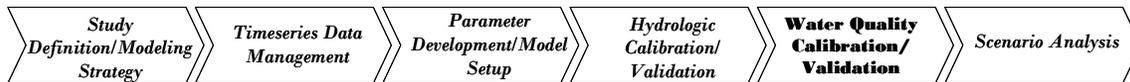




## Exercise 10 – Bacteria and Temperature Modeling

### BASINS/HSPF Application Steps



In this exercise, we will add temperature and fecal coliform to the calibrated WinHSPF hydrology model. We will discuss: 1.) Using the *Bacterial Indicator Tool* to estimate coliform buildup and washoff parameters; 2.) Adding temperature to the hydrology model; 3.) Adding fecal coliform to the hydrology model using the estimated input parameters from the *Bacterial Indicator Tool*; and 4.) Calibrating temperature and fecal coliform.

### Questions addressed in this section:

- 1.) How do I use the Bacterial Indicator Tool to estimate accumulation rates and limits for fecal coliform on various land use segments?
- 2.) How do I add temperature and fecal coliform to my calibrated hydrology model?
- 3.) Which parameters do I adjust to calibrate temperature and fecal coliform bacteria?

### A. Use Fecal Bacterial Tool to Estimate Fecal Coliform Loadings

#### QUESTION ANSWERED:

- 1.) *How do I use the Bacterial Indicator Tool to estimate accumulation rates and limits for fecal coliform on various land use segments?*

The *Bacterial Indicator Tool* is a Microsoft Excel-based program that estimates loadings of fecal coliform based on literature values of bacterial counts from animal populations. We will discuss most aspects of the tool briefly, but because of time constraints, we have already entered most of the information for you. Many explanations have been added to this exercise and are taken directly from the “*BacteriaTool.pdf*” (found in *c:\basins\modelout\bacteria*), which provides full documentation of the tool.

1. From the **Start** menu under **Programs**, select **Microsoft Excel**.
2. Click  (Open File).
3. Navigate to *c:\basins\modelout\bacteria\* and select “*Patuxent Fecal Tool.xls*.” Click OPEN.

**Note:** Spreadsheet entries in **red font** are to be set or modified by the user. Black font denotes values calculated by the formulas in the spreadsheet. **Blue font** is used for descriptive notes.

- At the bottom of your screen, there are 13 tabs. Click the first tab, named “Land Use.”

**Note:** The spreadsheet considers only four land use types: Built-up, Forest, Cropland, and Pastureland. The land use categories in the Patuxent model must be mapped to these as follows:

- Forest (PERLND 101) → Forest
- Urban (PERLND 102) → Built-up
- Agriculture (PERLND 103) → Cropland

We will not assign “Barren” to any of these land uses since its characteristics are significantly different from the available land use options in the tool. Instead we will use accumulation rates slightly lower than those for Forest when we enter the values computed by the Bacterial Tool into WinHSPF. We will assume that the inputs for the wetlands land use will be slightly less than agriculture due to the number of waterfowl within in the area.

The following section explains how to populate the “Land Use” worksheet given the information available in the WinHSPF model. We will open WinHSPF to obtain some information and then we will return to the *Bacterial Indicator Tool*.

- From the **Start** menu under **Programs**, select **BASINS** and then **WinHSPF**.
- From the **File** menu, select **Open**.
- Navigate to *c:\basins\modelout\Bacteria* and select “*bacteria.uci*.” Click OPEN.

**Note:** This \*.uci file is the calibrated hydrology version of the model that has been renamed for this exercise so we can add temperature and bacteria and keep a clean copy of the calibrated hydrology file.

- In the WinHSPF interface, click on the “RCHRES 1”, , segment in the watershed schematic (it should now be highlighted blue in the background).
- Make sure the “Land Surface” tab (on the left) is selected and select the “Forest Land”, “Urban or Built Up Land”, and “Agricultural Land” land use categories. The area corresponding to Reach 1 will appear in the auxiliary table below the watershed schematic. The auxiliary table should look like the following:

Land Use	Reaches	Implnd (Acres)	Perlnd (Acres)	Total (Acres)
Forest Land	RCHRES 1	0.0	5785.0	5785.0
Urban or Built-up La	RCHRES 1	2830.0	2830.0	5660.0
Agricultural Land	RCHRES 1	0.0	6255.0	6255.0
<b>Total</b>		2830.0	14870.0	17700.0

**Note:** The areas reported in the auxiliary table shown above represent the pervious

and impervious land segment areas (separated out by land use) that are draining to RCHRES 1.

10. Toggle to the *Bacterial Indicator Tool* (i.e., the Excel spreadsheet) and make sure that the “Land Use” tab is selected. Notice that the *Bacterial Indicator Tool* allows up to 10 subwatersheds (P1 – P10). Since our subbasin has six subwatersheds, we will use only P1 through P6, corresponding to subwatersheds 1 through 6, respectively.
11. Enter the areas from the auxiliary table in WinHSPF into the cells corresponding to P1. Your screen should look like the following:

Areas are listed in acres.					
SUBWATERSHED	BUILT-UP	CROPLAND	PASTURELAND	FOREST	TOTAL
P1	5660	6255		5785	17700
P2					0
P3					0
P4					0
P5					0
P6					0
P7					
P8					
P9					
P10					
TOTAL	5660	6255	0	5785	17700

**Note:** Notice that the value entered for “Built-Up” was the sum of the Urban or Built Up Land impervious and pervious land segment area.

12. Repeat step 8-11 for all the reaches (6 total). Make sure you only have one reach selected at a time (highlighted blue in the background). You can unselect a reach by clicking on it again. When you have completed these steps for each reach, your screen should look like the following:

Areas are listed in acres.					
SUBWATERSHED	BUILT-UP	CROPLAND	PASTURELAND	FOREST	TOTAL
P1	5660	6255		5785	17700
P2	4776	8870		6048	19694
P3	972	1483		1873	4328
P4	560	225		840	1625
P5	164				164
P6	1282	4569		2774	8625
P7					0
P8					0
P9					0
P10					0
TOTAL	13414	21402	0	17320	52136

In the following section, we will view and briefly discuss each sheet in the tool. Remember that the discussion is taken primarily based on information available in the *Bacterial Indicator Tool User’s Guide* (referenced below). As mentioned previously, all of the numbers for the West Branch Patuxent have already been entered due to time constraints.

13. Click on the “Animals” tab and look over the required inputs.

**Note:** In this sheet, the user specifies the number of various animals in the subbasin. Livestock are entered in number per watershed (total population), and wildlife

are entered as number / sq. mile. Finding livestock population and wildlife density data can be difficult. Many states conduct informal livestock counts and wildlife management groups sometimes have wildlife density estimates for certain areas. You may need to make guesses based on available estimates from other, similar watersheds.

The screenshot shows the 'Patuxent Fecal Tool.xls' spreadsheet. The 'Agricultural Animals' section (rows 9-20) lists 10 subwatersheds (P1-P10) and their total counts for six animal types: Beef Cattle, Swine (Hogs), Dairy Cattle, Chickens, Horses, and Sheep. The 'Wildlife' section (rows 23-30) lists densities for Ducks, Geese, Deer, Beaver, and Rabbits across three land use categories: Cropland, Pastureland, and Forest.

Agricultural Animals						
SUBWATERSHED	BEEF CATTLE	SWINE (HOGS)	DAIRY CATTLE	CHICKENS	HORSES	SHEEP
P1	156	120	31	96	45	
P2	192	148	38	118	75	
P3	43	34	9	28	15	
P4	14	10	3	9	5	
P5	0	0	0	0	0	
P6	95	73	19	59	25	
P7	0	0	0	0	0	
P8	0	0	0	0	0	
P9	0	0	0	0	0	
P10	0	0	0	0	0	
TOTAL	500	385	100	310	165	

Wildlife						
	CROPLAND	CROPLAND	PASTURELAND	PASTURELAND	FOREST	FOREST
	Animals/sq mile	Density/acre	Density/sq mile	Density/acre	Density/sq mile	Density/acre
Ducks	10	0.015625	0	0	20	0.003125
Geese	5	0.0078125	0	0	10	0.003125
Deer	5	0.0078125	0	0	5	0.003125
Beaver	1	0.0015625	0	0	2	0.003125
Rabbits	2	0.003125	0	0	5	0.003125

- Click the “Manure Application” tab and look at the required inputs.

**Note:** The Manure Application worksheet calculates the fraction of the annual manure produced that is available for washoff based on the amount applied to cropland and pastureland in each month and the fraction of manure incorporated into the soil (for hog, beef cattle, dairy cattle, horse, and poultry manure).

- Click the “Grazing” tab and look at the required inputs.

**Note:** The Grazing worksheet lists the days spent confined and grazing for beef cattle, horses, sheep, and other. Beef cattle are assumed to have access to streams while grazing.

- Click the “References” tab and look through the worksheet.

**Note:** The Reference worksheet lists literature and assumed values for manure content, wildlife densities, and built-up fecal coliform accumulation rates. These values are used in calculations in the remaining worksheets.

17. Click the “Wildlife” tab and look through the worksheet.

**Note:** The Wildlife worksheet calculates the fecal coliform bacteria produced by wildlife by land use category. The calculations are based on the animal population and densities specified in the Animal worksheet.

18. Click the “Cropland” tab and look through the worksheet.

**Note:** The Cropland worksheet calculates the monthly rate of accumulation of fecal coliform bacteria on cropland from wildlife, hog, cattle, and poultry manure.

19. Click the “Forest” tab and look through the worksheet.

**Note:** The Forest worksheet calculates the rate of accumulation of fecal coliform bacteria on forestland from wildlife.

20. Click the “Built-up” tab and look at the required inputs.

**Note:** The Built-Up worksheet calculates the rate of accumulation of fecal coliform bacteria on built-up land using literature values. No distinction is made between pervious and impervious land. Because the bacterial tool breaks down urban land rather differently than the land use classifications in WinHSPF, the divisions in the spreadsheet have been left at default values for this exercise.

21. Click the “Pastureland” tab and look through the worksheet.

**Note:** The Pastureland worksheet calculates the monthly rate of accumulation of fecal coliform bacteria on pastureland from wildlife, cattle, and horse manure, and cattle, horse, sheep, and other grazing.

22. Click the “Cattle in Streams” tab and look through the worksheet.

**Note:** The Cattle in Streams worksheet calculates the monthly loading and flow rate of fecal coliform bacteria contributed directly to the stream by beef cattle.

23. Click the “Septics” tab and look through the worksheet.

**Note:** The Septics worksheet calculates the monthly loading and flow rate of fecal coliform bacteria from failing septic systems. The user must provide an estimate of the number of septic systems in the area, and the number of people served by the septic systems. The sheet uses these values and literature values for flow rates and coliform concentrations in overflows.

24. Click the “ACQOP&SQOLIM (for land uses)” tab and look through the worksheet.

**Note:** This worksheet summarizes the monthly rate of accumulation (used for the

HSPF parameter(s) ACQOP/MON-ACCUM) of fecal coliform bacteria on the four land uses and calculates the build-up limit (used for the HSPF parameter(s) SQOLIM/MON-SQOLIM) for each land use. The following section details where these values should be entered within the WinHSPF interface.

## B. Modeling Bacteria in WinHSPF

### QUESTION ANSWERED:

2.) *How do I add temperature and fecal coliform to my calibrated hydrology model?*

In this section, we will return to WinHSPF and add temperature and fecal coliform to the WinHSPF model. WinHSPF handles fecal coliform in a general manner; using modules that can be applied to any constituent by modeling fate and transport simplistically (e.g., first order decay, etc.). This will be explained further throughout the section.

1. If WinHSPF isn't already open, from the **Start** menu under **Programs**, select **BASINS** and then **WinHSPF**.
2. From the **File** menu, select **Open**.
3. Navigate to *c:\Basins\Modelout\Bacteria* and select "*bacteria.uci.*" Click OPEN.
4. Click the "Pollutant Selection" button, .
5. Click "F.COLIFORM" and "WATERTEMP" in the "Available" window while holding the "Ctrl" key down.
6. Click ADD.

**Note:** "F.COLIFORM" and "WATERTEMP" should appear in the "Selected" window.

7. Click OK.

**Note:** Appendix F explains what occurred when "F.COLIFORM" and "WATERTEMP" were selected within the "Pollutant Selection" tool and how to manually complete the same task. This information is included to help the user: 1.) Better understand how WinHSPF handles different constituents, and 2.) Ensure that the model is doing what the user wants. In short, when using the "Pollutant Selection" tool the required "Control Cards" are selected, the corresponding tables are added for each constituent selected, and the appropriate mass-links are added. Additionally, some of the fields within the tables were updated with required information. We will look at the control cards that were automatically added, open some of the key tables, and discuss

some of the key required inputs.

8. Click the “Edit Control Cards” button, .
9. Click DESCRIPTIONS.
10. Make sure the “Pervious Land” tab is active. Notice the boxes beside ATEMP, PSTEMP, PWTGAS and PQUAL are now checked.

**ATEMP** - Module that estimates the surface air temperature over the land segment by correcting for elevation differences between the gage and the land segments.

**PSTEMP** - Module that simulates soil temperatures for the surface, upper, and lower/groundwater layers of a land segment for use in module section PWTGAS and the agri-chemical sections.

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

**PQUAL** - Module that simulates water quality constituents or pollutants in the outflows from a pervious land segment using simple relationships with water and/or sediment yield. Any constituent can be simulated by this module section. However, more detailed methods of simulating sediment, heat, dissolved oxygen, dissolved carbon dioxide, nitrogen, phosphorus, soluble tracers, and pesticide removal from a pervious land segment are available, in other module sections.

**Note:** ATEMP, PSTEMP, and PWTGAS were turned on when “WATERTEMP” was selected in the “Pollutant Selection” tool. PQUAL was turned on when “F.COLIFORM” was selected in the “Pollutant Selection” tool.

11. Click the “Impervious Land” tab. Notice that ATEMP, IQUAL, and IWTGAS are now selected.

**ATEMP** - Module that estimates the surface air temperature over the land segment by correcting for elevation differences between the gage and the land segments.

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

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

**Note:** ATEMP and IWTGAS were turned on when “WATERTEMP” was selected in the “Pollutant Selection” tool. IQUAL was turned on when “F.COLIFORM” was selected in the “Pollutant Selection” tool.

12. Click the “Reaches/Reservoirs” tab. Notice the boxes beside ADCALC, HTRCH, and GQUAL are now selected.

**ADCALC** - Module that calculates values for the variables necessary to simulate longitudinal advection of dissolved or entrained constituents. These variables are dependent upon the volume and outflow values calculated in the hydraulics section (HYDR).

**HTRCH** - Module that simulates the processes that determines the water temperature in a reach or mixed reservoir.

***GQUAL** – Module that allows the model user to simulate the behavior of a generalized constituent. The constituent which is modeled may be present in the RCHRES only in a dissolved state, or it may also be sediment-associated.*

**Note:** HTRCH was turned on when “WATERTEMP” was selected using the “Pollutant Selection” tool. ADCALC and GQUAL were turned on when F.COLIFORM was selected in the “Pollutant Selection” tool.

13. Click OK.

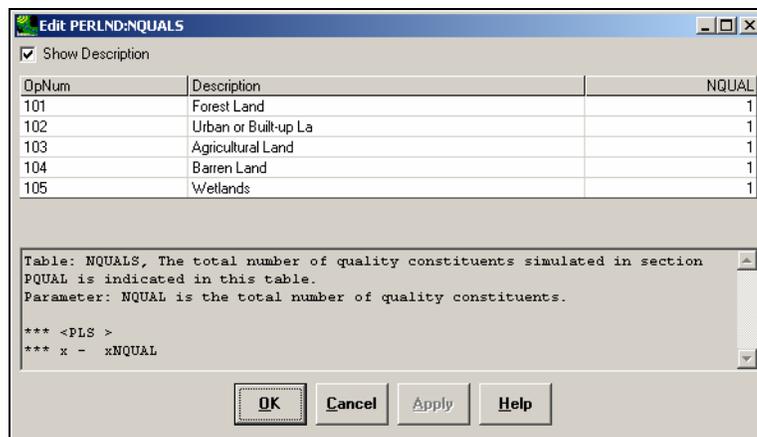
14. Click the “Input Data Editor” button, . Take some time to look through the tables that are associated (and automatically added (in bold)) with each newly selected module. An outline of the tables and parameters associated with these modules are included at the end of the exercise. It is critical to understand how the tables within each module relate to each other. Additionally, it is important to understand how flags set in one table predict the required inputs in another.

In the next section, we will look at a few of the inputs that were automatically populated when using the “Pollutant Selection” tool.

## PERVIOUS LAND

### PQUAL

1. **Double click** PERLND → PQUAL → NQUALS. Click OK if asked whether to add the table. Notice that the value for NQUAL is “1” for each pervious land segment. This specifies that we will model one general quality constituent, fecal coliform.



2. Click OK or CANCEL.

3. **Double click** QUAL-PROPS. Notice that the QUALID (constituent name) and QTYID (units of constituent) columns were automatically populated for you when you selected F.COLIFORM in the “Pollutant Selection” tool. Also notice that fecal coliforms are assumed to be associated with overland flow (QSOFG), interflow (QIFWFG), and groundwater (QAGWFG) by these flags being turned on (set to 1)

automatically. See definitions in outline at the end of the exercise for clarification of each of the flags in this table.

OpNum	Description	QUALID	QTYID	QSDFG	VPPWFG	VPPSFG	QSOFG	VQOFG	QIFWFG	VIQCFG	QAGWFG	VAQCFG
101	Forest Land	F.COLIFORM	#ORG	0	0	0	1	1	1	1	1	1
102	Urban or Built-up La	F.COLIFORM	#ORG	0	0	0	1	1	1	1	1	1
103	Agricultural Land	F.COLIFORM	#ORG	0	0	0	1	1	1	1	1	1
104	Barren Land	F.COLIFORM	#ORG	0	0	0	1	1	1	1	1	1
105	Wetlands	F.COLIFORM	#ORG	0	0	0	1	1	1	1	1	1

4. Click OK.
5. **Double click** QUAL-INPUT. Read the following parameter explanations:

**SQO:** The initial storage of QUALOF on the surface of the PLS.

**POTFW:** The washoff potency factor for a QUALSD. A potency factor is the ratio of constituent yield to sediment (washoff or scour) outflow.

**POTFS:** The scour potency factor for a QUALSD. A potency factor is the ratio of constituent yield to sediment (washoff or scour) outflow.

**ACQOP:** The rate of accumulation of QUALOF if QSOFG is positive. If QSOFG is negative, then ACQOP is the concentration of QUALOF in the surface outflow in mg/l.

**SQOLIM:** The maximum storage of QUALOF if QSOFG is positive.

**WSQOP:** The rate of surface runoff that will remove 90 percent of stored QUALOF per hour.

**IOQC:** The concentration of the constituent in interflow outflow (meaningful only if this is a QUALIF).

**AOQC:** The concentration of the constituent in active groundwater outflow (meaningful only if this is a QUALGW)

Although these definitions can be confusing and difficult to keep track of, it is helpful to begin to understand the acronyms and abbreviations used within WinHSPF. In the above definitions, QUALOF stands for the “Quality associated with Overland Flow,” QUALSD stands for the “Quality associated with Sediment,” QUALIF stands for the “Quality associated with InterFlow,” etc.

The values determined for ACQOP (accumulation of constituent) and SQOLIM (storage limits of constituents) in the *Bacterial Indicator Tool* can be entered in this table if you choose to use an annual average value. In this case, however, when using the “Pollutant Selection” tool to add fecal coliform to our model, the monthly flag for accumulation and storage was automatically turned on (VQOFG value set to “1”). This means that the model is expecting the user to enter the monthly values for ACQOP and SQOLIM calculated in the Bacterial Indicator Tool into the MON-ACCUM and MON-SQOLIM tables respectively.

Remember that the *Bacterial Indicator Tool* provided us with monthly values for ACQO and SQOLIM for each subwatershed for both Cropland and Pastureland. Average yearly values were produced for Forest and Built-Up land by the *Bacterial Indicator Tool*. This tool assigns these values for each land use category within each subwatershed. The West Branch Patuxent model currently has not been segmented, meaning that separate parameter inputs are not allowed for individual subwatersheds. We are therefore required to use an average monthly or annual ACQO and SQOLIM value across subwatersheds for each land use category.

6. Click OK.

## IMPERVIOUS LAND

### IQUAL

1. **Double click** IMPLND → IQUAL → NQUALS. Notice that the value in the “NQUAL” column is “1.” This specifies that we will model one quality constituent.

OpNum	Description	NQUAL
101	Urban or Built-up La	1

2. Click CANCEL.
3. **Double click** QUAL-PROPS. Notice that QUALID and QTYID are already populated.

OpNum	Description	QUALID	QTYID	QSDFG	VPFWFG	QSOFG	VQOFG
101	Urban or Built-up La	F. Coli	# ORG	0	0	1	0

4. Click OK.
5. **Double click** QUAL-INPUT. The parameters in this table are similar to those in the PQUAL → QUAL-INPUT table. The difference is that the quality constituent(s) cannot be associated with interflow and groundwater since impervious land does not include these hydrologic components.

In this table, we used the values for accumulation (ACQOP) and storage limits (SQOLIM) from the Bacterial Indicator Tool for Built-Up and Urban land and entered them into this table.

6. Click OK.

## REACHES AND RESERVOIRS

### GQUAL

1. **Double click** RCHRES → GQUAL → GQ-GENDATA.
2. **Double click** GQ-GENDATA. The following screen will appear. Notice that the values in the “NQUAL” column are all “1.” This means that we will model one

quality constituent.

OpNum	Description	NGQUAL	TEMPFG	PHFLAG	ROXFG	CLDFG	SDFG	PHYTFG	LAT
1	Western Branch Patux	1	2	2	2	2	2	2	0
2	Southwest Branch Wes	1	2	2	2	2	2	2	0
3	South Collington Bra	1	2	2	2	2	2	2	0
4	South Reach, Western	1	2	2	2	2	2	2	0
5	Western Branch Patux	1	2	2	2	2	2	2	0
6	North Collington Bra	1	2	2	2	2	2	2	0

- Click OK.
- Double click GQ-QALDATA. Read the following explanations:

*DQAL: The initial concentration of the quality constituent.*

*CONCID: Specifies the concentration units (implied that it is "per liter"), e.g., "mg"/(l).*

*CONV: The factor to convert from Qty/volume to concentration units: Conc= CONV\* Qty/volume (in English system, volume is in ft<sup>3</sup>) (in Metric system, volume is in m<sup>3</sup>).*

OpNum	Description	GQID	DQAL	CONCID	CONV	QTYID
1	Western Branch Patux	F.COLIFORM	50	OR/L	0.0353	#ORG
2	Southwest Branch Wes	F.COLIFORM	50	OR/L	0.0353	#ORG
3	South Collington Bra	F.COLIFORM	50	OR/L	0.0353	#ORG
4	South Reach, Western	F.COLIFORM	50	OR/L	0.0353	#ORG
5	Western Branch Patux	F.COLIFORM	50	OR/L	0.0353	#ORG
6	North Collington Bra	F.COLIFORM	50	OR/L	0.0353	#ORG

All fields in this section were populated when “F.COLIFORM” was chosen in the “Pollutant Selection” tool.

- Click OK.

Now that the general constituent to be modeled has been identified and the units and required conversions have been specified, we need to decide how this particular constituent will react in the stream. Because we are modeling fecal coliform as a “dissolved constituent” (meaning that the constituent is entrained in the water column and only decay processes are considered if it is not associated with sediment), we can choose among many different decay options including hydrolysis, oxidation, photolysis, volatilization, biodegradation, general first order decay, and adsorption/desorption. The accepted practice for fecal coliform modeling is to apply a first order decay rate with possible adsorption/desorption if sediment is being concurrently modeled. When we selected “F.COLIFORM” in the “Pollutant Selection” tool, the first order decay rate option was automatically selected by setting a flag (QUALFG6 assigned a value of “1”) in the GQ-QUALFG table. Because this flag was set to “1,” the GQ-GENDECAY (general first order decay) table was added. Sediment association is not automatically assumed when using the “Pollutant Selection” tool. For more information about modeling fecal coliform as sediment associated, please refer to the “Additional Notes” section at the end of the exercise.

6. **Double click** GQ-GENDECAY. Read the following explanations:

*FSTDEC*: The first order decay rate for the quality constituent.

*THFST*: The temperature correction coefficient for first order decay.

7. Click OK.
8. Click CLOSE.

### C. Calibrating Temperature and Fecal Coliform

#### QUESTION ANSWERED:

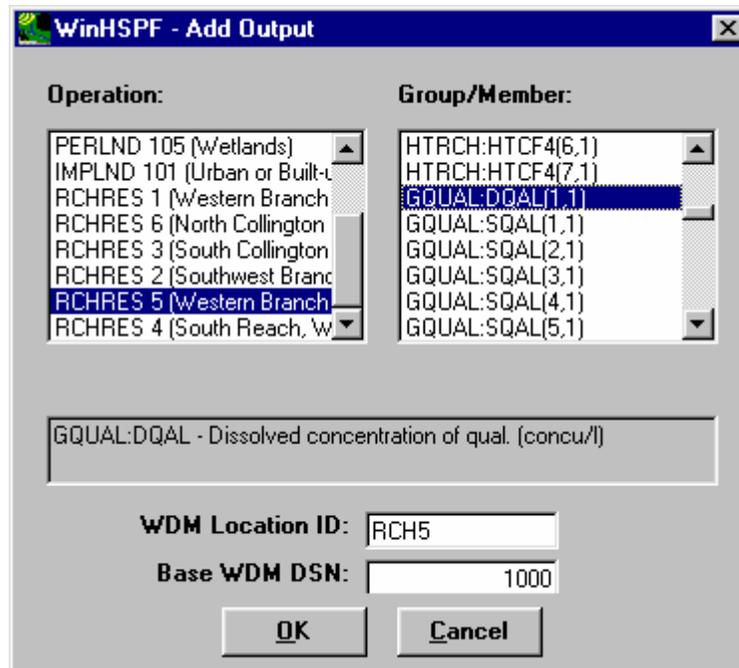
- 3.) Which parameters do I adjust to calibrate temperature and fecal coliform bacteria?

In previous sections, you were not required to enter or change any values within all the newly added tables. Recall that default values are almost always provided for required inputs; however, most of the inputs require updating with local information. Appendix F explains the values that should be updated as well as the procedure for doing this. In this section, we will open a \*.uci file that has all the required inputs including the monthly accumulation and storage limitation values calculated within the *Bacterial Indicator Tool*. We will run some scenarios, explain the key calibration parameters, and discuss management options that will help shareholders comply with the instream water quality standard.

1. From the **File** menu in WinHSPF, select **Open**.
2. Click OK when informed that you can only have one .uci active.
3. Navigate to *c:\basins\modelout\bacteria\* and select “*Bact\_2.uci*.” Click OPEN.

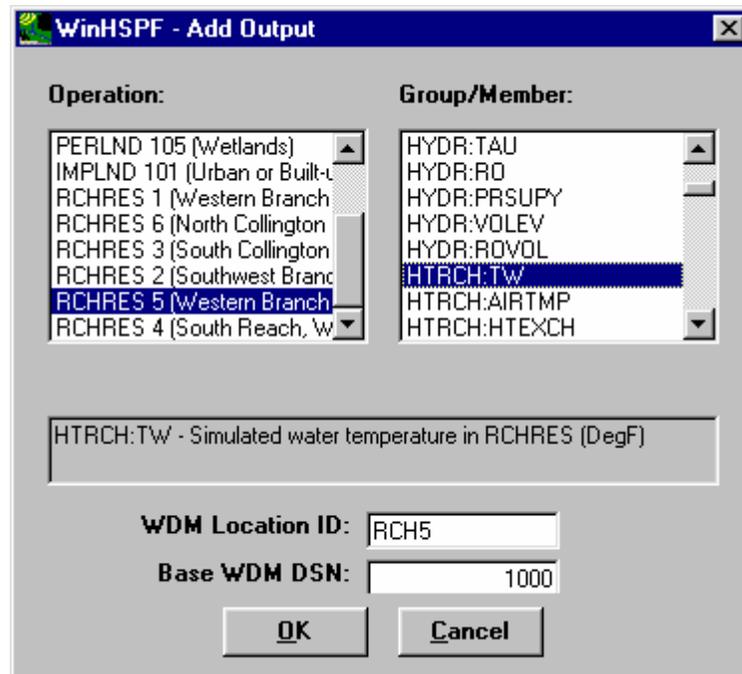
**Note:** This new \*.uci file contains all the monthly tables mentioned in previous steps.

4. Click the “Output Manager” button, .
5. Click the button beside “Other.”
6. Click ADD.
7. In the “Operation” frame, select “RCHRES 5 (Western Branch Patuxent).”
8. In the “Group/Member” frame, select “GQUAL:DQUAL(1,1).” Your screen should look like the following:



**Note:** By selecting GQUAL:DQAL (1,1) we are specifying that we want to see the dissolved concentration in Reach 5 of the first general quality constituent we are modeling (depicted by the first subscript).

9. Click OK.
10. In the “Operation” frame, select “RCHRES 5 (Western Branch Patuxent).”
11. In the “Group/Member” frame, select “HTRCH:TW.” Your screen should look like the following:



**Note:** By selecting HTRCH:TW, we are specifying that we want to see the simulated water temperature (° Fahrenheit) in Reach 5.

12. Click OK. The “Output Locations” frame for “Other” should look like the following:

Output Locations:		
Name	Description	Group/Member
RCHRES 5	Western Branch Patux	GQUAL:DQAL
RCHRES 5	Western Branch Patux	HTRCH:TW

13. Click CLOSE.

14. Click  (Run HSPF).

15. Click SAVE/RUN.

16. Click  (View Output through GENSCN).

17. Click the “HSPF Output” tab.

18. Check the box beside “Bact\_WB.wdm.”

19. Click OK.

20. In the “Scenarios” frame, select “BACT\_2.”

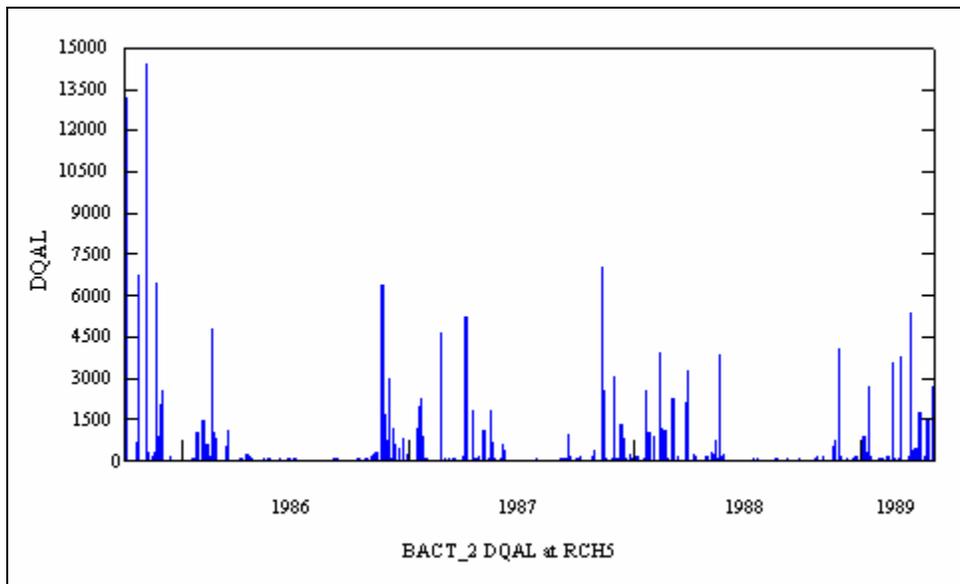
21. In the “Constituents” frame, select “DQAL1.”

22. Click the “Add to time series list” button, .

23. Select the DQAL time series.

24. Click the “Generate Graphs” button, .

25. Click GENERATE. Your plot should look like the following:



26. Close the plot and the “Graph” window. Toggle to GenScn.

27. In the “Scenarios” frame, select “OBSERVED.”

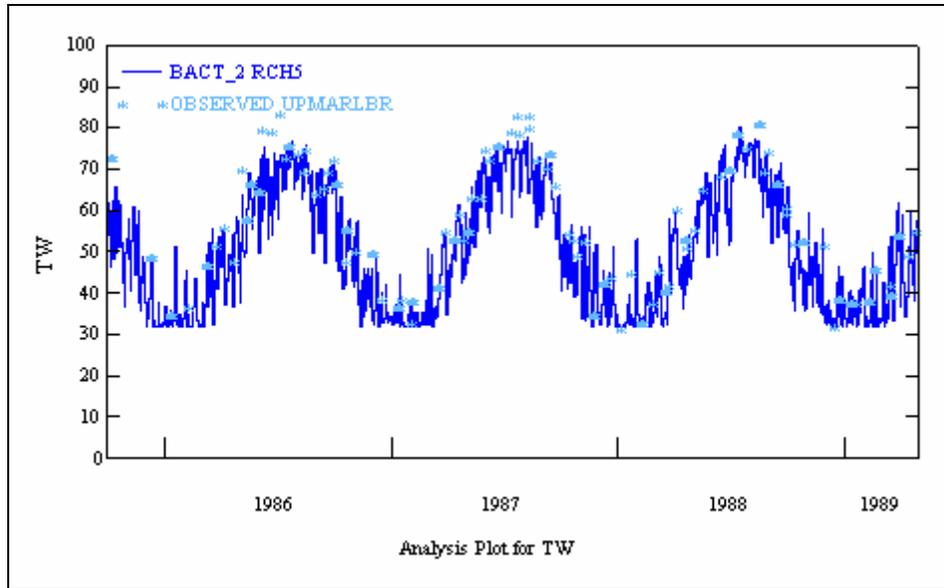
28. In the “Constituents” frame, select “TW.”

29. Click the “Add to time series list” button, .

30. Select both the observed and simulated TW time series.

31. Click the “Generate Graphs” button, .

32. Click GENERATE. Your plot should look like the following:



33. Close the plot and the “Graph” window.

### *Calibrating Simulated Temperature*

In this following section, we will discuss simulated temperature calibration in our model. Many parameters can be adjusted in temperature calibration, including PSTEMP (ASLT, BSLT, ULTP1, ULTP2), IWTGAS (AWTF, BWTF) and RCHRES (KATRAD, KCOND, KEVAP, etc.) Although the PSTEMP and IWTGAS parameters can be very important, in general, the amount of surface flow is small relative to that within the stream channel. This means that the temperature of the overland flow will generally will quickly come into a dynamic equilibrium with the instream flow (without drastically changing the instream temperatures) due to the heat capacity within the stream being much larger than that in the surface flow. The RCHRES parameters KATRAD, KCOND, EVAP, and CFSAEX are generally the most important calibration parameters. CFSAEX is a key parameter because it attempts to capture (or make up for) the large variability in the amount of solar radiation actually reaching the stream. For smaller, shallower streams, there are some additional optional bed sediment heat transfer processes that may be necessary to implement to account for higher temperatures.

Additional options for calibrating temperature besides parameter adjustment include:

- Increasing detail in the lower flow portions of the F-table so that during extremely low flow events realistic water depths are present. If there is inadequate resolution in the F-tables for low flows, it is possible for the model to become unstable and predict temperatures erroneously.
- Adjusting the weather data by adding a multiplicative factor or possibly finding more representative data for the area being modeled.

Given this information, we will attempt to calibrate temperature in the Western Branch Patuxent model. Because of time constraints, we will vary only CFSAEX. The general

calibration procedure should be to (a) examine hourly temperature values to ensure there are only reasonable values, (b) focus the calibration efforts on ensuring daily averages are accurate, and (c) if detailed data are available, adjust parameters to ensure the model is predicting the maximum and minimum temperatures accurately. In this exercise, we will not look at the hourly output. Instead we will focus on step (b) mentioned above.

**Note:** In order to inspect the hourly output in GenScn, you must add an External Target in the EXTERNAL TARGETS do this by (a) opening the EXT TARGETS block within the “Input Data Editor” (there should only be the two output time series you selected in the “Output Manager” in the table), (b) clicking ADD, (c) copying the information from the already existing TW timeseries with the exception of the value for the “Volld”<sup>1</sup> column (this column contains the DSN number which needs to be one greater than the DSN numbers already in the EXTERNAL TARGETS), and (d) clicking APPLY. An “Add Data Set” window will appear in which you will need to change the “Time Units” column from “4” (daily output) to “3” (hourly output).

34. Close the plot and the “Graph” window.
35. Plot both the observed and simulated temperature for 1986, 1987, and 1988 individually. You will see that we are consistently under-predicting water temperatures.

Spend some time calibrating temperature by adjusting CFSAEX (*RCHRES* → *HTRCH* → *HEAT-PARM*) between 0 (completely shaded) and 1 (completely exposed). See how close you can get the simulated daily average values to the observed daily average values.

### *Calibrating Fecal Coliform*

Since there are no observed fecal coliform data for comparison and/or calibration, we will make parameter adjustments to observe the effects and sensitivity of various parameters. We will focus on a subset of the output to simplify this activity. Key calibration parameters are:

**ACQOP** – Accumulation rate (PERLND & IMPLND). (*PERLND* → *PQUAL* → *MON-ACCUM*)

**SQOLIM** – Storage limits (PERLND & IMPLND). (*PERLND* → *PQUAL* → *MON-SQOLIM*)

**FSTDEC** – First order decay coefficient. (*RCHRES* → *GQ-GENDECAY*)

To determine a range of reasonable estimates for the accumulation (ACQOP) and storage limit (SQOLIM) inputs, it might be helpful to return to the *Bacterial Indicator Tool* and change the animal populations in the spreadsheet that were most uncertain, change the septic tank population and/or failure rates in the spreadsheet if uncertain estimates were used, or change built-up fractions to more closely reflect the breakdown between Residential and Industrial/Transportation subcategories. For the purposes of this exercise, you may want to spend some time changing the accumulation and storage limit parameters to help you understand the effects the adjustments.

<sup>1</sup> There are 2 “Volld” columns. Click in both “Volld” columns to determine which one corresponds to the Data Set Number (or DSN) given the information provided in the information box below the table.

### ***Running Scenarios***

Now that you have “calibrated” the temperature and fecal coliform, scenarios can be run. Assume that the fecal coliform standard states that organism levels shall not exceed a threshold of 400 colonies/100 mL. Try to identify management options (using parameter adjustments) to ensure that there will be no exceedance of this standard. Suggestions include changing the land use distribution, decreasing livestock in the area, decreasing application of manure, scaring all the geese into the neighboring drainage, etc.

### ***Additional Notes***

Current research suggests that the association of coliform with sediment is strong in many areas. Assuming sediment was simulated, you could turn “on” instream sediment association by setting the flag SDAS (QALFG(7)) in table GQ-QALFG to “1,” allowing for the coliform to adsorb and desorb sediment both in the water column and in the bed. In this situation, important parameters are the partition coefficients in the water column and bed (table GQ-KD); adsorption rate parameters (table GQ-ADRATE); adsorption temperature correction coefficients. (table GQ-ADTHETA); and decay rates for sorbed bacteria (GQ-SEDDECAY).

### **Reference:**

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## **TEMPERATURE & BACTERIA INPUTS**

### MODULE

#### TABLE

#### PARAMETER

### **PERVIOUS LAND**

**ATEMP** Module that estimates the surface air temperature over the land segment by correcting for elevation differences between the gage and the land segments.

#### ATEMP-DAT (ATEMP Data)

**ELDAT:** The difference in elevation between the temperature gage and the previous land segment; it is used to estimate the temperature over the pervious land segment by application of a lapse rate. It is positive if the pervious land segment is higher than the gage, and negative if the land segment is lower than the gage.

**AIRTMP:** The initial (i.e., at the starting time of the RUN) air temperature over the land segment.

**PSTEMP** Module that simulates soil temperatures for the surface, upper, and lower/groundwater layers of a land segment for use in module section PWTGAS and the agri-chemical sections.

#### PSTEMP-PARM1 (Soil Temperature Simulation Flags)

**SLTVFG:** If this is 1, parameters for estimating surface layer temperature can vary monthly.

**ULTVFG:** If this is 1, parameters for estimating upper layer temperature can vary monthly.

**LGTVFG:** If this is 1, parameters for estimating lower layer and active groundwater layer temperature calculations can vary monthly.

**TSOPFG:** Governs the methods used to estimate subsurface soil temperatures. If TSOPFG is 0, they are computed using a mean departure from air temperature, together with smoothing factors. If TSOPFG is 1, upper layer soil temperature is estimated by regression on air temperature (like surface temperature). The lower layer/groundwater layer temperature is supplied directly by the user (a different value may be specified for each month). If it is 2, the same method is used as for a value of 0, except that the upper layer temperature is used instead of the air temperature to compute the lower layer/groundwater layer temperature.

#### PSTEMP-PARM2 (Soil Temperature Estimation Inputs)

**ASLT:** The surface layer temperature when the air temperature is 32 degrees F (0 degrees C). It is the intercept of the surface layer temperature regression equation.

**BSLT:** The slope of the surface layer temperature regression equation.

**ULTP1:** The smoothing factor in upper layer temperature calculation, if TSOPFG = 0 or 2. ULP1 is the intercept in the upper layer soil temperature regression equation (like ASLT and BSLT for the surface layer), if TSOPFG = 1.

**ULTP2:** The mean difference between upper layer soil temperature and air temperature, if TSOPFG = 0 or 2. ULP2 is the slope in the upper layer soil temperature regression equation (similar to ASLT and BSLT for the surface layer), if TSOPFG = 1.

**LGTP1:** The smoothing factor for calculating lower layer/groundwater soil temperature, if TSOPFG = 0 or 2. LGTP1 is the lower layer/groundwater layer soil temperature, if TSOPFG = 1.

**LGTP2:** The mean departure from air temperature for calculating lower layer/groundwater soil temperature, if TSOPFG = 0 or 2. LGTP2 is not used if TSOPFG is 1.

#### PSTEMP-TEMPS (Soil Temperature Initial Conditions)

**AIRTC:** The initial air temperature.

**SLTMP:** The initial surface layer soil temperature.

**ULTMP:** The initial upper layer soil temperature.

*LGTMP: The initial lower layer/groundwater layer soil temperature.*

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

**PWT-PARM1** (Dissolved Oxygen and Carbon Dioxide Flags)

*IDVFG: If IDVFG is 1, interflow DO concentration may vary monthly.*

*ICVFG: If ICVFG is 1, interflow CO2 concentration may vary monthly.*

*GDVFG: If GDVFG is 1, groundwater DO concentration may vary monthly.*

*GCVFG: If GCVFG is 1, groundwater CO2 concentration may vary monthly.*

**PWT-PARM2** (Water Temperature and Gas Input Estimations)

*ELEV: The elevation of the PLS above sea level (used to adjust saturation concentrations of dissolved gasses in surface outflow).*

*IDOXP: The concentration of dissolved oxygen in interflow outflow.*

*ICO2P: The concentration of dissolved CO2 in interflow outflow.*

*ADOXP: The concentration of dissolved oxygen in active groundwater outflow.*

*ACO2P: The concentration of dissolved CO2 in active groundwater outflow.*

**PWT-GASES** (Initial Conditions for DO and CO2 concentrations)

*SODOX: The initial DO concentration in surface outflow.*

*SOCO2: The initial CO2 concentration in surface outflow.*

*IDOIX: The initial DO concentration in interflow outflow.*

*ICO2: The initial CO2 concentration in interflow outflow.*

*AODOX: The initial DO concentration in active groundwater outflow.*

*AOCO2: The initial CO2 concentration in active groundwater outflow.*

**PQUAL** Module that simulates water quality constituents or pollutants in the outflows from a pervious land segment using simple relationships with water and/or sediment yield.

**NQUALS** (Contains the number of quality constituents to be modeled)

*NQUAL: The total number of quality constituents to be modeled.*

**QUAL-PROPS** (Identifiers and Flags for Quality Constituents)

*QUALID: A string of up to 10 characters that identifies the quality constituent.*

*QTYID: A string of up to 4 characters that identifies the units associated with this constituent (e.g., kg, (for coliforms)). These are the units referred to as "qty" subsequent tables (eg. Table-type QUAL-INPUT).*

*QSDFG: If 1, this constituent is a QUALSD (sediment associated).*

*VPFWFG: If 1, the washoff potency factor may vary monthly. If VPWFG is 2, the daily factors are not interpolated between monthly values.*

*VPFSFG: If 1, the scour potency factor may vary monthly.*

*QSOFG: If 1 or 2, this constituent is a QUALOF (directly associated with overland flow). If 1, then accumulation and removal are performed daily, and the removal rate is dependent only on the accumulation and storage limit parameters (ACQ and SQOLIM). If 2, accumulation and removal are performed every interval, and the removal rate also takes into account atmospheric deposition plus lateral inflows.*

*VQOFG: If 1 then the rate of accumulation and the limiting storage of QUALOF may vary monthly.*

*QIFWFG: If 1 this constituent is a QUALIF (interflow associated).*

*VIQCFG: If 1 or greater, then the concentration of this constituent in interflow outflow may vary monthly. If 2 or 4, no interpolation is used. If 3 or 4, units are mg/L. This requires QTYID to be LB (English or KG (Metric)).*

*QAGWFG: If 1, this constituent is a QUALGW (groundwater associated).*

**VAQCFG:** If 1, the concentration of this constituent in groundwater outflow may vary monthly. If VAQCFG is 2 or 4, the daily values are obtained directly from the monthly values; no interpolation between monthly values is performed. If VAQCFG is 3 or 4, the units of the input concentrations are mg/l; note: this option requires that the "qty" units be pounds (English system) or kilograms (Metric system).

#### QUAL-INPUT (Quality Storage Parameters)

**SQO:** The initial storage of QUALOF on the surface of the PLS.

**POTFW:** The washoff potency factor for a QUALSD. A potency factor is the ratio of constituent yield to sediment (washoff or scour) outflow.

**POTFS:** The scour potency factor for a QUALSD. A potency factor is the ratio of constituent yield to sediment (washoff or scour) outflow.

**ACQOP:** The rate of accumulation of QUALOF if QSOFG is positive. If QSOFG is negative, then ACQOP is the concentration of QUALOF in the surface outflow in mg/l.

**SQOLIM:** The maximum storage of QUALOF if QSOFG is positive.

**WSQOP:** The rate of surface runoff that will remove 90 percent of stored QUALOF per hour.

**IOQC:** The concentration of the constituent in interflow outflow (meaningful only if this is a QUALIF).

**AOQC:** The concentration of the constituent in active groundwater outflow (meaningful only if this is a QUALGW).

## IMPERVIOUS LAND

**ATEMP** Module that estimates the surface air temperature over the land segment by correcting for elevation differences between the gage and the land segments.

#### ATEMP-DAT (ATEMP data)

**ELDAT** - The difference in elevation between the temperature gage and the impervious land segment; it is used to estimate the temperature over the impervious land segment by application of a lapse rate. It is positive if the impervious land segment is higher than the gage, and negative if the land segment is lower than the gage.

**AIRTMP** – The initial (i.e., at the starting time of the RUN) air temperature over the land segment.

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

#### IWT-PARM1 (IWTGAS Flags)

**WTFVFG:** A value of 1 means to vary the water temperature regression parameters (AWTF and BWTF) monthly; 0 means use annual values.

**CSNOFG:** A value of 1 means the effects of snow accumulation and melt are being considered; if it is zero, they are not. If section IWATER is active the value of CSNOFG supplied here is ignored because it was first supplied in the input for that section.

#### IWT-PARM2 (Temperature Estimation Parameters)

**ELEV:** The elevation of the ILS above sea level (used to adjust saturation concentrations of dissolved gasses in surface outflow).

**AWTF:** The surface water temperature, when the air temperature is 32 degrees F (0 degrees C). It is the intercept of the surface water temperature regression equation.

**BWTF:** The slope of the surface water temperature regression equation.

**IQUAL** Module that simulates water quality constituents or pollutants in the outflows from an impervious land segment using simple relationships with water yield and/or solids.

**NQUALS** (Contains the number of quality constituents to be modeled)

*NQUAL: The total number of quality constituents to be modeled.*

**QUAL-PROPS** (Identifiers and Flags for Quality Constituents)

*QUALID: A string of up to 10 characters that identifies the quality constituent.*

*QTYID: A string of up to 4 characters that identifies the units associated with this constituent (e.g., kg, (for coliforms)). These are the units referred to as "qty" subsequent tables (eg. Table-type QUAL-INPUT).*

*QSDFG: If 1, this constituent is a QUALSD (sediment associated).*

*VPWFG: If 1, the washoff potency factor may vary monthly. If VPWFG is 2, the daily factors are not interpolated between monthly values.*

*QSOFG: If 1 or 2, this constituent is a QUALOF (directly associated with overland flow). If 1, then accumulation and removal are performed daily, and the removal rate is dependent only on the accumulation and storage limit parameters (ACQ and SQOLIM). If 2, accumulation and removal are performed every interval, and the removal rate also takes into account atmospheric deposition plus lateral inflows.*

*VQOFG: If 1 then the rate of accumulation and the limiting storage of QUALOF may vary monthly.*

**QUAL-INPUT** (Quality Storage Parameters)

*SQO: The initial storage of QUALOF on the surface of the impervious land segment.*

*POTFW: The wash off potency factor for a QUALSD. A potency factor is the ratio of constituent yield to sediment outflow.*

*ACQOP: The rate of accumulation of QUALOF if QSOFG is positive. If QSOFG is negative, then ACQOP is the concentration of QUALOF in the surface outflow in mg/l.*

*SQOLIM: The maximum storage of QUALOF if QSOFG is positive.*

*WSQOP: The rate of surface runoff that will remove 90 percent of stored QUALOF per hour.*

## **REACHES AND RESERVOIRS**

**ADCALC** Module that calculates values for the variables necessary to simulate longitudinal advection of dissolved or entrained constituents.

**HTRCH** Module that simulates the processes that determines the water temperature in a reach or mixed reservoir.

**HEAT-PARM** (Correction Factors and Energy Balance Coefficients)

*ELEV: The mean RCHRES elevation.*

*ELDAT: The difference in elevation between the RCHRES and the air temperature gage (positive if RCHRES is higher than the gage).*

*CFSAX: The correction factor for solar radiation (it includes fraction of RCHRES surface exposed to radiation).*

*KATRAD: The long-wave radiation coefficient.*

*KCOND: The conduction-convection heat transport coefficient.*

*KEVAP: The evaporation coefficient.*

**HEAT-INIT** (Initial Temperature Conditions)

*TW: The initial water temperature in the RCHRES.*

*AIRTMP: The initial air temperature at the RCHRES*

**GQUAL** Module that allows the model user to simulate the behavior of a generalized constituent. The constituent which is modeled may be present in the RCHRES only in a dissolved state, or it may also be sediment-associated.

**GENDATA** (General Input Data Information)

**NGQUAL:** The number of generalized constituents (quals) being simulated.

**TEMPFG:** Indicates the source of water temperature data; 1 means a time series (either input or computed), 2 means an annual value, and 3 means 12 monthly values.

**PHFLAG:** Indicates the source of pH data; 1 means a time series (either input or computed), 2 means an annual value, and 3 means 12 monthly values. Input only if any  $QALFG(1)=1$ .

**ROXFG:** Indicates the source of free radical oxygen data; 1 means a time series (either input or computed), 2 means an annual value, and 3 means 12 monthly values. Input only if any  $QALFG(2)=1$ .

**CLDFG:** Indicates the source of cloud cover data; 1 means a time series (either input or computed), 2 means an annual value, and 3 means 12 monthly values. Input only if any  $QALFG(3)=1$ .

**SDFG:** Indicates the source of total sediment concentration data; 1 means a time series (either input or computed), 2 means an annual value, and 3 means 12 monthly values. Input only if any  $QALFG(3)=1$ .

**PHYTFG:** Indicates the source of phytoplankton data; 1 means a time series (either input or computed), 2 means an annual value, and 3 means 12 monthly values. Input only if any  $QALFG(3)=1$ .

**LAT:** The latitude of the RCHRES. Input only if any  $QALFG(3)=1$ . Positive for northern hemisphere.

**GQ-QUALDATA** (Identifiers and Information About Quality Constituent)

**DQUAL:** The initial concentration of the quality constituent.

**CONCID:** Specifies the concentration units (implied that it is "per liter"), eg. "mg"/(l).

**CONV:** The factor to convert from Qty/volume to concentration units:  $Conc = CONV * Qty/volume$  (in English system, volume is in  $ft^3$ ) (in Metric system, volume is in  $m^3$ ).

**GQ-GENDECAY** (Parameters for General Decay)

**FSTDEC:** The first order decay rate for the quality constituent.

**THFST:** The temperature correction coefficient for first order decay.