Water Balance Model for a Pervious Catchment
A GoldSim Model Based on HSPF

Introduction
This document introduces a recently developed GoldSim model for predicting runoff in ungaged catchments. The model uses the structure and empirical relations of the pervious catchment water balance module in the Hydrological Simulation Program – Fortran (HSPF – PERLND PWATER module). The reader is directed to the HSPF Version 12 User's Manual pages 49 to 69 for more information about this module's structure, empirical relations, and history (http://www.epa.gov/waterscience/BASINS/b3docs/HSPF.pdf). The GoldSim model itself also provides some documentation.

Inputs to run the model are rainfall time series and monthly pan evaporation rates, as well as values for 27 runoff and evapotranspiration parameters and initial conditions. In the model, rainfall is routed to interception storage. The overflow from interception storage meets the land surface and is subsequently distributed among several reservoirs, including surface detention, interflow storage, upper and lower zones of soil, and active and inactive groundwater. Modeled discharge is the sum of surface runoff, interflow, and active groundwater outflow, which can also be viewed separately. The model is typically run with time steps of an hour or less for better resolution of infiltration and overland flow processes.

The GoldSim implementation is currently written for deterministic modeling of runoff as a function of fixed parameters and rainfall and pan evaporation rates. It could easily be extended to include snowmelt or time variable or stochastic parameters. It could also be cut and pasted into a container in another model to simulate a catchment within a larger system (discussed below).

GoldSim Advantages
Relative to HSPF, advantages of the GoldSim implementation of the water balance model include:

1) Options for Monte Carlo simulation and/or mathematical optimization of parameter values,
2) Transparency of calculations that makes it possible to plot or examine any internal variable's values,
3) Ability to take input data from spreadsheets rather than the unwieldy binary file required by HSPF, and
4) More quality assurance and error checking of input data and parameters.

Parameterization
The numerous runoff and evapotranspiration parameters of the model can be overwhelming at first glance, but they offer flexibility for many pervious catchment modeling situations. For example, there is a parameter called BaseflowAETfraction in GoldSim and BASETP in HSPF whose primary use is to simulate evapotranspiration of

baseflow by phreatophytic vegetation. As a starting point for parameterization, Table 1 lists parameter sets commonly used in the Puget Sound region of the northwestern U.S. More information for other regions can be found in the U.S. Environmental Protection Agency Program HSPFParm, which has collected HSPF parameters from applications across the U.S. (http://www.epa.gov/waterscience/basins/bsn3faqs.htm). When runoff observations are available, regional parameters are typically used only as starting values for manual or automated calibration.

Table 1. Puget Sound regional parameter sets for several vegetation and soil types[a]

GoldSim Name	HSPF Name	Soil and Vegetation Type				Units
		A/B Soils[a]		C Soils[a]		
		Forest	Pasture	Forest	Pasture	
LowerZoneNominalCapacity	LZSN	5	5	4.5	4.5	in
InfiltrationRate	Infilt	2	1.5	0.08	0.06	in/hr
Length	LSUR	Values depend on specific catchment				
Slope	SLSUR	Values depend on specific catchment				
SlopeIndexMultiplier	KVARY	0.3	0.3	0.5	0.5	1/in
ActiveGroundwaterRecessionCoef	AGWRC	0.996	0.996	0.996	0.996	1/day
InfiltrationExponent	INFEXP	2	2	2	2	-
Infil_DistributionParameter	INFILD	2	2	2	2	-
InactiveGroundwaterFraction	DEEPFR	0	0	0	0	-
BaseflowAETFraction	BASETP	0	0	0	0	-
ActiveGroundwaterAETFraction	AGWETP	0	0	0	0	-
InterceptionCapacity	CEPSC	0.2	0.15	0.2	0.15	in
UpperZoneNominalCapacity	UZSN	0.5	0.5	0.5	0.4	in
ManningsN	NSUR	0.35	0.3	0.35	0.3	-
InterflowRatio	INTFW	0	0	6	6	-
InterflowRecessionCoefficient	IRC	0.7	0.7	0.5	0.5	1/day
LowerZoneAETParameter	LZETP	0.7	0.4	0.7	0.4	-

a Regional parameter sets taken from the Western Washington Hydrology Model, a Washington Department of Ecology wrapper for HSPF
b Soil types are Natural Resource Conservation Service hydrologic soil group classifications (See http://www.wsi.nrcs.usda.gov/products/w2q/h&h/docs/H&H_papers/curve_number/hyd_soil_grp_assignment.pdf)

User Interface and Spreadsheet Inputs/Outputs

The GoldSim model can be edited and run either through the model elements themselves or through dashboards. There is one input dashboard and one output dashboard. The input dashboard defines the catchment parameters and the initial water storages. Also on the input dashboard is a link to edit monthly pan evaporation rates.

The inputs dashboard allows selection of a spreadsheet containing rainfall data. To use this dashboard feature, the spreadsheet needs to contain rainfall data in inches per hour and the dates and data need to be in columns beginning in cells A2 and B2, respectively. If your data are not in this format, you can enter them by exiting the dashboard, and editing the Rainfall time series element directly.

On completion of a model run, the catchment model exports its time series results (surface runoff, interflow, baseflow, and total flow) to a spreadsheet called Results.xls. To change this export process or filename, which may be required in a model of several catchments, edit the clearly labeled spreadsheet export element in the Results\Runoff_Time_Series container.

Modeling Watersheds with Multiple Catchments

The model is set up in three containers: Inputs, MainModelView, and Results. In the simplest case for a watershed of multiple catchments, these three containers will be cut and pasted into localized containers, with a localized container for each catchment of the watershed. This would allow separate runoff parameters and weather data for each catchment.

In other cases, there may be an interest in modeling a watershed with one set of input rainfall and pan evaporation data, but multiple catchments and runoff parameter sets. In these situations, localized containers can be used for each catchment, but the rainfall and evaporation container can be placed outside of the localized containers so that each localized catchment container can reference the same input data.

In smaller scale watershed modeling there is sometimes a need for lateral inflows into a catchment's water storage reservoirs, e.g. routing the surface runoff from one catchment onto another catchment's surface. This would require editing the inputs to the water storage reservoirs in the MainModelView container in the receiving catchment's localized container. It would also be good to edit the mass balance calculations for the receiving catchment so that a mass balance warning is not thrown. This can be done in the MainModelView\Mass_Balance_Verification container.

GoldSim Model Quality Assurance

Eleven verification tests showed excellent agreement between the HSPF and GoldSim water balance model implementations. Each verification test consisted of running the same parameters and input data in the two models and comparing their outputs, specifically their differences in runoff volume over the model duration and their differences in peak flow rates.

Minor differences in the model outputs can be partially attributed to a difference in evapotranspiration calculations. In HSPF, on each time step, evapotranspiration calculations are completed *after* the current time step's excess rainfall has been routed to the various storage reservoirs. GoldSim's evapotranspiration calculations on each time step use Euler integration and reference reservoir storages as they existed on the previous time step. The difference between the two models should remain negligible for small time steps (an hour or less).

HSPF uses a number of slightly inaccurate time-saving shortcuts in solving its equations. For the most part these are not listed in the user's manual. For example, LZFRAC, the fraction of the percolation and infiltration which enter the lower zone instead of groundwater, is recalculated only when the lower zone water storage has changed appreciably. When the verification tests were run, GoldSim was set up to copy this logic. However, in the interest of presenting a simpler and more accurate model after the verification tests were complete, the GoldSim model was modified to recalculate

LZFRAC on every time step. Both versions are retained and a user input parameter (Calculate_LZFRAC_on_every_step) can be used to choose the method of calculation. In informal testing, the difference in total runoff volume over the model duration between the two LZFRAC methods was 0 to +/- 0.8 percent.

Table 2. Comparison of HSPF and GoldSim water balance model implementations

Test ID	Percent Differences in Discharge Volume over Model Duration Surface Runoff	Interflow	Baseflow	Total	Percent Difference in Peak Flow
7	0.007%	0.006%	-0.093%	-0.026%	0.006%
8	0.244%	NA	-0.019%	-0.019%	0.954%
8b	0.145%	NA	-0.044%	-0.043%	0.950%
8c	0.143%	NA	-0.041%	-0.041%	0.850%
8d	-0.102%	NA	-0.054%	-0.055%	0.316%
9	-0.079%	-0.022%	-0.042%	-0.034%	0.008%
10	-0.087%	-0.022%	-0.042%	-0.034%	0.009%
11	0.131%	NA	-0.038%	-0.038%	-0.029%
12	-0.454%	NA	-0.056%	-0.057%	-0.199%
13	0.131%	NA	-0.031%	-0.031%	-0.037%
14	-1.260%	NA	0.000%	-0.001%	0.003%

a Negative numbers indicate GoldSim outputs were greater than HSPF outputs

Update as of 7/27/2010

This folder now contains two GoldSim models. The calculations are identical, except one of them, "Probabilistic_Pervious_Catchment_Water_Balance_from_HSPF.gsm," is set up for probabilistic simulation. In this model, rather than entering single values for the parameters, you enter the three parameters of a triangular distribution for each parameter. It allows examination of the effect of parameter uncertainty on the rainfall runoff response. This uncertainty is often overlooked since traditional hydrologic analysis codes do not support Monte Carlo simulation.