Comparison of Hydrologic Calibration of HSPF Using Automatic and Manual Methods

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Background

The Hydrological Simulation Program-FORTRAN (HSPF) is a complex, comprehensive watershed-scale water quality model used to develop Total Maximum Daily Loads (TMDLs). Because manual model calibration can be difficult and time-consuming, researchers have developed more efficient automatic calibration procedures. PEST is flexible, model-independent software that can utilize multiple-objective functions in the model calibration process. PEST has been widely used in the field of groundwater modeling, but there have been very few applications of PEST to surface water models. This study compares the hydrologic calibration of HSPF using automatic and manual methods.

Objective

This research compared the hydrologic performance of HSPF calibrated automatically using PEST and manually using advice provided by the Expert System for the Calibration of HSPF (HSPEXP).

Study Watershed

- North River Watershed (972.8 km^2)
- Tributary of the South Fork of the Shenandoah River (USGS Hydrologic Unit Code 02070005), which flows into the Potomac River and eventually discharges into the Chesapeake Bay
- Meteorological data source: Dale Enterprise (COOPID: 442208) of National Climatic Data Center's (NCDC) Cooperative Weather Station
- Annual mean precipitation: 903.5 mm
- Average annual daily temperature: 11.8°C
- Land use: forest (62%), pasture (29%), cropland (5%), residential (4%)

Figure 1. North River watershed location

Methods and Results

Objective Functions

- PEST objective functions were based on HSPEXP-based model performance measures of runoff, 10% highest flows, 50% lowest flows, storm peaks, and seasonal and storm volume

Goodness-of-fit Measures

- HSPEXP model performance criteria
- Coefficient of determination (R^2), coefficient of efficiency (E), and root mean square error ($RMSE$)

Model Calibration

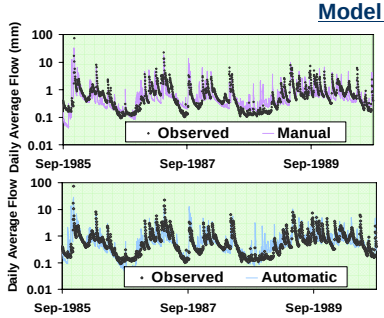

Figure 2. Observed and simulated daily flows.

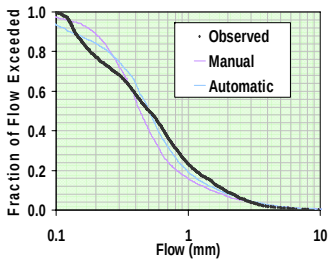

Figure 3. Observed and simulated fraction of flow exceedance.

Table 1. Summary of calibration statistics.

Measures	Observed	Automatic Method Simulated	Automatic Method Percent Error	Manual Method Simulated	Manual Method Percent Error	HSPEXP Model Performance Criteria (%)
Total Runoff (mm)	1618.6	1571.2	-2.93	1463.3	-9.59	±10
Total of Highest 10% Flows (mm)	699.1	706.6	1.07	694.2	-0.71	±15
Total of Lowest 50% Flows (mm)	233.6	259.6	11.15	254.3	8.86	±10
Seasonal Volume Error (%)	–	–	6.53	–	3.49	±10
Average of Storm Peaks (m^3/s)	68.4	55.1	-19.52	59.1	-13.66	±15
Summer Storm Volume (mm)	37.2	39.9	7.31	41.1	10.73	±15
Coefficient of Determination (R^2)	–	0.51		0.49		–
Coefficient of Efficiency (E)	–	0.35		0.29		–
$RMSE$ (mm)	–	1.50		1.54		–

Discussion

- Overall, both calibrated parameter sets over-predicted low flows, under-predicted mid-range flows and under-predicted baseflow indices.
- Important factors that greatly affect surface water quality modeling – amount of surface runoff, storm peaks, and summer storm volumes – were noticeably different between the automatic and manual calibration methods.
- Determining which calibration method provides better estimates of the breakdown between surface flow and interflow is challenging. That a discrepancy exists means that the modeled pollutant loads will be different for each calibration method.

Table 2. Flow partitioning for calibration and validation periods.

Average Annual Flow (mm)	Calibration Obs.	Calibration Auto.	Calibration Man.	Validation Obs.	Validation Auto.	Validation Man.
Total Annual Flow	323.6	314.2	292.7	382.8	382.3	354.9
Surface flow	–	6.8	30.9	–	9.9	49.6
Interflow	–	154.6	124.2	–	205.6	165.6
Surface flow + interflow	146.7	161.4	155.1	171.5	215.5	215.2
Baseflow	176.9	152.9	137.5	211.3	166.7	139.7
Baseflow Index	0.55	0.49	0.47	0.55	0.44	0.39

Summary and Conclusions

- The PEST (automatic) parameter set satisfied most of the HSPEXP model performance criteria and performed better than the manual calibration with respect to R^2, E, and $RMSE$. This result suggests that PEST may be a suitable alternative to HSPEXP for hydrologic calibration of HSPF. Further research is needed to investigate the ramifications of manual vs. automatic calibration on water quality modeling.

Citation: Kim, S.M., B.L. Benham, K.M. Brannan, R.W. Zeckoski, and J. Doherty. 2007. Comparison of hydrologic calibration of HSPF using automatic and manual methods. *Water Resources Research* (43).