King County Watershed Modeling Services – Green River Water Quality Assessment, and Sammamish-Washington, Analysis and Modeling Program Watershed Modeling Calibration Report

In Progress

King County

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Section 2—Modeling Framework and Approach

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2 MODELING FRAMEWORK AND APPROACH

The modeling framework has been specifically developed to address each of the objectives of the study areas for fate and transport modeling effort, as described the simulation plan. In this section, the modeling framework and its significant components are described, including a summary of the models selected to represent the watersheds and the receiving water bodies in SWAMP and Green WQA study areas, the physical domain of each model, and the manner in which the models will be linked to each other for hydrodynamic, sediment transport, and pollutant fate and transport simulations.

The Sammamish-Washington, Analysis, and Modeling Program (SWAMP), and Green River Water Quality Assessment (Green WQA) studies are being performed to provide hydrologic and water quality information for use by King County to evaluate existing conditions and plan for the future. Addressing these objectives requires developing an appropriate modeling framework to serve as one of the primary technical tools for decision making. Such a framework must be able to address both historical and future conditions and questions involving various alternative scenarios.

Details of the modeling framework are provided in the *Watershed Simulation Plan* (currently under development). As such, they have not been repeated in this calibration report and the reader is referred to the simulation plan document.

2.1 Basin Selection for Calibration

To maximize efficiencies, models that were previously developed (typically water quantity only) may either be further calibrated to locally specific water quantity/quality data, or using surrogate parameters derived from similar calibrated subbasins. Under this paradigm, and as result of data available at the time of calibration, amount of resources allocated for the subbasin development, and previously calibrated models available for integration into the SWAMP and Green WQA study areas, model development is classified into three groups (type I, II, and III). Type I models are calibrated to local water quantity and quality data. Type II are models previously calibrated to locally observed water quantity data and using similar subbasins with calibrated water quality parameters, with type III models consisting of regional water quantity parameters, again using surrogate water quality parameters extracted from similar calibrated subbasins.

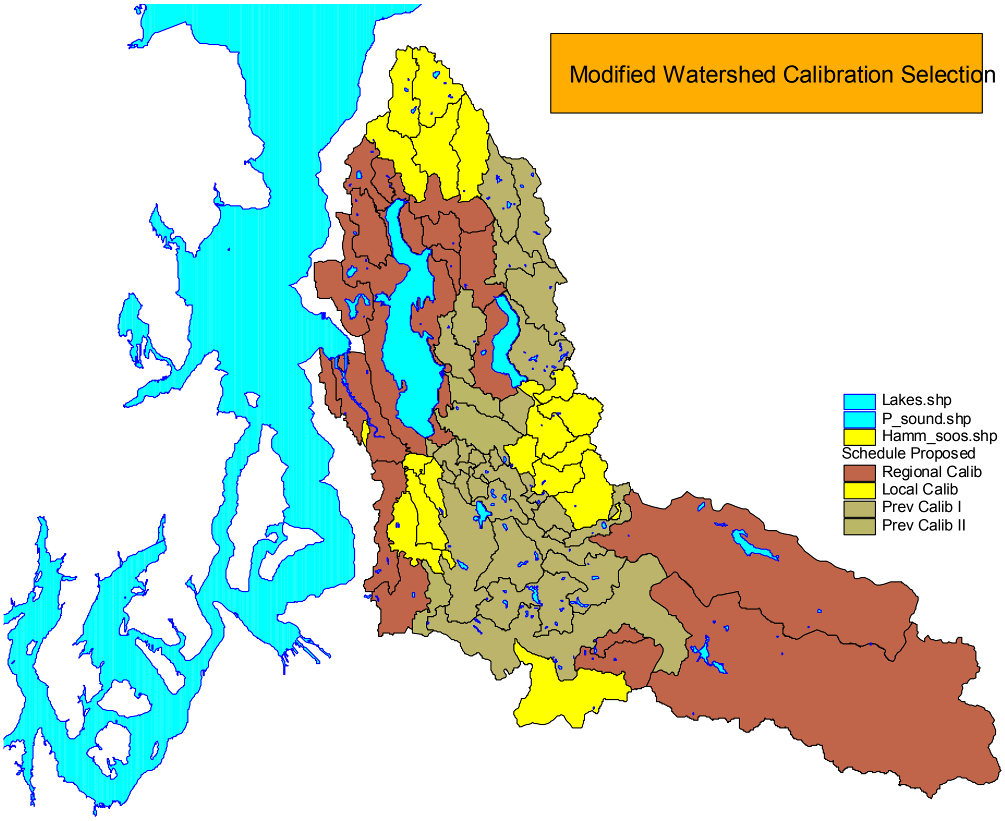

Figure 2.1-1 Level of Calibration per Subbasin

In Figure 2.1-1 above, subbasins are identified by color what level of calibration they receive. Yellow highlighted subbasins represent type I calibration, olive subbasins represent type II, and brown highlighted subbasins represent type III calibration (see Table 2.1-1 below for listing of subbasins, type III are remaining subbasins not listed)

Table 2.1-1 Classification of Subbasins Calibrations

Subbasin	Calibration Type
Little Bear Creek	I
North Creek	I
Swamp Creek	I
Black River / Springbrook Creek	I
Newaukum Creek	I
Catchment in Soosette	I
South Fork Hamm Creek	I
Issaquah Creek	I

East Lake Sammamish	II
Bear Creek	II
Evans Creek	II
Kelsy Creek	II
May Creek	II
Tibbets Creek	II
Lower Cedar River	II
Soos Creek	II
Middle Green	II
Mill Creek (Auburn)	II

One aspect of the modeling framework process is the determination of what observed data are available to develop the model application and perform calibration/validation. In general, the observed data should provide a sound basis for performing the hydrologic and water quality calibration for the constituents determined to be important in the previous two steps. Because the initial hydrology calibration results in parameters similar to those developed by previous HSPF applications performed within the region (i.e., the regional parameter set), the hydrology calibration provides an opportunity for performing the water quality calibration over a longer time period. This method also provides a basis for performing a water quality validation.

2.2 COMPONENT MODELS

HSPF is briefly described in this section. For additional detail, see the user manual that is referenced below.

2.2.1 HSPF Overview

HSPF (Bicknell et al., 2000) is a watershed-scale hydrologic and water quality model that allows simulation of both water quantity and quality in simple to complex watersheds. It provides the capability to handle a diversity of water quality constituents, represent complex multi-land use watersheds, include hydraulic structures and complex operational scenarios, and to represent impacts of point and nonpoint sources, diversions, and various land management (urban, agricultural, forest) practices.

HSPF contains three application modules and five utility modules. The three application modules simulate the hydrologic/hydraulic and water quality components of the watershed. The utility modules are used to manipulate and analyze time-series data. A brief description of the application modules follows:

(1) PERLND—Simulates runoff and water quality constituents from pervious land areas in the watershed.

(2) IMPLND—Simulates impervious land area runoff and water quality.

(3) RCHRES—Simulates the movement of runoff water and its associated water quality constituents in stream channels and mixed reservoirs.

2.3 PERLND Module

Because PERLND simulates the water quality and quantity processes that occur on pervious land areas, it is the most frequently used part of HSPF. To simulate these processes, PERLND models the movement of water along three paths: overland flow, interflow, and groundwater flow. Each of these three paths experiences differences in time delay and differences in interactions between water and its various dissolved constituents. A variety of storage zones are used to represent the processes that occur on the land surface and in the soil horizons. Snow accumulation and melt are also included in the PERLND module so that the complete range of physical processes affecting the generation of water and associated water quality constituents can be represented. Some of the many capabilities available in the PERLND module include the simulation of:

- Water budget and runoff components.
- Snow accumulation and melt.
- Sediment production and removal.
- Accumulation and washoff of user-defined nonpoint pollutants.
- Nitrogen and phosphorus fate and runoff.
- Pesticide fate and runoff.
- Movement of a tracer chemical.

Figure 2.3-1 defines the structure and contents of the PERLND module. The PERLND module features individual sections or sub-modules for specific modeling capabilities, including: air temperature as a function of elevation (ATEMP), snow accumulation and melting (SNOW), hydrologic water budget (PWATER), sediment production and removal (SEDMNT), soil temperature (PSTEMP), surface runoff water temperature and gas concentrations (PWTGAS), generalized water quality constituents (PQUAL), solute transport (MSTLAY), pesticides (PEST), nitrogen (NITR), phosphorus (PHOS), and conservatives (TRACER).

PWATER is used to calculate the water budget components resulting from precipitation on pervious land areas; as a result, it is the key component of the PERLND module. The basis of the water budget computations contained in HSPF is the Stanford Watershed Model (Crawford and Linsley, 1966). Like the SNOW code, the PWATER code uses both physical and empirical formulations to model the movement of water through the hydrologic cycle. PWATER considers such processes as evapotranspiration; surface detention; surface runoff; infiltration; shallow subsurface flow (interflow); baseflow; and percolation to deep groundwater. Lateral inflows to surface and shallow subsurface storages can also be modeled.

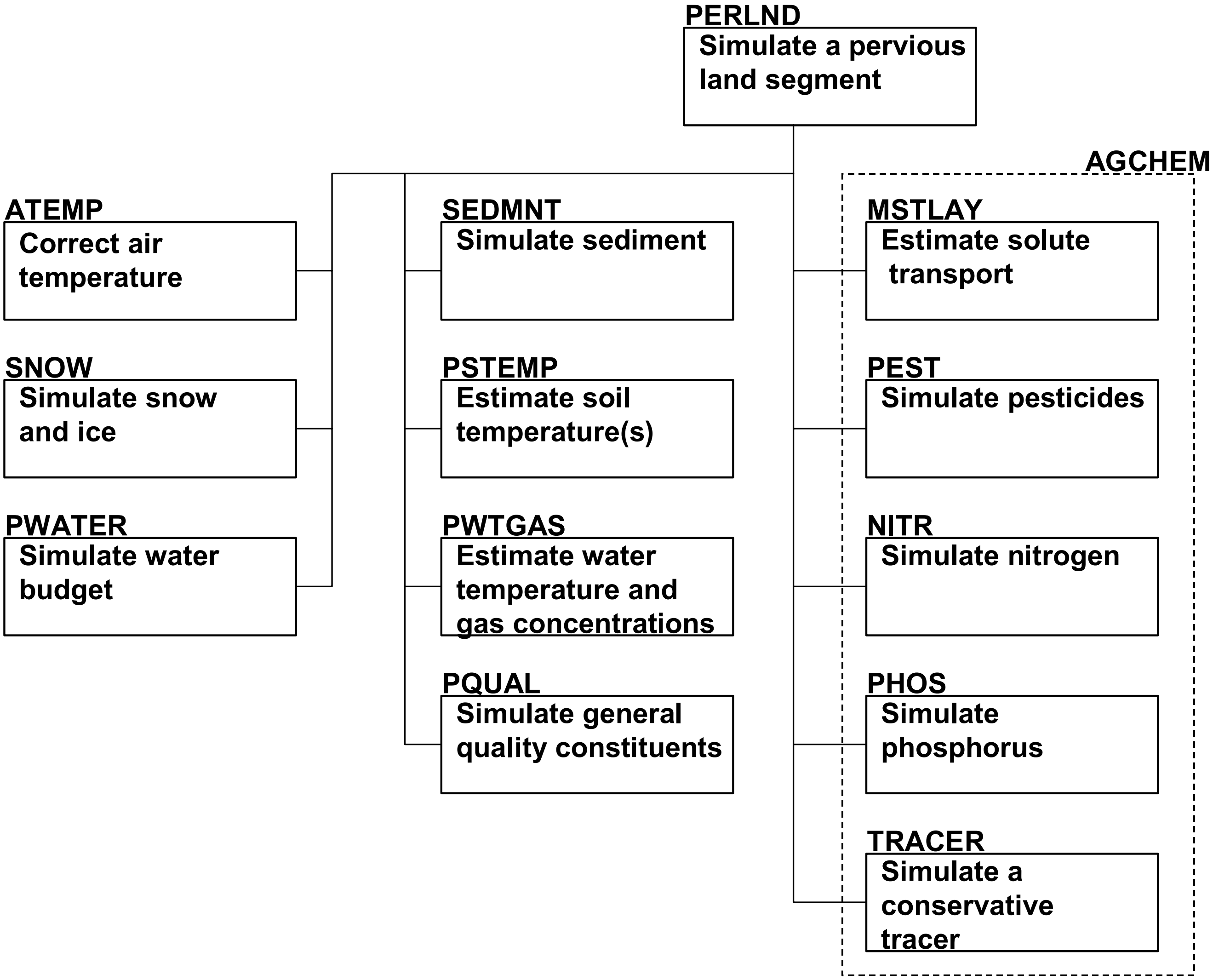

Figure 2.3-1 PERLND Structure Chart

2.4 IMPLND Module

IMPLND is used for impervious land surfaces, primarily for urban land categories, where little or no infiltration occurs. However, some land processes do occur, and water, solids, and various pollutants are removed from the land surface by moving laterally downslope to a pervious area, stream channel, or reservoir. IMPLND includes most of the pollutant washoff capabilities of the commonly used urban runoff models, such as the STORM, SWMM, and NPS models. Figure 2.4-1defines the structure and contents of the IMPLND module. The module shares much of its code with PERLND, but is simplified since infiltration and other interactions with the subsurface cannot occur. The module features individual sub-modules/sections for modeling air temperature as a function of elevation (ATEMP), snow accumulation and melting (SNOW), hydrologic water budget (IWATER), solids accumulation and removal (SOLIDS), surface runoff water temperature and gas concentrations (IWTGAS), and generalized water quality constituents (IQUAL).

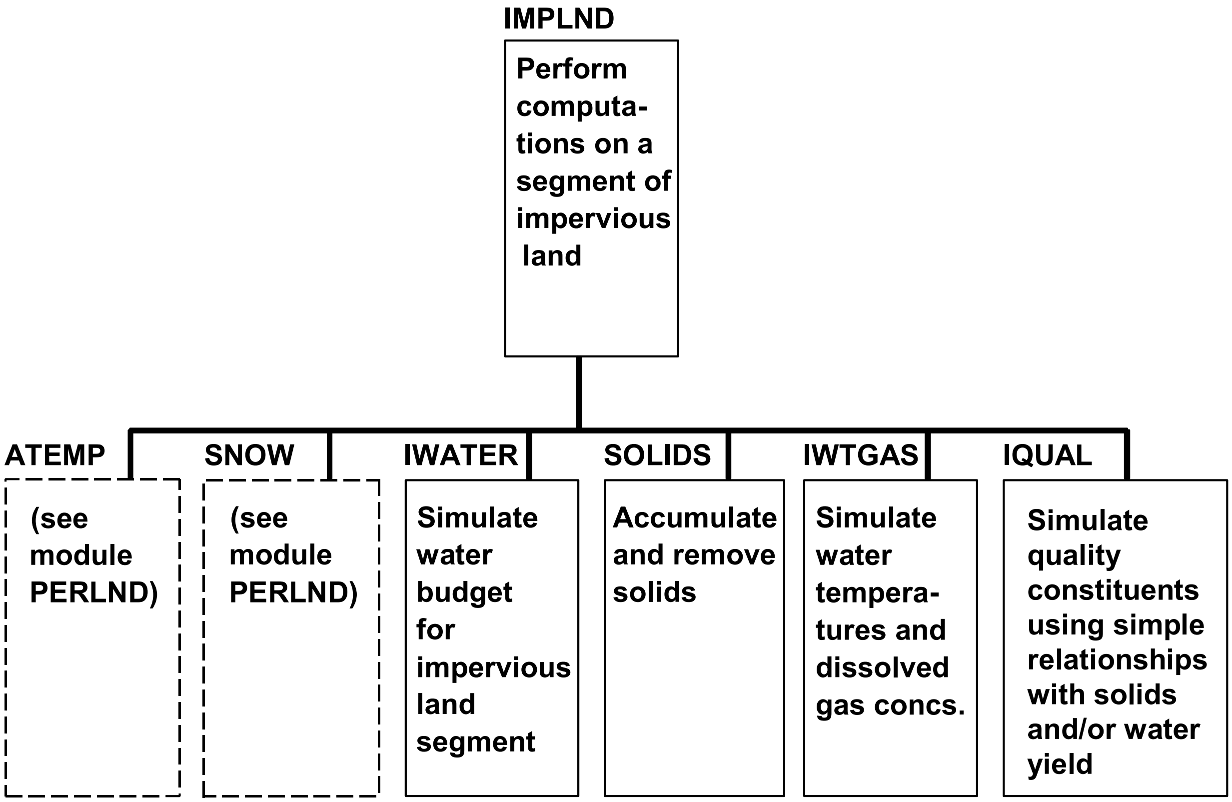

Figure 2.4-1 IMPLND Structure Chart

2.5 RCHRES Module

RCHRES is used to route runoff and water quality constituents simulated by PERLND and IMPLND through stream channel networks and reservoirs. The module simulates the processes that occur in a series of open or closed channel reaches or a completely mixed lake. Flow is modeled as unidirectional. A number of processes can be modeled, including the following:

- Hydraulic behavior.
- Heat balance processes that determine water temperature.
- Inorganic sediment deposition, scour, and transport by particle size.
- Chemical partitioning, hydrolysis, volatilization, oxidation, biodegradation, and generalized first-order (e.g., radionuclides) decay, parent chemical/metabolite transformations.
- DO and BOD balances.
- Inorganic nitrogen and phosphorus balances.
- Plankton populations.
- pH, carbon dioxide, total inorganic carbon, and alkalinity.

Figure 2.5-1 defines the structure and contents of the RCHRES module. The module features individual sub-modules for modeling hydraulics (HYDR), constituent advection (ADCALC), conservatives (CONS), water temperature (HTRCH), inorganic sediment (SEDTRN), generalized quality constituents (GQUAL), and specific constituents involved in biochemical transformations (RQUAL).

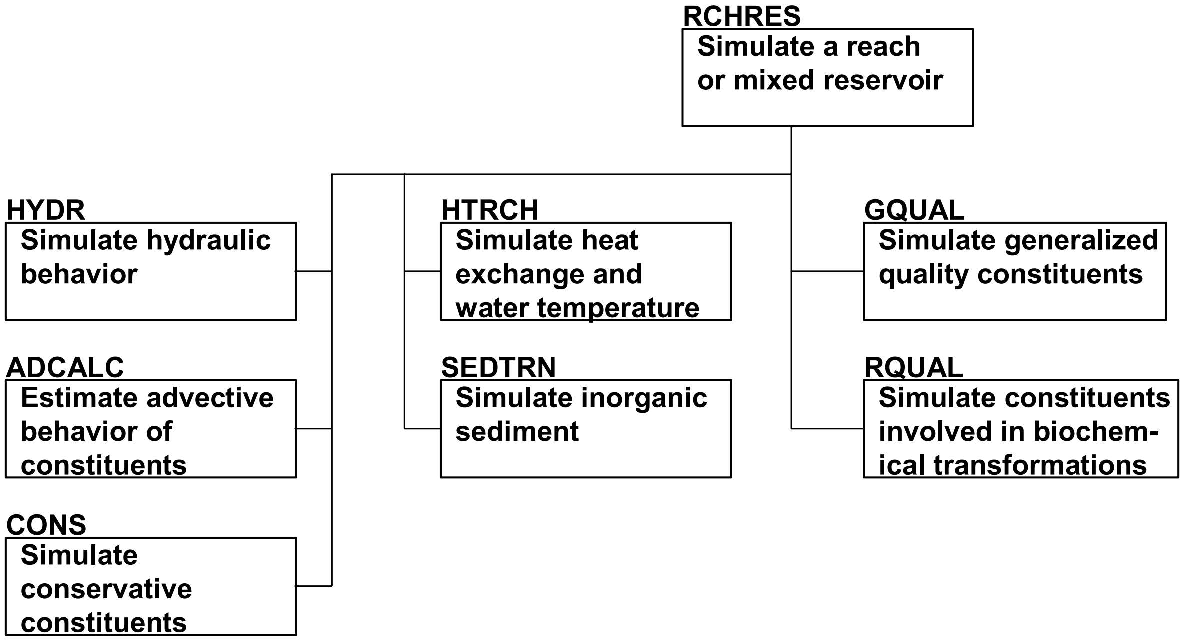

Figure 2.5-1 RCHRES Structure Chart

HYDR simulates the processes that occur in a single reach of an open channel or a completely mixed lake. Hydraulic behavior is modeled using the kinematic wave assumption. All inflows to a reach are assumed to enter at a single upstream point. The outflow of a reach may be distributed across several targets that might represent normal outflows, diversions, and multiple gates of a reservoir. In HSPF, outflows can be represented by either, or both, of two methods:

1) Outflow can be modeled as a function of reach volume for situations where there is no control of flows, or gate settings are only a function of water level.

2) Outflow can be modeled as a function of time to represent demands for municipal, industrial, or agricultural use. To do so, the modeler must provide a time series of outflow values for the outflow target that is time-dependent and independent of reach volume.

If an outflow demand has both volume-dependent and time-dependent components, the modeler can, and must, specify how the components are combined to define the resulting outflow demand. HSPF allows the modeler to define the resulting demand in one of three manners: (1) as the minimum of the two components, (2) as the maximum of the two components, or (3) as the sum of the two components.

HSPF makes no assumptions regarding the shape of a reach; however, the following assumptions are made:

1) There is a fixed, user-defined relation between water depth, surface area, volume, and discharge. This is specified in a Function Table (FTABLE) defined for each reach by the user.
2) For any outflow demand with a volume-dependent component, the relation between the above variables is usually constant in time; however, predetermined seasonal or daily variations in discharge values can be represented by the user.

These assumptions rule out cases where flow reverses direction (e.g., estuaries) or where one stream reach influences another upstream of it in a time-dependent manner. Momentum is not considered, and the routing technique falls in the class known as storage routing or kinematic wave methods.

In addition to calculating outflow rates and reach water volumes, HYDR computes the values for additional hydraulic parameters that are used in the other code sections of RCHRES including depth, stage, surface area, average depth, top width, hydraulic radius, bed shear stress and shear velocity.

2.6 MODEL LINKAGES

There are effectively two models to be considered when developing the linkage issues. The two models are:

(1) HSPF(land) (PERLND/IMPLND)
(2) HSPF(stream) (RCHRES)

Because HSPF has such a large number of user-defined options and different methods for modeling the same species, it is necessary to explicitly include discussion of the HSPF(land) – HSPF(stream) linkage.

2.6.1 HSPF (land) ⇒ HSPF (stream)

HSPF(land) produces loadings of flow, sediment, heat, and constituents for input to tributary water bodies. In this situation, the receiving water body is the HSPF RCHRES module. This linkage is well known and relatively straightforward, since the two components of HSPF are generally used together, and they are combined in a single, integrated software system. However, there are issues to consider in this linkage due to the optional methods for simulating various water quality constituents in the program.

Within the HSPF input structure, all land area that drains to a stream reach is easily connected to the reach, and, since HSPF stream reaches are assumed to be completely mixed, there is no additional spatial relationship that needs to be defined. Also, the two components of HSPF are operated at the same (usually a constant, one-hour) timestep.