILE, USER'S CONTROL INPUT, AND WATERSHED DATA MANAGEMENT FOR SENSITIVITY/UNCERTAINTY ANALYSIS

To use the Multi Simulation Manager, ensure that the model output WDM file and the UCI file have the same name. If the model does not output to a WDM file, the multi simulation manager will not process any output from the simulations. Ensure that the model outputs at least one-time series to the output WDM in the EXT TARGETS block.

If you do not have a multi simulation specification file, HSPEXP+ generates a default specification file. To generate the default specification file, start HSPEXP+, browse to the UCI file of an existing working HSPF model, and select the box next to Multi Simulation Model Manager. This process will automatically generate a multi simulation specification file named as MultiSimSpecFile.csv. This default file contains information about, at most, two datasets that will be analyzed for each simulation and information about the parameters LZSN and INFILT that will be varied for each simulation. The format of specification file is described later in this section. HSPEXP+ will then copy the existing UCI file to the name MultSim.uci and run the model simulation. The statistical analysis of the datasets identified in the multi simulation specification file will be saved in MultiSimOutput.xml. The output file contains several statistics of the two output datasets that can be used to calculate model sensitivity and uncertainty.

The specification file can be modified to add more output datasets, include more parameters to vary, and provide more combinations of parameter variability. Depending on the modeling objective, sensitivity analysis, uncertainty analysis, model calibration, and model scenario analysis can be conducted using Multi Simulation manager.

The lines that contain **** in the multi simulation specification file are comments and ignored by HSPEXP+. As illustrated in Figures 3-7 and 3-8, rows 1 and 2 are comments. The first column in the third row is labeled DSN. The following columns in this row refer to the DSN in the model output WDM file (file with the same name as the UCI). Statistical analyses of these datasets are produced in the output file for

each model iteration. The fourth row is a comment, and the following row is a heading for model parameters, as described in Table 3-3.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	***Generic Parameter List For Sensitivity/Uncertainty Analysis And Output DSN from the UCI file													
2	***Following Output IDs are the first two ID read from the EXT TARGET block of the UCI file. You can add more if you want to.													
3	DSN	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2100	2200	2300
4	***The operation number, land use, tied with next, and multiplier can be left blank													
5	PARMID	OPN_TYPE	TABLE_NAME	PARM_NAME	OCCURENCE	MULT_FACTOR?	OPN_NUMBER_NAME	LOWERLIMIT	UPPERLIMIT					
6	1	PERLND	PWAT-PARM2	LZSN		1		3	8					
7	2	PERLND	PWAT-PARM2	INFILT		1		0.01	0.5					
8	3	PERLND	PWAT-PARM2	AGWRC		1		0.8	0.999					
9	4	PERLND	PWAT-PARM4	IRC		1	Pasture	0.4	0.9					
10	5	RCHRES	HEAT-PARM	CFSAEX		1		0.5	1					
11	6	RCHRES	SILT-CLAY-PM	TAUCD	2	0	510	5.00E-10	5					
12	7	RCHRES	OX-REAPARM	REAK		1	510	0.1	0.7					
13	8	PERLND	MON-IFLW-CONC		1	1	Pasture	0.001	9.9					
14	9	PERLND	MON-IFLW-CONC		2	1		0.001	9.9					
15	10	RCHRES	PHYTO-PARM	SEED		1	Mainstem	2	7					
16														
17	Delete intermediate UCI files?	0												
18	***Following lines list the multiplication factor for each parameter for each simulation.													
19	Simulation ID	Parameter1	Parameter2	Parameter3	Parameter4	Parameter5	Parameter6	Parameter7	Parameter8	Parameter9	Parameter10			
20	1	0.9												
21	2	1.1												
22	3		0.9											
23	4		1.1											
24	5			0.9										
25	6			1.1										
26	7				0.9									
27	8				1.1									
28	9					0.5								
29	10					0.8								
30	11					1.2								
31	12					1.5								
32	13						0.000005							
33	14						0.5							
34	15							0.9						
35	16							1.1						
36	17								0.9					
37	18								1.1					
38	19									0.9				
39	20									1.1				
40	21										0.9			
41	22										1.1			
42														

Figure 3-7. Example Multi Sim Spec File for Sensitivity Analysis.

	A	B	C	D	E	F	G	H	I
1	***Generic Parameter List For Sensitivity/Uncertainty Analysis And Output DSN from the UCI file								
2	***Following Output IDs are the first two ID read from the EXT TARGET block of the UCI file. You can add more if you want to.								
3	DSN	1000							
4	***The operation number, land use, tied with next, and multiplier can be left blank								
5	PARMID	OPN_TYPE	TABLE_NAME	PARM_NAME	OCCURENCE	MULT_FACTOR?	OPN_NUMBER_NAME	LOWERLIMIT	UPPERLIMIT
6	1	PERLND	PWAT-PARM2	LZSN		1		2	15
7	2	PERLND	PWAT-PARM2	INFILT		1		0.001	0.5
8	3	PERLND	PWAT-PARM2	AGWRC		1		0.85	0.999
9	4	PERLND	PWAT-PARM4	IRC		1		0.3	0.85
10	5	PERLND	MON-UZSN			1		0.05	2
11	6	PERLND	MON-LZETPARM			1		0.1	0.9
12									
13	Delete intermediate UCI files?	0							
14	***Following lines list the multiplication factor for each parameter for each simulation.								
15	Simulation ID	Parameter1	Parameter2	Parameter3	Parameter4	Parameter5	Parameter6		
16	1	0.3883	0.1639	0.3573	0.7325	1.0528	0.3011		
17	2	0.4905	0.5051	0.4298	0.4189	1.9453	0.4615		
18	3	2.2863	0.5626	0.4924	0.8008	0.249	0.3805		
19	4	0.0776	0.4453	0.68	0.8491	0.4218	1.1281		
20	5	0.2381	0.2402	0.0986	0.9253	0.5658	0.1587		
21	6	2.467	0.1227	0.136	1.147	2.4224	0.5737		
22	7	2.3882	0.2661	1.393	0.5893	0.3132	2.3149		
23	8	0.4729	0.9204	0.3308	0.4586	2.07	0.1925		
24	9	0.099	0.0998	0.6171	0.7906	1.4005	1.6056		
25	10	0.3379	0.7153	0.0935	0.8428	2.1149	0.2965		
26	11	0.7026	0.4641	0.3535	1.7474	2.1177	0.9203		
27	12	0.9173	0.1978	0.7284	0.7214	1.0015	1.8831		
28	13	0.2958	0.1249	0.6198	0.6298	2.2751	0.1885		
29	14	0.5645	0.2837	0.4713	0.6243	1.8283	3.3049		
30	15	0.1313	0.3285	0.3943	0.3784	2.5316	0.3698		
31	16	0.2406	0.573	2.7554	0.7682	1.0246	0.6144		
32	17	2.9636	0.3731	0.7987	0.9233	2.0115	0.3913		
33	18	0.604	0.2626	0.2249	1.483	1.158	0.8882		
34	19	0.2675	0.5823	2.2245	1.0065	2.0226	0.435		
35	20	0.9407	0.5452	1.5331	1.1323	1.9728	0.9635		
36	21	0.3598	0.3064	0.3903	0.8518	2.2693	1.7053		
37	22	2.3144	0.9754	0.5095	1.0868	1.6837	0.4724		
38	23	0.3043	0.2655	2.9686	1.2255	2.8444	0.8284		

Figure 3-8. Example Multi Simulation Specification File for Uncertainty Analysis.

Table 3-3. Description of Model Parameter Headings

Parameter Table Heading	Description
ParmID	An integer indicating parameter number. It starts sequentially from 1 to the total number of parameters that may be varied.
OPN_Type	The type of operation for the parameter (PERLND, IMPLND, or RCHRES). If the modeler wants to change the multiplication factor to a point source, then this value will be Point. If a modeler wants to change the point-source time series, then this value will be Point_TS.
Table_Name	The table in which the model parameter is found.
Parm_Name	Model parameter name. If a MASS-LINK factor must be changed, then this should contain the Source Group, Source Member Name, Source Member Subscript1, Source Member Subscript2, Target Group, Target Member Name, Target Member Subscript1, and Target Member Subscript 2. All of these values must be separated by a colon (:). If a point-source factor or a point-source time series must be changed, then this value should be Target Member Subscript1, and Target Member Subscript 2. All of these values must be separated by full colon (:).
Occur_Or_MLNumber	Some tables occur multiple times (QUAL-PROPS, MON-ACCUM etc.). This column indicates the occurrence number of that column. If Table_Name is MASS-LINK, this column should indicate the MASS-LINK table number.
Mult_Factor_FG	A flag with a value of 0 or 1. A value of 0 indicates that the absolute value of the parameter will be provided. A value of 1 indicates the multiplication factor of that parameter will be provided.
OPN_Number_Or_Name	If this value is blank, all the operations and tables that satisfy the criteria that are specified in previous columns will be varied. To change the parameters of only specific operations, either the operation number or operation name (as specified in the GEN-INFO block of the UCI file) must be provided.
Lower_Limit and Upper_Limit	If a lower limit and or upper limit is provided, HSPEXP+ will check the parameter value against the limits and make sure that the generated parameter value does not violate the limits.

Following the description of model parameters that will be varied in the Multi Simulation Manager, the next row contains a flag for whether the intermediate UCI must be deleted. If this flag is 0, then the UCI file for each model iteration will be saved; if this flag is set to 1, then the UCI file for each simulation will be deleted following the simulation. The user may want to set this flag to 0 during testing.

The following row in the specification file contains a header line for the model simulations. The first column is an integer that indicates the simulation ID, and the following column contains the model parameter multiplication factor or the model parameter value (as specified in the table above). If a column is empty, then the model parameter for that specific simulation is not varied.

An example Multi Simulation Specification File for a sensitivity analysis is shown in Figure 3-7, and an example Multi Simulation Specification File for uncertainty analysis is shown in Figure 3-8. The model parameter values and multiplication factors for sensitivity analysis, uncertainty analysis, scenario generation, or model calibration must be developed by the user independently. Once the Multi Simulation Specification File is updated, the user can start HSPEXP+, check the box for the Multi Simulation Manager, and click on **Start**.

3.1.7 MULTI SIMULATION MANAGER OUTPUT

Once the Multi Simulation Manager process is complete, HSPEXP+ will give a message to indicate the same and open the folder with the output file. The output file can be opened in any XML editor, including MS Excel. Part of an example output file is shown in Figure 3-9. The output file contains the SimID, ID of the analyzed dataset, and statistics (e.g., sum; annual sum; mean; geometric mean; maximum of 30-day geometric mean; average annual peak; 10, 25, and 50 percent highs; 2, 5, 10, and 25 percent lows; and 17 different percentiles) for each dataset for each simulation. If the output file does not populate with statistics, the FILES block, the EXT TARGETS block, and/or the WDM file are likely set up incorrectly and should be reevaluated. UCI files that are generated can be reviewed if the 'Delete intermediate UCI files' flag was set to 0.

	A	B	C	D	E	F	G	H	I	J	K
1	SimID	ID	Sum	mean	SumAnnual	geometric mean	max(30-day GeoMean)	AvAnnPeak	10%High	25%High	50%High
2	0	1001	12257.81	11.19	4088.74	10.92	14.44	14.77	1614.09	3926.32	7268.60
3	0	1002	867.98	0.79	289.52	0.58	1.16	4.82	297.81	504.21	673.17
4	1	1001	12260.43	11.20	4089.61	10.93	14.44	14.77	1614.14	3926.98	7270.41
5	1	1002	867.81	0.79	289.47	0.58	1.16	4.83	299.35	505.76	673.76
6	2	1001	12256.17	11.19	4088.19	10.92	14.44	14.77	1614.05	3925.86	7267.15
7	2	1002	871.39	0.80	290.66	0.59	1.16	4.83	297.47	503.90	674.32
8	3	1001	12260.51	11.20	4089.64	10.92	14.44	14.78	1614.40	3927.22	7270.69
9	3	1002	894.94	0.82	298.52	0.60	1.20	4.93	306.03	518.75	692.61
10	4	1001	12255.38	11.19	4087.92	10.92	14.44	14.77	1613.80	3925.43	7266.42
11	4	1002	843.83	0.77	281.47	0.56	1.13	4.73	291.12	491.26	655.69

Figure 3-9. Example Output File.

Additionally, a WDM file is also produced by the Multi Simulation Manager including a copy of the datasets identified in the specification file for each individual model simulation. The user can review the WDM file to generate any other statistics that are not available in the default output file.

3.1.8 RUNNING HSPEXP+

Running HSPEXP+ is straightforward, provided that all the set-up procedures have been followed. Browse to HSPEXP+ from the program menu on your computer and click on it to open. Browse to the UCI file and then set the start and/or end date of the analysis period if it differs from the model simulation period specified in the UCI file. Select options as needed and click on **Start**.

3.2 HSPEXP+ OUTPUT REPORTS AND GRAPHS

HSPEXP+ generates multiple outputs and reports based on the options selected by the user. This section describes some of the reports that are generated by HSPEXP+. Note that this list is not exhaustive and as the HSPEXP+ development continues, additional reports and may be added or the existing reports may be modified.

3.2.1 HYDROLOGY CALIBRATION REPORTS

As noted in Section 3.1.1, the user can generate hydrology calibration statistics and graphs in the HSPEXP+ interface. The following reports and graphs are output when this option is selected. In the following list, XXX refers to the modeling location for which the EXS file was provided, and all the statistics and graphs are produced for flow at a daily time step. If observed and simulated flow are available for shorter time steps, HSPEXP+ generates average daily flow before calculating the statistics.

- ExpertSysStats-XXX.text: This file contains model expert statistics for the entire model analysis period and on an annual average basis. To read more about the statistics generated in this report, please refer to Lumb et. al [1994].
- XXXadvice.txt: This file includes advice on how to adjust model parameters for improved calibration. To read more about the advice, please refer to Lumb et al. [1994].
- AnnualFlowStats-XXX.txt: This file reports the annual comparison of observed and simulated flow volume.
- DailyMonthlyFlowStats-XXX.txt: This file reports the model fit statistics for daily and monthly flow volume.
- MonthlyAverageFlowStats-XXX.txt: This file reports the monthly comparison of observed and simulated flow volume.
- FlowXXX.png: Daily time-series plot of observed and simulated flow along with the weighted flow.
- Flow_XXX_month.png: Monthly time-series plot of observed and simulated flow.
- Flow_XXX_monthlog.png: Monthly time-series plot of observed and simulated flow at log scale.
- FlowXXX_YYYY.png: A time-series plot of the observed and simulated flow for the year 'YYYY.'
- FlowXXX_YYYYlog.png: A time-series plot of the observed and simulated flow for the year 'YYYY,' with log scale.
- Flow_XXX_cum.png: Cumulative flow rate plot for the period of analysis.
- Flow_XXX_cumDif.png: Cumulative difference plot of observed and simulated flow.
- Flow_XXX_dur.png: Frequency duration curves of observed and simulated flow.
- Flow_XXX_Components.png: Components of simulated flow and weighted precipitation plotted as daily time series.
- Flow_XXX_Components_month.png: Components of simulated flow and weighted precipitation plotted as monthly time series.
- Flow_XXX_Error_LZS.png: Error in observed and simulated flow plotted as a function of lower zone storage in inches.
- Flow_XXX_Error_ObsFlow.png: Error in observed and simulated flow plotted as a function of observed flow.
- Flow_XXX_Error_UZS.png: Error in observed and simulated flow plotted as a function of upper zone storage in inches.
- Flow_XXX_ET.png: Weekly time-series plot of observed potential and actual evapotranspiration.
- Flow_XXX_scatDay.png: Scatter plot of observed and simulated flow volumes.
- Flow_XXX_scatDaylog.png: Scatter plot of observed and simulated daily flow volumes at log scale.

3.2.2 REGAN PLOTS

Regan plots are a collection of plots generated from the simulated data to gain insights into model operation and stability. The datasets are read from the HSPF binary output file (.hbn). These automatic graphs do not compare observed and simulated data. The following are descriptions of automated graphs produced in HSPEXP+:

- DO_Concentration_RCHRES_X.png: Daily time-series plot of maximum and minimum daily simulated concentration of DO at RCHRES X in the model. This graph is only produced for RCHRES operations that output DO concentration at an hourly interval in the binary or WDM file.
- Nutrient_RCHRES_X.png: Time-series plot of simulated phytoplankton, dissolved ammonia, dissolved nitrate, dissolved orthophosphate and benthic algae for RCHRES X. The time step of this graph depends on the timestep of the data in the binary file. Please refer to Mishra et al. [2017] for more details on this graph.
- TSS_RCHRES_X.png – Time-series plot of TSS, bed depth, and flow for the RCHRES X.
- LoadDurationTP_RCHRES_X.png – Load duration curves of the RCHRES with simulated data and the RES standard. These graphs are produced for the RCHRES for which the RES_TP_Standard.csv file is provided.

3.2.3 CONSTITUENT BALANCE REPORTS

Constituent balance reports for the entire watershed can be generated for multiple constituents (water, TP, TN, sediment, DO, and heat) by checking appropriate boxes. Additionally, constituent balance reports for specific locations can be generated by entering the reach number in the red box at the bottom of the interface. The example reports below assume that the constituent balance reports are generated for total phosphorus at RCHRES 1 in the watershed. All these reports can be opened in any spreadsheet program. Some reports are formatted in such a way that the automatic filtering can be used to extract and view relevant information. In the following labels, XXX refers to the UCI file name.

- TotalP_landLoadings.txt: Loadings of phosphorus and its constituents from each operation from different pathways for each analysis year and the entire analysis period. This report does not include PERLND operations where phosphorus is simulated by using the AGCHEM module.
- PO4_Reach_Budget.txt: Annual average reach budget of orthophosphorus for each reach for the entire analysis period.
- TP_XXX_Grp_By_OPN_LU_Ann_Avg: Annual average fluxes of P and its constituent through different pathways in PERLND, IMPLND, and RCHRES operations.
- TP_XXX_LoadAllocation.txt: P load allocated to all the sources in the watershed for all of the RCHRES on an annual average basis, after taking into account the losses that may occur in the RCHRES. More description of this report is available in Section 3.3.
- TP_XXX_Per_OPN_Per_Year: This report is similar to TP_XXX_Grp_By_OPN_LU_Ann_Avg, but the values are presented at an annual basis.
- TP_XXX_Per_RCH_Ann_Avg_Budget: Annual average budget of total P for each reach in the model.
- MonthlyLoadings/TotalP_Monthly_Land_Loadings.txt: Average monthly loadings of P and its constituents on an average monthly basis.

In addition to the text-based reports, HSPEXP+ also generates two kinds of graphs in a PNG format that give a quick summary of model constituents. These graphs are described as follows:

- PO4_BoxWhisker.png – A box-and-whisker graph of annual average PO4 loading rates grouped by land-use types.
- MonthlyLoadings/PO4_P_LandUse_BoxWhisker.png – A box-and-whisker graph of PO4 loading rates from LandUse grouped by the 12 months of the year.

3.2.4 QA/QC REPORTS

HSPEXP+ has a feature specifically designed for watershed model QA/QC. To use this feature, the users clicks the Model QA/QC check box on the main form, selects constituents to report as desired, and then clicks **Start**.

The default QA/QC report will contain sections checking watershed area, parameter values, and diurnal patterns. In addition, based on the constituents checked in the main user interface form, further analyses of loading rates, land use comparisons, and constituent storages will be performed.

A status window appears on the screen while the QA/QC report is in being generated. Once it is complete, it will appear on the screen within a web browser as seen in Figure 3-10.

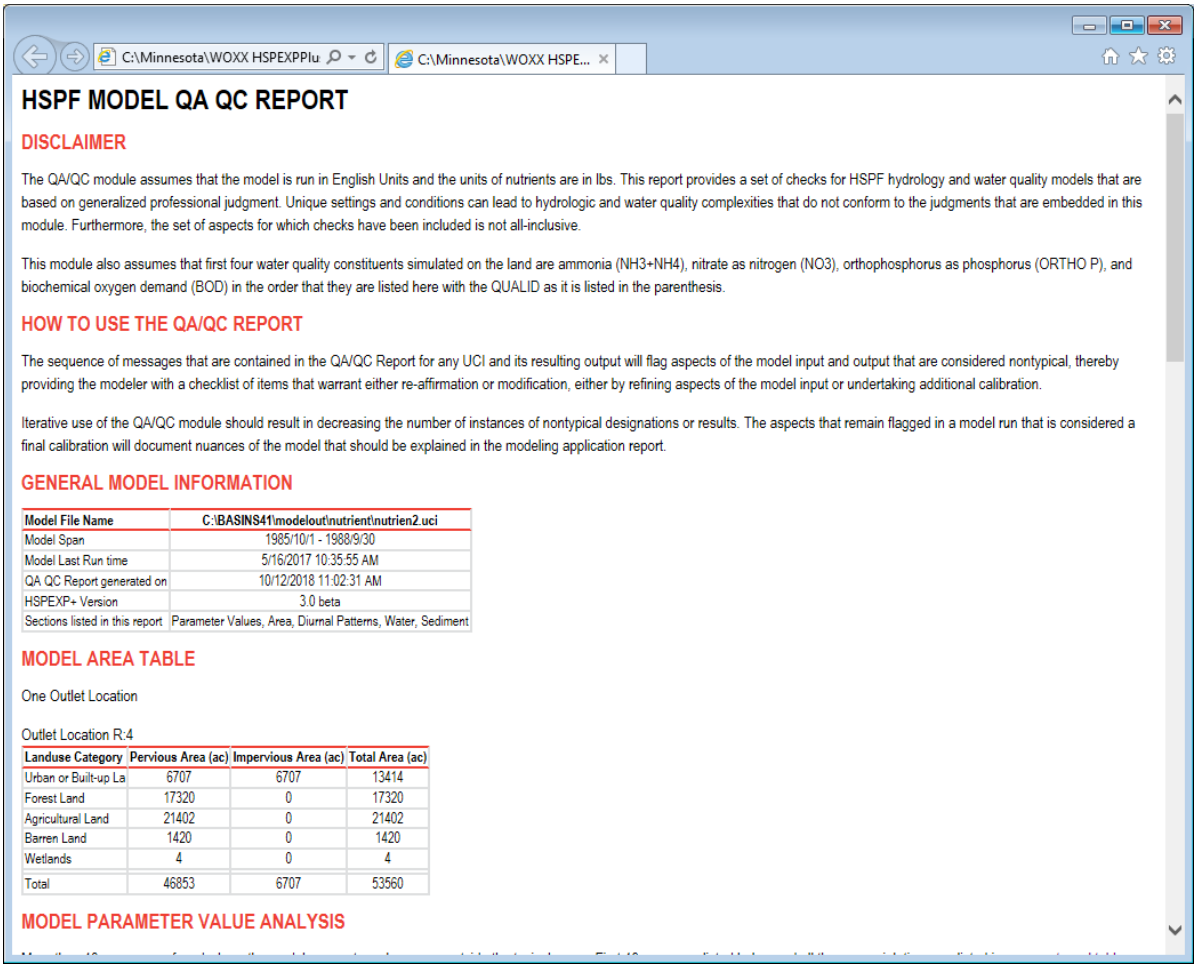
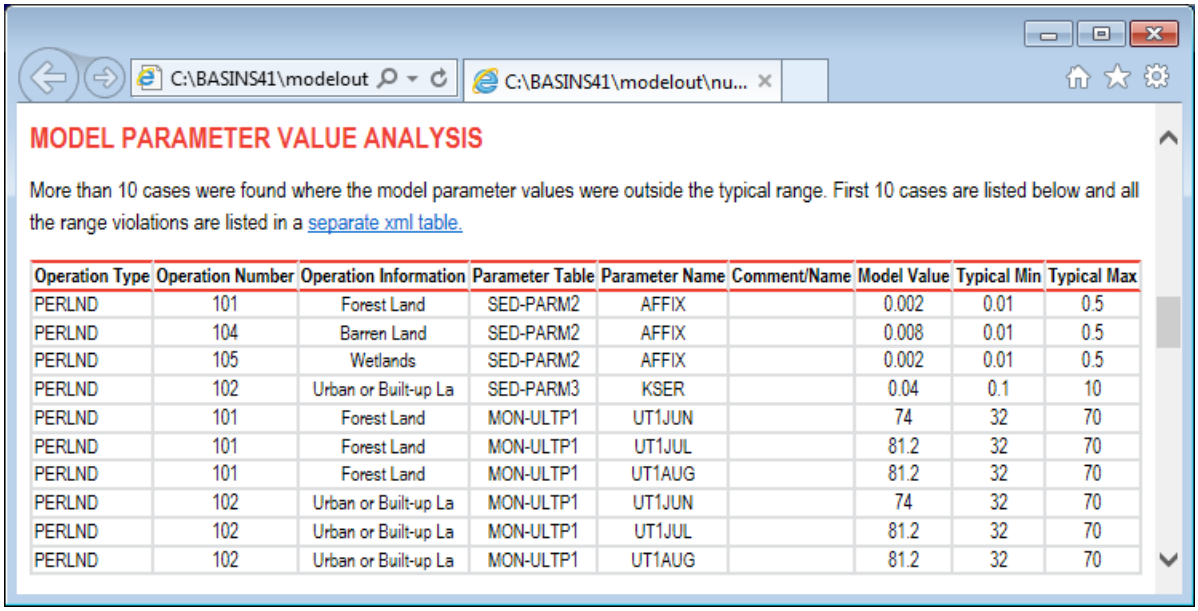


Figure 3-10. QA/QC Report Window View.

The Parameter Values Analysis uses a database of typical model parameter values for hydrology, sediment, temperature, dissolved oxygen, nitrogen, phosphorus, and biological oxygen demand as organics based on the modeling guidance developed for MPCA and BASINS technical notes. HSPEXP+ compares parameter values of each operation with this database and reports the parameters that are beyond the typical limits. The QA/QC report table lists for each parameter outside the typical limits its operation number, description, table name, value, and typical minimum and maximum values. If more than 10 parameter values are beyond the typical limits, a supplemental XML table is referenced, as seen in Figure 3-11.



Operation Type	Operation Number	Operation Information	Parameter Table	Parameter Name	Comment/Name	Model Value	Typical Min	Typical Max
PERLND	101	Forest Land	SED-PARM2	AFFIX		0.002	0.01	0.5
PERLND	104	Barren Land	SED-PARM2	AFFIX		0.008	0.01	0.5
PERLND	105	Wetlands	SED-PARM2	AFFIX		0.002	0.01	0.5
PERLND	102	Urban or Built-up La	SED-PARM3	KSER		0.04	0.1	10
PERLND	101	Forest Land	MON-ULTP1	UT1JUN		74	32	70
PERLND	101	Forest Land	MON-ULTP1	UT1JUL		81.2	32	70
PERLND	101	Forest Land	MON-ULTP1	UT1AUG		81.2	32	70
PERLND	102	Urban or Built-up La	MON-ULTP1	UT1JUN		74	32	70
PERLND	102	Urban or Built-up La	MON-ULTP1	UT1JUL		81.2	32	70
PERLND	102	Urban or Built-up La	MON-ULTP1	UT1AUG		81.2	32	70

Figure 3-11. Model Parameter Value Analysis Window View.

The Constituent Loading Rates for selected constituents are presented in a box-whisker plot, along with information regarding comparison of the loading rates to target rates and comparison of loading rates among land uses. The box-whisker plot shows the variation in average annual loading among the model segments within each land use category. If there is only one model segment, there will be only a single tick at the average annual load for that land use. If there are multiple model segments, the tick will be at the median, and the extent of the box will indicate the interquartile range (25th and 75th percentile). The whiskers extend to the highest and lowest average annual loading rate for the segments of that land use classification. Results of an example loading rate comparison report is shown in Figure 3-12, followed by an example whisker box-plot of loading rates in Figure 3-13.

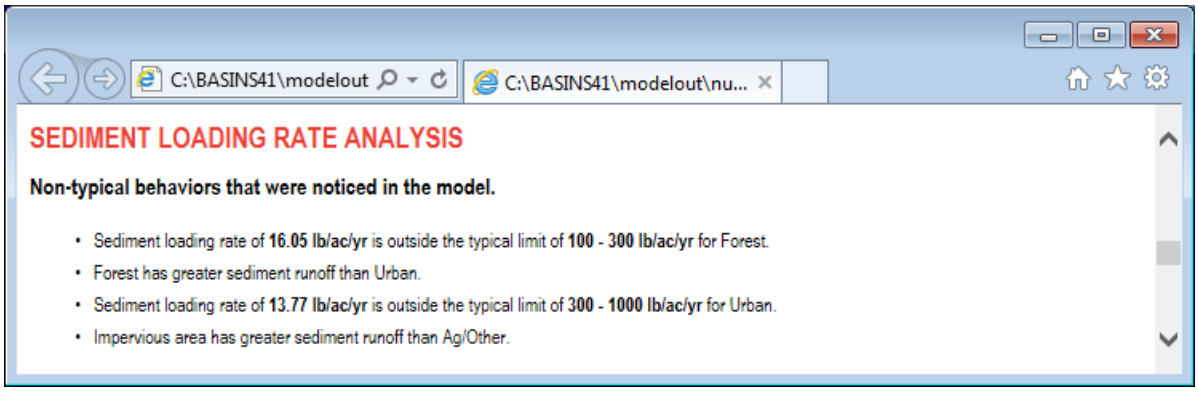


Figure 3-12. Sediment Loading Rate Analysis Window View.

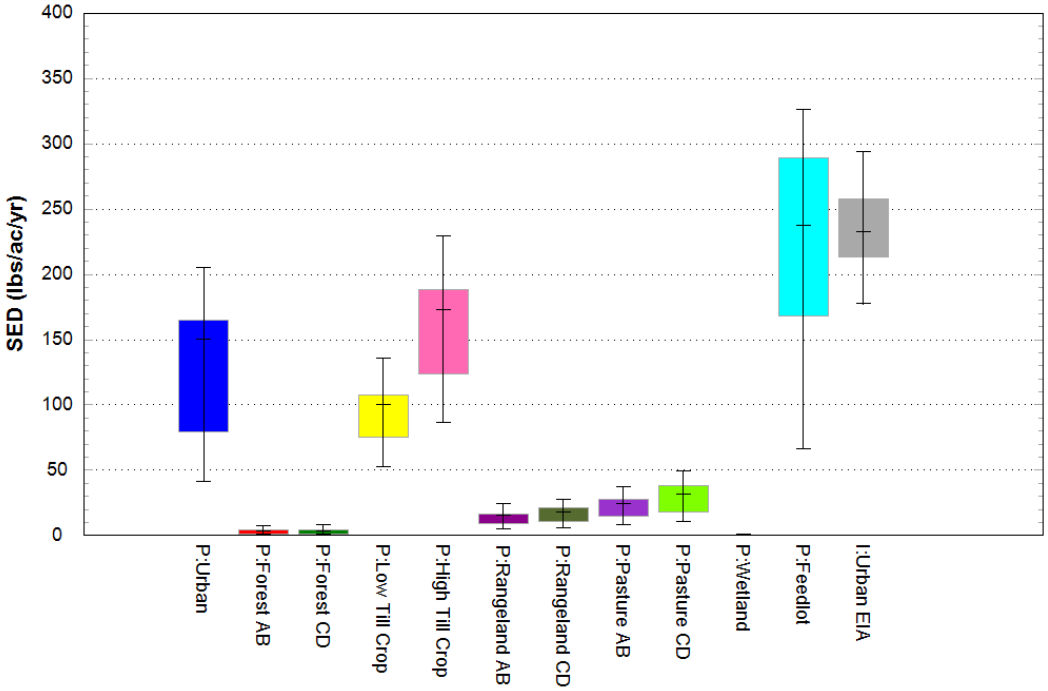
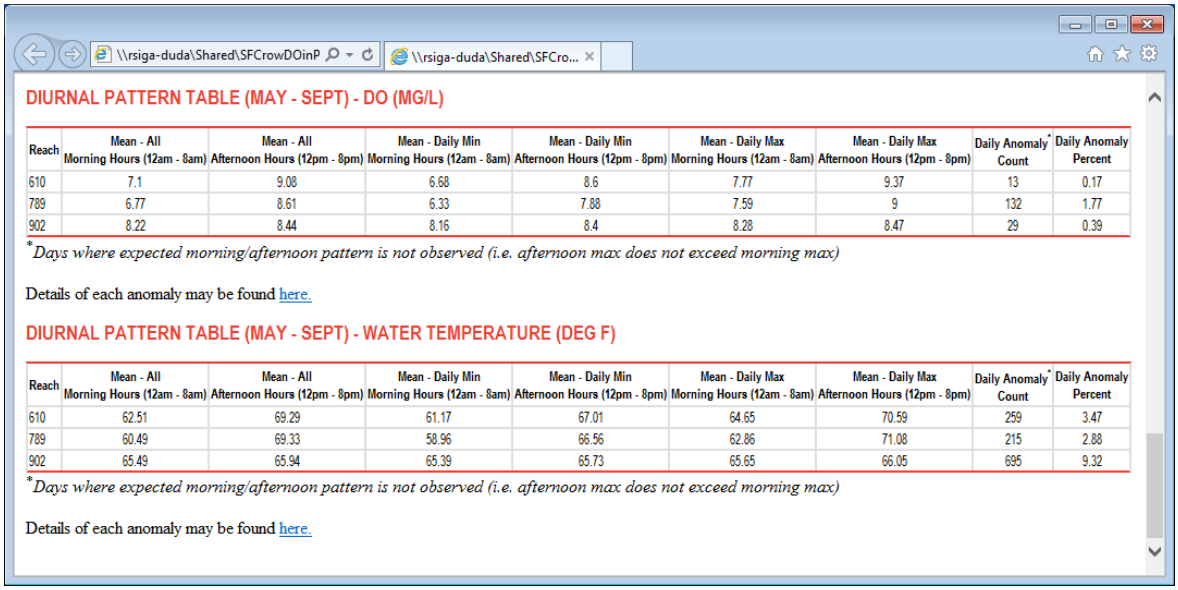


Figure 3-13. Example Whisker Box-Plot of Loading Rates.

The Diurnal Pattern Analysis reviews daily fluctuations in constituents such as DO and Water Temperature, which typically follow a pattern of lower values in the early morning and increased values in the afternoon and early evening, and reports anomalies, or days where the normal pattern are not upheld. These patterns are most notable in non-winter months, thus only the period from May through September is reviewed. A small number of days that do not follow the normal patterns is not uncommon, but a substantial percentage of exceptions may indicate the need for further review of the model's simulation of these constituents. Note that the Diurnal Pattern Analysis requires that the simulation results are written to the binary output (HBN) file on an hourly time step or shorter, as seen in Figure 3-14.



DIURNAL PATTERN TABLE (MAY - SEPT) - DO (MG/L)

Reach	Mean - All Morning Hours (12am - 8am)	Mean - All Afternoon Hours (12pm - 8pm)	Mean - Daily Min Morning Hours (12am - 8am)	Mean - Daily Min Afternoon Hours (12pm - 8pm)	Mean - Daily Max Morning Hours (12am - 8am)	Mean - Daily Max Afternoon Hours (12pm - 8pm)	Daily Anomaly* Count	Daily Anomaly Percent
610	7.1	9.08	6.68	8.6	7.77	9.37	13	0.17
789	6.77	8.61	6.33	7.88	7.59	9	132	1.77
902	8.22	8.44	8.16	8.4	8.28	8.47	29	0.39

*Days where expected morning/afternoon pattern is not observed (i.e. afternoon max does not exceed morning max)

Details of each anomaly may be found here.

DIURNAL PATTERN TABLE (MAY - SEPT) - WATER TEMPERATURE (DEG F)

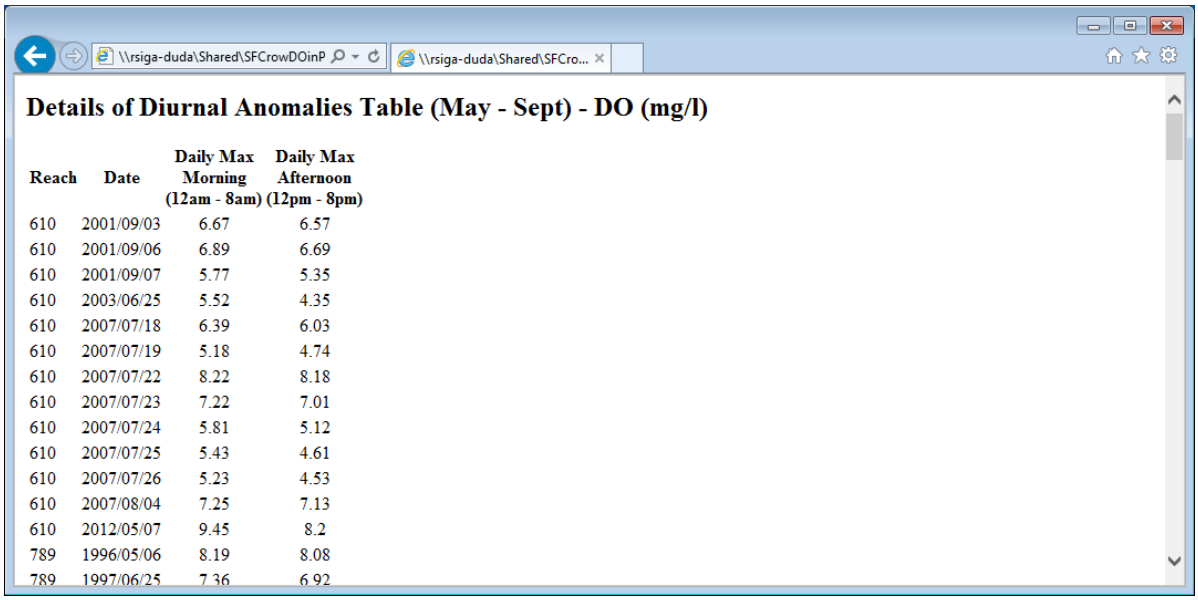
Reach	Mean - All Morning Hours (12am - 8am)	Mean - All Afternoon Hours (12pm - 8pm)	Mean - Daily Min Morning Hours (12am - 8am)	Mean - Daily Min Afternoon Hours (12pm - 8pm)	Mean - Daily Max Morning Hours (12am - 8am)	Mean - Daily Max Afternoon Hours (12pm - 8pm)	Daily Anomaly* Count	Daily Anomaly Percent
610	62.51	69.29	61.17	67.01	64.65	70.59	259	3.47
789	60.49	69.33	58.96	66.56	62.86	71.08	215	2.88
902	65.49	65.94	65.39	65.73	65.65	66.05	695	9.32

*Days where expected morning/afternoon pattern is not observed (i.e. afternoon max does not exceed morning max)

Details of each anomaly may be found here.

Figure 3-14. Diurnal Pattern Analysis Window View.

Figure 3-15 shows that when exceptions are found, an additional file is generated containing details of each exception.

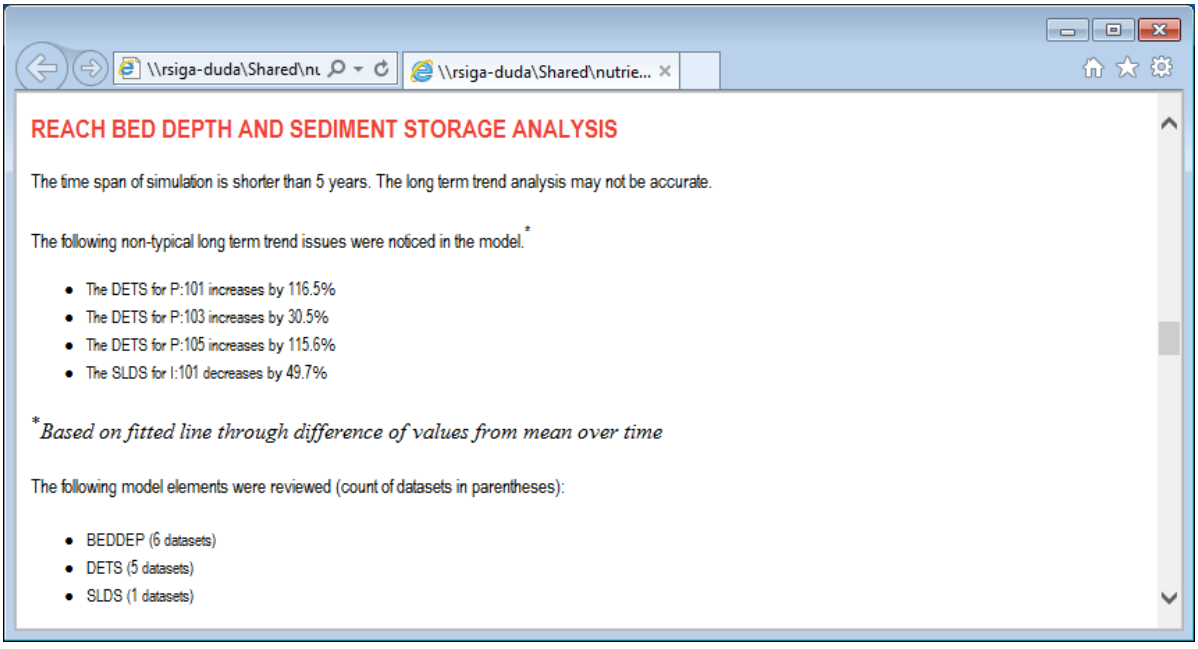


Details of Diurnal Anomalies Table (May - Sept) - DO (mg/l)

Reach	Date	Daily Max Morning (12am - 8am)	Daily Max Afternoon (12pm - 8pm)
610	2001/09/03	6.67	6.57
610	2001/09/06	6.89	6.69
610	2001/09/07	5.77	5.35
610	2003/06/25	5.52	4.35
610	2007/07/18	6.39	6.03
610	2007/07/19	5.18	4.74
610	2007/07/22	8.22	8.18
610	2007/07/23	7.22	7.01
610	2007/07/24	5.81	5.12
610	2007/07/25	5.43	4.61
610	2007/07/26	5.23	4.53
610	2007/08/04	7.25	7.13
610	2012/05/07	9.45	8.2
789	1996/05/06	8.19	8.08
789	1997/06/25	7.36	6.92

Figure 3-15. Diurnal Anomalies Window View.

The Constituent Storage Analysis checks model storage time series for increasing/decreasing trends for each selected constituent. This analysis is conducted by computing the difference of the time-series' values from its mean over the time span of the model. Should the slope of a best fit line through these resulting differences be significant enough to indicate an increasing or decreasing trend, the difference between the best fit line's starting and ending points is used to estimate the percent change. A summary of all model outputs reviewed for the current constituent is provided at the end of the section, and an example can be seen in Figure 3-16.



REACH BED DEPTH AND SEDIMENT STORAGE ANALYSIS

The time span of simulation is shorter than 5 years. The long term trend analysis may not be accurate.

The following non-typical long term trend issues were noticed in the model.*

- The DETS for P:101 increases by 116.5%
- The DETS for P:103 increases by 30.5%
- The DETS for P:105 increases by 115.6%
- The SLDS for I:101 decreases by 49.7%

**Based on fitted line through difference of values from mean over time*

The following model elements were reviewed (count of datasets in parentheses):

- BEDDEP (6 datasets)
- DETS (5 datasets)
- SLDS (1 datasets)

Figure 3-16. Constituent Storage Analysis Window View.

3.3 LOAD ALLOCATION TOOL

Under MPCA Work Order #9 (Shell No. 79375), AQUA TERRA Consultants (acquired by RESPEC in September 2015) was contracted to develop a Source Allocation Tool to allow users of BASINS/HSPF to identify which contaminant sources are the major contributors to water quality impairments (and the focus of Total Maximum Daily Loads [TMDLs]) so that remediation strategies and plans can be efficiently prepared.

RESPEC developed this tool as part of HSPEXP+, which is currently used for calibrating hydrology, and supporting water quality calibration. HSPEXP+ uses the output WDM file for hydrology calibration and the binary output file for generating water and nutrient balance reports. HSPEXP+ also generates graphs for hydrology and water quality calibration.

HSPEXP+ outputs the source-load allocation report as a simple text file that is formatted for viewing and editing in any spreadsheet program. The source-load allocation is also output as a bar graph for specific locations when the user specifies these locations on the HSPEXP+ form. The source-load allocation files are generated in a time-stamped (time of the last successful HSPF run) folder in the folder containing the HSPF UCI with a name of XX_YYY_LoadAllocation.txt, where XX is replaced by the nutrient of interest (TP or TN), and YYY is replaced by the UCI base file name. If the user requests load allocation reports at specific locations (reach end points) in the watershed, additional files (XX_YYY_LoadAllocation_Locations.txt and XX_YYY_ZZZ_LoadingAlloation.png, where zzz refers to the reach number) are generated that contain the load allocation reports at only the requested locations.

In addition to the source-load allocation report, HSPEXP+ generates several other nutrient balance reports that include nutrient loadings from each PERLND and IMPLND, as well as the fate and transport of nutrients in each RCHRES on an annual basis and annual average basis. HSPEXP+ also generates reports with a detailed nutrient budget for each RCHRES on an annual average basis. For every nutrient balance, a box-and-whisker plot of the nutrient loading rate is also generated.

To calculate the source-load allocation, the average annual contribution of each individual source (nonpoint, point, direct atmospheric deposition) is calculated at each reach starting at the most upstream reach. If any losses of nutrient occur in the stream on an average annual basis because of settling/deposition to the channel bottom or other biochemical processes, then the losses are applied back to each individual source proportional to its relative contribution. As we move downstream, the contribution of each source is recalculated, including the upstream sources. If losses occur at a downstream reach, they are applied proportionally (as reductions) to the cumulative sources. This calculation is performed for all the reaches in the watershed. If any pollutant gains occur in the reach, the gains are not applied back to the sources, since they are derived from the channel and not the upstream sources. The losses and gains are accumulated separately for each reach, and the gains are reported as a separate source.

The output locations for the Illinois River watershed (IRW) model are shown in Figure 3-17. The typical output in the load allocation file is shown in the example Tables 3-5 and 3-6 for the IRW model [AQUA TERRA Consultants, 2015]. Table 3-5 provides the loads allocated to each source, and Table 3-6 shows the load percentages derived from each source. The column headings for the two tables are described in Table 3-4. Note that Pasture1 and Pasture1-Litter from the IRW watershed modeling report were combined to Pasture1, and the three urban categories were combined to one urban category, developed, to save space.

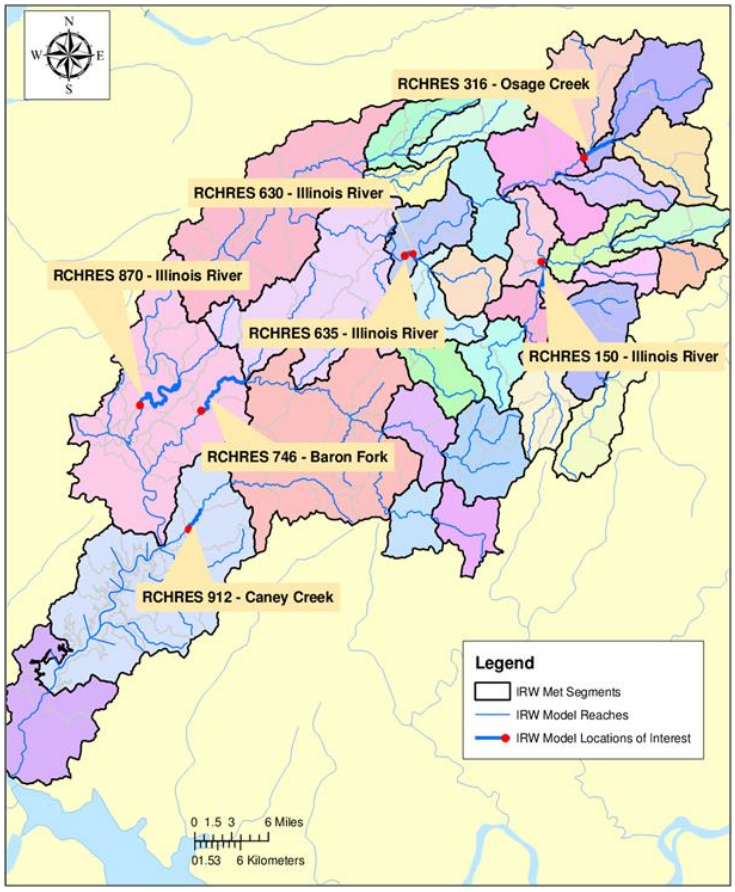


Figure 3-17. Locations in Illinois River Watershed Model at Which Load Allocation Reports Are Generated.

Table 3-4. Explanation of Column Headings for Tables 3-5 and 3-6

Column Heading	Explanation
Reach	Name and number of reach. This value is read from the GEN-INFO table for the RCHRES section. This section should be as descriptive as possible in the UCI file.
P: PERLND Name or I: IMPLND Name	These column names are generated from the GEN-INFO table in the UCI file for the PERLND and IMPLND sections. Each land use is listed in these columns. The values in these columns represent the loading from the respective land use to the respective reach once the losses in the reach have been accounted for.
Point Sources	Contribution of point sources to the specific reach, once losses have been accounted for.
Direct Atmospheric Deposition in the Reach	Direct atmospheric deposition that falls on the reach surface. The contribution of direct deposition is reduced, proportionally if losses occur in the reach.
Mass Balance Errors/Additional Sources*	Pollutant loads that cannot be accounted for by nonpoint source, point source, or atmospheric deposition. This column also includes any mass balance errors that may result because of precision errors in the HSPF code.
Diversions	If any of the reaches have diversions, the diversion loads are listed here. The diversions are considered lost from the system and are not applied back to the sources.
Cumulative Instream Losses	The losses are added for each reach and the cumulative losses are reported in this column.
Cumulative Instream Gains	The gains are added for each reach and the cumulative gains are reported in this column. For load allocation, gains are considered a source.
Total	Total of all sources

*This includes mass balance errors and any additional source that is not accounted for in listed sources.

Table 3-5. Allocation of Loading of Total Nitrogen (pounds) to Individual Sources After Applying the Losses in the Stream

Reach	P: Forest	P: Pasture1	P: Pasture2	P: Pasture3	P: Grass/ Shrub/ Barren	P: Developed	P: Wetlands	P: Cropland	I: Developed	Point Sources	Direct Atmospheric Deposition on the Reach	Mass Balance Errors/ Additional Sources[a]	Diversion	Cumulative Instream Losses	Cumulative Instream Gains	Total[b]
RCHRES 150 Illinois River	210,426	291,959	125,820	232,360	13,862	83,898	1,895	4,321	3,003	30,505	32	88	0	–4,840	–	998,168
RCHRES 316 Osage Creek	45,241	261,821	72,806	257,788	9,071	315,855	444	4,680	29,494	476,590	29	139	0	–12,281	–	1,473,958
RCHRES 630 Illinois River	443,651	734,760	282,550	822,441	43,399	619,124	5,012	11,649	52,237	599,796	145	331	0	–49,109	–	3,615,095
RCHRES 635 Illinois River	444,594	736,430	282,957	823,118	43,515	619,556	5,057	11,646	52,230	599,635	148	331	0	–50,080	–	3,619,216
RCHRES 746 Baron Fork	519,203	357,183	187,292	405,728	110,723	97,807	2,095	3,040	1,487	14,667	73	150	0	–12,542	–	1,699,449
RCHRES 870 Illinois River	1,023,887	1,196,426	414,927	1,090,350	178,289	760,938	12,107	18,652	59,083	709,303	369	500	–48,221[b]	–137,356	–	5,416,609
RCHRES 912 Caney Creek	128,561	119,365	62,122	143,470	14,167	36,423	194	1,531	1,663	19,202	12	46	0	–2,779	–	526,755

(a) This column shows mass balance errors because of unit conversion and any additional sources that are not represented traditionally.

(b) The total does not include instream losses because they have already been applied to the individual sources.

Table 3-6. Percent Contribution of Individual Sources at Each Reach

Reach	P: Forest	P: Pasture1	P: Pasture2	P: Pasture3	P: Grass/Shrub/ Barren	P: Developed	P: Wetlands	P: Cropland	I: Developed	Point Sources	Direct Atmospheric Deposition on the Reach	Mass Balance Errors/ Additional Sources[a]	Diversion	Cumulative Instream Losses	Cumulative Instream Gains	Total[b]
RCHRES 150 Illinois River	21.1	29.3	12.6	23.3	1.4	8.4	0.2	0.4	0.3	3.1	0.0	0.0	0.0	–0.5	0.0	100.0
RCHRES 316 Osage Creek	3.1	17.8	4.9	17.5	0.6	21.4	0.0	0.3	2.0	32.3	0.0	0.0	0.0	–0.8	0.0	100.0
RCHRES 630 Illinois River	12.3	20.3	7.8	22.8	1.2	17.1	0.1	0.3	1.5	16.6	0.0	0.0	0.0	–1.4	0.0	100.0
RCHRES 635 Illinois River	12.3	20.4	7.8	22.7	1.2	17.1	0.1	0.3	1.4	16.6	0.0	0.0	0.0	–1.4	0.0	100.0
RCHRES 746 Baron Fork	30.6	21.0	11.0	23.9	6.5	5.8	0.1	0.2	0.1	0.9	0.0	0.0	0.0	–0.7	0.0	100.0
RCHRES 870 Illinois River	18.9	22.1	7.7	20.1	3.3	14.0	0.2	0.3	1.1	13.1	0.0	0.0	–0.9[b]	–2.5	0.0	100.0
RCHRES 912 Caney Creek	24.4	22.7	11.8	27.2	2.7	6.9	0.0	0.3	0.3	3.7	0.0	0.0	0.0	–0.5	0.0	100.0

(a) This column shows mass balance errors because of unit conversion and any additional sources that are not represented traditionally.
(b) The total does not include Instream losses because they have already been applied to the individual sources.

3.4 RECEIVING WATER MODELS

HSPF models have traditionally been used to provide boundary conditions for more detailed lake models like WASP, EFDC etc., or simpler models like BATHTUB. However, developing input for these models requires significant expertise of HSPF software as well. Version 3.0 of HSPEXP+ has been enhanced to automatically generate model input files for BATHTUB and WASP for any HSPF reach of interest.

3.4.1 BATHTUB MODEL SETUP

For each location specified as an output location in the HSPEXP+ GUI, the software builds a Bathtub input file using these assumptions.

- Start and end dates of the simulation period taken from the HSPEXP+ GUI
- Global parameters taken from the HBN file for the simulation period
    - Assumed averaging period of 1 year
    - Precipitation (and CVmean) calculated as the quotient of PRSUPY precipitation (volume) and SAREA (surface area)
    - Evaporation (and CVmean) from VOLEV
    - Increase in storage as the difference between the final and beginning values from the AVDEP time series
- Model selections as outlined in the table below

Model	Option
Conservative substance:	0: Not computed
Phosphorus Balance:	8: Canfield & Bachmann, natural lakes
Nitrogen Balance	0: Not computed
Chlorophyll-a	2: P, Light, Flushing
Secchi Depth	1: Secchi vs. chlorophyll-a and turbidity
Dispersion	1: Fischer-numeric
Phosphorus Calibration	1: Apply calibration factors to predicted concentrations
Nitrogen Calibration	1: Apply calibration factors to predicted concentrations
Error Analysis	1: Consider model error and input error
Availability Factors	0: Ignore
Mass-Balance Tables	1: Use estimated concentrations
Output Destination	2: Excel worksheet

- Model coefficients taken from Bathtub default values:

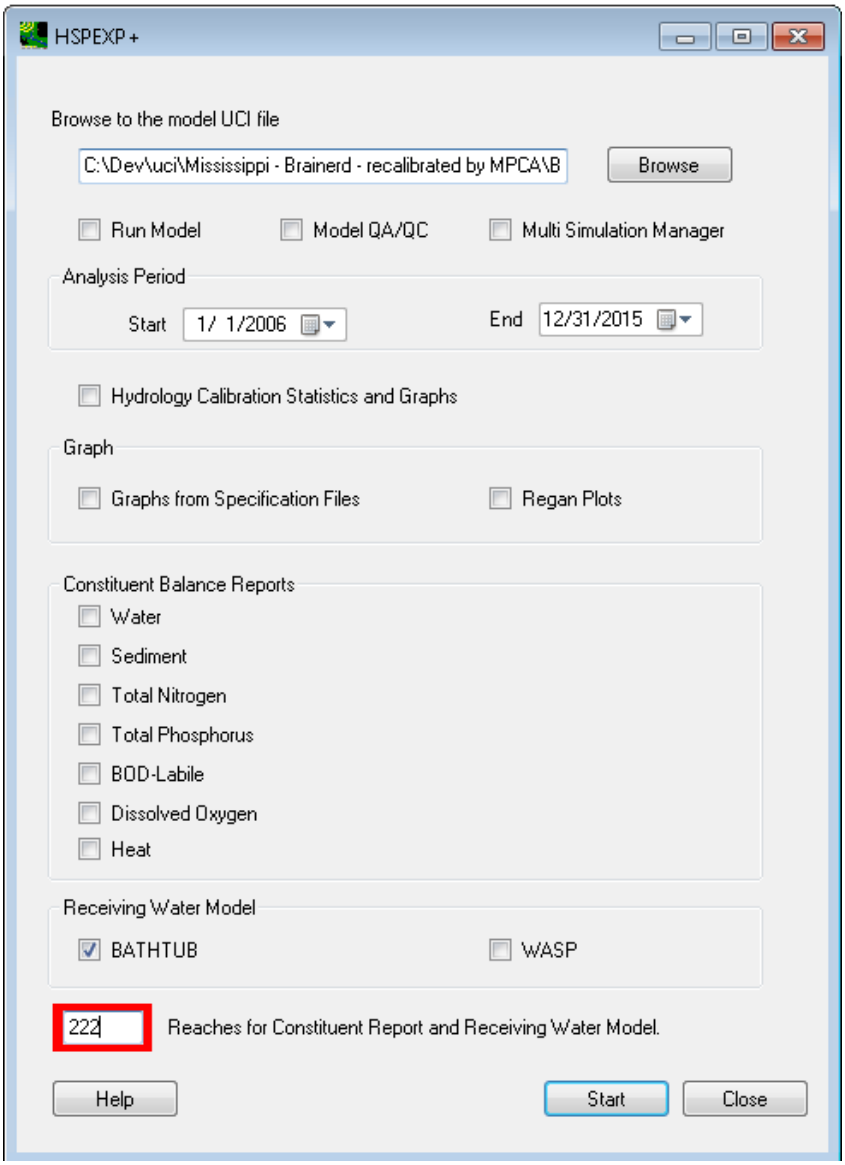
Model	Mean	CVmean
Dispersion Rate	1	0.7
Total Phosphorus	1	0.45
Total Nitrogen	1	0.55
Chlorophyll-a	1	0.26
Secchi Depth	1	0.1
Organic Nitrogen	1	0.12
Total P - Ortho P	1	0.15
Hypolimnetic Oxygen Depletion	1	0.15
Metalimnetic Oxygen Depletion	1	0.22
Secchi/Chl-a Slope (mg/m^2)	0.25	0
Minimum Q_s (m/yr)	1	0
Chl-a Flushing Term	1	0
Chl-a Temporal CV	0.62	0

TP Availability Factor	0.33	0
OP Availability Factor	1.93	0
TN Availability Factor	0.59	0
Inorganic N Availability Factor	0.79	0

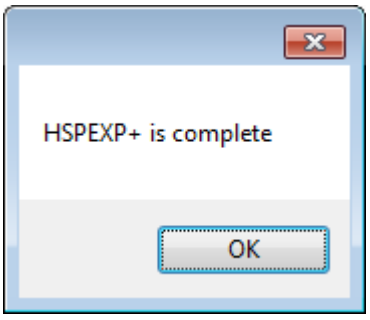
- Atmospheric loads taken from the HBN file for the simulation period:
    - Conservative substance is assumed zero
    - Total Phosphorus from PO4-ATMDEPTOT
    - Total Nitrogen from the sum of TAM-ATMDEPTOT, NO3-ATMDEPTOT, and NO2-ATMDEPTOT
    - Ortho Phosphorus is assumed to be half of Total Phosphorus atmospheric load
    - Inorganic Nitrogen is assumed to be half of Total Nitrogen atmospheric load
- Lake segment characterization
    - Assumption of one lake segment; additional segments may be added within Bathtub
    - Outflow is routed out of reservoir
    - Segment group 1
    - Surface area taken as the mean of SAREA
    - Mean depth taken as the mean of AVDEP
    - Length taken as the reach length LEN from HYDR-PARM2
    - Mixed layer depth assumed equal to mean depth as outlined above; mixed layer depth CVmean calculated from AVDEP
    - Hypolimnetic thickness (and its CVmean) assumed zero
    - Non-algal turbidity assumed as mean = 0.08 and CVmean = 0.05
    - Assumed internal load of zero for conservative substance, TP, and TN
    - No observed water quality data (user must provide from monitoring data)
        - All observed water quality fields are written as zeroes
    - Calibration factors are all assumed equal to 1 and CVmean equal to zero
- Tributary loading: RCHRES sources are used to identify tributaries upstream of the specified lake subwatershed as specified in the HSPEXP+ interface); the following parameters are extracted from the HBN for each tributary
    - The tributary is assumed to discharge to segment 1
    - The tributary type is assumed to be monitored outflow
    - Watershed area is calculated as the sum of all land use areas
    - Mean annual flow rate and CVmean from ROVOL
    - Flow-weighted mean concentrations and associated CVmean values are calculated using the values listed below and the annual flow rate as defined above:
        - Conservative substance is assumed equal to zero
        - Total P taken from PLANK and TPKCF1 if the time series is in the WDM; otherwise taken from P-TOT-OUT
        - Total N taken from PLANK and TPKCF1 if the time series is in the WDM; otherwise taken from N-TOT-OUT
        - Ortho P taken from NUTRX and DNUST if the time series is in the WDM; otherwise taken from PO4-CONCDIS
        - Inorganic N taken as the sum of nitrate, nitrite, and total ammonia, which are taken from NUTRX and DNUST if the time series are in the WDM; otherwise they are taken from NO3-CONCDIS, NO2-CONCDIS, and TAM-CONCDIS
    - Land use areas are not used and are written as zeroes
- Lakeshed loading (special case of tributary loading) from the lake subwatershed specified in the HSPEXP+ interface
    - The lakeshed is assumed to discharge to segment 1
    - The tributary type is assumed to be monitored outflow
    - Watershed area is calculated as the sum of areas of each IMPLND and PRLND in the lakeshed

- Mean annual flow rate is developed as the sum of mean annual flow rates for each of the PRLNDs and IMPLNDs in the lakeshed
    - Note that difficulties were encountered in the calculation of the CVmean values for runoff and flow-weighted mean concentrations from the lakeshed; as a surrogate, CVmean values from the last tributary written to the Bathtub file are applied to the CVmean values for the lakeshed. This assumes that values will vary similarly (relative to long-term means) within the lakeshed as they do within tributaries. Future enhancements could address this limitation
  - Flow-weighted mean concentrations were computed as the total load of each constituent, which is calculated as the sum of loads from each PRLND and IMPLND, divided by the total runoff as calculated above
  - Land use areas are not used and are written as zeroes
    - Originally, it was planned that land use areas and export coefficients (for runoff, TP, TN, etc.) for the lakeshed would be written to Bathtub and that total lakeshed runoff and loading would be calculated within Bathtub. However, Bathtub only allows for up to 8 land uses to be entered and used for these calculations; this limit was exceeded with the first Bathtub test model as there were 12 IMPLND/PRLND classifications within the lakeshed. Thus, these data are not written out to Bathtub and are the associated calculations are instead handled entirely within HSPEXP+
- No channels are included
- Land use export categories values are all written as zero (see note above in the lakeshed loading section for more details)

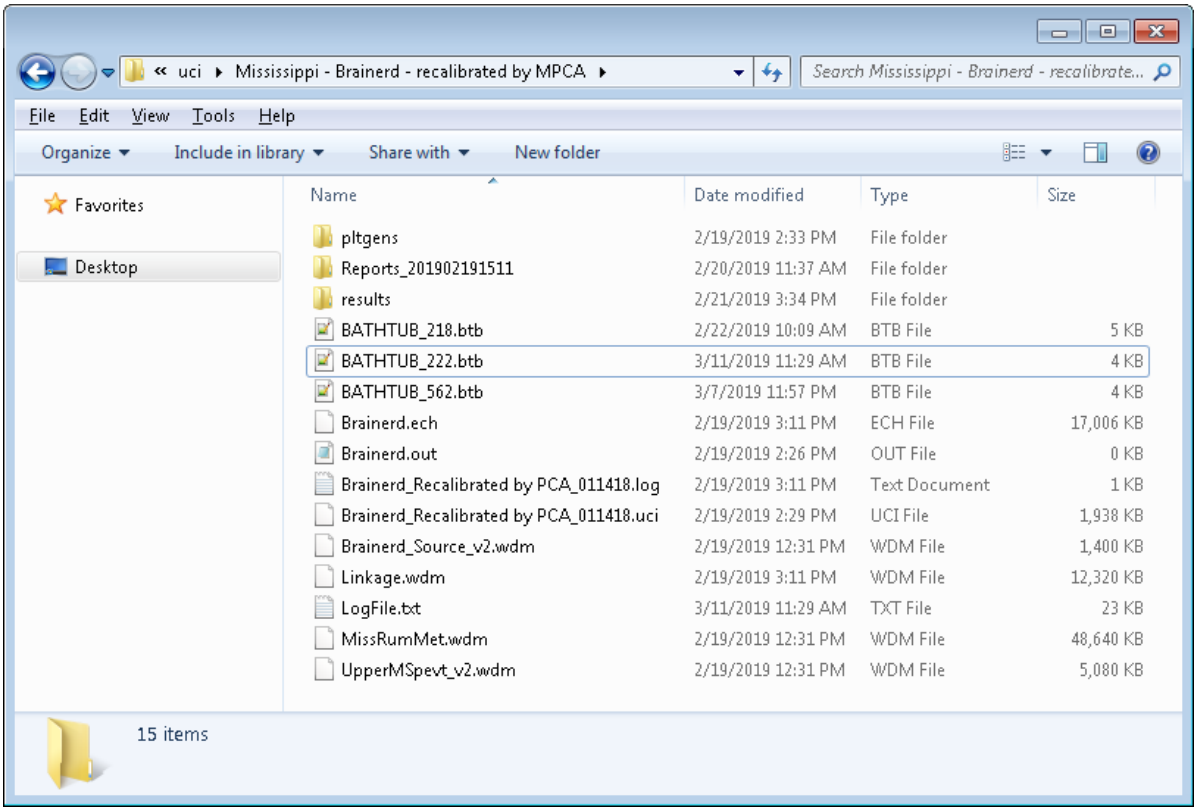
To use this feature, the UCI file is set to the desired HSPF project, the Reach Number is set to the desired number, and the Receiving Water Model is set to Bathtub, as shown below:



After clicking Start, the software processes for a few seconds. When complete, the following message appears:



The Bathtub model input file, named BATHTUB_XXX.inp (where XXX is the HSPF model reach number), will be written to the folder containing the UCI file.



To open the Bathtub model, first start Bathtub, and then from the Case menu, read the new case (.btb) file.

3.4.2 WASP MODEL SETUP

For each location specified as an output location in the HSPEXP+ GUI, the software builds a WASP input file using these assumptions:

- The start and end dates of the WASP simulation are taken from the HSPEXP+ GUI.
- The WASP8 advanced eutrophication model is assumed, simulating WASP eutrophication constituents shown below:
    - Ammonia Nitrogen
    - Nitrate Nitrogen
    - Dissolved Organic Nitrogen
    - Inorganic Phosphate
    - Dissolved Organic Phosphorus
    - CBOD (Ultimate)
    - Dissolved Oxygen
    - Detrital Carbon
    - Detrital Nitrogen
    - Detrital Phosphorus
    - Inorganic Solids
    - Phytoplankton Chla
- A single WASP segment is assumed (initially, it can be broken up later if needed) with the following characteristics:
    - Length from the RCHRES HYDR LEN parameter

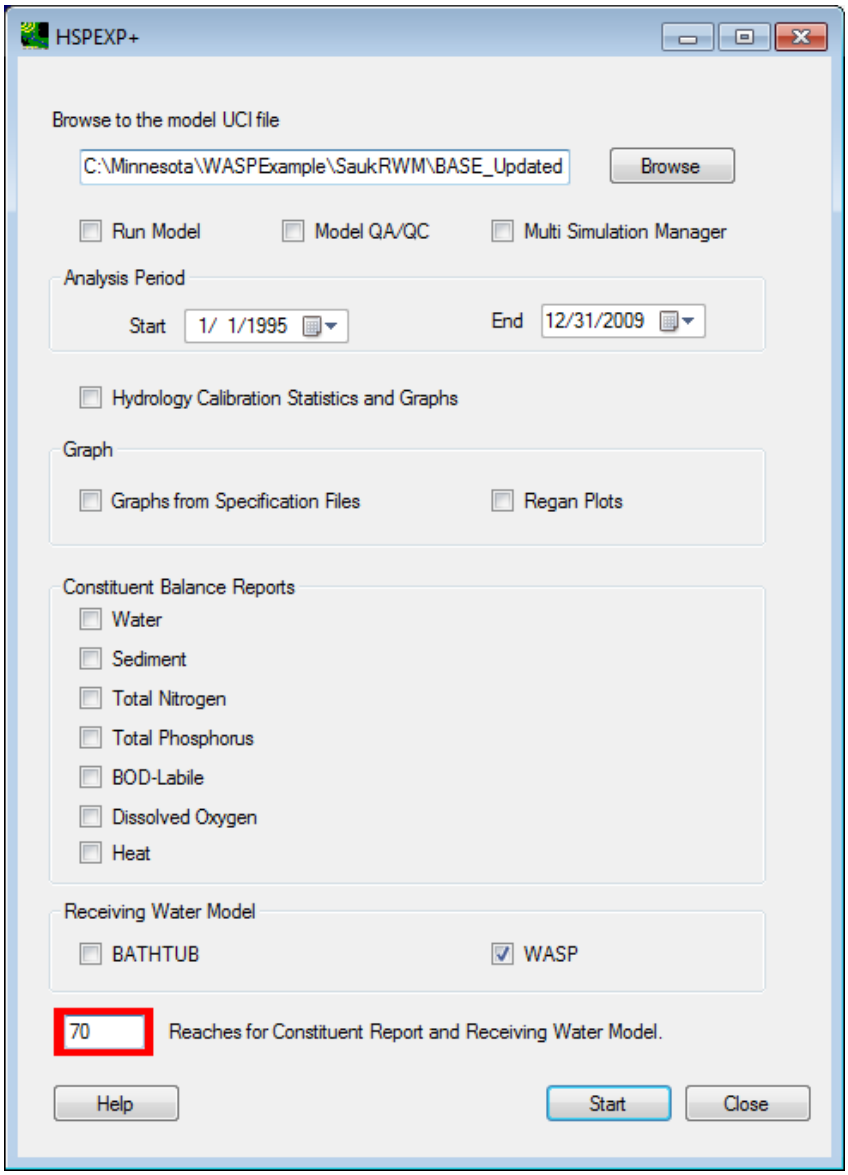
- Slope derived from the RCHRES HYDR DELTH parameter
- Depth as the mean depth (DEP) from the HBN file over the simulation period
- Width as the mean top width (TWID) from the HBN file over the simulation period
- Volume as the mean volume term (VOL) from the HBN file over the simulation period
- If the HBN file is not available with the depth, width, and volume data, an alternate is to compute those using:
  - Depth computed from RCHRES drainage area by a power function used in the BASINS WASP setup plugin
  - Width derived from the respective RCHRES FTABLE at the corresponding depth
  - Volume derived from the respective RCHRES FTABLE at the corresponding depth

- Break that one segment into multiple longitudinal segments if needed through the following process:
  - Compute mean flow-thru time for the segment using the mean flow rate and mean volume from the HBN file over the simulation period.
  - If the flow-thru time is greater than 0.1 days, divide the segment into multiple segments in order to meet this condition (0.1 days is arbitrary, but this is a general guideline for riverine segments)
  - If the resulting segments are many times wider than they are in length, make the segments about as long as they are wide, as is general WASP practice.
- From the HSPF binary output file, use the HYDR:IVOL timeseries for the RCHRES, transformed to daily, as the input flow to the WASP segment (IVOL is going to represent both the upstream inflow as well as the local inflows, converted to cms)
- Use the following timeseries from the HSPF binary output file for the subject RCHRES, transformed to daily, as input loads to the WASP segment (or upstream-most segment if there are multiple WASP segments):

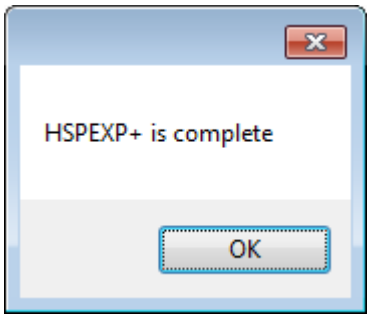
HSPF Timeseries…	Connected as Load to WASP Advanced Eutrophication Constituent …	Units
TAM-INTOT	Ammonia Nitrogen	Converted from lbs to kg
NO3-INTOT	Nitrate Nitrogen	Converted from lbs to kg
N-TOTORG-IN	Dissolved Organic Nitrogen	Converted from lbs to kg
PO4-INTOT	Inorganic Phosphate	Converted from lbs to kg
P-TOTORG-IN	Dissolved Organic Phosphorus	Converted from lbs to kg
BODIN	CBOD (Ultimate)	Converted from lbs to kg
DOXIN	Dissolved Oxygen	Converted from lbs to kg
C-REFORG-IN	Detrital Carbon	Converted from lbs to kg
N-REFORG-IN	Detrital Nitrogen	Converted from lbs to kg
P-REFORG-IN	Detrital Phosphorus	Converted from lbs to kg
ISED-TOT	Solids	Converted from tons to kg
PHYTO-IN	Phytoplankton Chla	Converted from lbs to kg

Note that this design assumes the user is writing HSPF binary output at an appropriate timestep. This design is functional for a basic case where the segmentation can be assumed, and all inflows (reach flows/loads and land surface flows/loads) are assumed to enter the upstream-most segment.

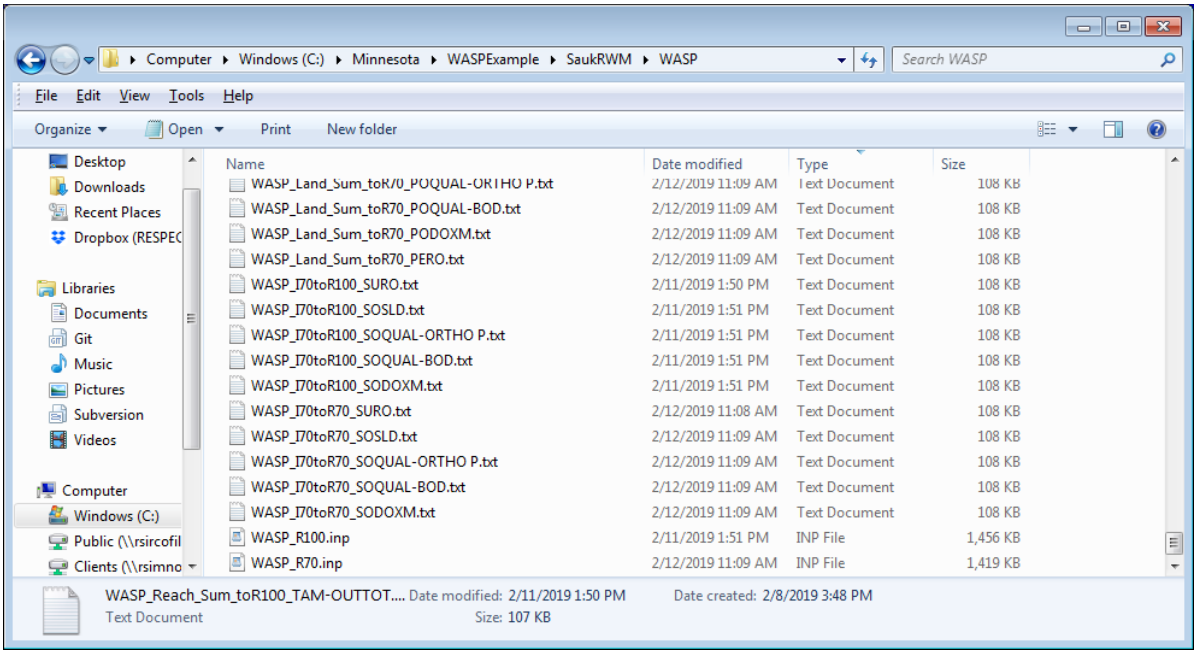
To use this feature, the UCI file is set to the desired HSPF project, the Reach Number is set to the desired reach, and the Receiving Water Model is set to WASP, as shown below:



After clicking Start, the software processes for a few seconds. When complete, the following message appears:



The WASP model input file, named WASP_RXX.inp (where XX is the HSPF model reach number), will be written to a folder named 'WASP' within the folder containing the UCI file.



To open the WASP model, first start WASP, and then use the 'File:Import' menu in WASP to import the WASP .inp file.

If the WASP modeler would like to segment the WASP model in a way other than the default, it is left up to the WASP modeler to re-segment as desired thru the WASP user interface in conjunction with the BASINS WASP setup tool. In case the user wants to do further segmentation, HSPEXP+ also outputs the contributing reach flows/loads and contributing land surface flows/loads separately as individual text files. With these files the user can input these timeseries through the WASP interface into the desired WASP model segment as desired.

The timeseries written include the following:

Timeseries Written from Each Contributing HSPF RCHRES	For Potential Use as Input to WASP Advanced Eutrophication Constituent …	Units
RO	Flow	Converted from cfs to cms
TAM-OUTTOT	Ammonia Nitrogen	Converted from lbs to kg
NO3-OUTTOT	Nitrate Nitrogen	Converted from lbs to kg
N-TOTORG-OUT	Dissolved Organic Nitrogen	Converted from lbs to kg
PO4-OUTTOT	Inorganic Phosphate	Converted from lbs to kg
P-TOTORG-OUT	Dissolved Organic Phosphorus	Converted from lbs to kg
BODOUTTOT	CBOD (Ultimate)	Converted from lbs to kg
DOXOUTTOT	Dissolved Oxygen	Converted from lbs to kg
C-REFORG-OUT	Detrital Carbon	Converted from lbs to kg
N-REFORG-OUT	Detrital Nitrogen	Converted from lbs to kg
P-REFORG-OUT	Detrital Phosphorus	Converted from lbs to kg
ROSED-TOT	Solids	Converted from tons to kg
PHYTO-OUT	Phytoplankton Chla	Converted from lbs to kg

Timeseries Written from Each Contributing HSPF PERLND/IMPLND	For Potential Use as Input to WASP Advanced Eutrophication Constituent …	Units
PERO / SURO	Flow	Converted from watershed inches/time step to cms
SOSED / SOSLD	Solids	Converted from tons to kg
PODOXM / SODOXM	Dissolved Oxygen	Converted from lbs to kg
POQUAL-NH4 / SOQUAL-NH4	Ammonia Nitrogen	Converted from lbs to kg
POQUAL-NO3 / SOQUAL-NO3	Nitrate Nitrogen	Converted from lbs to kg
POQUAL-ORTHO P / SOQUAL-ORTHO P	Inorganic Phosphate	Converted from lbs to kg
POQUAL-BOD / SOQUAL-BOD	Total Organic Nitrogen, Phosphorus, and BOD	Converted from lbs to kg

Note that while the above timeseries are written for easy copy/paste into the WASP input file, there may be additional transformations that would be appropriate. For instance, in HSPF the BOD constituent from the land surface is partitioned into organic nitrogen, organic phosphorus, and BOD components entering the stream reach. A similar partitioning would be appropriate for WASP.

The naming of the output timeseries is self-explanatory, showing the operation number, the target operation, and the constituent, such as:

WASP_R5toR4_RO.txt

Indictating that timeseries represents the RO timeseries from reach 5 contributing to reach 4, and

WASP_R5toR4_DOXOUTTOT.txt

Indictating that timeseries represents the DOXOUTTOT timeseries from reach 5 contributing to reach 4.

In addition to writing the timeseries from each contributing reach and each contributing PERLND/IMPLND, HSPEXP+ also writes a combined (sum) timeseries of all reaches contributing to the desired reach as well as a combined (sum) timeseries of all land uses contributing to the desired reach, for each indicated constituent. For example, setting up WASP for Reach 4 where the following are contributing operations to Reach 4:

- Reach 5
- Reach 6
- Reach 7
- PERLND 101
- PERLND 102
- IMPLND 101

The following combined timeseries are also written:

WASP_R5toR4_RO.txt |
WASP_R6toR4_RO.txt | → **combined to** WASP_Reach_Sum_toR4_RO.txt
WASP_R7toR4_RO.txt |

WASP_R5toR4_DOXOUTTOT.txt |
WASP_R6toR4_DOXOUTTOT.txt | → **combined to** WASP_Reach_Sum_toR4_DOXOUTTOT.txt
WASP_R7toR4_DOXOUTTOT.txt |

WASP_P101toR4_PERO.txt |
WASP_I101toR4_SURO.txt | → **combined to** WASP_Land_Sum_toR4_PERO.txt
WASP_P102toR4_PERO.txt |

WASP_P101toR4_PODOXM.txt |
WASP_I101toR4_SODOXM.txt | → **combined to** WASP_Land_Sum_toR4_PODOXM.txt
WASP_P102toR4_PODOXM.txt |

It is left up to the user to apply these timeseries to the WASP model as appropriate, based on the WASP model segmentation.

3.5 RESOLVING ERRORS

HSPEXP+ assumes that the user has provided correct data in all the model set-up files; currently, error checking in HSPEXP+ is minimal and rudimentary. In some cases, HSPEXP+ may generate some common errors as a pop-up if the format of some input in the EXS file is incorrect or if some required files are missing. HSPEXP+ also produces a log file every time it is run. Referring to the log file may give some indication of the cause of the error. In most cases, the user may have to refer to the help manual and ensure that all input files are set up correctly. An example of an error in HSPEXP+ is shown in Figure 3-18.

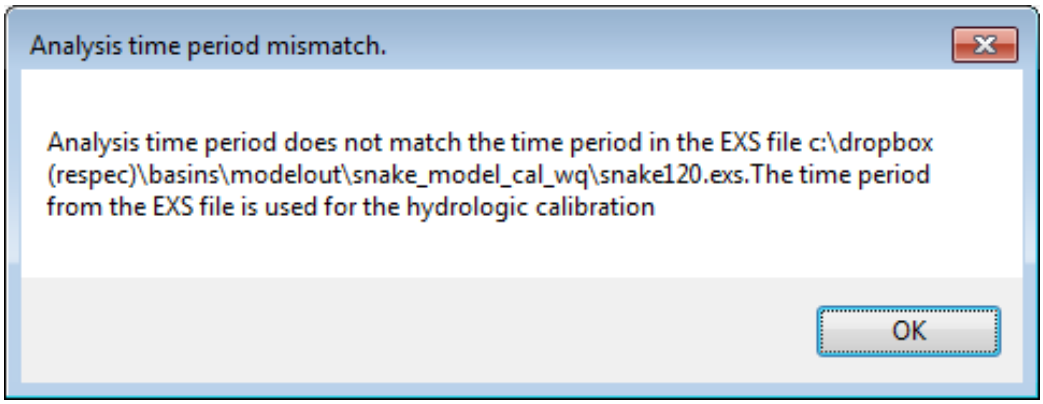


Figure 3-18. Example HSPEXP+ Error.

4.0 LIMITATIONS

Currently, HSPEXP+ can only take into account nonpoint sources, point sources, GENER Sources applied through the SCHEMATIC Block, NETWORK Block, and direct atmospheric deposition to water surfaces. This program cannot account for additional sources such as pollutant loads from tile drainage if represented in an unconventional manner (e.g., through SPEC-ACTIONS). Because of the flexibility of HSPF, additional sources can be modeled several different ways; therefore, including them in a standard reporting program is difficult.

In the versions following HSPEXP+ 1.0, when HSPEXP+ encounters a GENER operation that contributes to a REACH (through a SCHEMATIC or NETWORK block), it checks if the GENER time series is output to a WDM dataset. If the output WDM time series is available, HSPEXP+ reads the time series, obtains the applicable multiplication factors from the MASS-LINK and SCHEMATIC blocks, and calculates the loadings. These loadings are included in the GENER Sources category of the Constituent Budget Report. If the GENER time series is not output to a WDM dataset, the GENER loadings for that reach are included in the Mass Balance Differences/Additional Sources category of the Constituent Budget Report. The user can also tabulate these nonconventional sources separately and recalculate the resulting totals and contribution percent.

Another possible limitation of using HSPEXP+ arises in the case of models with multiple UCI files. For example, models of the Redeye, Long Prairie, and Crow Wing rivers were developed as separate watershed models, where the Redeye and Long Prairie Rivers contributed flow and nutrients to the Crow Wing River, as illustrated in Figure 4-1. When the load allocation report is prepared for the Crow Wing River model, the Redeye and Long Prairie Rivers are considered point sources. When losses occur in the Crow Wing River reaches, they are applied back to the Redeye and Long Prairie Watersheds as point sources, instead of distributing them to the sources upstream of the confluence points of the Redeye and the Long Prairie rivers with the Crow Wing River. The user may have to manually redistribute these losses back to the individual sources of contributing models (in this case, Redeye and Long Prairie River watersheds). HSPEXP+ does not produce reliable loading allocation reports for models that have a complex network (e.g., models where diversions get rerouted back to the model, or different routing based on surface or groundwater flows).

Figure 4-1. Hydrography of Redeye, Long Prairie, and Crow Wing River Watersheds.

5.0 REFERENCES

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Lumb, A. M., R. B. McCammon, and J. L. Kittle, Jr., 1994. *User's Manual for an Expert System (HSPEXP) for Calibration of the Hydrological Simulation Program-FORTRAN*, Water-Resources Investigations Report 94-4168, prepared by the US Geological Survey, Reston, VA.

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