3.6.5 - Leakage and Evapotranspiration Rates

Maps of average calculated leakage rates for the SDP show a zone of strong upward leakage on the southern side of Tamiami Trail (figs. 1 and 23). This zone of upward leakage is created by ground water flowing beneath the trail as a result of higher ground-water heads on the northern side of the trail. Conversely, a zone of strong downward leakage and eastward ground-water flow exists along Levee 31, and results from the drained conditions in developed coastal areas east of the levee. Zones of relatively minor upward leakage occur where relatively low land-surface altitudes are present south and west of the C-111 Canal and in waterways along the coast.

Total flux, including (1) upward and downward surface- and ground-water leakage, and (2) ground-water ET during the SDP, was summed spatially and temporally (fig. 24). Consumptive ground-water use due to evapotranspiration during a period of 7 years (3.64×10^9 m^3) exceeds losses asociated with upward ground-water leakage (2.40×10^9 m^3); the sum of vertical flux and consumptive losses closely corresponds to downward vertical leakage of surface water (5.94×10^9 m^3). Head-dependent ground-water boundary flux across all GHBs should equal the net volume of vertical flow. In this instance:

  5.94×10^9 m^3 (downward vertical surface-water leakage)
- 3.64×10^9 m^3 (consumptive losses by evapotranspiration)
- 2.40×10^9 m^3 (head-dependent ground-water boundary flux)

-0.10×10^9 m^3 (negative sign indicates leakage of ground water from aquifer to surface)

The model budget shows a head-dependent flow into the aquifer of 2.07×10^9 m^3 compared to an outflow of 1.9637×10^9 m^3, which is presumed to be leakage to coastal canals, resulting in a net inflow to the aquifer of about 0.10×10^9 m^3. This

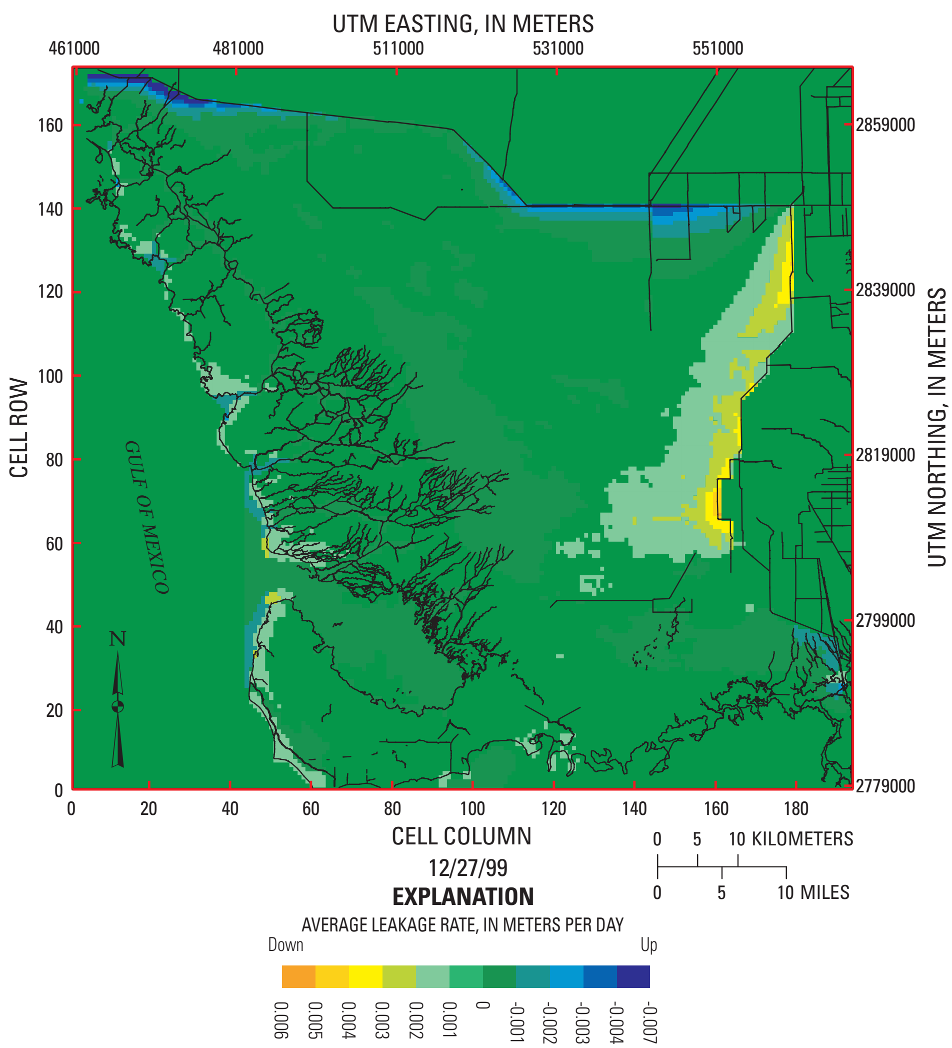

Figure 23. Average leakage rates in the TIME area.

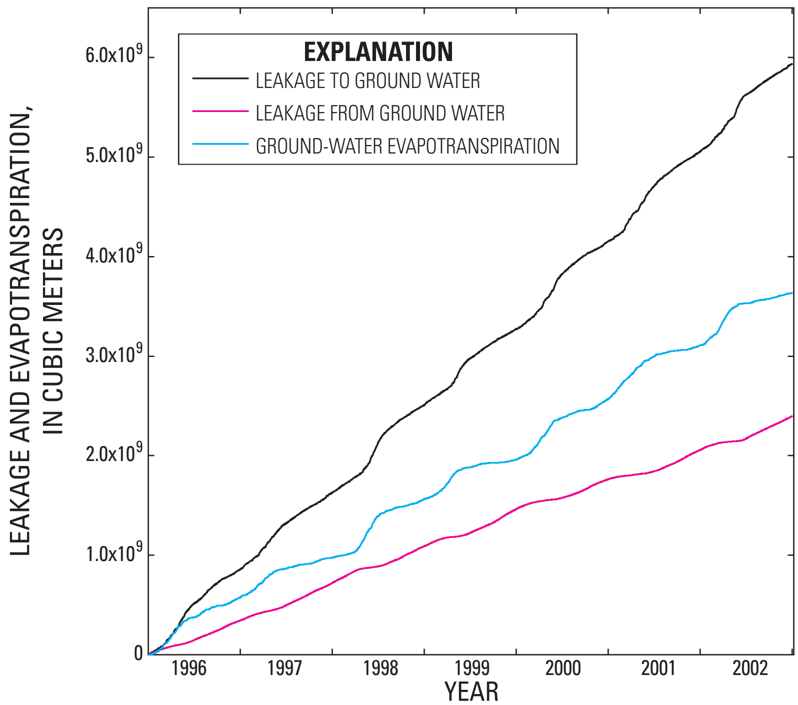

Figure 24. Cumulative leakage and evapotranspiration from ground water in the TIME area for the standard data period.

is equal and opposite to the net vertical volume flow and is relatively small compared to leakage or ET from ground water.

Nemeth and others (2000) estimated that leakage beneath Levee 31N ranges from –18.7 to +46.5 m^3/d per meter of levee. Assuming an average leakage of 30 m^3/d per meter and a levee length of 25 km yields a total leakage of 1.92 x10^9 m^3 for the SDP, which is in good agreement with the model result noted earlier. In contrast, the total flow from S-12D noted earlier is 2×10^9 m^3, which is an order of magnitude greater than the net head-dependent ground-water inflow. Thus, the ground acts as a surface-water sink, with total volume into ground water equal to 2.3 x10^9 m^3. This is a small fraction of the total flow from all culverts and structures, and therefore, perhaps of secondary importance.

3.6.6 - Ground-Water Flows and Salinities

The ground-water flows in layer 1 of the model reflect the leakage pattern, with flows directed toward the east along most of Levee 31 and toward the south along Tamiami Trail. In lower layers, flow divergence is evident along the salinity front. The flows at the beginning and end of the simulation are similar, indicating that ground-water flow adjustments occur slowly and may take several decades to reach equilibrium.

Ground-water salinities are influenced by the assumed initial conditions and additionally are affected by open-boundary conditions in the surface-water model. The simulations, however, show that the salinity front is far inland on the western side of the domain as indicated by resistivity studies (Fitterman and Deszcz-Pan, 2002). Until better boundary conditions can be prescribed and simulations can be run for longer time periods, computed ground-water salinities are not significant, and therefore, are not shown.

3.7 - Model Sensitivity Studies

To better understand model response and the robustness of calculated flows to the coast, a number of runs were conducted in which the major assumptions and parameters were varied. Several indices were used to measure model performance: (1) the sum of the absolute values of the difference in means, (2) the sum of squares of the difference in means, (3) the sum of correlations, and (4) the sum of PEV values for all 105 stage stations for which comparisons were made between model output and field data. These measures are not completely independent, but are reported in table 5 to accommodate different aspects of the analysis. Additionally, the average flows to the coast for the SDP are compared in figure 25, which shows the average flow at: (1) open-boundary

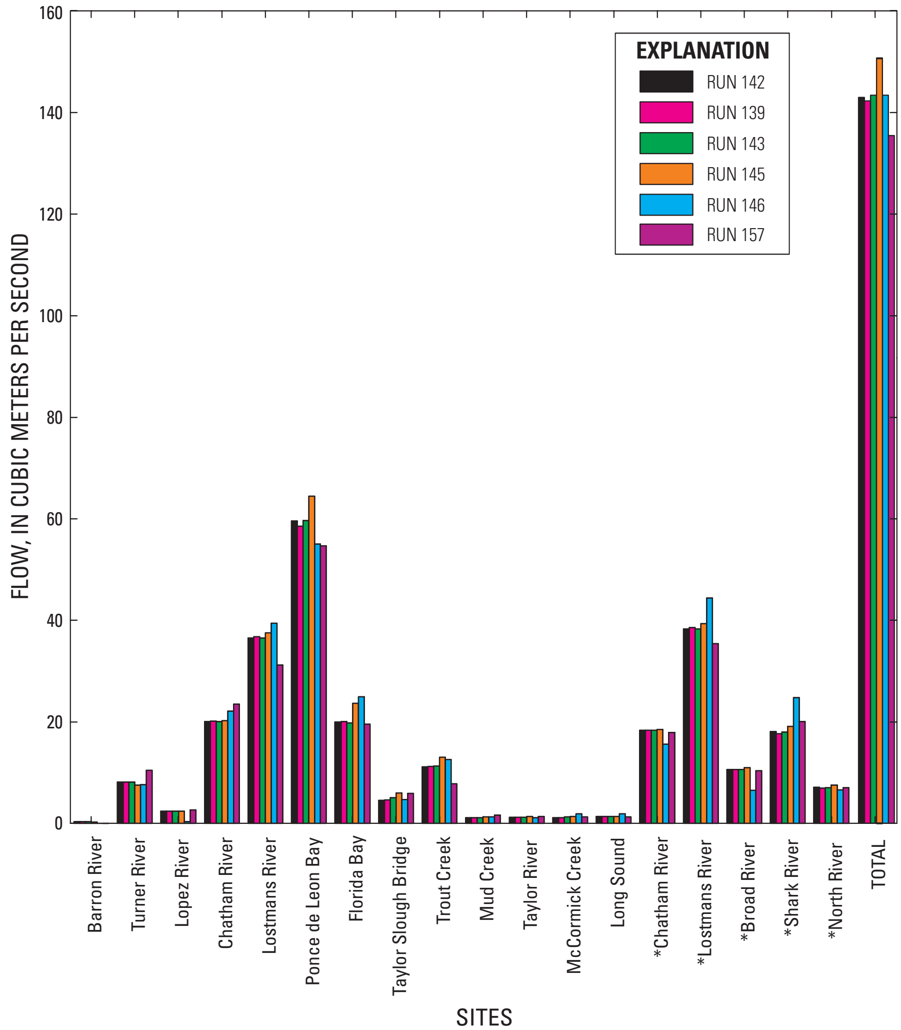

Figure 25. Average flows to the coast for the standard data period. Asterisk indicates flow at location of U.S. Geological Survey monitoring station.

locations, (2) mouths of creeks along the Florida Bay coastline, (3) USGS monitoring stations along the west coast rivers, and (4) TSB.

3.7.1 - Comparison of Versions 2.1 and 2.2 of the FTLOADDS Code

The TIME application can be further examined in the Taylor Slough area by comparison to the previous SICS application. Toward this end, a simulation was developed that isolates the SICS domain within the TIME domain. This simulation permitted direct comparison between applications using the same domain and boundary conditions, but with somewhat different model formulations, rainfall distributions, and grid resolutions.

As discussed in section 2.2, the FTLOADDS code version 2.2 in the TIME application includes several modifications not available in the version 2.1 SICS application. The TIME application also has inherent differences in grid spacing, time-step length, creek representation, and boundary conditions. It was, therefore, of interest to compare the new and old formulations and applications. To accomplish this, the area of the TIME application grid outside the domain of the original SICS application was made inactive, and boundaries around the active region were defined with the same flow and water-level conditions used in the SICS application. This modified application is referred to as the Embedded SICS (ESICS) application, the domain of which is shown in figure 26. Boundaries were modified by specifying: flow at TSB, Levee 31W Canal, and C-111 Canal, water levels along Old Ingraham Highway, and ground-water heads beneath the levee along the northern part of C-111 Canal. The

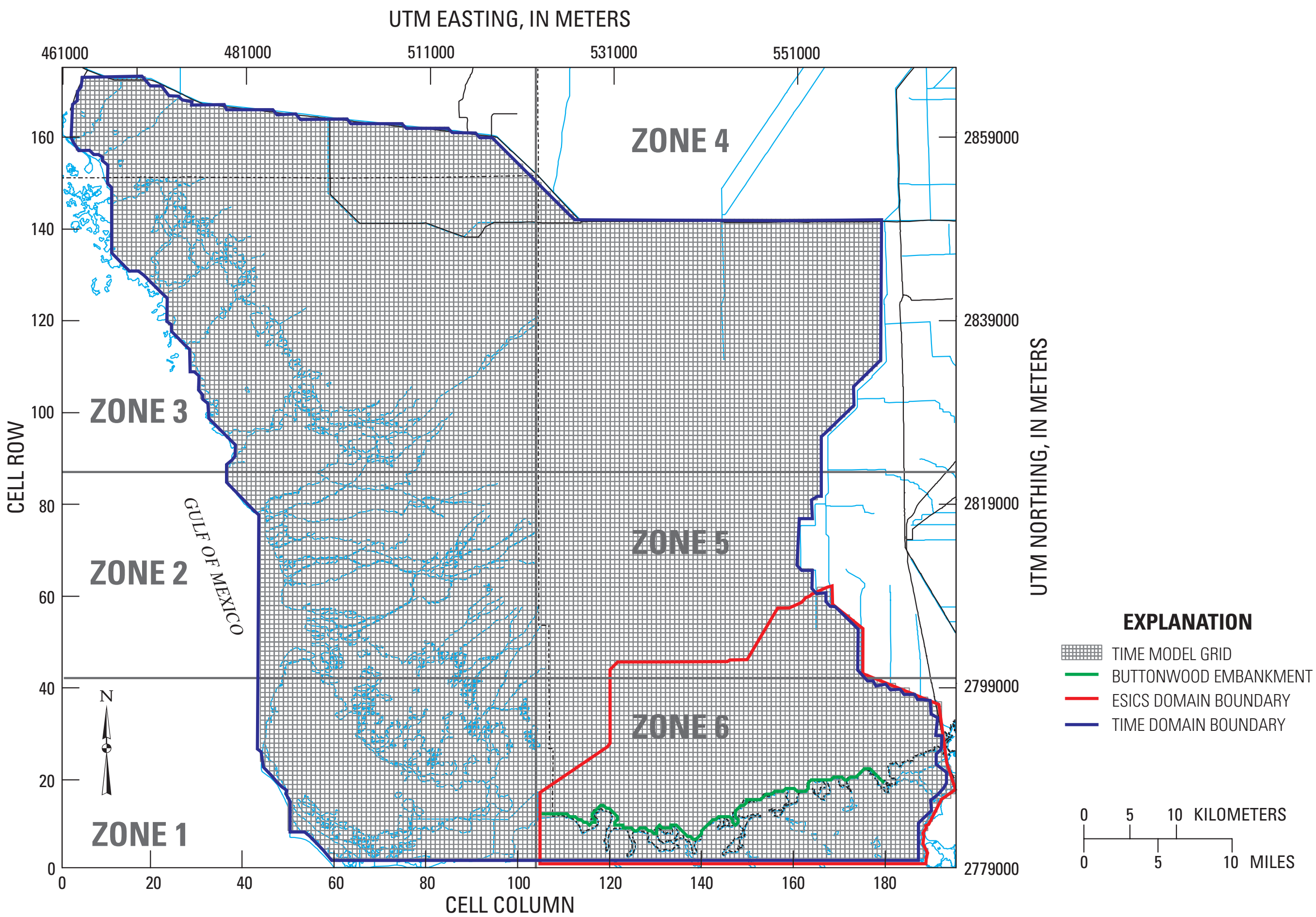

Figure 26. Area of the TIME domain used to create the ESICS domain.

Table 8. Comparison of SICS and ESICS applications.

[SICS, Southern Inland and Coastal Systems; ESICS, Embedded Southern Inland and Coastal Systems]

Model characteristic	Model	
	SICS	ESICS
Grid Spacing	305 meters	500 meters
Rainfall	Specified at 15-minute intervals and spatially interpolated for each model cell	Specified as 6-hour averages and partially uniform over zones defined for the TIME application.
Evapotranspiration	Computed cell-by-cell according to the best-fit equation discussed by Swain and others (2004)	Computed using the modified Penman method
Wetting and drying	Model cell removed from computational domain when water-level drops below user-defined depth	Algorithm modified to allow for rewetting directly from rainfall recharge and evapotranspiration from residual water
Frictional-resistance terms	Defined at cell centers	Defined at cell faces
Coastal embankment	Defined by the formulation of barriers originally designed to represent weirs; coastal rivers are defined as low barriers with a representative flow coefficient	Defined by modified cell-face frictional-resistance terms; coastal creeks are defined as gaps with specified friction terms

boundary conditions of the ESICS application were defined with the same field time-series data used for the original SICS application. The basic differences between the SICS and ESICS applications are the same as those between SICS and TIME, and versions 2.1 and 2.2 of FTLOADDS (table 8).

The ESICS and TIME applications are identical (or nearly so) in several respects:

- The TIME grid is retained in ESICS; therefore, the same 500-m grid spacing is used.
- Rainfall zonation is identical in ESICS and TIME, although only rainfall zones 5 and 6 have portions within the ESICS domain.
- Evapotranspiration is identical for equivalent cells in ESICS and TIME.
- Frictional terms used at the cell faces are identical in ESICS and TIME. The terms are varied at the coastal embankment and at the coastal creeks as part of the calibration procedure. After the terms are calibrated in the ESICS application, they are transferred to the TIME application for use in representing the embankment and creeks.

SICS and ESICS application results were compared to evaluate the implications of differences between versions 2.1 and 2.2 of the FTLOADDS code. The comparison also provides insight into the relative accuracy of the TIME and SICS applications. One of the version differences is in the representation of coastal creeks. The calibrated frictional values (Manning's *n*) at the cell faces representing the creeks cannot be equated directly to the properties of the actual creeks, primarily because cell cross-sectional areas are greater than the actual creeks and cell depths are generally less than the actual creeks. Additionally, a given creek may occupy only a fraction of the distance between centers of adjacent cells. In order to relate cell frictional resistance to the actual creek, it is useful to visualize the total head loss between the two cells representing the creek in three parts: head loss between the upstream cell center and the upstream end of the creek, h_1; head loss through the creek, h_2; and head loss between the end of the creek and the center of the downstream cell, h_3. Using Manning's equation, the sum of these three variables must equal the head loss depicted in the model:

$$h_1 + h_2 + h_3 = \frac{Q^2 n_{cell}^2 l_{cell}}{d_{cell}^{10/3} w_{cell}^2}\,, \tag{5}$$

where Q is flow rate, n_{cell} is Manning's n in the cell, l_{cell} is length dimension of the cell, d_{cell} is cell depth, and w_{cell} is cell width (the same as the cell length for a square cell). The head loss terms take the form:

$$h_1 = \frac{Q^2 n_{up}^2 \left(\frac{l_{cell} - l_{creek}}{2}\right)}{d_{cell}^{10/3} w_{cell}^2}\,, \tag{6}$$

$$h_2 = \frac{Q^2 n_{creek}^2 l_{creek}}{d_{creek}^{10/3} w_{creek}^2}\,, \tag{7}$$

and:

$$h_3 = \frac{Q^2 n_{dn}^2 \left(\frac{l_{cell} - l_{creek}}{2}\right)}{d_{cell}^{10/3} w_{cell}^2}\,, \tag{8}$$

where

n_{up} is Manning's n in the upstream cell area,
l_{creek} is creek length,
n_{creek} is Manning's n in the creek,
n_{dn} is Manning's n in the downstream cell area,
d_{creek} is creek depth, and
w_{creek} is cell depth.

Combining these three equations yields:

$$n_{creek} = \sqrt{\frac{n_{cell}^2 l_{rat} - \frac{(n_{up} + n_{dn})}{2}(l_{rat} - 1)}{d_{rat}^{10/3} w_{rat}^2}}\,, \tag{9}$$

where l_{rat} is the ratio of cell length to creek length, d_{rat} is the ratio of cell depth to creek depth, and w_{rat} is the ratio of cell width to creek width. Using a model cell width of 500 m and known creek widths from Swain and others (2004), the ratios of cell to creek widths are as follows: McCormick Creek w_{rat} is 29.76, Taylor River w_{rat} is 74.63, Mud Creek w_{rat} is 40.98, Trout Creek w_{rat} is 13.66, and West Highway Creek w_{rat} is 23.47.

The ratios of cell to creek depths vary with water level, thus a representative mean stage must be used. With an assigned stage of about 0 m relative to NAVD 88, the ratios are as follows: McCormick Creek d_{rat} is 0.658, Taylor River d_{rat} is 0.691, Mud Creek d_{rat} is 0.592, Trout Creek d_{rat} is 0.789, and West Highway Creek d_{rat} is 1.0.

Creek length was determined from digital maps of the area. For a creek longer than a cell dimension, the cell dimension was used because it is the relevant distance over which the water-level difference is represented. The following ratios of cell length to creek length were then calculated: McCormick l_{rat} = 1.0, Taylor l_{rat} = 1.0, Mud l_{rat} = 1.21, Trout l_{rat} = 3.29, and West Highway l_{rat} = 1.66. This results in the following n values: McCormick Creek n_{cell} = 0.7, n_{creek} = 0.047; Taylor River n_{cell} = 1.0, n_{creek} = 0.047; Mud Creek n_{cell} = 0.7, n_{creek} = 0.045; Trout Creek n_{cell} = 0.08, n_{creek} = 0.015; and West Highway Creek n_{cell} = 0.4, n_{creek} = 0.022.

This computation yields low Manning's n values compared to previously accepted values (Swain and others, 2004); however, this easily could be due to the different representation of the creeks. The ability of the model to represent coastal flow conditions is the best measure of the utility of each method.

The primary model output used for comparison is the discharge at the coastal creeks, primarily McCormick Creek, Taylor River, Mud Creek, Trout Creek, and West Highway Creek. It is generally more difficult to represent discharge than water levels in numerical models. Coastal discharges are of primary interest, however, to the restoration efforts as a measure of freshwater flow to the estuaries. A comparison between flows from field data, the original SICS application, and ESICS is shown in figure 27. The improvement with ESICS is apparent, especially in the representation of flow peaks. Computing the mean absolute error (MAE) between each of the applications (SICS and ESICS) and the field data yields the following results:

Creek	Mean absolute error (cubic meter per second)	
	SICS	ESICS
McCormick Creek	1.69	1.27
Taylor River	.928	.900
Mud Creek	.962	.801
Trout Creek	6.20	5.07
West Highway Creek	1.42	1.27

A consistent reduction in the MAE occurs at all flow locations with ESICS versions 2.1 and 2.2

Two different methods for representing the frictional-resistance term are used in the ESICS comparison. The constant Manning's *n* representation uses the standard representation of Manning's frictional resistance with a constant value to compute the Chezy *C* value (Swain, 2005, p. 11). The variable Manning's *n* representation uses the empirically derived variation of *n* with depth from Swain and others (2004). This variable formulation is designed to approximate the effects of emergent vegetation and microtopography on the frictional resistance. The coefficients in the formulation were varied empirically, however, to obtain the best fit with the original SICS application, and thus the method had no theoretical foundation. The comparison of these two methods is shown in figure 28. The variable Manning's *n* method provides results that are closer to field measurements, but still reduces the rapid recessions when regional drying occurs. A comparison of stages produced by SICS and ESICS at selected wetland stations is shown in figure 29. Although model performance is demonstrated more critically with comparisons of volume fluxes, the ability to represent similar stage values also indicates coherence and agreement between SICS and ESICS.

3.7.2 - Sensitivity to Manning's *n* Adjustment

In run 139, Manning's *n* is adjusted in the arbitrary rectangles shown in figure 5 to determine the effects of gross changes in friction. The locations of the rectangles were chosen to affect the mean bias at NP201, S12B, S12C, NE2, and P34 (fig. 9). As evidenced by the stage comparison statistics for runs 139 and 142 (the base run) in tables 9 and 10, respectively, the simulated mean (compared to the measured mean) changes at these sites as follows:

Site	Model mean compared to measured mean (meters)	
	Original Manning's *n*	Adjusted Manning's *n*
NP201	0.04 low	0.06 high
S-12B	.15 low	.06 high
S-12C	.06 low	.05 low
NE2	.11 high	.09 high
P34	.004 high	.106 high

There are few substantial changes in mean stage difference other than at stations NP201, S12B, S12C, NE2, and P34, and these represent mixed results. The spatial distribution of mean stage difference, defined as abs[DIFMEAN(run 142)-abs(DIFMEAN(run 139)], is shown in figure 30. The map shows improvements in stage mean differences, which are defined as being closer to the data mean, as positive values and deteriorations in stage mean differences as negative values. The local changes to Manning's *n* result in local changes to (mean) stages, such as those south of the S-12 structures (figs. 1 and 30).

The improvements achieved at some locations were not sufficient to improve substantially the overall performance indices because these improvements are cancelled effectively by deteriorations at other locations (table 9) and coastal discharges probably are not affected substantially. Any applicable change in Manning's *n* would have to be more physically based than this sensitivity test.

3.7.3 - Neglecting Ground-Water Leakage Effects

A scenario also was made with TIME to investigate the effect of neglecting surface-water and ground-water leakage (run 145). Net-average flows were reduced up to 20 percent in Barron River and 7 percent in Turner River, whereas flows into Ponce De Leon Bay and Florida Bay increased by 8 and 20 percent, respectively.

The spatial distribution of mean stage differences [mean(R142)-mean (R145)] is shown in figure 31, which indicates that neglecting leakage adversely affects all model performance indices (stage means, correlation, and PEV). This effect is due primarily to the substantial changes that occur in ground-water heads, which differ substantially when leakage is neglected. Surface-water stages change slightly at most sites, although substantial differences occur at some locations (table 11). At these sites, however, stage is influenced strongly by ground-water head. By not having any vertical leakage, surface water along the eastern domain boundary flows

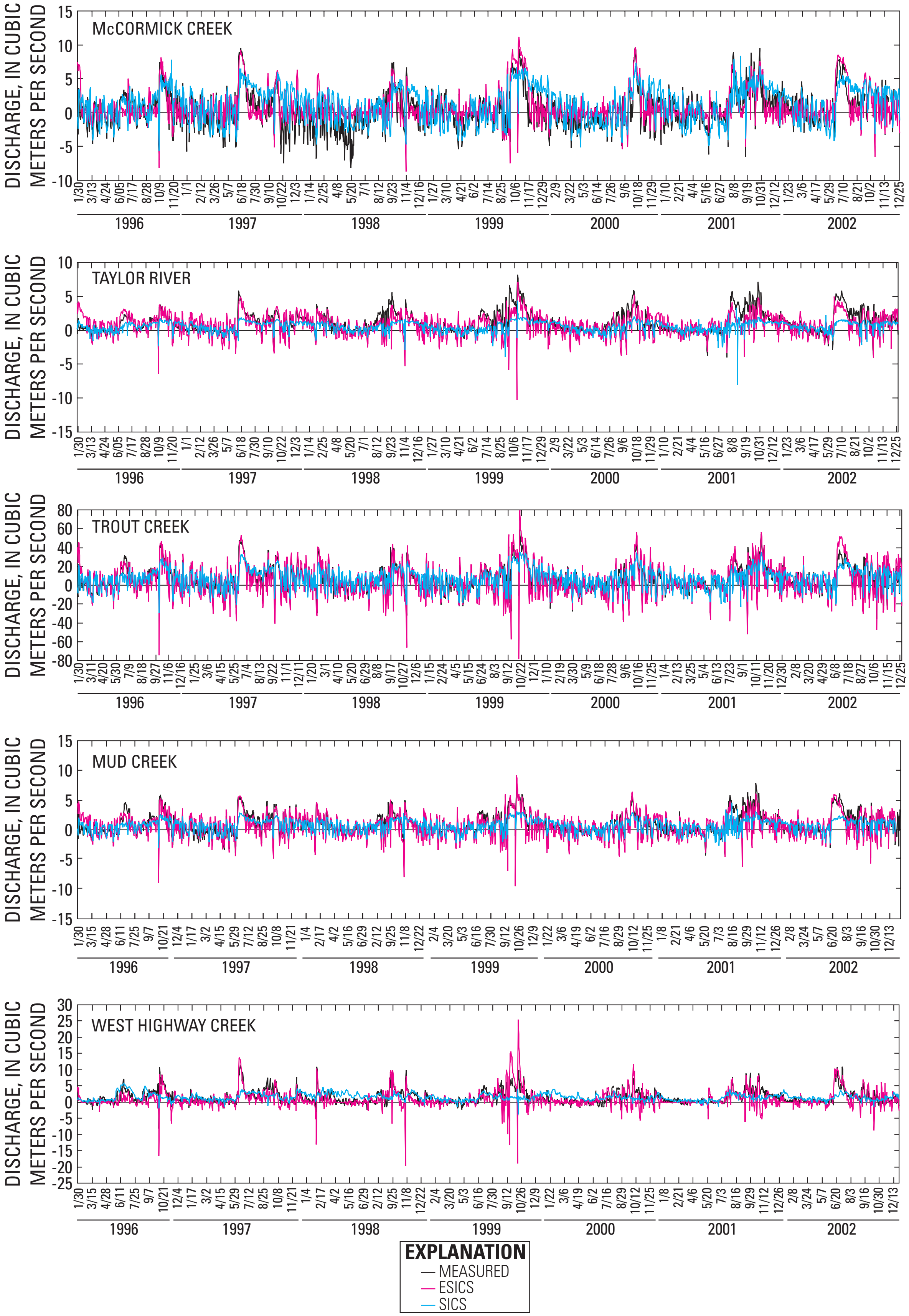

Figure 27. Comparison of flows from field data and the SICS and ESICS applications at selected coastal creeks, 1996-2002.

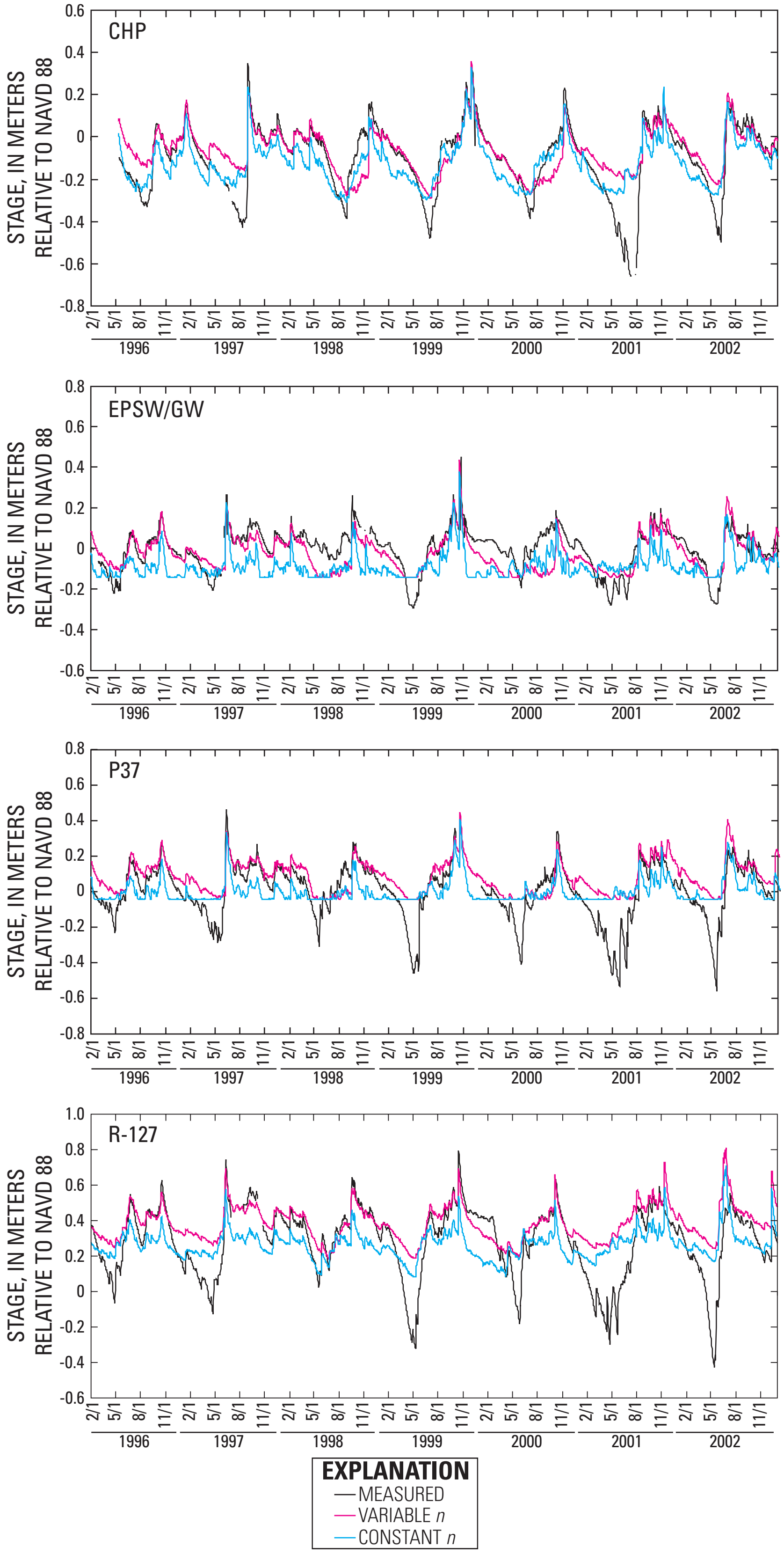

Figure 28. Comparison of wetland stages using constant and variable Manning's *n* values at selected sites.

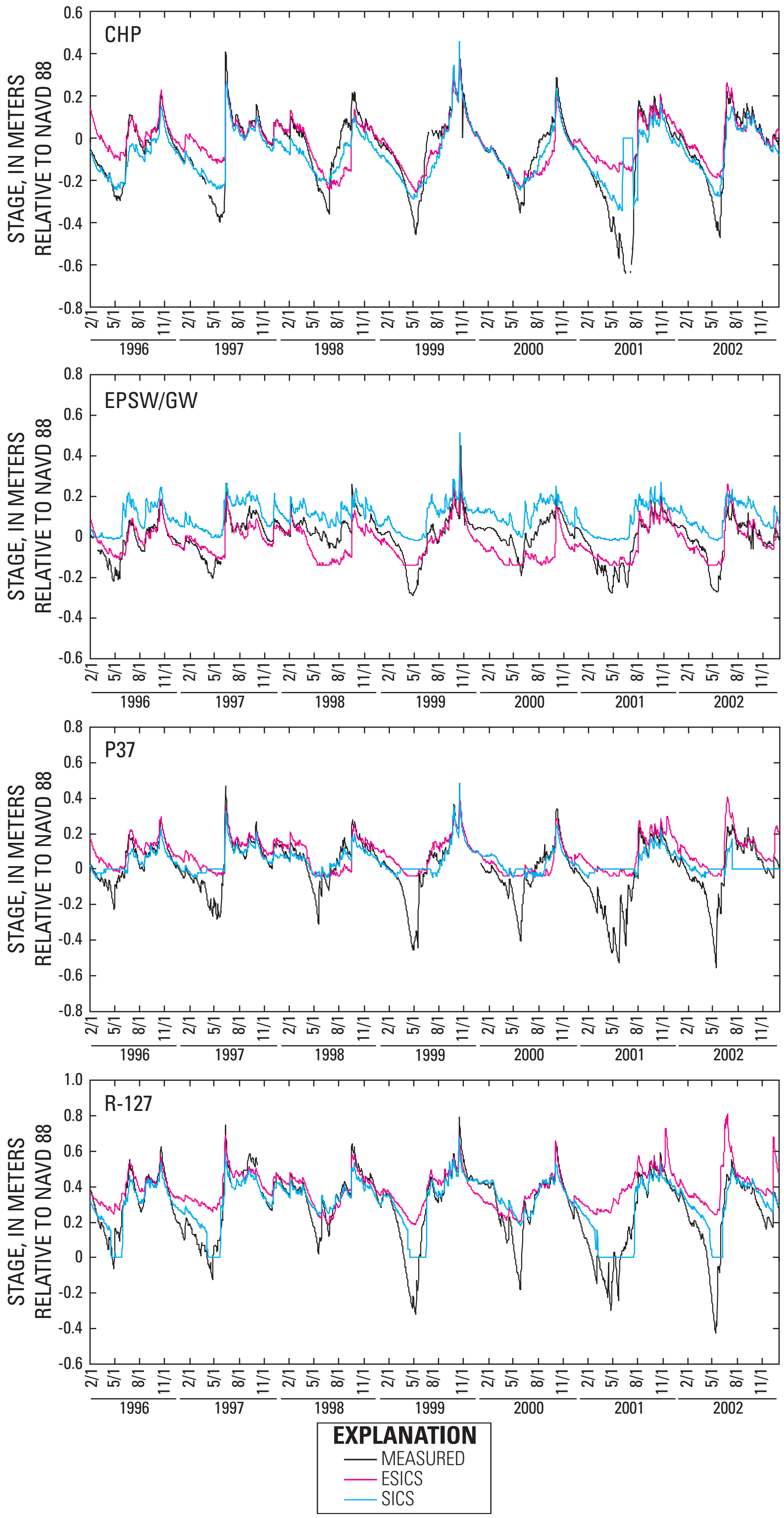

Figure 29. Comparison of stages between the SICS and ESICS applications at selected wetland stations.

Table 9. Water-level comparison statistics for run 139, local Manning's *n* adjustments.

[NAVD 88, North American Vertical Datum of 1988; n, number of points utilized from the time series]

Station	Mean stage (NAVD 88)		Stage standard deviation		Correlation coefficient	Mean difference between measured and computed values		Percentage of explained variance	n	Land surface altitude (NAVD 88)	
	Measured (meters)	Computed (meters)	Measured (meters)	Computed (meters)		Stage (meters)	Standard deviation (meters)			Model input (meters)	Measured (meters)
A13	0.968	1.091	0.259	0.144	0.867	-0.123	0.152	65.4	2197	0.980	0.969
Angels	1.329	1.500	.264	.282	.741	-.171	.197	44.3	2557	1.730	1.451
BD	.826	.062	.123	.088	.412	.764	.118	7.4	1945	.010	2.612
BICYA8	.215	.850	.328	.457	.217	-.635	.501	-133.9	1959	.270	--
BICYA9	1.726	1.853	.211	.189	.763	-.126	.139	56.3	1869	2.060	--
BICYA10	.718	.788	.303	.228	.780	-.071	.190	60.8	1854	.890	--
BICYA11	.920	.938	.380	.172	.718	-.017	.283	44.4	1883	.880	--
BR	1.074	.025	.131	.114	.837	1.049	.072	69.8	2331	-.150	1.838
CN	.713	.025	.123	.079	.860	.688	.068	69.1	2447	-.080	1.323
CP	-.056	-.081	.169	.120	.879	.025	.085	74.4	2479	-.440	-.503
CR2	1.121	1.283	.307	.289	.895	-.162	.138	79.9	2161	1.330	1.231
CR3	1.119	1.270	.298	.228	.879	-.151	.146	75.9	2212	1.310	1.234
CT27R	.143	.082	.148	.126	.570	.062	.128	24.8	1903	-.060	-.085
CT50R	.106	.100	.140	.091	.859	.005	.078	69.3	1896	.010	.088
CV1NR	.121	.080	.149	.128	.400	.041	.153	-5.3	1840	-.060	--
CV5S	.123	.115	.132	.103	.441	.008	.127	7.9	601	-.060	--
CW	-.048	-.065	.103	.126	.486	.017	.118	-31.0	2261	-1.830	--
CYP2	.235	.292	.206	.205	.787	-.057	.134	57.5	2157	.480	1.643
CY3	.202	.195	.214	.169	.785	.008	.133	61.6	2206	.280	1.518
DK	-.207	-.177	.118	.096	.712	-.030	.083	49.6	1317	-1.860	--
DO1	.349	.479	.267	.181	.845	-.130	.149	68.6	2451	.560	.567
DO2	.432	.450	.278	.199	.825	-.018	.160	67.0	2237	.700	.570
E112	.846	.979	.301	.406	.880	-.133	.201	55.7	2320	1.050	.527
E146	-.096	-.083	.147	.132	.864	-.013	.074	74.5	2435	-.210	-.369
EP1R	.044	.065	.132	.120	.415	-.021	.137	-7.1	2406	-.060	-.262
EP9R	-.159	-.117	.087	.057	.840	-.042	.050	67.2	366	-.160	-.314
EPGW/SW	-.015	-.066	.099	.074	.696	.051	.071	48.1	2387	-.110	-.158
EVER4	.170	.327	.145	.174	.925	-.157	.068	78.2	2521	.240	.085
EVER5A	-.097	-.026	.153	.101	.829	-.071	.089	66.0	1945	-.080	-.174
EVER6	.141	.033	.126	.083	.780	.107	.080	59.4	2294	.000	-.006
EVER7	.201	.103	.120	.109	.891	.098	.054	79.3	2342	.040	.131
G1251	.185	.230	.168	.178	.901	-.045	.078	78.7	2026	.230	.390
G1502	1.485	1.697	.242	.143	.780	-.211	.158	57.3	2453	1.580	2.060
G3272	1.491	1.699	.247	.144	.821	-.208	.153	61.8	2528	1.570	1.612
G3273	1.476	1.695	.239	.147	.822	-.219	.145	63.2	2557	1.600	1.667

Table 9. Water-level comparison statistics for run 139, local Manning's *n* adjustments.—Continued

[NAVD 88, North American Vertical Datum of 1988; n, number of points utilized from the time series]

Station	Mean stage (NAVD 88)		Stage standard deviation		Correlation coefficient	Mean difference between measured and computed values		Percentage of explained variance	n	Land surface altitude (NAVD 88)	
	Measured (meters)	Computed (meters)	Measured (meters)	Computed (meters)		Stage (meters)	Standard deviation (meters)			Model input (meters)	Measured (meters)
G3353	-0.058	-0.001	0.137	0.108	0.858	-0.057	0.071	73.0	2519	-0.020	1.149
G3437	1.194	1.124	.259	.273	.682	.070	.213	32.4	2510	1.850	1.615
G3576	1.562	1.698	.207	.113	.898	-.136	.117	68.2	1965	1.370	1.353
G3577	1.426	1.703	.272	.112	.849	-.277	.186	53.0	2014	1.360	1.356
G3578	1.520	1.710	.213	.103	.887	-.190	.131	62.3	2494	1.370	1.356
G3619	.326	.391	.147	.155	.894	-.065	.070	77.5	2446	.210	.579
G3622	.879	1.231	.239	.418	.677	-.352	.311	-68.8	2306	1.390	1.347
G3626	.975	1.122	.174	.304	.409	-.147	.282	-161.8	2357	2.030	1.743
G3627	.860	1.247	.167	.264	.534	-.386	.225	-81.3	2368	1.910	1.942
G3628	1.011	1.473	.203	.396	.497	-.462	.343	-186.0	2336	1.730	1.667
G596	1.146	1.292	.197	.313	.595	-.146	.252	-62.7	2546	1.810	1.753
G618	1.696	1.714	.146	.088	.731	-.018	.101	51.9	2457	1.480	1.466
G620	1.574	1.680	.205	.192	.930	-.106	.075	86.6	2451	1.380	1.311
GI	1.363	-.081	.113	.179	.378	1.444	.172	-130.0	1616	-2.500	--
HC	-.186	.158	.111	.222	.599	-.344	.179	-159.2	1434	.560	--
HR	.931	.017	.119	.144	.624	.915	.116	5.3	1461	.120	--
L67XW	1.761	1.706	.237	.098	.832	.055	.165	51.5	1883	1.350	--
LN	1.524	-.033	.120	.100	.821	1.557	.069	67.4	1430	-.410	--
LO	.818	-.069	.119	.249	.145	.887	.260	-378.1	1335	-2.000	--
LOOP1T	1.910	1.841	.158	.172	.727	.070	.123	39.8	2024	1.860	--
LOOP2T	1.540	1.498	.220	.178	.698	.042	.159	47.4	2086	1.480	--
LS	-.190	-.174	.106	.099	.775	-.016	.069	57.5	1461	-1.520	--
NCL	-.015	-.086	.190	.161	.834	.071	.105	69.5	2390	-.240	--
NE1	1.664	1.711	.131	.093	.903	-.047	.062	77.7	2509	1.290	1.314
NE2	1.627	1.713	.156	.090	.890	-.087	.086	69.4	2503	1.340	1.241
NE3	1.695	1.721	.115	.075	.808	-.027	.070	63.0	1838	1.340	--
NE4	1.606	1.706	.158	.095	.882	-.100	.087	70.0	2416	1.260	1.213
NE5	1.601	1.700	.146	.096	.895	-.100	.074	74.5	2539	1.270	--
NMP	-.118	-.106	.151	.167	.856	-.012	.087	67.1	2113	.010	--
NP201	1.869	1.934	.257	.236	.865	-.065	.130	74.7	2439	1.650	1.420
NP202	1.679	1.752	.196	.183	.970	-.073	.048	94.0	2309	1.350	1.164
NP203	1.471	1.508	.181	.124	.938	-.038	.078	81.6	2426	1.220	.890
NP205	1.478	1.520	.264	.165	.853	-.042	.150	67.6	2447	1.440	1.332
NP206	1.282	1.425	.272	.136	.819	-.143	.179	56.8	2453	1.380	1.366
NP44	.636	.783	.351	.232	.765	-.147	.229	57.4	2342	1.270	1.073
NP46	0.018	-0.018	0.171	0.147	0.740	0.036	0.117	53.3	2429	0.050	-0.052

Table 9. Water-level comparison statistics for run 139, local Manning's *n* adjustments.—Continued

[NAVD 88, North American Vertical Datum of 1988; n, number of points utilized from the time series]

Station	Mean stage (NAVD 88)		Stage standard deviation		Correlation coefficient	Mean difference between measured and computed values		Percentage of explained variance	n	Land surface altitude (NAVD 88)	
	Measured (meters)	Computed (meters)	Measured (meters)	Computed (meters)		Stage (meters)	Standard deviation (meters)			Model input (meters)	Measured (meters)
NP62	.399	.417	.197	.120	.798	-.018	.124	60.1	2229	.310	.835
NP67	.215	.274	.179	.151	.899	-.059	.079	80.4	2406	.240	.582
NP72	.503	.613	.316	.221	.788	-.110	.197	61.3	2222	.980	.899
NR	1.181	-.049	.117	.109	.772	1.230	.077	56.9	1380	-1.200	1.682
NTS1	.841	1.171	.293	.302	.766	-.330	.204	51.7	2457	1.020	1.076
NTS10	.927	1.060	.310	.369	.889	-.133	.170	70.0	2152	1.270	1.237
NTS14	.732	.863	.386	.339	.787	-.131	.241	61.1	2395	1.380	.756
OL1	-.059	-.089	.160	.121	.898	.030	.074	78.7	2447	-.220	--
OT	.251	.152	.189	.150	.916	.099	.079	82.4	2464	-.170	--
P33	1.509	1.558	.148	.095	.930	-.049	.070	78.0	2406	1.230	1.024
P34	.419	.312	.213	.172	.890	.108	.099	78.5	2428	.160	.119
P35	.118	.174	.171	.129	.945	-.056	.065	85.6	2552	-.400	-.195
P36	.868	.886	.146	.094	.920	-.018	.070	77.0	2407	.630	.530
P37	.002	.014	.155	.116	.867	-.012	.079	73.7	2465	-.140	-.183
P38	.069	.047	.148	.110	.836	.022	.082	68.9	2360	-.130	-.192
R127	.267	.363	.197	.147	.932	-.096	.080	83.4	2384	.060	--
R158	.416	.665	.239	.380	.810	-.250	.233	5.2	2445	.980	.927
R3110	.919	1.010	.331	.346	.893	-.091	.157	77.4	2456	1.240	1.094
RG1	1.242	1.605	.284	.124	.723	-.363	.212	44.1	1941	1.460	1.061
RG2	1.138	1.401	.286	.260	.852	-.264	.151	72.2	2108	1.450	1.390
Rutzke	.940	1.089	.260	.390	.804	-.149	.238	16.2	2432	1.510	1.103
S12AT	2.182	2.091	.288	.191	.878	.091	.151	72.5	2530	1.870	--
S12BT	2.205	2.142	.317	.248	.956	.063	.108	88.4	2532	1.860	--
S12CT	2.239	2.288	.323	.250	.829	-.049	.181	68.5	2520	1.870	--
S12DT	2.209	2.140	.419	.279	.819	.069	.249	64.7	2526	1.690	--
SP	.211	.263	.217	.176	.770	-.052	.139	59.2	2188	.480	.280
SR	.886	-.097	.109	.216	.260	.983	.215	-290.9	1354	-2.800	--
TE	1.242	.016	.127	.093	.857	1.226	.067	71.9	1438	-.190	--
TMC	.902	.894	.239	.133	.892	.008	.135	68.3	2232	.770	.732
TSB	.628	.854	.278	.248	.961	-.226	.080	91.8	1327	.490	.610
TSH	.156	.178	.163	.141	.911	-.022	.068	82.7	2445	.000	-.021
WE	1.611	-.053	.114	.122	.631	1.664	.102	20.3	1461	-1.610	--
WP	1.365	-.029	.128	.171	.385	1.394	.169	-74.6	1096	-1.870	--
WW	1.435	.047	.151	.144	.853	1.388	.080	71.8	1461	-.230	--

Table 10. Water-level comparison statistics for run 142, base case simulation.

[NAVD 88, North American Vertical Datum of 1988; n, number of points utilized from the time series]

Station	Mean stage (NAVD 88)		Stage standard deviation		Correlation coefficient	Mean difference between measured and computed values		Percentage of explained variance	n	Land surface altitude (NAVD 88)	
	Measured (meters)	Computed (meters)	Measured (meters)	Computed (meters)		Stage (meters)	Standard deviation (meters)			Model input (meters)	Measured (meters)
A13	0.968	1.077	0.259	0.161	0.861	-0.109	0.145	68.5	2,197	0.980	0.969
Angels	1.329	1.534	.264	.285	.719	-.206	.207	38.9	2,557	1.730	1.451
BD	.826	.062	.123	.089	.407	.764	.119	6.1	1,945	.010	2.612
BICYA8	.215	.848	.328	.457	.223	-.633	.499	-132.6	1,959	.270	--
BICYA9	1.726	1.849	.211	.188	.761	-.123	.139	56.3	1,869	2.060	--
BICYA10	.718	.786	.303	.228	.781	-.068	.189	61.0	1,854	.890	--
BICYA11	.920	.938	.380	.171	.715	-.018	.284	44.2	1,883	.880	--
BR	1.074	.026	.131	.116	.837	1.048	.072	69.8	2,331	-.150	1.838
CN	.713	.026	.123	.082	.867	.688	.066	71.1	2,447	-.080	1.323
CP	-.056	-.081	.169	.120	.879	.025	.085	74.4	2,479	-.440	-.503
CR2	1.121	1.256	.307	.302	.896	-.136	.139	79.6	2,161	1.330	1.231
CR3	1.119	1.249	.298	.244	.868	-.130	.149	75.1	2,212	1.310	1.234
CT27R	.143	.082	.148	.126	.570	.062	.128	24.8	1,903	-.060	-.085
CT50R	.106	.100	.140	.091	.858	.006	.078	69.1	1,896	.010	.088
CV1NR	.121	.080	.149	.128	.399	.041	.153	-5.4	1,840	-.060	--
CV5S	.123	.115	.132	.103	.441	.008	.127	7.9	601	-.060	--
CW	-.048	-.065	.103	.126	.485	.017	.118	-31.3	2,261	-1.830	--
CYP2	.235	.290	.206	.206	.787	-.055	.134	57.2	2,157	.480	1.643
CY3	.202	.194	.214	.170	.783	.008	.133	61.2	2,206	.280	1.518
DK	-.207	-.177	.118	.096	.712	-.030	.083	49.7	1,317	-1.860	--
DO1	.349	.477	.267	.182	.844	-.129	.149	68.6	2,451	.560	.567
DO2	.432	.448	.278	.202	.828	-.016	.158	67.5	2,237	.700	.570
E112	.846	.976	.301	.406	.875	-.130	.204	54.3	2,320	1.050	.527
E146	-.096	-.083	.147	.133	.863	-.012	.075	74.2	2,435	-.210	-.369
EP1R	.044	.065	.132	.120	.415	-.021	.137	-7.0	2,406	-.060	-.262
EP9R	-.159	-.117	.087	.057	.838	-.042	.050	66.8	366	-.160	-.314
EPGW/SW	-.015	-.066	.099	.074	.696	.051	.071	48.2	2,387	-.110	-.158
EVER4	.170	.326	.145	.175	.924	-.156	.069	77.7	2,521	.240	.085
EVER5A	-.097	-.027	.153	.101	.830	-.070	.089	66.1	1,945	-.080	-.174
EVER6	.141	.033	.126	.083	.777	.107	.081	59.0	2,294	.000	-.006
EVER7	.201	.103	.120	.109	.889	.099	.055	79.0	2,342	.040	.131
G1251	.185	.230	.168	.178	.899	-.044	.078	78.4	2,026	.230	.390
G1502	1.485	1.700	.242	.132	.749	-.214	.168	51.9	2,453	1.580	2.060
G3272	1.491	1.716	.247	.143	.792	-.225	.160	58.1	2,528	1.570	1.612
G3273	1.476	1.705	.239	.138	.793	-.229	.155	58.3	2,557	1.600	1.667
G3353	-0.058	-0.002	0.137	0.108	0.857	-0.056	0.071	72.9	2,519	-0.020	1.149

Table 10. Water-level comparison statistics for run 142, base case simulation.—Continued

[NAVD 88, North American Vertical Datum of 1988; n, number of points utilized from the time series]

Station	Mean stage (NAVD 88)		Stage standard deviation		Correlation coefficient	Mean difference between measured and computed values		Percentage of explained variance	n	Land surface altitude (NAVD 88)	
	Measured (meters)	Computed (meters)	Measured (meters)	Computed (meters)		Stage (meters)	Standard deviation (meters)			Model input (meters)	Measured (meters)
G3437	1.194	1.118	.259	.277	.683	.076	.214	31.6	2,510	1.850	1.615
G3576	1.562	1.725	.207	.105	.902	-.163	.121	65.8	1,965	1.370	1.353
G3577	1.426	1.728	.272	.096	.885	-.302	.193	49.8	2,014	1.360	1.356
G3578	1.520	1.733	.213	.094	.872	-.214	.139	57.4	2,494	1.370	1.356
G3619	.326	.390	.147	.154	.894	-.064	.070	77.5	2,446	.210	.579
G3622	.879	1.218	.239	.419	.670	-.339	.314	-72.5	2,306	1.390	1.347
G3626	.975	1.111	.174	.287	.423	-.136	.265	-131.9	2,357	2.030	1.743
G3627	.860	1.247	.167	.263	.558	-.387	.219	-71.8	2,368	1.910	1.942
G3628	1.011	1.466	.203	.398	.482	-.455	.349	-194.9	2,336	1.730	1.667
G596	1.146	1.330	.197	.334	.598	-.184	.268	-84.1	2,546	1.810	1.753
G618	1.696	1.740	.146	.087	.804	-.044	.092	60.4	2,457	1.480	1.466
G620	1.574	1.578	.205	.179	.928	-.004	.078	85.7	2,451	1.380	1.311
GI	1.363	-.082	.113	.179	.385	1.445	.171	-126.7	1,616	-2.500	--
HC	-.186	.158	.111	.221	.599	-.343	.178	-157.7	1,434	.560	--
HR	.931	.018	.119	.144	.626	.913	.116	5.0	1,461	.120	--
L67XW	1.761	1.720	.237	.090	.743	.040	.181	41.9	1,883	1.350	--
LN	1.524	-.033	.120	.101	.821	1.557	.069	67.3	1,430	-.410	--
LO	.818	-.070	.119	.248	.141	.888	.260	-377.9	1,335	-2.000	--
LOOP1T	1.910	1.837	.158	.170	.722	.073	.123	39.7	2,024	1.860	--
LOOP2T	1.540	1.494	.220	.181	.712	.046	.156	49.5	2,086	1.480	--
LS	-.190	-.173	.106	.098	.777	-.017	.069	58.0	1,461	-1.520	--
NCL	-.015	-.086	.190	.162	.834	.071	.105	69.5	2,390	-.240	--
NE1	1.664	1.727	.131	.088	.853	-.063	.072	69.4	2,509	1.290	1.314
NE2	1.627	1.737	.156	.087	.863	-.110	.092	65.2	2,503	1.340	1.241
NE3	1.695	1.748	.115	.069	.774	-.054	.075	56.9	1,838	1.340	--
NE4	1.606	1.705	.158	.086	.835	-.099	.098	61.4	2,416	1.260	1.213
NE5	1.601	1.687	.146	.085	.854	-.086	.086	65.6	2,539	1.270	--
NMP	-.118	-.106	.151	.167	.856	-.012	.087	66.9	2,113	.010	--
NP201	1.869	1.825	.257	.183	.855	.044	.139	71.0	2,439	1.650	1.420
NP202	1.679	1.646	.196	.156	.960	.033	.063	89.5	2,309	1.350	1.164
NP203	1.471	1.467	.181	.126	.920	.004	.082	79.7	2,426	1.220	.890
NP205	1.478	1.484	.264	.179	.828	-.006	.153	66.2	2,447	1.440	1.332
NP206	1.282	1.380	.272	.170	.851	-.098	.156	67.2	2,453	1.380	1.366
NP44	.636	.777	.351	.237	.771	-.141	.226	58.5	2,342	1.270	1.073
NP46	.018	-.017	.171	.148	.742	.035	.117	53.6	2,429	.050	-.052
NP62	0.399	0.418	0.197	0.128	0.811	-0.019	0.119	63.2	2,229	0.310	0.835
NP67	.215	.273	.179	.151	.899	-.058	.079	80.5	2,406	.240	.582

Table 10. Water-level comparison statistics for run 142, base case simulation.—Continued

[NAVD 88, North American Vertical Datum of 1988; n, number of points utilized from the time series]

Station	Mean stage (NAVD 88)		Stage standard deviation		Correlation coefficient	Mean difference between measured and computed values		Percentage of explained variance	n	Land surface altitude (NAVD 88)	
	Measured (meters)	Computed (meters)	Measured (meters)	Computed (meters)		Stage (meters)	Standard deviation (meters)			Model input (meters)	Measured (meters)
NP72	.503	.610	.316	.223	.785	-.107	.198	60.9	2,222	.980	.899
NR	1.181	-.048	.117	.110	.773	1.230	.077	56.9	1,380	-1.200	1.682
NTS1	.841	1.168	.293	.302	.765	-.327	.204	51.3	2,457	1.020	1.076
NTS10	.927	1.047	.310	.370	.884	-.120	.174	68.6	2,152	1.270	1.237
NTS14	.732	.856	.386	.339	.787	-.124	.241	61.2	2,395	1.380	.756
OL1	-.059	-.090	.160	.121	.897	.031	.074	78.6	2,447	-.220	--
OT	.251	.149	.189	.160	.905	.102	.081	81.5	2,464	-.170	--
P33	1.509	1.532	.148	.104	.919	-.023	.067	79.6	2,406	1.230	1.024
P34	.419	.259	.213	.156	.855	.160	.113	71.6	2,428	.160	.119
P35	.118	.176	.171	.141	.947	-.058	.059	88.2	2,552	-.400	-.195
P36	.868	.888	.146	.109	.908	-.020	.066	79.7	2,407	.630	.530
P37	.002	.013	.155	.116	.866	-.012	.080	73.6	2,465	-.140	-.183
P38	.069	.049	.148	.115	.849	.020	.079	71.5	2,360	-.130	-.192
R127	.267	.362	.197	.147	.931	-.095	.081	83.3	2,384	.060	--
R158	.416	.664	.239	.380	.810	-.248	.233	4.8	2,445	.980	.927
R3110	.919	.999	.331	.349	.893	-.080	.159	77.0	2,456	1.240	1.094
RG1	1.242	1.589	.284	.128	.673	-.347	.219	40.4	1,941	1.460	1.061
RG2	1.138	1.357	.286	.278	.828	-.220	.166	66.4	2,108	1.450	1.390
Rutzke	.940	1.068	.260	.385	.800	-.128	.236	17.6	2,432	1.510	1.103
S12AT	2.182	2.069	.288	.173	.811	.113	.179	61.5	2,530	1.870	--
S12BT	2.205	2.051	.317	.172	.886	.154	.183	66.7	2,532	1.860	--
S12CT	2.239	2.182	.323	.184	.484	.057	.284	22.6	2,520	1.870	--
S12DT	2.209	2.064	.419	.222	.686	.144	.311	44.7	2,526	1.690	--
SP	.211	.262	.217	.180	.777	-.052	.137	60.0	2,188	.480	.280
SR	.886	-.097	.109	.216	.264	.983	.215	-290.6	1,354	-2.800	--
TE	1.242	.016	.127	.095	.858	1.226	.067	72.3	1,438	-.190	--
TMC	.902	.894	.239	.153	.885	.008	.126	72.3	2,232	.770	.732
TSB	.628	.852	.278	.247	.959	-.224	.082	91.4	1,327	.490	.610
TSH	.156	.176	.163	.142	.910	-.020	.068	82.6	2,445	.000	-.021
WE	1.611	-.054	.114	.122	.632	1.664	.101	20.5	1,461	-1.610	--
WP	1.365	-.031	.128	.167	.376	1.396	.168	-71.8	1,096	-1.870	--
WW	1.435	.043	.151	.145	.856	1.392	.080	72.1	1,461	-.230	--

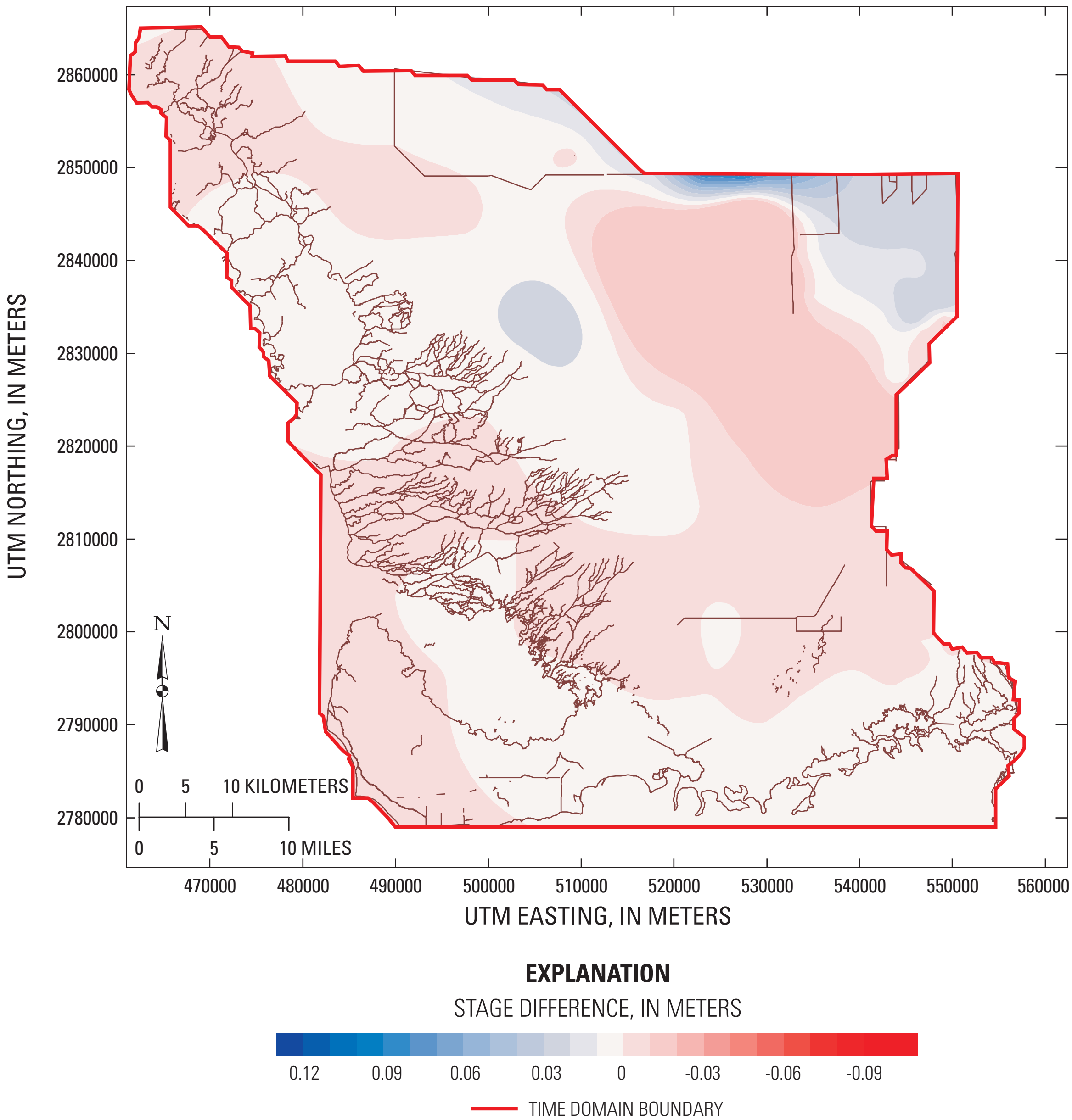

Figure 30. Spatial distribution of mean stage difference between simulations with adjusted Manning's *n*. Positive values indicate better fit, and negative values indicate a poorer fit.

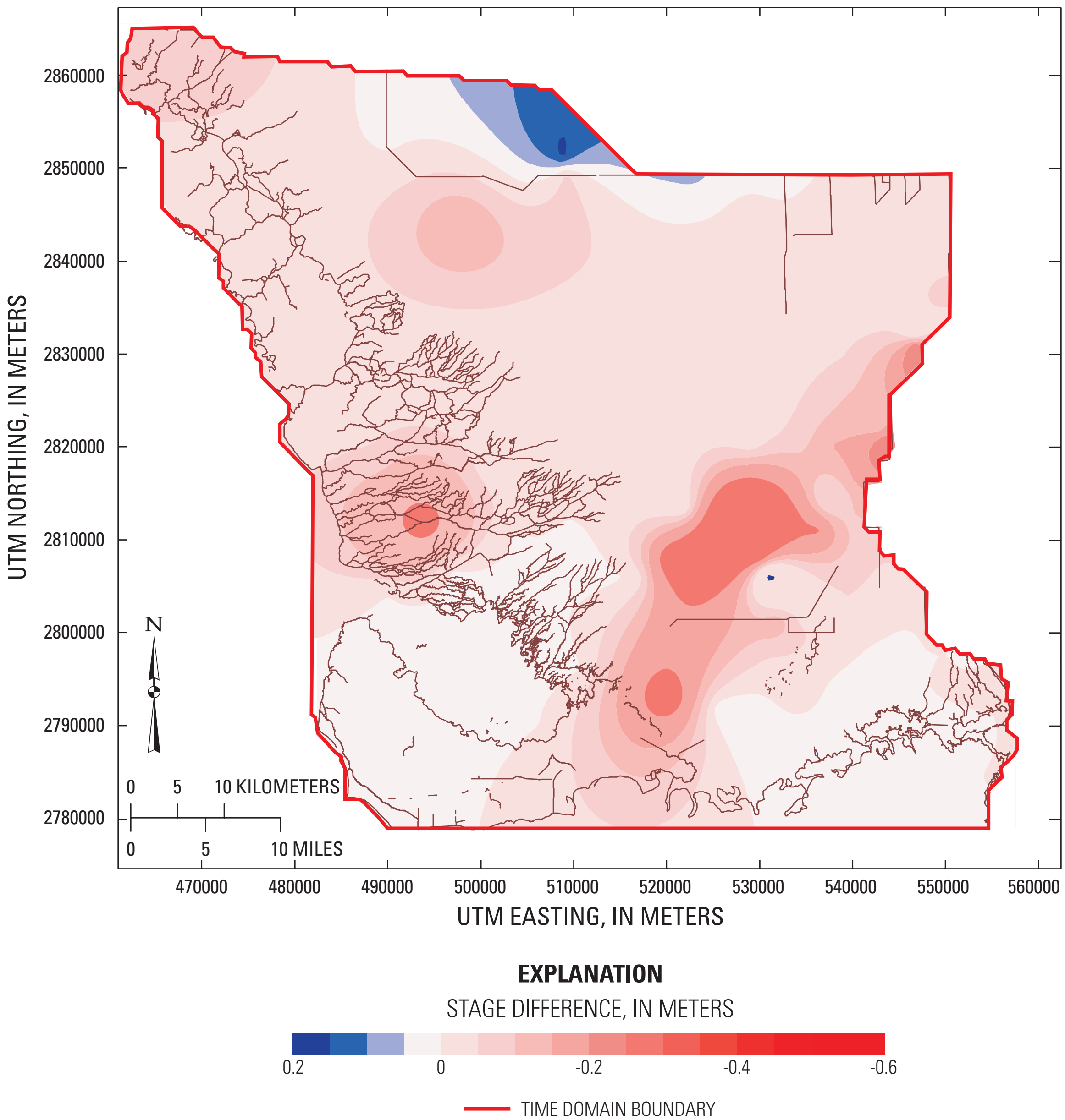

Figure 31. Spatial distribution of mean stage difference between simulations with and without leakage. Positive values indicate better fit, and negative values indicate a poorer fit.

Table 11. Water-level comparison statistics for run 145, leakage neglected.

[NAVD 88, North American Vertical Datum of 1988; n, number of points utilized from the time series]

Station	Mean stage (NAVD 88)		Stage standard deviation		Correlation coefficient	Mean difference between measured and computed values		Percentage of explained variance	n	Land surface altitude (NAVD 88)	
	Measured (meters)	Computed (meters)	Measured (meters)	Computed (meters)		Stage (meters)	Standard deviation (meters)			Model input (meters)	Measured (meters)
A13	0.968	1.093	0.259	0.221	0.664	-0.125	0.200	40.5	2,197	0.980	0.969
Angels	1.329	1.545	.264	.383	.656	-.216	.289	-19.9	2,557	1.730	1.451
BD	.826	-.006	.123	.247	.412	.832	.226	-240.6	1,945	.010	2.612
BICYA8	.215	.934	.328	.462	.283	-.718	.485	-119.3	1,959	.270	--
BICYA9	1.726	1.691	.211	.282	.614	.035	.225	-14.3	1,869	2.060	--
BICYA10	.718	.616	.303	.406	.633	.101	.317	-9.8	1,854	.890	--
BICYA11	.920	.932	.380	.208	.588	-.012	.308	34.4	1,883	.880	--
BR	1.074	.011	.131	.160	.767	1.063	.103	38.0	2,331	-.150	1.838
CN	.713	.017	.123	.123	.760	.696	.085	52.0	2,447	-.080	1.323
CP	-.056	-.053	.169	.101	.828	-.003	.102	63.4	2,479	-.440	-.503
CR2	1.121	1.409	.307	.237	.610	-.289	.248	34.7	2,161	1.330	1.231
CR3	1.119	1.335	.298	.266	.613	-.215	.249	29.8	2,212	1.310	1.234
CT27R	.143	.088	.148	.142	.593	.055	.131	21.5	1,903	-.060	-.085
CT50R	.106	.119	.140	.092	.853	-.013	.078	68.9	1,896	.010	.088
CV1NR	.121	.091	.149	.136	.455	.029	.149	-0.5	1,840	-.060	--
CV5S	.123	.128	.132	.119	.480	-.005	.129	5.5	601	-.060	--
CW	-.048	-.064	.103	.127	.485	.016	.119	-32.9	2,261	-1.830	--
CYP2	.235	.153	.206	.336	.603	.082	.268	-70.1	2,157	.480	1.643
CY3	.202	.001	.214	.323	.531	.201	.277	-67.3	2,206	.280	1.518
DK	-.207	-.177	.118	.096	.713	-.030	.083	49.8	1,317	-1.860	--
DO1	.349	.281	.267	.335	.548	.068	.292	-20.1	2,451	.560	.567
DO2	.432	.011	.278	.310	.354	.421	.335	-45.7	2,237	.700	.570
E112	.846	1.058	.301	.401	.870	-.212	.204	54.3	2,320	1.050	.527
E146	-.096	-.062	.147	.140	.768	-.034	.098	55.6	2,435	-.210	-.369
EP1R	.044	.076	.132	.130	.462	-.032	.136	-5.7	2,406	-.060	-.262
EP9R	-.159	-.118	.087	.070	.864	-.041	.044	74.3	366	-.160	-.314
EPGW/SW	-.015	-.072	.099	.093	.758	.057	.067	54.0	2,387	-.110	-.158
EVER4	.170	.374	.145	.160	.881	-.204	.076	72.7	2,521	.240	.085
EVER5A	-.097	-.044	.153	.134	.899	-.053	.067	80.8	1,945	-.080	-.174
EVER6	.141	.033	.126	.096	.816	.108	.073	66.3	2,294	.000	-.006
EVER7	.201	.123	.120	.118	.872	.078	.060	74.8	2,342	.040	.131
G1251	.185	.245	.168	.208	.873	-.060	.102	63.2	2,026	.230	.390
G1502	1.485	1.736	.242	.103	.627	-.250	.195	35.2	2,453	1.580	2.060
G3272	1.491	1.744	.247	.144	.734	-.253	.172	51.6	2,528	1.570	1.612
G3273	1.476	1.732	.239	.151	.703	-.256	.171	48.9	2,557	1.600	1.667
G3353	-0.058	-0.020	0.137	0.142	0.891	-0.038	0.065	77.3	2,519	-0.020	1.149

Table 11. Water-level comparison statistics for run 145, leakage neglected.—Continued

[NAVD 88, North American Vertical Datum of 1988; n, number of points utilized from the time series]

Station	Mean stage (NAVD 88)		Stage standard deviation		Correlation coefficient	Mean difference between measured and computed values		Percentage of explained variance	n	Land surface altitude (NAVD 88)	
	Measured (meters)	Computed (meters)	Measured (meters)	Computed (meters)		Stage (meters)	Standard deviation (meters)			Model input (meters)	Measured (meters)
G3437	1.194	.968	.259	.353	.557	.226	.300	-34.3	2,510	1.850	1.615
G3576	1.562	1.747	.207	.092	.861	-.185	.136	56.7	1,965	1.370	1.353
G3577	1.426	1.750	.272	.089	.861	-.324	.201	45.5	2,014	1.360	1.356
G3578	1.520	1.757	.213	.088	.829	-.237	.148	51.4	2,494	1.370	1.356
G3619	.326	.431	.147	.149	.886	-.105	.071	76.9	2,446	.210	.579
G3622	.879	1.469	.239	.205	.515	-.591	.221	14.6	2,306	1.390	1.347
G3626	.975	1.095	.174	.345	.388	-.120	.321	-239.2	2,357	2.030	1.743
G3627	.860	1.166	.167	.391	.418	-.305	.355	-352.0	2,368	1.910	1.942
G3628	1.011	1.721	.203	.273	.342	-.710	.279	-88.4	2,336	1.730	1.667
G596	1.146	1.402	.197	.420	.531	-.256	.357	-227.0	2,546	1.810	1.753
G618	1.696	1.753	.146	.089	.783	-.058	.094	58.3	2,457	1.480	1.466
G620	1.574	1.545	.205	.247	.886	.029	.115	68.4	2,451	1.380	1.311
GI	1.363	-.079	.113	.179	.378	1.442	.172	-129.5	1,616	-2.500	--
HC	-.186	.184	.111	.241	.567	-.370	.200	-224.8	1,434	.560	--
HR	.931	-.320	.119	.422	.573	1.251	.367	-846.6	1,461	.120	--
L67XW	1.761	1.735	.237	.089	.694	.025	.187	38.0	1,883	1.350	--
LN	1.524	-.030	.120	.100	.821	1.554	.069	67.3	1,430	-.410	--
LO	.818	-.068	.119	.249	.147	.886	.260	-376.4	1,335	-2.000	--
LOOP1T	1.910	1.779	.158	.261	.682	.131	.192	-47.0	2,024	1.860	--
LOOP2T	1.540	1.480	.220	.250	.526	.060	.230	-9.9	2,086	1.480	--
LS	-.190	-.178	.106	.103	.786	-.011	.068	58.3	1,461	-1.520	--
NCL	-.015	-.051	.190	.153	.730	.036	.130	52.7	2,390	-.240	--
NE1	1.664	1.744	.131	.087	.805	-.081	.080	62.8	2,509	1.290	1.314
NE2	1.627	1.756	.156	.085	.801	-.129	.101	57.7	2,503	1.340	1.241
NE3	1.695	1.766	.115	.070	.718	-.071	.081	50.5	1,838	1.340	--
NE4	1.606	1.722	.158	.085	.788	-.116	.105	55.9	2,416	1.260	1.213
NE5	1.601	1.703	.146	.084	.810	-.103	.093	59.9	2,539	1.270	--
NMP	-.118	-.444	.151	.386	.683	.326	.304	-304.7	2,113	.010	--
NP201	1.869	1.807	.257	.205	.865	.061	.130	74.4	2,439	1.650	1.420
NP202	1.679	1.644	.196	.158	.957	.036	.064	89.4	2,309	1.350	1.164
NP203	1.471	1.471	.181	.126	.912	.000	.084	78.4	2,426	1.220	.890
NP205	1.478	1.448	.264	.260	.722	.031	.195	45.2	2,447	1.440	1.332
NP206	1.282	1.414	.272	.222	.614	-.133	.222	33.8	2,453	1.380	1.366
NP44	.636	.187	.351	.279	.050	.449	.438	-55.2	2,342	1.270	1.073
NP46	.018	-.241	.171	.322	.556	.259	.268	-145.0	2,429	.050	-.052
NP62	0.399	0.402	0.197	0.206	0.745	-0.003	0.144	46.3	2,229	0.310	0.835
NP67	.215	.302	.179	.172	.790	-.086	.114	59.4	2,406	.240	.582

Table 11. Water-level comparison statistics for run 145, leakage neglected.—Continued

[NAVD 88, North American Vertical Datum of 1988; n, number of points utilized from the time series]

Station	Mean stage (NAVD 88)		Stage standard deviation		Correlation coefficient	Mean difference between measured and computed values		Percentage of explained variance	n	Land surface altitude (NAVD 88)	
	Measured (meters)	Computed (meters)	Measured (meters)	Computed (meters)		Stage (meters)	Standard deviation (meters)			Model input (meters)	Measured (meters)
NP72	.503	.168	.316	.353	.277	.335	.403	-62.6	2,222	.980	.899
NR	1.181	-.046	.117	.110	.772	1.228	.077	56.8	1,380	-1.200	1.682
NTS1	.841	1.292	.293	.133	.920	-.451	.178	62.9	2,457	1.020	1.076
NTS10	.927	1.185	.310	.404	.748	-.258	.268	25.4	2,152	1.270	1.237
NTS14	.732	.591	.386	.540	.596	.141	.439	-28.9	2,395	1.380	.756
OL1	-.059	-.075	.160	.128	.863	.016	.081	74.1	2,447	-.220	--
OT	.251	.152	.189	.154	.877	.098	.092	76.5	2,464	-.170	--
P33	1.509	1.540	.148	.102	.902	-.031	.072	76.7	2,406	1.230	1.024
P34	.419	.240	.213	.197	.823	.179	.123	66.8	2,428	.160	.119
P35	.118	.187	.171	.141	.945	-.069	.059	87.9	2,552	-.400	-.195
P36	.868	.900	.146	.108	.889	-.032	.071	76.7	2,407	.630	.530
P37	.002	.040	.155	.105	.804	-.039	.094	63.0	2,465	-.140	-.183
P38	.069	.045	.148	.148	.802	.024	.093	60.4	2,360	-.130	-.192
R127	.267	.413	.197	.123	.902	-.146	.101	73.6	2,384	.060	--
R158	.416	.734	.239	.401	.735	-.319	.277	-34.6	2,445	.980	.927
R3110	.919	.986	.331	.497	.881	-.067	.259	38.8	2,456	1.240	1.094
RG1	1.242	1.644	.284	.073	.681	-.402	.240	28.3	1,941	1.460	1.061
RG2	1.138	1.464	.286	.289	.588	-.326	.261	16.7	2,108	1.450	1.390
Rutzke	.940	1.174	.260	.478	.754	-.234	.330	-61.0	2,432	1.510	1.103
S12AT	2.182	2.122	.288	.197	.514	.060	.252	23.5	2,530	1.870	--
S12BT	2.205	2.116	.317	.197	.480	.089	.282	21.1	2,532	1.860	--
S12CT	2.239	2.195	.323	.183	.411	.044	.299	14.4	2,520	1.870	--
S12DT	2.209	2.076	.419	.221	.607	.133	.335	36.2	2,526	1.690	--
SP	.211	-.089	.217	.283	.313	.299	.298	-88.8	2,188	.480	.280
SR	.886	-.096	.109	.216	.267	.982	.214	-288.9	1,354	-2.800	--
TE	1.242	.019	.127	.095	.856	1.223	.067	72.2	1,438	-.190	--
TMC	.902	.877	.239	.219	.759	.025	.160	55.1	2,232	.770	.732
TSB	.628	.950	.278	.186	.957	-.322	.114	83.2	1,327	.490	.610
TSH	.156	.216	.163	.136	.855	-.060	.085	73.1	2,445	.000	-.021
WE	1.611	-.052	.114	.122	.635	1.663	.101	20.9	1,461	-1.610	--
WP	1.365	-.029	.128	.169	.383	1.394	.169	-72.8	1,096	-1.870	--
WW	1.435	.047	.151	.143	.857	1.389	.079	72.7	1,461	-.230	--

westward and southward instead of recharging the aquifer and moving eastward. This "surplus" surface water primarily increases flows to Florida Bay and Ponce de Leon Bay (fig. 1). Mean stage improves locally near OIH and Forty-Mile Bend; these areas may have less conductive peat layers, which if confirmed, could be placed in the model.

3.7.4 - Sensitivity to Incorporation of Main Park Road as a Barrier

A scenario (run 143) was made to investigate the effect of Main Park Road (fig. 1) functioning as a complete barrier to flow. Redirection of Main Park Road flows caused TSB flows to increase by 10 percent; however, total flow to Florida Bay remained unchanged. The presence of the road influenced the local distribution and timing of flow; however, the changes in total flow and individual creekflows were negligible. The TSB flows are in better agreement with observations when the road is not included as a barrier in the model, indicating that the culverts convey enough flow to prevent the road from being an effective barrier. The model results are consistent with the earlier assumption that the road is not a substantial barrier to coastal flows. Stage comparison statistics are provided in table 12, and a comparison of all stage means with those from run 142 is shown in figure 32. The only noticeable changes occur near Main Park Road; therefore, including this road as a barrier has a negligible effect on overall model performance indices (table 12).

3.7.5 - Sensitivity to Lowering of Land-Surface Altitude

To test the sensitivity of model response to a vertical shift in topography, the model land surface was lowered by 0.1 m throughout the model domain in run 146. Subgrid-scale topographic variations could be on this order of magnitude. As expected, the stages also were lowered by about 0.1 m in most places, except near the coast where the prescribed sea-level conditions at the boundaries control stages. Although some stage differences showed substantial deterioration, others such as RG1 (location shown in fig. 3) improved. Overall, the stage comparison statistics in table 13 do not improve definitively compared to the base run. The spatial plot of the mean stage difference is more informative; lowering the land surface improves the predicted mean stage in the eastern and northwestern areas of the domain, and worsens mean stage in the Shark River Slough area (figs. 1 and 33). This result may indicate that the model topography does not match the true topography uniformly well around the study area. A better fit with recorded stages might be achieved with further adjustment of the model land-surface altitudes and friction coefficients; however, such adjustments were not made because an objective procedure has yet to be devised. The topographic shift affected flows by redistributing volumes between the different rivers, although total flow to the coast was minimally affected. Runoff from Chatham and Lostmans Rivers increased by about 10 percent, runoff to Ponce de Leon Bay decreased by 10 percent, and runoff to Florida Bay increased by 20 percent.

3.8 - Final Model Calibration – Run 157

Based on the results from the base run and sensitivity analyses, a final model calibration (run 157) was performed to improve model performance prior to scenario simulation. The final model calibration addressed the following problems with the initially calibrated TIME model (run 142): (1) underprediction of stage in the northwestern region of the TIME domain; (2) discrepancies in mean stage values and explained variances near parts of Levee 31N Canal, Levee-31W Canal and C-111 Canal; and (3) a tendency to underpredict the ground-water table decline during dry seasons, especially in areas where unsaturated zones of substantial depth, on the order of 1 m, are present.

3.8.1 - Northwestern Region

Few surface-water stage measurement sites exist in the northwestern region of the domain (fig. 9). Consequently, model comparison results in this area (fig. 16) are based entirely on measured data from gage BICYA8 (fig. 9) and indicate that model mean stage is higher than observed stage. Gage BICYA8 is located along Turner River just north of U.S. Highway 41. Turner River Road to the east (fig. 1) obstructs flow; and stage on the east side of the road is usually much higher (R. Sobczak, Big Cypress National Preserve, oral commun., 2005). The gage more closely represents river stage than wetland stage and thus, is lower because of the hydraulic connection between the river and ocean. Based on this information, Turner River was included in the model topography and the model cell used to compare computed stage to BICYA8 was placed in the river at row 168, column 24 of the model grid (fig. 3). The results in table 5 show a much better model fit in stage mean bias and explained variance.

3.8.2 - Levee 31 Area

In the area just west of Levee 31 (fig. 1), computed mean stage is too high (fig. 16). It is difficult to identify with complete certainty the factors that contribute to these discrepancies. Gage information taken from the station descriptions indicates that the model-input land-surface altitude used in the TIME application may be substantially higher than the actual land-surface altitude at the gage. This would allow standing surface water at a gage located in a dry model cell. If surface water was present, computed stage was used to compute statistics; however, some gages are believed to measure only ground water even when surface water is present (that is, G-prefix gages). In addition to these inherent problems, adequate data are not available to fully prescribe boundary stages.

Table 12. Water-level comparison statistics for run 143, Main Park Road as a barrier.

[NAVD 88, North American Vertical Datum of 1988; n, number of points utilized from the time series]

Station	Mean stage (NAVD 88)		Stage standard deviation		Correlation coefficient	Mean difference between measured and computed values		Percentage of explained variance	n	Land surface altitude (NAVD 88)	
	Measured (meters)	Computed (meters)	Measured (meters)	Computed (meters)		Stage (meters)	Standard deviation (meters)			Model input (meters)	Measured (meters)
A13	0.968	1.077	0.259	0.162	0.861	-0.110	0.145	68.6	2,197	0.980	0.969
Angels	1.329	1.534	.264	.285	.721	-.206	.206	39.2	2,557	1.730	1.451
BD	.826	.063	.123	.090	.405	.763	.119	5.4	1,945	.010	2.612
BICYA8	.215	.852	.328	.457	.219	-.637	.500	-133.3	1,959	.270	--
BICYA9	1.726	1.849	.211	.187	.760	-.123	.140	56.1	1,869	2.060	--
BICYA10	.718	.788	.303	.227	.777	-.070	.191	60.3	1,854	.890	--
BICYA11	.920	.939	.380	.170	.711	-.018	.285	43.6	1,883	.880	--
BR	1.074	.026	.131	.116	.836	1.048	.072	69.7	2,331	-.150	1.838
CN	.713	.026	.123	.082	.866	.688	.066	71.0	2,447	-.080	1.323
CP	-.056	-.078	.169	.122	.886	.022	.083	76.0	2,479	-.440	-.503
CR2	1.121	1.257	.307	.303	.897	-.136	.139	79.6	2,161	1.330	1.231
CR3	1.119	1.250	.298	.244	.870	-.130	.148	75.4	2,212	1.310	1.234
CT27R	.143	.083	.148	.126	.580	.060	.127	26.2	1,903	-.060	-.085
CT50R	.106	.100	.140	.090	.858	.006	.078	69.0	1,896	.010	.088
CV1NR	.121	.081	.149	.129	.401	.040	.153	-5.2	1,840	-.060	--
CV5S	.123	.116	.132	.103	.458	.007	.125	10.5	601	-.060	--
CW	-.048	-.065	.103	.126	.491	.017	.117	-29.0	2,261	-1.830	--
CYP2	.235	.292	.206	.206	.792	-.057	.133	58.2	2,157	.480	1.643
CY3	.202	.199	.214	.171	.791	.003	.131	62.6	2,206	.280	1.518
DK	-.207	-.177	.118	.096	.712	-.030	.083	49.6	1,317	-1.860	--
DO1	.349	.480	.267	.182	.845	-.131	.149	68.7	2,451	.560	.567
DO2	.432	.458	.278	.206	.833	-.026	.156	68.6	2,237	.700	.570
E112	.846	.981	.301	.408	.875	-.135	.205	53.8	2,320	1.050	.527
E146	-.096	-.081	.147	.134	.865	-.015	.074	74.7	2,435	-.210	-.369
EP1R	.044	.066	.132	.120	.414	-.022	.137	-7.2	2,406	-.060	-.262
EP9R	-.159	-.116	.087	.056	.837	-.042	.051	66.4	366	-.160	-.314
EPGW/SW	-.015	-.066	.099	.074	.694	.051	.072	47.9	2,387	-.110	-.158
EVER4	.170	.325	.145	.173	.924	-.155	.068	78.1	2,521	.240	.085
EVER5A	-.097	-.027	.153	.101	.828	-.070	.089	65.8	1,945	-.080	-.174
EVER6	.141	.033	.126	.083	.777	.108	.081	59.0	2,294	.000	-.006
EVER7	.201	.102	.120	.109	.891	.099	.054	79.3	2,342	.040	.131
G1251	.185	.229	.168	.177	.899	-.044	.078	78.5	2,02,6	.230	.390
G1502	1.485	1.700	.242	.132	.749	-.214	.168	51.9	2,453	1.580	2.060
G3272	1.491	1.716	.247	.144	.790	-.225	.160	58.2	2,528	1.570	1.612
G3273	1.476	1.705	.239	.139	.793	-.229	.154	58.3	2,557	1.600	1.667
G3353	-.058	-.002	.137	.107	.857	-.056	.071	72.9	2,519	-.020	1.149
G3437	1.194	1.117	0.259	0.275	0.680	0.077	0.214	31.8	2,510	1.850	1.615

Table 12. Water-level comparison statistics for run 143, Main Park Road as a barrier.—Continued

[NAVD 88, North American Vertical Datum of 1988; n, number of points utilized from the time series]

Station	Mean stage (NAVD 88)		Stage standard deviation		Correlation coefficient	Mean difference between measured and computed values		Percentage of explained variance	n	Land surface altitude (NAVD 88)	
	Measured (meters)	Computed (meters)	Measured (meters)	Computed (meters)		Stage (meters)	Standard deviation (meters)			Model input (meters)	Measured (meters)
G3576	1.562	1.725	.207	.105	.902	-.163	.121	65.8	1,965	1.370	1.353
G3577	1.426	1.728	.272	.096	.885	-.302	.193	49.8	2,014	1.360	1.356
G3578	1.520	1.733	.213	.094	.872	-.214	.139	57.4	2,494	1.370	1.356
G3619	.326	.388	.147	.152	.896	-.062	.068	78.4	2,446	.210	.579
G3622	.879	1.218	.239	.419	.669	-.339	.314	-72.8	2,306	1.390	1.347
G3626	.975	1.113	.174	.289	.424	-.138	.267	-135.0	2,357	2.030	1.743
G3627	.860	1.249	.167	.266	.551	-.389	.223	-77.7	2,368	1.910	1.942
G3628	1.011	1.466	.203	.398	.482	-.455	.349	-194.9	2,336	1.730	1.667
G596	1.146	1.330	.197	.334	.596	-.184	.268	-84.5	2,546	1.810	1.753
G618	1.696	1.740	.146	.087	.800	-.044	.092	60.0	2,457	1.480	1.466
G620	1.574	1.577	.205	.180	.927	-.004	.078	85.7	2,451	1.380	1.311
GI	1.363	-.081	.113	.179	.384	1.443	.171	-128.7	1,616	-2.500	--
HC	-.186	.158	.111	.221	.598	-.343	.179	-158.4	1,434	.560	--
HR	.931	.017	.119	.145	.623	.915	.117	4.3	1,461	.120	--
L67XW	1.761	1.720	.237	.090	.743	.040	.181	41.9	1,883	1.350	--
LN	1.524	-.033	.120	.101	.819	1.557	.069	66.9	1,430	-.410	--
LO	.818	-.069	.119	.249	.147	.887	.260	-376.8	1,335	-2.000	--
LOOP1T	1.910	1.837	.158	.170	.721	.073	.123	39.4	2,024	1.860	--
LOOP2T	1.540	1.495	.220	.179	.716	.045	.155	50.3	2,086	1.480	--
LS	-.190	-.174	.106	.099	.778	-.015	.069	58.0	1,461	-1.520	--
NCL	-.015	-.083	.190	.166	.850	.068	.100	72.2	2,390	-.240	--
NE1	1.664	1.727	.131	.088	.853	-.064	.072	69.4	2,509	1.290	1.314
NE2	1.627	1.737	.156	.087	.862	-.110	.092	65.2	2,503	1.340	1.241
NE3	1.695	1.748	.115	.069	.774	-.054	.075	56.9	1,838	1.340	--
NE4	1.606	1.705	.158	.086	.835	-.099	.098	61.4	2,416	1.260	1.213
NE5	1.601	1.687	.146	.085	.855	-.086	.086	65.6	2,539	1.270	--
NMP	-.118	-.097	.151	.171	.855	-.021	.089	65.1	2,113	.010	--
NP201	1.869	1.825	.257	.183	.855	.044	.139	71.0	2,439	1.650	1.420
NP202	1.679	1.646	.196	.156	.960	.033	.063	89.5	2,309	1.350	1.164
NP203	1.471	1.467	.181	.126	.920	.004	.082	79.7	2,426	1.220	.890
NP205	1.478	1.484	.264	.179	.828	-.006	.153	66.2	2,447	1.440	1.332
NP206	1.282	1.380	.272	.169	.846	-.098	.158	66.5	2,453	1.380	1.366
NP44	.636	.782	.351	.238	.769	-.145	.227	58.3	2,342	1.270	1.073
NP46	.018	.033	.171	.166	.751	-.015	.119	51.7	2,429	.050	-.052
NP62	.399	.420	.197	.127	.814	-.021	.119	63.4	2,229	.310	.835
NP67	0.215	0.273	0.179	0.151	0.898	-0.058	0.079	80.4	2,406	0.240	0.582
NP72	.503	.615	.316	.222	.786	-.111	.197	61.1	2,222	.980	.899

Table 12. Water-level comparison statistics for run 143, Main Park Road as a barrier.—Continued

[NAVD 88, North American Vertical Datum of 1988; n, number of points utilized from the time series]

Station	Mean stage (NAVD 88)		Stage standard deviation		Correlation coefficient	Mean difference between measured and computed values		Percentage of explained variance	n	Land surface altitude (NAVD 88)	
	Measured (meters)	Computed (meters)	Measured (meters)	Computed (meters)		Stage (meters)	Standard deviation (meters)			Model input (meters)	Measured (meters)
NR	1.181	-.049	.117	.110	.773	1.230	.077	56.9	1,380	-1.200	1.682
NTS1	.841	1.169	.293	.303	.767	-.328	.203	51.7	2,457	1.020	1.076
NTS10	.927	1.048	.310	.372	.887	-.121	.173	68.9	2,152	1.270	1.237
NTS14	.732	.863	.386	.345	.788	-.131	.241	61.0	2,395	1.380	.756
OL1	-.059	-.089	.160	.121	.897	.030	.074	78.6	2,447	-.220	--
OT	.251	.149	.189	.160	.905	.102	.081	81.6	2,464	-.170	--
P33	1.509	1.532	.148	.104	.919	-.023	.067	79.6	2,406	1.230	1.024
P34	.419	.259	.213	.156	.856	.160	.113	71.7	2,428	.160	.119
P35	.118	.176	.171	.141	.946	-.057	.059	88.0	2,552	-.400	-.195
P36	.868	.888	.146	.109	.908	-.020	.066	79.7	2,407	.630	.530
P37	.002	.014	.155	.117	.866	-.012	.079	73.8	2,465	-.140	-.183
P38	.069	.048	.148	.113	.851	.021	.079	71.6	2,360	-.130	-.192
R127	.267	.362	.197	.147	.932	-.095	.081	83.3	2,384	.060	--
R158	.416	.687	.239	.401	.834	-.272	.241	-1.6	2,445	.980	.927
R3110	.919	1.001	.331	.351	.890	-.082	.161	76.4	2,456	1.240	1.094
RG1	1.242	1.589	.284	.128	.673	-.347	.219	40.4	1,941	1.460	1.061
RG2	1.138	1.358	.286	.278	.829	-.220	.165	66.6	2,108	1.450	1.390
Rutzke	.940	1.067	.260	.385	.801	-.127	.236	17.9	2,432	1.510	1.103
S12AT	2.182	2.069	.288	.173	.809	.113	.179	61.1	2,530	1.870	--
S12BT	2.205	2.051	.317	.172	.887	.154	.183	66.7	2,532	1.860	--
S12CT	2.239	2.182	.323	.185	.480	.056	.285	22.2	2,520	1.870	--
S12DT	2.209	2.064	.419	.222	.685	.144	.312	44.5	2,526	1.690	--
SP	.211	.306	.217	.210	.788	-.095	.139	58.9	2,188	.480	.280
SR	.886	-.096	.109	.216	.265	.983	.214	-289.7	1,354	-2.800	--
TE	1.242	.017	.127	.095	.857	1.226	.067	72.2	1,438	-.190	--
TMC	.902	.894	.239	.153	.886	.008	.125	72.5	2,232	.770	.732
TSB	.628	.865	.278	.259	.962	-.237	.076	92.5	1,327	.490	.610
TSH	.156	.177	.163	.141	.909	-.021	.069	82.3	2,445	.000	-.021
WE	1.611	-.053	.114	.122	.636	1.664	.101	21.0	1,461	-1.610	--
WP	1.365	-.031	.128	.170	.383	1.396	.169	-73.6	1,096	-1.870	--
WW	1.435	.043	.151	.145	.855	1.392	.080	72.1	1,461	-.230	--

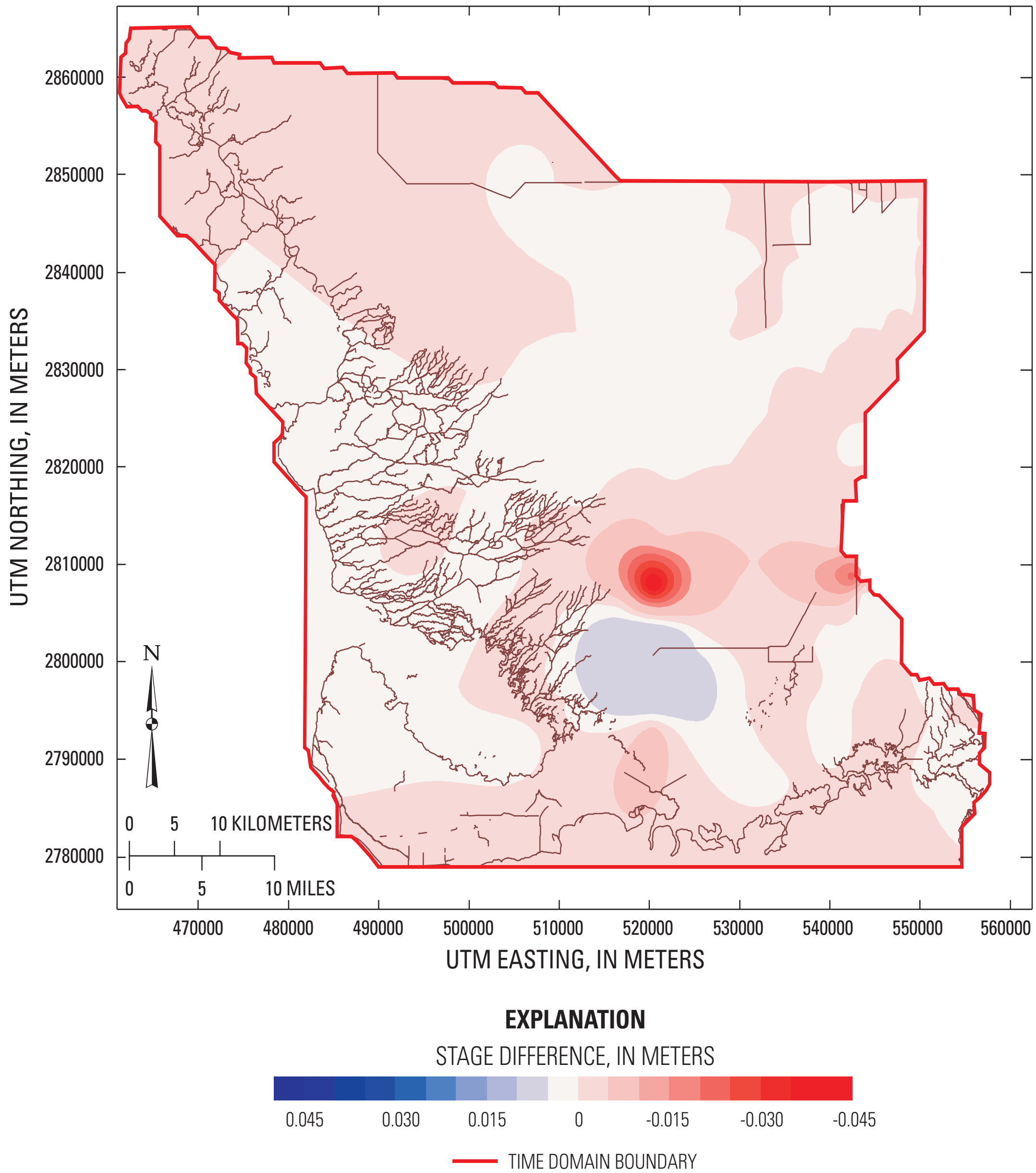

Figure 32. Spatial distribution of mean stage difference between simulations with and without the Main Park Road as a barrier. Positive values indicate better fit, and negative values indicate a poorer fit.

Table 13. Water-level comparison statistics for run 146, land-surface altitude lowered 0.1 meter.

[NAVD 88, North American Vertical Datum of 1988; n, number of points utilized from the time series]

Station	Mean stage (NAVD 88)		Stage standard deviation		Correlation coefficient	Mean difference between measured and computed values		Percentage of explained variance	n	Land surface altitude (NAVD 88)	
	Measured (meters)	Computed (meters)	Measured (meters)	Computed (meters)		Stage (meters)	Standard deviation (meters)			Model input (meters)	Measured (meters)
A13	0.968	0.259	0.985	0.157	0.861	-0.017	0.147	67.7	2,197	0.880	0.969
Angels	1.329	.264	1.493	.256	.726	-.165	.193	46.9	2,557	1.630	1.451
BD	.826	.123	.029	.099	.427	.797	.120	3.4	1,945	-.090	2.612
BICYA8	.215	.328	.764	.486	.099	-.549	.559	-190.9	1,959	.170	--
BICYA9	1.726	.211	1.763	.175	.784	-.036	.131	61.3	1,869	1.960	--
BICYA10	.718	.303	.693	.225	.775	.025	.192	60.0	1,854	.790	--
BICYA11	.920	.380	.844	.164	.719	.076	.286	43.5	1,883	.780	--
BR	1.074	.131	.018	.112	.844	1.056	.070	71.3	2,331	-.250	1.838
CN	.713	.123	-.005	.087	.864	.719	.065	72.0	2,447	-.180	1.323
CP	-.056	.169	-.106	.112	.792	.050	.105	61.0	2,479	-.540	-.503
CR2	1.121	.307	1.185	.278	.900	-.064	.134	81.0	2,161	1.230	1.231
CR3	1.119	.298	1.166	.230	.872	-.047	.149	75.0	2,212	1.210	1.234
CT27R	.143	.148	.085	.141	.597	.058	.130	23.0	1,903	-.160	-.085
CT50R	.106	.140	.020	.081	.785	.086	.092	57.3	1,896	-.090	.088
CV1NR	.121	.149	.003	.128	.109	.118	.185	-54.8	1,840	-.160	--
CV5S	.123	.132	.129	.109	.651	-.006	.103	39.5	601	-.160	--
CW	-.048	.103	-.067	.114	.520	.019	.107	-7.4	2,261	-1.930	--
CYP2	.235	.206	.205	.195	.790	.030	.130	59.9	2,157	.380	1.643
CY3	.202	.214	.116	.154	.782	.087	.134	60.7	2,206	.180	1.518
DK	-.207	.118	-.177	.096	.710	-.030	.084	49.4	1,317	-1.960	--
DO1	.349	.267	.390	.174	.843	-.041	.152	67.5	2,451	.460	.567
DO2	.432	.278	.360	.196	.828	.072	.159	67.1	2,237	.600	.570
E112	.846	.301	.908	.371	.888	-.062	.173	67.0	2,320	.950	.527
E146	-.096	.147	-.112	.113	.831	.016	.082	68.6	2,435	-.310	-.369
EP1R	.044	.132	-.005	.118	.093	.049	.169	-63.7	2,406	-.160	-.262
EP9R	-.159	.087	-.183	.061	.726	.024	.060	52.7	366	-.260	-.314
EPGW/SW	-.015	.099	-.117	.077	.579	.102	.083	29.4	2,387	-.210	-.158
EVER4	.170	.145	.250	.149	.926	-.080	.057	84.8	2,521	.140	.085
EVER5A	-.097	.153	-.083	.091	.741	-.014	.105	52.9	1,945	-.180	-.174
EVER6	.141	.126	-.028	.071	.577	.169	.103	33.2	2,294	-.100	-.006
EVER7	.201	.120	.025	.091	.877	.176	.059	75.6	2,342	-.060	.131
G1251	.185	.168	.157	.153	.906	.028	.071	82.2	2,026	.130	.390
G1502	1.485	.242	1.613	.122	.760	-.128	.169	51.1	2,453	1.480	2.060
G3272	1.491	.247	1.633	.128	.797	-.142	.164	55.8	2,528	1.470	1.612
G3273	1.476	.239	1.621	.126	.792	-.145	.159	55.6	2,557	1.500	1.667
G3353	-.058	.137	-.060	.090	.794	.002	.086	61.1	2,519	-.120	1.149

Table 13. Water-level comparison statistics for run 146, land-surface altitude lowered 0.1 meter.—Continued

[NAVD 88, North American Vertical Datum of 1988; n, number of points utilized from the time series]

Station	Mean stage (NAVD 88)		Stage standard deviation		Correlation coefficient	Mean difference between measured and computed values		Percentage of explained variance	n	Land surface altitude (NAVD 88)	
	Measured (meters)	Computed (meters)	Measured (meters)	Computed (meters)		Stage (meters)	Standard deviation (meters)			Model input (meters)	Measured (meters)
G3437	1.194	0.259	1.089	0.259	0.704	0.105	0.199	40.9	2,510	1.750	1.615
G3576	1.562	.207	1.640	.096	.898	-.078	.128	61.9	1,965	1.270	1.353
G3577	1.426	.272	1.642	.093	.876	-.216	.196	48.1	2,014	1.260	1.356
G3578	1.520	.213	1.647	.090	.866	-.127	.142	55.4	2,494	1.270	1.356
G3619	.326	.147	.303	.142	.878	.024	.072	76.4	2,446	.110	.579
G3622	.879	.239	1.160	.375	.689	-.282	.273	-30.1	2,306	1.290	1.347
G3626	.975	.174	1.099	.267	.435	-.124	.248	-102.3	2,357	1.930	1.743
G3627	.860	.167	1.216	.242	.558	-.356	.203	-48.5	2,368	1.810	1.942
G3628	1.011	.203	1.410	.355	.496	-.399	.310	-132.4	2,336	1.630	1.667
G596	1.146	.197	1.312	.306	.603	-.165	.244	-53.0	2,546	1.710	1.753
G618	1.696	.146	1.652	.086	.773	.044	.096	56.5	2,457	1.380	1.466
G620	1.574	.205	1.482	.177	.924	.092	.080	85.0	2,451	1.280	1.311
GI	1.363	.113	-.079	.166	.414	1.442	.158	-93.3	1,616	-2.600	--
HC	-.186	.111	.147	.201	.605	-.332	.161	-109.3	1,434	.460	--
HR	.931	.119	.012	.099	.663	.919	.092	41.1	1,461	.020	--
L67XW	1.761	.237	1.633	.089	.743	.128	.181	41.6	1,883	1.250	--
LN	1.524	.120	-.046	.102	.823	1.570	.068	67.6	1,430	-.510	--
LO	.818	.119	-.072	.250	.152	.890	.260	-377.3	1,335	-2.100	--
LOOP1T	1.910	.158	1.747	.161	.715	.164	.120	42.1	2,024	1.760	--
LOOP2T	1.540	.220	1.399	.174	.705	.140	.157	48.9	2,086	1.380	--
LS	-.190	.106	-.173	.099	.813	-.017	.063	64.7	1,461	-1.620	--
NCL	-.015	.190	-.091	.119	.770	.076	.124	57.4	2,390	-.340	--
NE1	1.664	.131	1.639	.087	.849	.025	.073	68.5	2,509	1.190	1.314
NE2	1.627	.156	1.649	.085	.853	-.022	.094	63.4	2,503	1.240	1.241
NE3	1.695	.115	1.661	.068	.756	.033	.077	54.6	1,838	1.240	--
NE4	1.606	.158	1.616	.085	.832	-.010	.099	60.6	2,416	1.160	1.213
NE5	1.601	.146	1.597	.084	.852	.004	.087	64.8	2,539	1.170	--
NMP	-.118	.151	-.093	.124	.807	-.024	.089	65.2	2,113	-.090	--
NP201	1.869	.257	1.730	.178	.847	.139	.142	69.4	2,439	1.550	1.420
NP202	1.679	.196	1.550	.155	.958	.129	.065	89.0	2,309	1.250	1.164
NP203	1.471	.181	1.372	.126	.918	.099	.083	79.2	2426	1.120	.890
NP205	1.478	.264	1.389	.175	.827	.090	.155	65.7	2,447	1.340	1.332
NP206	1.282	.272	1.298	.155	.837	-.017	.166	62.8	2,453	1.280	1.366
NP44	.636	.351	.691	.231	.769	-.055	.228	57.9	2,342	1.170	1.073
NP46	.018	.171	-.056	.122	.742	.074	.115	55.0	2,429	-.050	-.052
NP62	.399	.197	.327	.129	.815	.072	.118	63.8	2,229	.210	.835
NP67	.215	.179	.185	.141	.899	.030	.081	79.7	2,406	.140	.582

Table 13. Water-level comparison statistics for run 146, land-surface altitude lowered 0.1 meter.—Continued

[NAVD 88, North American Vertical Datum of 1988; n, number of points utilized from the time series]

Station	Mean stage (NAVD 88)		Stage standard deviation		Correlation coefficient	Mean difference between measured and computed values		Percentage of explained variance	n	Land surface altitude (NAVD 88)	
	Measured (meters)	Computed (meters)	Measured (meters)	Computed (meters)		Stage (meters)	Standard deviation (meters)			Model input (meters)	Measured (meters)
NP72	0.503	0.316	0.527	0.217	0.790	-0.024	0.197	61.3	2,222	0.880	0.899
NR	1.181	.117	-.053	.106	.775	1.234	.075	58.4	1,380	-1.300	1.682
NTS1	.841	.293	1.083	.279	.786	-.242	.187	59.0	2,457	.920	1.076
NTS10	.927	.310	.997	.340	.888	-.070	.156	74.6	2,152	1.170	1.237
NTS14	.732	.386	.791	.328	.793	-.059	.236	62.6	2,395	1.280	.756
OL1	-.059	.160	-.126	.111	.833	.067	.091	67.6	2,447	-.320	--
OT	.251	.189	.091	.151	.864	.159	.096	74.2	2,464	-.270	--
P33	1.509	.148	1.438	.103	.916	.071	.068	79.0	2,406	1.130	1.024
P34	.419	.213	.177	.152	.852	.243	.115	70.7	2,428	.060	.119
P35	.118	.171	.113	.137	.950	.005	.059	88.0	2,552	-.500	-.195
P36	.868	.146	.794	.109	.905	.074	.066	79.4	2,407	.530	.530
P37	.002	.155	-.060	.113	.867	.062	.080	73.4	2,465	-.240	-.183
P38	.069	.148	.009	.109	.802	.060	.089	63.9	2,360	-.230	-.192
R127	.267	.197	.272	.141	.928	-.005	.085	81.6	2,384	-.040	--
R158	.416	.239	.612	.340	.812	-.196	.202	28.5	2,445	.880	.927
R3110	.919	.331	.940	.327	.896	-.021	.150	79.5	2,456	1.140	1.094
RG1	1.242	.284	1.504	.114	.692	-.262	.221	39.4	1,941	1.360	1.061
RG2	1.138	.286	1.299	.250	.817	-.161	.166	66.4	2,108	1.350	1.390
Rutzke	.940	.260	1.042	.357	.813	-.102	.210	34.9	2,432	1.410	1.103
S12AT	2.182	.288	1.971	.177	.779	.211	.186	58.0	2,530	1.770	--
S12BT	2.205	.317	1.947	.172	.913	.257	.175	69.7	2,532	1.760	--
S12CT	2.239	.323	2.103	.201	.337	.135	.317	3.2	2,520	1.770	--
S12DT	2.209	.419	1.974	.230	.609	.235	.333	36.7	2,526	1.590	--
SP	.211	.217	.184	.171	.779	.026	.136	60.7	2,188	.380	.280
SR	.886	.109	-.098	.215	.268	.984	.213	-285.4	1,354	-2.900	--
TE	1.242	.127	-.009	.101	.855	1.252	.066	72.8	1,438	-.290	--
TMC	.902	.239	.797	.150	.882	.105	.128	71.3	2,232	.670	.732
TSB	.628	.278	.766	.236	.965	-.138	.080	91.8	1,327	.390	.610
TSH	.156	.163	.089	.134	.903	.067	.072	80.8	2,445	-.100	-.021
WE	1.611	.114	-.056	.116	.642	1.667	.097	26.5	1,461	-1.710	--
WP	1.365	.128	-.026	.159	.414	1.391	.157	-50.8	1,096	-1.970	--
WW	1.435	.151	.027	.136	.872	1.408	.074	76.0	1,461	-.330	--

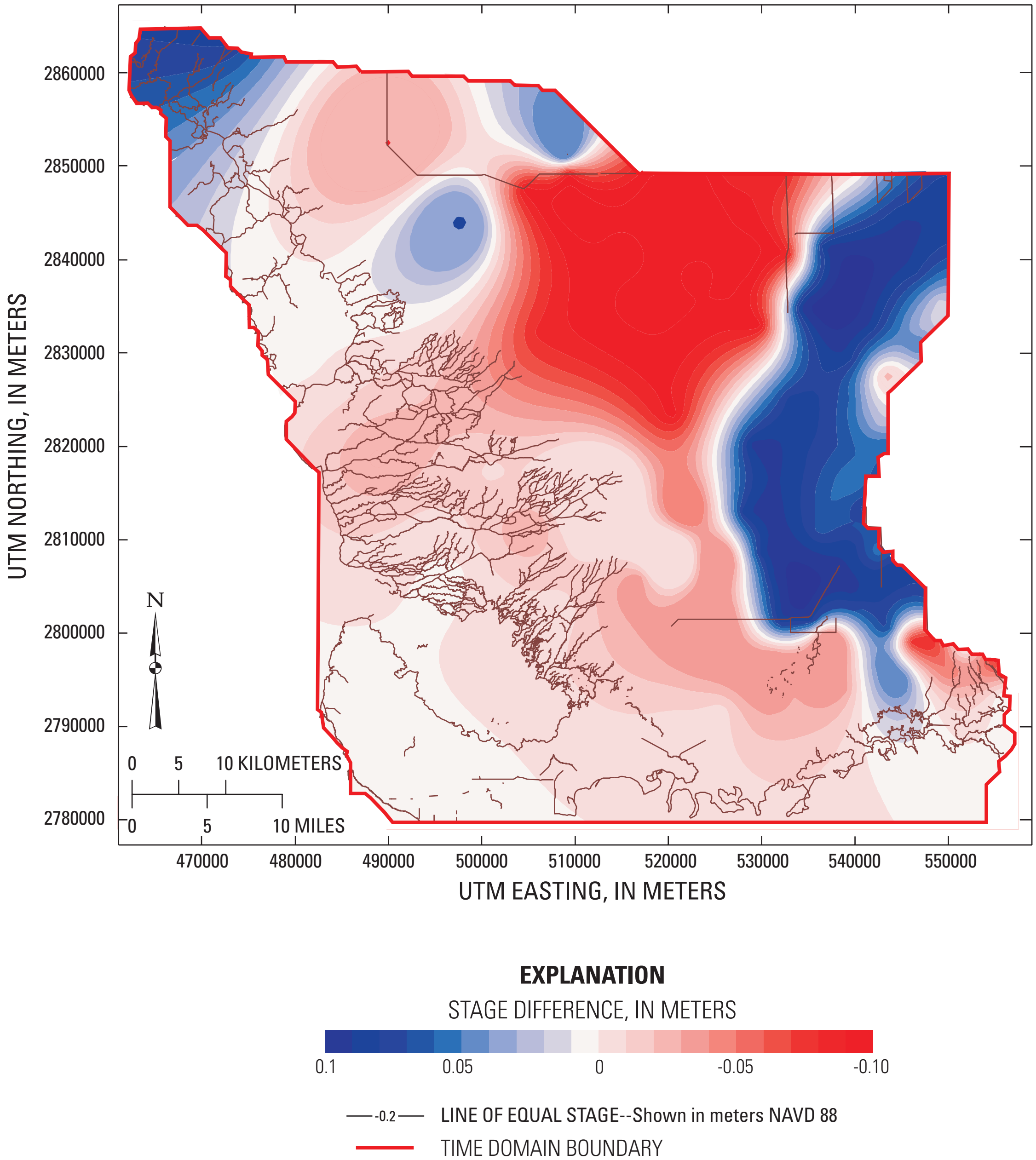

Figure 33. Spatial distribution of mean stage difference between simulations with and without lowered land surface. Positive values indicate better fit, and negative values indicate a poorer fit.

The station information for gage G-1502 (fig. 9) indicates the land-surface altitude near the gage is 2.06 m NAVD 88; therefore, the recorded water level for the entire data record is below land surface. The TIME application land-surface altitude at this location, however, is 1.58 m NAVD 88 based on the regional topography. Using this lower altitude, the TIME application shows surface water present most of the time, and consequently, the statistics routine compares mostly computed surface-water stage with measured ground-water head. This illustrates the problems that result from discrepancies between measured and model land-surface altitudes and from uncertainties in interpreting gage records. Similar discrepancies exist at other locations where the mean model and measured stage differ by 0.1 m; for example, CR2, CR3, RG1, RG2, and many of the G-prefix gages in the area.

Examples of how model results at many locations with substantial ponding could improve by lowering the model land-surface altitude can be seen by comparing the statistics for runs 142 and 146 (tables 10 and 13) for CR2, CR3, NTS10, NTS14, RG1, and RG2. In these cases, the simulated surface-water depth agrees reasonably well with the field data although stages are too high, indicating that land-surface altitude at the gage is higher in the model than measured in the field. Reducing stage by decreasing the frictional component is not feasible because stage at P33 is higher than RG1, indicating the flow gradient is to the southeast. The only apparent alternatives are to lower land-surface altitudes in the model and/or promote more flow through Taylor Slough. Because the model overestimates stage near TSB (figs. 9 and 16), an adjustment is made for the final calibration to facilitate flow through the slough, thereby lowering surface-water stages within it.

3.8.3 - C-111 Area

At gage HC (fig. 9) near the C-111 Canal (fig. 1), model response is controlled mainly by the prescribed ground-water head boundary because the water level is entirely below land surface. For previously reported runs, the prescribed ground-water head is equivalent to the measurement at EVER3 since there is a lack of other data. If data from HC were to be used to prescribe stage, the model fit likely would improve substantially; however, using HC to prescribe model boundary stage eliminates this gage as a calibration comparison site. Because these are boundary data issues in a calibration run using field-measured data, these issues should be nonexistent for model scenario runs that do not use field-measured data for boundaries.

The following calibration stations given in table 10 have: (1) an absolute value of mean bias (DIFMEAN) greater than 0.1 m, (2) a correlation of less than 0.8, and (3) an error standard deviation greater than 0.1 m or explained variance of less than 0.7 (DO1, DO2, E112, EP9R, EPGW/SW, EVER4, EVER5A, EVER6, EVER7, NCL, NMP, NP44, NP72, NTS10, NTS14, R127, and TSB). An examination of these statistics yields information that is useful for further calibration.

For run 142, mean biases at DO1, E112, EVER4, NP44, NP72, NTS10, NTS14, R127, and TSB are negative, which means the model overestimates mean stage (table 10). This indicates that statistics at these sites should improve if model land-surface altitudes are adjusted downward or friction is reduced; for EVER6 and EVER7, the opposite is true. It is undesirable to adjust land-surface altitudes without a careful field verification, however, and adjusting friction coefficients is considered more justifiable. At EVER4, computed stage is too high, but the model land-surface altitude is also high by 0.15 m. The neighboring station G-1251 shows a better fit, and the associated model land-surface altitude is below the corresponding observed altitude. The computed mean stage is reasonable at EPGW/SW, but the correlation and explained variance are lower than normal.

At stations EVER5A, EP9R, and G-3353, the model-input land-surface altitudes are higher than those measured at the stations. Model land-surface altitudes at EVER5A, EP9R, and G-3353 are higher by 0.09 m, 0.15 m, and 1.169 m, respectively. Figure 15 shows that the model reasonably simulates stage at these sites, except during periods of low water levels (below land surface), which may indicate inadequate simulated ground-water drainage or a combination of inadequate ET and an excessive aquifer specific yield.

The comparison at NCL in figure 15 is degraded by a relatively poor fit for the first 2 years, which also occurred at other locations in Everglades National Park. The model performance is substantially better for the later 5 years.

Assessing the fit between simulated and measured stage values at DO1, DO2, NMP, NP44, NP72, NTS10 and NTS14 (table 10) is problematic, owing to the difficulty of comparing simulated surface-water stage with measured data that most likely represent ground-water head. In this case, the water-table decline during the annual dry season is underestimated.

3.8.4 - Results of Final Calibration

A number of runs were made that incorporate the findings just described; specifically, the friction was reduced through TSB, the ET extinction function and depth were varied, and the friction coefficient was increased just south of the degraded portion of C-111 Canal. Additional stage data from stations CV1NR and HC were used for GHBs from east of EVER3 to Florida Bay. Finally, the friction coefficient was increased from 0.008 to 0.2 for Trout Creek to divert some of its flow to other creeks.

This final calibration (run 157) incorporates a modified ET extinction function for ground water in order to improve the model ground-water head response during the dry season. The actual ET equals PET(1-DIST^2), if DIST is less than or equal to 1 m, where PET is potential ET and DIST is the distance between the land surface and water table. The open-boundary conditions are based on the hydrodynamic model of Florida Bay using the Environmental Fluid Dynamic Code (EFDC) (John Hamrick, Tetra Tech, written commun., 2005). Hydrographs for water-level stations based on model output are provided in figure 34.

Comparisons with measured data are quantified as in previous runs (table 14). Table 15, however, presents recalculated statistics using only computed ground-water head for every station where the computed land-surface altitude is higher than the mean observed stage. This is referred to as run 157GW and is an attempt to identify ground-water gages (as opposed to surface-water gages) and avoid comparisons between model surface-water stages with what may be measured ground-water heads. Statistics for run 157 indicate tangible model improvements and bring the majority of stations to the desired levels of correlation and explained variance. Figures 35 and 36 show the spatial distribution of the mean stage bias and PEV, respectively, for run 157. The degree of model improvement is illustrated also by the

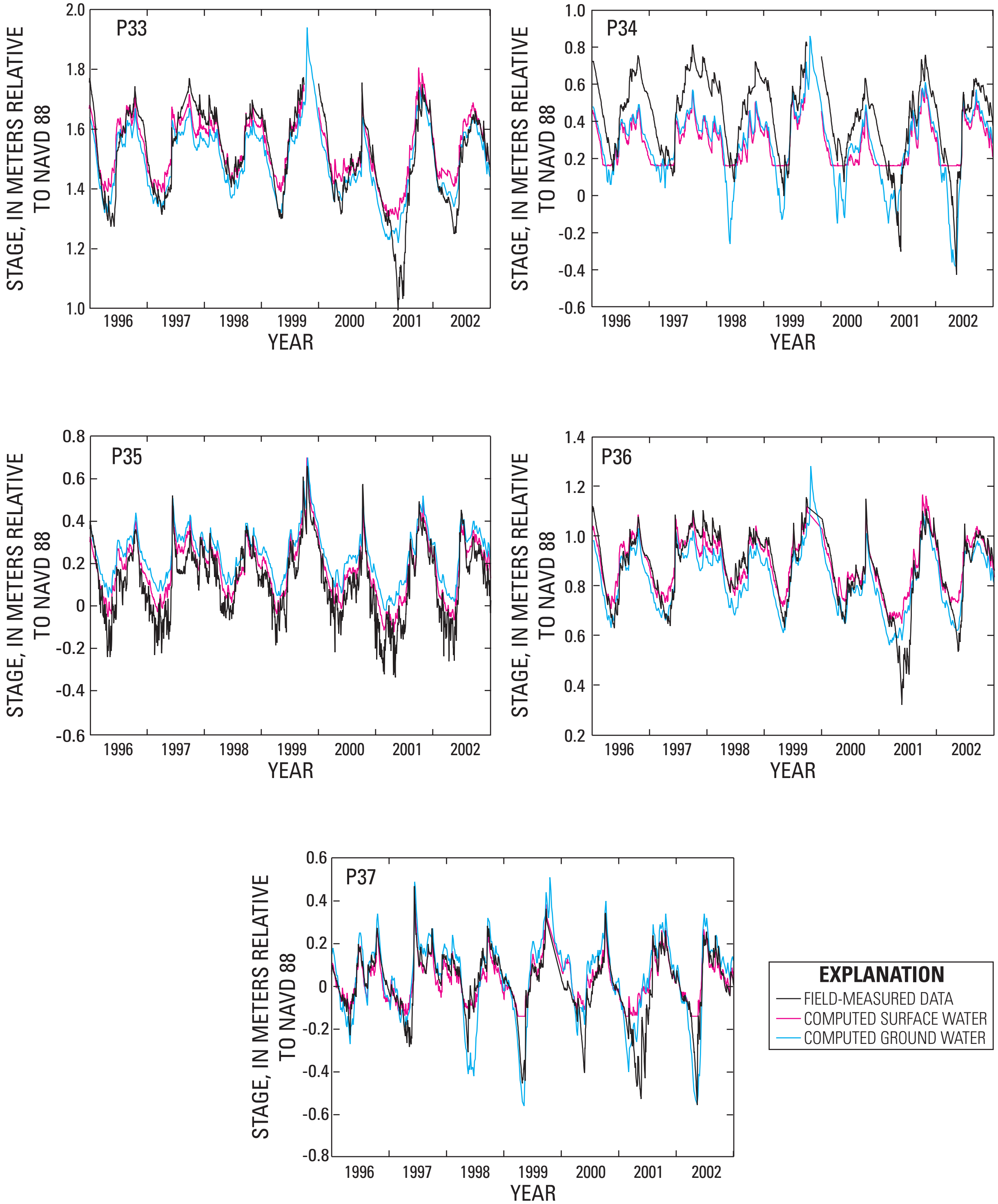

Figure 34. Comparison of water levels at selected stations in the TIME area for run 157.

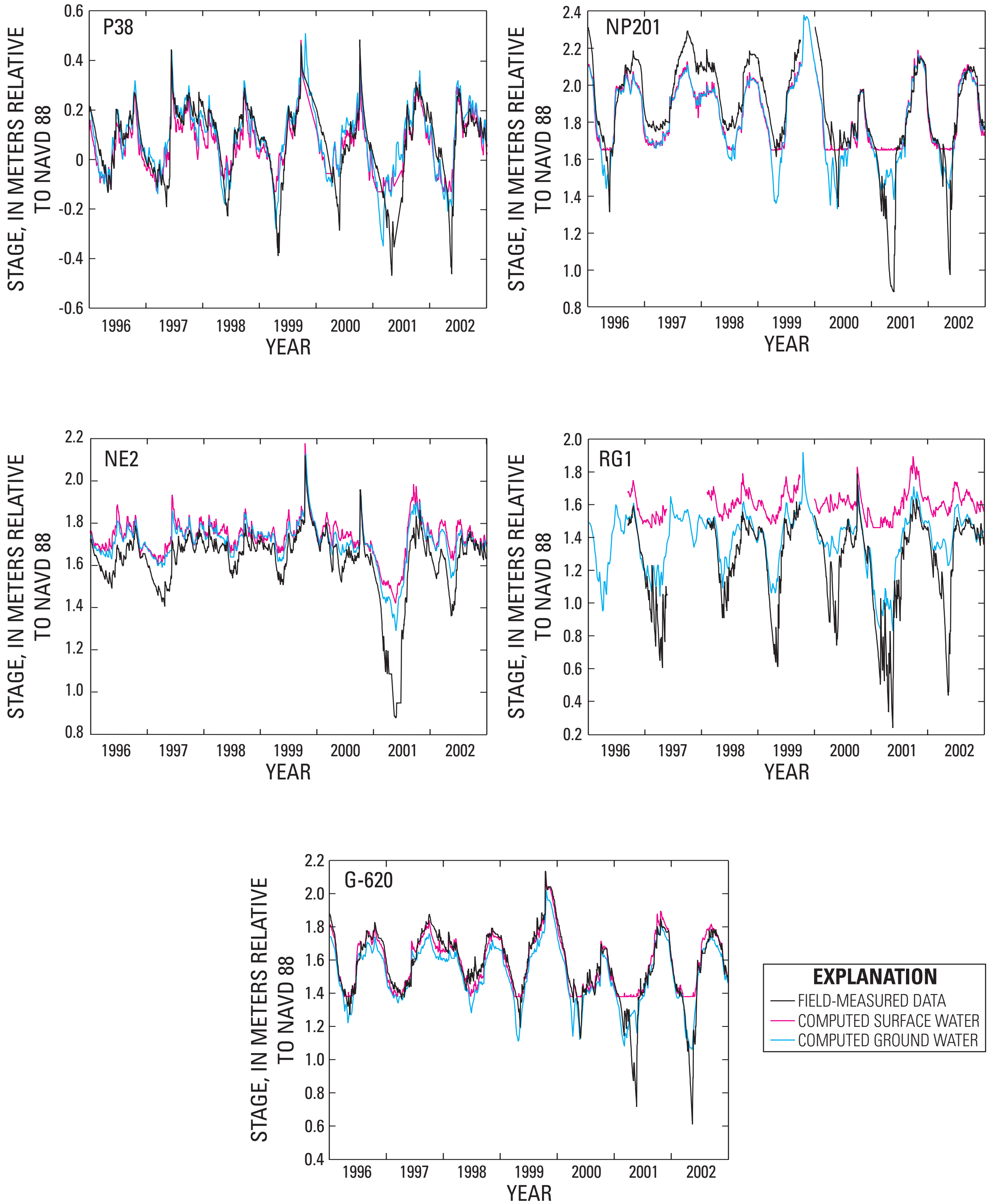

Figure 34. Comparison of water levels at selected stations in the TIME area for run 157.—Continued

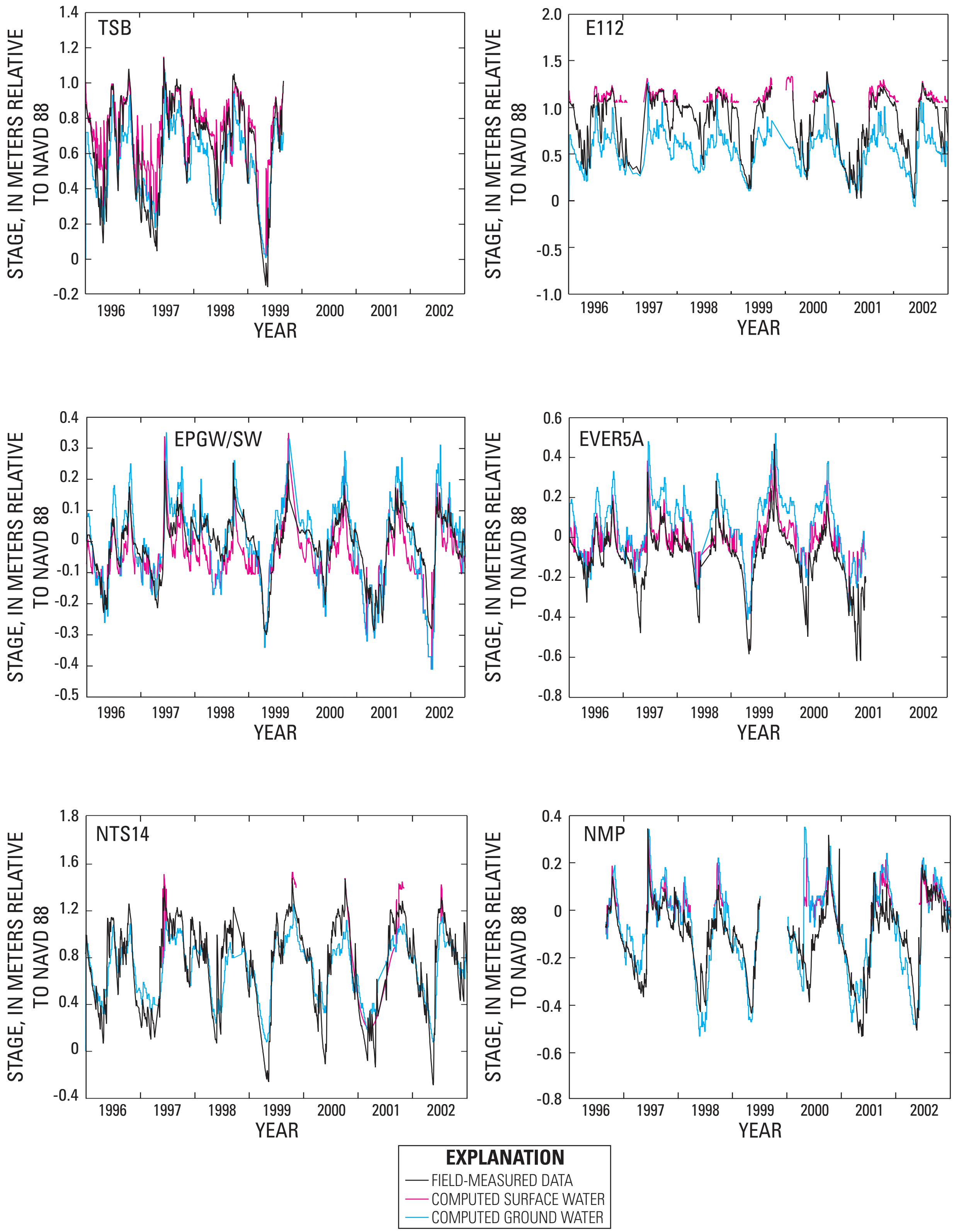

Figure 34. Comparison of water levels at selected stations in the TIME area for run 157.—Continued

Table 14. Water level comparison statistics for run 157, final calibration.

[NAVD 88, North American Vertical Datum of 1988; n, number of points utilized from the time series]

Station	Mean stage (NAVD 88)		Stage standard deviation		Correlation coefficient	Mean difference between measured and computed values		Percentage of explained variance	n	Land surface altitude (NAVD 88)	
	Measured (meters)	Computed (meters)	Measured (meters)	Computed (meters)		Stage (meters)	Standard deviation (meters)			Model input (meters)	Measured (meters)
A13	0.968	1.057	0.259	0.190	0.862	-0.090	0.135	72.7	2,197	0.980	0.969
Angels	1.329	1.302	.264	.122	.774	.026	.186	50.2	2,557	1.730	1.451
BD	.826	.090	.123	.095	.505	.736	.111	17.9	1,945	.010	2.612
BICYA10	.718	.721	.303	.286	.837	-.004	.169	68.8	1,854	.890	--
BICYA11	.920	.919	.380	.213	.727	.001	.268	50.1	1,883	.880	--
BICYA8	.215	-.008	.328	.159	.648	.223	.255	39.3	1,959	-1.000	--
BICYA9	1.726	1.803	.211	.215	.813	-.077	.130	61.8	1,869	2.060	--
BR	1.074	.040	.131	.117	.902	1.034	.056	81.4	2,331	-.150	1.838
CN	.713	.036	.123	.084	.900	.677	.060	76.3	2,447	-.080	1.323
CP	-.056	-.052	.169	.122	.826	-.004	.097	67.1	2,479	-.440	-.503
CR2	1.121	1.055	.307	.256	.925	.066	.120	84.7	2,161	1.330	1.231
CR3	1.119	1.219	.298	.282	.863	-.100	.152	73.8	2,212	1.310	1.234
CT27R	.143	-.005	.148	.096	.707	.148	.105	49.7	1,903	-.060	-.085
CT50R	.106	.120	.140	.142	.889	-.014	.067	77.5	1,896	.010	.088
CW	-.048	-.058	.103	.146	.754	.010	.096	12.8	2,261	-1.830	--
CY3	.202	.150	.214	.226	.810	.053	.136	59.7	2,206	.280	1.518
CYP2	.235	.206	.206	.222	.855	.029	.116	68.1	2,157	.480	1.643
DK	-.207	-.202	.118	.190	.861	-.005	.107	17.6	1,317	-1.860	--
DO1	.349	.395	.267	.230	.858	-.047	.137	73.6	2,451	.560	.567
DO2	.432	.361	.278	.221	.853	.071	.146	72.5	2,237	.700	.570
E112	.846	.907	.301	.356	.821	-.061	.203	54.5	2,320	1.050	.527
E146	-.096	-.059	.147	.140	.831	-.037	.084	67.7	2,435	-.210	-.369
EP1R	.044	-.033	.132	.093	.816	.077	.078	65.4	2,406	-.060	-.262
EP9R	-.159	-.107	.087	.070	.804	-.052	.052	64.7	366	-.160	-.314
EPGW/SW	-.015	-.056	.099	.103	.841	.041	.057	66.9	2,387	-.110	-.158
EVER4	.170	.232	.145	.176	.894	-.062	.080	69.8	2,521	.240	.085
EVER5A	-.097	-.018	.153	.119	.838	-.079	.084	69.9	1,945	-.080	-.174
EVER6	.141	.023	.126	.101	.874	.118	.062	75.9	2,294	.000	-.006
EVER7	.201	.100	.120	.123	.891	.102	.057	77.5	2,342	.040	.131
G1251	.185	.173	.168	.193	.884	.012	.090	71.1	2,026	.230	.390
G1502	1.485	1.461	.242	.145	.821	.024	.148	62.4	2,453	1.580	2.060
G3272	1.491	1.471	.247	.111	.766	.020	.177	48.6	2,528	1.570	1.612
G3273	1.476	1.509	.239	.131	.818	-.033	.152	59.6	2,557	1.600	1.667
G3353	-.058	.000	.137	.127	.876	-.058	.066	76.5	2,519	-.020	1.149
G3437	1.194	1.048	.259	.184	.855	.146	.139	71.1	2,510	1.850	1.615
G3576	1.562	1.724	0.207	0.105	0.901	-0.161	0.121	65.9	1,965	1.370	1.353

Table 14. Water level comparison statistics for run 157, final calibration.—Continued

[NAVD 88, North American Vertical Datum of 1988; n, number of points utilized from the time series]

Station	Mean stage (NAVD 88)		Stage standard deviation		Correlation coefficient	Mean difference between measured and computed values		Percentage of explained variance	n	Land surface altitude (NAVD 88)	
	Measured (meters)	Computed (meters)	Measured (meters)	Computed (meters)		Stage (meters)	Standard deviation (meters)			Model input (meters)	Measured (meters)
G3577	1.426	1.726	.272	.096	.885	-.300	.192	50.0	2,014	1.360	1.356
G3578	1.520	1.732	.213	.095	.870	-.212	.138	57.8	2,494	1.370	1.356
G3619	.326	.390	.147	.162	.892	-.063	.073	75.2	2,446	.210	.579
G3622	.879	.735	.239	.205	.817	.144	.138	66.5	2,306	1.390	1.347
G3626	.975	1.034	.174	.118	.440	-.059	.162	13.7	2,357	2.030	1.743
G3627	.860	1.157	.167	.116	.618	-.296	.132	37.6	2,368	1.910	1.942
G3628	1.011	1.039	.203	.127	.732	-.028	.140	52.5	2,336	1.730	1.667
G596	1.146	1.141	.197	.109	.562	.005	.163	31.5	2,546	1.810	1.753
G618	1.696	1.739	.146	.087	.800	-.043	.092	60.0	2,457	1.480	1.466
G620	1.574	1.573	.205	.185	.931	.001	.075	86.5	2,451	1.380	1.311
GI	1.363	-.069	.113	.206	.627	1.432	.161	-101.5	1,616	-2.500	--
HC	-.186	-.212	.111	.114	.823	.027	.067	63.6	1,434	.560	--
HR	.931	.052	.119	.144	.668	.880	.110	15.5	1,461	.120	--
L67XW	1.761	1.719	.237	.090	.739	.042	.181	41.7	1,883	1.350	--
LN	1.524	-.019	.120	.104	.922	1.543	.047	84.7	1,430	-.410	--
LO	.818	-.045	.119	.283	.363	.864	.264	-393.3	1,335	-2.000	--
LOOP1T	1.910	1.818	.158	.203	.726	.092	.140	22.0	2,024	1.860	--
LOOP2T	1.540	1.474	.220	.225	.748	.066	.158	48.3	2,086	1.480	--
LS	-.190	-.156	.106	.131	.723	-.033	.091	25.8	1,461	-1.520	--
NCL	-.015	-.061	.190	.164	.775	.047	.121	59.3	2,390	-.240	--
NE1	1.664	1.726	.131	.088	.851	-.062	.073	69.2	2,509	1.290	1.314
NE2	1.627	1.736	.156	.087	.862	-.109	.092	65.3	2,503	1.340	1.241
NE3	1.695	1.747	.115	.069	.776	-.052	.075	57.2	1,838	1.340	--
NE4	1.606	1.704	.158	.087	.834	-.097	.099	61.3	2,416	1.260	1.213
NE5	1.601	1.686	.146	.085	.853	-.085	.086	65.4	2,539	1.270	--
NMP	-.118	-.087	.151	.190	.781	-.031	.118	38.4	2,113	.010	--
NP201	1.869	1.823	.257	.185	.857	.046	.137	71.5	2,439	1.650	1.420
NP202	1.679	1.645	.196	.156	.960	.034	.063	89.5	2,309	1.350	1.164
NP203	1.471	1.466	.181	.126	.921	.005	.082	79.8	2,426	1.220	.890
NP205	1.478	1.466	.264	.213	.827	.012	.148	68.4	2,447	1.440	1.332
NP206	1.282	1.280	.272	.186	.869	.002	.144	72.1	2,453	1.380	1.366
NP44	.636	.677	.351	.241	.864	-.041	.187	71.6	2,342	1.270	1.073
NP46	.018	-.029	.171	.170	.748	.047	.121	49.8	2,429	.050	-.052
NP62	.399	.399	.197	.148	.817	.000	.114	66.3	2,229	.310	.835
NP67	.215	.256	.179	.183	.895	-.041	.083	78.4	2,406	.240	.582
NP72	0.503	0.505	0.316	0.222	0.849	-0.002	0.173	70.0	2,222	0.980	0.899
NR	1.181	-.037	.117	.125	.907	1.218	.053	79.6	1,380	-1.200	1.682

Table 14. Water level comparison statistics for run 157, final calibration.—Continued

[NAVD 88, North American Vertical Datum of 1988; n, number of points utilized from the time series]

Station	Mean stage (NAVD 88)		Stage standard deviation		Correlation coefficient	Mean difference between measured and computed values		Percentage of explained variance	n	Land surface altitude (NAVD 88)	
	Measured (meters)	Computed (meters)	Measured (meters)	Computed (meters)		Stage (meters)	Standard deviation (meters)			Model input (meters)	Measured (meters)
NTS1	.841	.517	.293	.213	.768	.323	.188	58.8	2,457	1.020	1.076
NTS10	.927	.792	.310	.236	.902	.135	.141	79.3	2,152	1.270	1.237
NTS14	.732	.704	.386	.254	.909	.028	.188	76.2	2,395	1.380	.756
OL1	-.059	-.063	.160	.136	.864	.004	.080	74.7	2,447	-.220	--
OT	.251	.153	.189	.159	.902	.098	.082	81.0	2,464	-.170	--
P33	1.509	1.531	.148	.104	.919	-.022	.067	79.6	2,406	1.230	1.024
P34	.419	.251	.213	.171	.864	.168	.108	74.2	2,428	.160	.119
P35	.118	.179	.171	.139	.952	-.061	.057	88.8	2,552	-.400	-.195
P36	.868	.886	.146	.109	.909	-.018	.065	80.0	2,407	.630	.530
P37	.002	.014	.155	.134	.855	-.012	.080	73.0	2,465	-.140	-.183
P38	.069	.057	.148	.113	.823	.012	.085	67.4	2,360	-.130	-.192
R127	.267	.360	.197	.163	.922	-.093	.079	84.0	2,384	.060	--
R158	.416	.390	.239	.191	.867	.025	.120	74.7	2,445	.980	.927
R3110	.919	.826	.331	.261	.915	.093	.140	82.1	2,456	1.240	1.094
RG1	1.242	1.372	.284	.171	.855	-.130	.164	66.7	1,941	1.460	1.061
RG2	1.138	1.183	.286	.218	.894	-.045	.133	78.3	2,108	1.450	1.390
Rutzke	.940	.881	.260	.210	.866	.059	.131	74.6	2,432	1.510	1.103
S12AT	2.182	2.070	.288	.173	.807	.113	.180	60.9	2,530	1.870	--
S12BT	2.205	2.050	.317	.171	.889	.154	.182	66.9	2,532	1.860	--
S12CT	2.239	2.182	.323	.184	.480	.056	.285	22.2	2,520	1.870	--
S12DT	2.209	2.065	.419	.222	.684	.144	.312	44.4	2,526	1.690	--
SP	.211	.196	.217	.192	.831	.014	.121	68.8	2,188	.480	.280
SR	.886	-.076	.109	.247	.482	.962	.216	-296.9	1,354	-2.800	--
TE	1.242	.029	.127	.102	.933	1.213	.049	85.3	1,438	-.190	--
TMC	.902	.884	.239	.174	.892	.018	.115	76.8	2,232	.770	.732
TSB	.628	.709	.278	.214	.926	-.081	.114	83.2	1,327	.490	.610
TSH	.156	.169	.163	.164	.903	-.013	.072	80.5	2,445	.000	-.021
WE	1.611	-.044	.114	.142	.825	1.655	.081	49.6	1,461	-1.610	--
WP	1.365	-.052	.128	.203	.709	1.417	.144	-25.6	1,096	-1.870	--
WW	1.435	.060	.151	.142	.883	1.375	.071	77.7	1,461	-.230	--

Table 15. Water-level comparison statistics for run 157GW, model ground water only.

[NAVD 88, North American Vertical Datum of 1988; n, number of points utilized from the time series]

Station	Mean stage (NAVD 88)		Standard deviation of stage		Correlation coefficient	Mean difference between measured and computed values		Percentage of explained variance	n	Land surface altitude (NAVD 88)	
	Measured (meters)	Computed (meters)	Measured (meters)	Computed (meters)		Stage (meters)	Standard deviation (meters)			Model input (meters)	Measured (meters)
A13	0.968	1.017	0.259	0.210	0.881	-0.050	0.124	77.1	2,197	0.980	0.969
Angels	1.329	1.302	.264	.122	.774	.026	.186	50.2	2,557	1.730	1.451
BD	.826	.176	.123	.109	.513	.650	.115	11.9	1,945	.010	2.612
BICYA8	.215	.805	.328	.294	.873	-.590	.160	76.1	1,959	-1.000	--
BICYA9	1.726	1.803	.211	.215	.813	-.077	.130	61.8	1,869	2.060	--
BICYA10	.718	.721	.303	.286	.837	-.004	.169	68.8	1,854	.890	--
BICYA11	.920	.893	.380	.236	.801	.028	.237	61.0	1,883	.880	--
BR	1.074	.097	.131	.117	.744	.977	.090	53.0	2,331	-.150	1.838
CN	.713	.066	.123	.096	.810	.648	.072	65.6	2,447	-.080	1.323
CP	-.056	-.060	.169	.181	.816	.004	.107	60.0	2,479	-.440	-.503
CR2	1.121	1.055	.307	.256	.925	.066	.120	84.7	2,161	1.330	1.231
CR3	1.119	1.099	.298	.258	.901	.020	.129	81.1	2,212	1.310	1.234
CT27R	.143	.063	.148	.138	.885	.080	.069	78.1	1,903	-.060	-.085
CT50R	.106	.120	.140	.142	.889	-.014	.067	77.5	1,896	.010	.088
CW	-.048	.041	.103	.099	.640	-.089	.086	30.7	2,261	-1.830	--
CYP2	.235	.206	.206	.222	.855	.029	.116	68.1	2,157	.480	1.643
CY3	.202	.150	.214	.226	.810	.053	.136	59.7	2,206	.280	1.518
DK	-.207	-.149	.118	.159	.456	-.058	.148	-58.8	1,317	-1.860	--
DO1	.349	.395	.267	.230	.858	-.047	.137	73.6	2,451	.560	.567
DO2	.432	.361	.278	.221	.853	.071	.146	72.5	2,237	.700	.570
E112	.846	.542	.301	.208	.842	.304	.169	68.6	2,320	1.050	.527
E146	-.096	-.035	.147	.172	.836	-.061	.095	58.7	2,435	-.210	-.369
EP1R	.044	.000	.132	.117	.911	.044	.054	83.0	2,406	-.060	-.262
EP9R	-.159	-.057	.087	.122	.818	-.102	.072	32.4	366	-.160	-.314
EPGW/SW	-.015	-.006	.099	.136	.871	-.009	.069	51.1	2,387	-.110	-.158
EVER4	.170	.232	.145	.176	.894	-.062	.080	69.8	2,521	.240	.085
EVER5A	-.097	.050	.153	.166	.863	-.147	.084	69.4	1,945	-.080	-.174
EVER6	.141	.062	.126	.137	.914	.079	.056	80.5	2,294	.000	-.006
EVER7	.201	.106	.120	.154	.901	.095	.070	66.3	2,342	.040	.131
G1251	.185	.173	.168	.193	.884	.012	.090	71.1	2,026	.230	.390
G1502	1.485	1.461	.242	.145	.821	.024	.148	62.4	2,453	1.580	2.060
G3272	1.491	1.471	.247	.111	.766	.020	.177	48.6	2,528	1.570	1.612
G3273	1.476	1.509	.239	.131	.818	-.033	.152	59.6	2,557	1.600	1.667
G3353	-.058	.063	.137	.174	.867	-.122	.088	58.9	2,519	-.020	1.149
G3437	1.194	1.048	.259	.184	.855	.146	.139	71.1	2,510	1.850	1.615
G3576	1.562	1.601	0.207	0.143	0.916	-0.039	0.095	78.8	1,965	1.370	1.353

Table 15. Water-level comparison statistics for run 157GW, model ground water only.—Continued

[NAVD 88, North American Vertical Datum of 1988; n, number of points utilized from the time series]

Station	Mean stage (NAVD 88)		Standard deviation of stage		Correlation coefficient	Mean difference between measured and computed values		Percentage of explained variance	n	Land surface altitude (NAVD 88)	
	Measured (meters)	Computed (meters)	Measured (meters)	Computed (meters)		Stage (meters)	Standard deviation (meters)			Model input (meters)	Measured (meters)
G3577	1.426	1.227	.272	.144	.804	.198	.178	57.1	2,014	1.360	1.356
G3578	1.520	1.367	.213	.122	.852	.153	.127	64.7	2,494	1.370	1.356
G3619	.326	.332	.147	.185	.815	-.006	.107	46.6	2,446	.210	.579
G3622	.879	.735	.239	.205	.817	.144	.138	66.5	2,306	1.390	1.347
G3626	.975	1.034	.174	.118	.440	-.059	.162	13.7	2,357	2.030	1.743
G3627	.860	1.157	.167	.116	.618	-.296	.132	37.6	2,368	1.910	1.942
G3628	1.011	1.039	.203	.127	.732	-.028	.140	52.5	2,336	1.730	1.667
G596	1.146	1.141	.197	.109	.562	.005	.163	31.5	2,546	1.810	1.753
G618	1.696	2.122	.146	.176	.841	-.426	.096	56.9	2,457	1.480	1.466
G620	1.574	1.546	.205	.182	.905	.028	.088	81.8	2,451	1.380	1.311
GI	1.363	.088	.113	.106	.669	1.274	.089	38.0	1,616	-2.500	--
HC	-.186	-.212	.111	.114	.823	.027	.067	63.6	1,434	.560	--
HR	.931	.044	.119	.158	.642	.887	.123	-05.3	1,461	.120	--
L67XW	1.761	1.721	.237	.133	.898	.040	.132	69.3	1,883	1.350	--
LN	1.524	.046	.120	.121	.714	1.478	.091	42.5	1,430	-.410	--
LO	.818	.223	.119	.153	.661	.595	.116	4.4	1,335	-2.000	--
LOOP1T	1.910	1.767	.158	.200	.767	.144	.129	34.0	2,024	1.860	--
LOOP2T	1.540	1.414	.220	.248	.797	.126	.151	52.6	2,086	1.480	--
LS	-.190	-.252	.106	.125	.728	.063	.087	32.1	1,461	-1.520	--
NCL	-.015	-.061	.190	.197	.774	.046	.130	52.9	2,390	-.240	--
NE1	1.664	1.743	.131	.105	.835	-.079	.072	69.8	2,509	1.290	1.314
NE2	1.627	1.710	.156	.105	.868	-.083	.083	71.7	2,503	1.340	1.241
NE3	1.695	1.410	.115	.122	.733	.285	.087	43.0	1,838	1.340	--
NE4	1.606	1.659	.158	.109	.834	-.052	.090	67.4	2,416	1.260	1.213
NE5	1.601	1.622	.146	.110	.854	-.021	.077	72.0	2,539	1.270	--
NMP	-.118	-.087	.151	.190	.781	-.031	.118	38.4	2,113	.010	--
NP201	1.869	1.839	.257	.203	.850	.030	.136	72.0	2,439	1.650	1.420
NP202	1.679	1.623	.196	.148	.924	.057	.082	82.6	2,309	1.350	1.164
NP203	1.471	1.452	.181	.133	.898	.019	.085	77.8	2,426	1.220	.890
NP205	1.478	1.400	.264	.235	.852	.079	.138	72.4	2,447	1.440	1.332
NP206	1.282	1.280	.272	.186	.869	.002	.144	72.1	2,453	1.380	1.366
NP44	.636	.677	.351	.241	.864	-.041	.187	71.6	2,342	1.270	1.073
NP46	.018	-.029	.171	.188	.786	.047	.118	52.1	2,429	.050	-.052
NP62	.399	.423	.197	.185	.855	-.024	.104	72.3	2,229	.310	.835
NP67	.215	.236	.179	.206	.909	-.021	.086	76.8	2,406	.240	.582
NP72	0.503	0.505	0.316	0.222	0.849	-0.002	0.173	70.0	2,222	0.980	0.899
NR	1.181	.048	.117	.113	.674	1.133	.093	37.0	1,380	-1.200	1.682

Table 15. Water-level comparison statistics for run 157GW, model ground water only.—Continued

[NAVD 88, North American Vertical Datum of 1988; n, number of points utilized from the time series]

Station	Mean stage (NAVD 88)		Standard deviation of stage		Correlation coefficient	Mean difference between measured and computed values		Percentage of explained variance	n	Land surface altitude (NAVD 88)	
	Measured (meters)	Computed (meters)	Measured (meters)	Computed (meters)		Stage (meters)	Standard deviation (meters)			Model input (meters)	Measured (meters)
NTS1	.841	.517	.293	.213	.768	.323	.188	58.8	2,457	1.020	1.076
NTS10	.927	.792	.310	.236	.902	.135	.141	79.3	2,152	1.270	1.237
NTS14	.732	.704	.386	.254	.909	.028	.188	76.2	2,395	1.380	.756
OL1	-.059	-.021	.160	.172	.864	-.037	.087	70.2	2,447	-.220	--
OT	.251	.201	.189	.168	.912	.050	.078	83.2	2,464	-.170	--
P33	1.509	1.508	.148	.115	.877	.001	.073	75.8	2,406	1.230	1.024
P34	.419	.292	.213	.199	.890	.127	.097	79.1	2,428	.160	.119
P35	.118	.263	.171	.126	.905	-.145	.078	79.2	2,552	-.400	-.195
P36	.868	.867	.146	.120	.891	.001	.067	78.9	2,407	.630	.530
P37	.002	.048	.155	.193	.827	-.047	.109	50.8	2,465	-.140	-.183
P38	.069	.103	.148	.142	.861	-.034	.077	73.3	2,360	-.130	-.192
R127	.267	.315	.197	.198	.919	-.049	.080	83.7	2,384	.060	--
R158	.416	.390	.239	.191	.867	.025	.120	74.7	2,445	.980	.927
R3110	.919	.826	.331	.261	.915	.093	.140	82.1	2,456	1.240	1.094
RG1	1.242	1.372	.284	.171	.855	-.130	.164	66.7	1,941	1.460	1.061
RG2	1.138	1.183	.286	.218	.894	-.045	.133	78.3	2,108	1.450	1.390
Rutzke	.940	.881	.260	.210	.866	.059	.131	74.6	2,432	1.510	1.103
S12AT	2.182	2.436	.288	.242	.689	-.254	.213	45.2	2,530	1.870	--
S12BT	2.205	2.436	.317	.242	.760	-.232	.206	57.8	2,532	1.860	--
S12CT	2.239	2.436	.323	.243	.795	-.197	.196	63.0	2,520	1.870	--
S12DT	2.209	2.438	.419	.241	.811	-.229	.264	60.2	2,526	1.690	--
SP	.211	.196	.217	.192	.831	.014	.121	68.8	2,188	.480	.280
SR	.886	.076	.109	.112	.637	.811	.094	24.9	1,354	-2.800	--
TE	1.242	.080	.127	.106	.758	1.163	.083	56.9	1,438	-.190	--
TMC	.902	.837	.239	.195	.909	.065	.102	81.8	2,232	.770	.732
TSB	.628	.538	.278	.207	.896	.090	.131	77.9	1,327	.490	.610
TSH	.156	.169	.163	.193	.896	-.013	.086	72.0	2,445	.000	-.021
WE	1.611	.071	.114	.201	.390	1.540	.188	-174.6	1,461	-1.610	--
WP	1.365	.132	.128	.139	.639	1.233	.114	21.2	1,096	-1.870	--
WW	1.435	.122	.151	.145	.801	1.314	.094	61.5	1,461	-.230	--

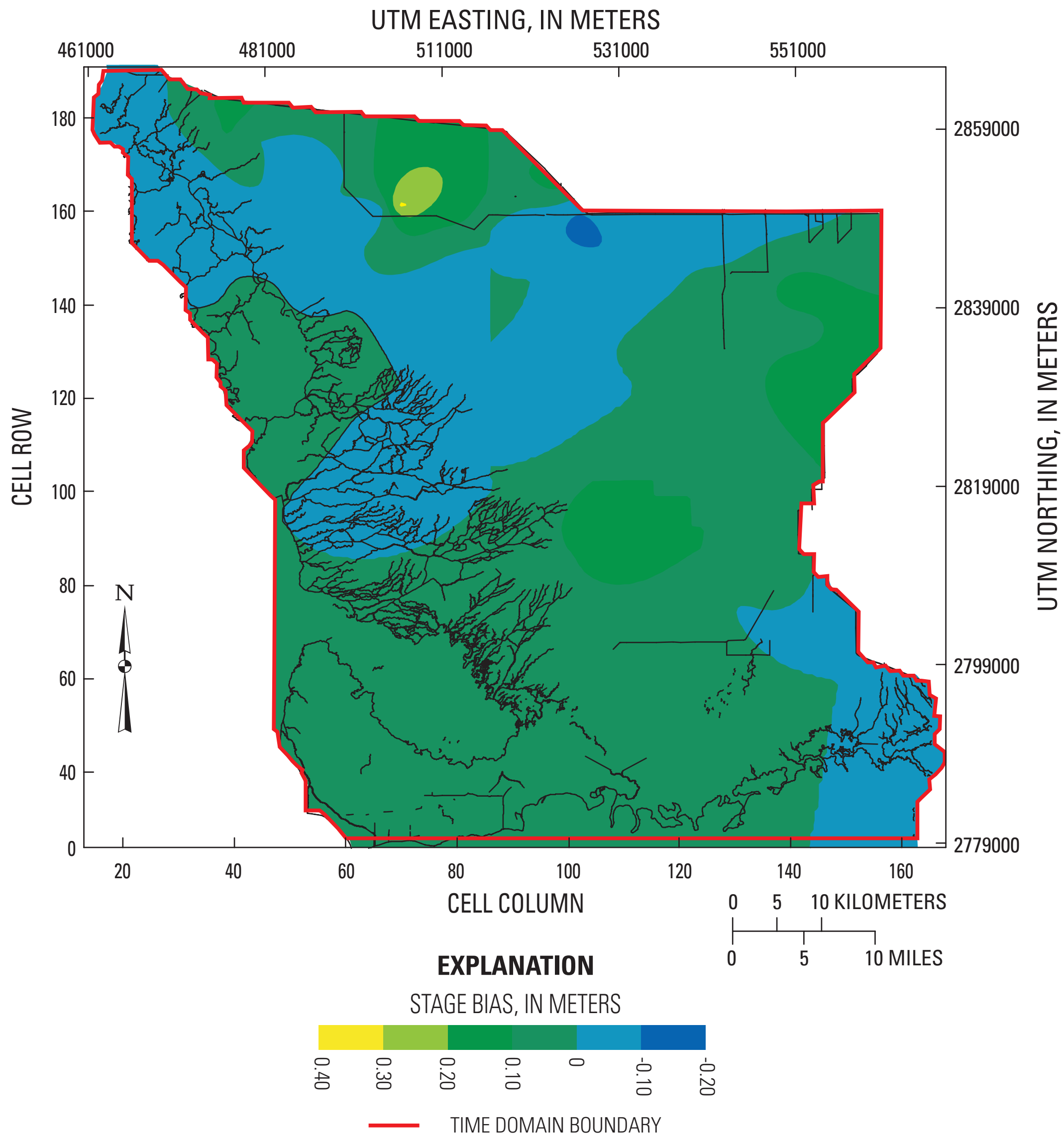

Figure 35. Spatial distribution of model mean stage bias in the TIME area for run 157.

summary statistics for 103 sites in table 5; run 157GW shows substantial improvement in each category. In figures showing the spatial distribution of statistical properties, the contour shapes are partly dependent upon the location and spacing of the field sites used for comparison. For example, an apparent horizontal offset of figure 36 contours can be explained by the interpolation between field sites and does not correspond to a distinct hydrologic feature.

The changes from run 142 to 157 decrease the total average flow to northeastern Florida Bay from 16.0 to 13.4 m^3/s. This reduction in flow, partly caused by reduced boundary seepage and increased ET, improves the agreement between model discharge to Florida Bay and measured flows of 10.2 m^3/s. The redistribution of flows through rivers and creeks is shown in figure 25.

Improvements in water-level representation are evident at a number of sites, especially TSB, E112, EPGW/SW, EVER5A, and NTS14 (fig. 34); however, EVER4, EVER6, and EVER7 are nearly unchanged. The computed surface-water values are actually a composite of model surface water (when present) and model ground water when land surface is dry. NTS14 is an example where model land-surface altitude is substantially (0.6 m) higher than the corresponding measured altitude. An altitude adjustment is probably necessary to obtain

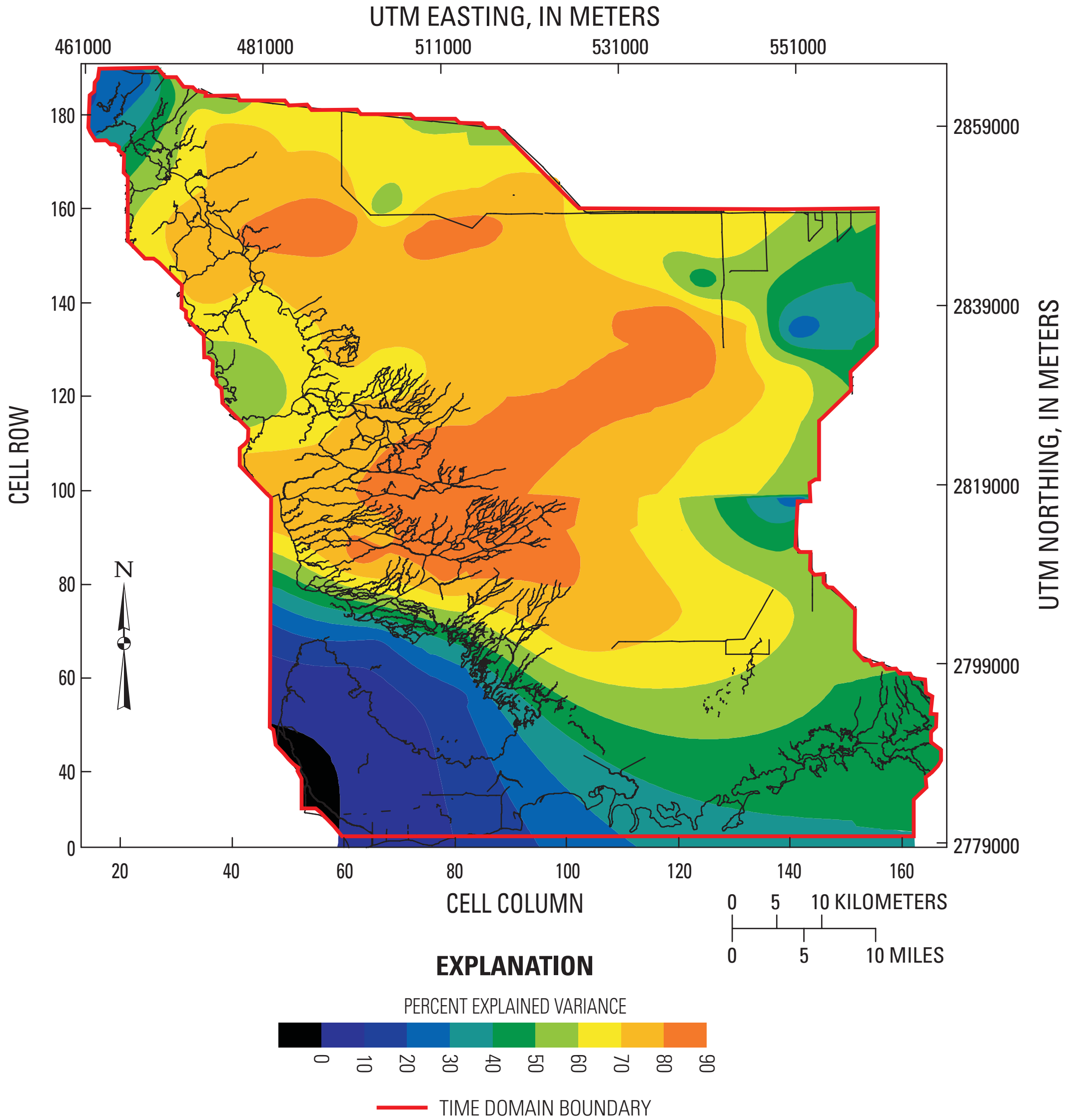

Figure 36. Spatial distribution of percentage of explained variance in the TIME area for run 157.

further improvement at sites were substantial land-altitude discrepancies exist. The EPGW/SW station is noteworthy because the data are bracketed by model ground water and surface water and because ground-water head is above the surface-water stage, indicating upward leakage.

The predicted salinities at Trout Creek for runs 142 and 157 are shown in figure 37. The open-boundary prescribed salinity of 36 psu for incoming flow in run 142 caused substantial phase errors and a range compression compared to observations. Using the EFDC model salinity boundary conditions improves the phase and also expands the range to reproduce more closely the data. Hypersalinity (greater than 36 psu) extremes are still underpredicted, which is related directly to the Florida Bay model representation. In contrast, the overestimation of low salinities primarily is due to a lack of sufficient resolution in the TIME model directly adjacent to creeks where spatial gradients in salinity are large; however, this should have little effect on predicted freshwater outflows.

3.9 - Future Uses of TIME application

In order to use the TIME application to evaluate the effects of proposed restoration scenarios on the coastal Everglades, boundary conditions for TIME must be developed from a linkage to the South Florida Water Management

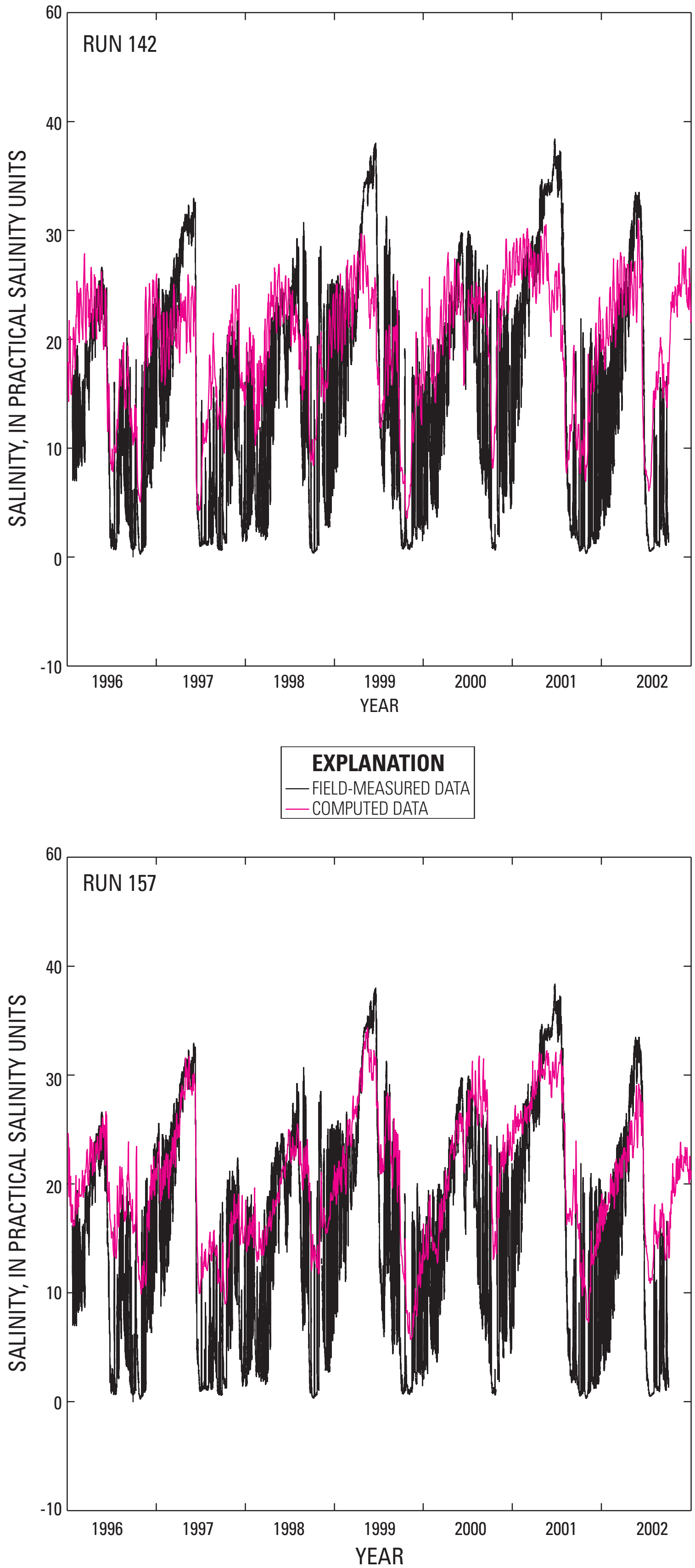

Figure 37. Comparison of salinities at Trout Creek for runs 142 and 157.

Model (SFWMM). This is implemented in a similar fashion to the SFWMM/SICS application link described in Wolfert and others (2004) and shown in appendix 1. The effects of restoration changes on stages, flows, and hydroperiods in the TIME domain can then be evaluated and ecologic implications determined. As shown in figure 2, the results of the TIME simulated scenarios can be used to supply coastal freshwater flow information for the Florida Bay Hydrodynamic model. The TIME application functions as an important representation of the interface between the inland region, represented by the SFWMM, and Florida Bay.

4 - Summary

The effort to develop numerical models to represent the inland and coastal areas of the Everglades has led to the development of the FTLOADDS model code, which couples the surface-water model SWIFT2D with the ground-water model SEAWAT. After a preliminary application to a small region of the coastal Everglades called SICS, the FTLOADDS code was applied, with further modifications, to the TIME domain—a larger region that includes practically all of Everglades National Park and the coastal waters. One purpose of developing TIME is to represent the complex coastal regime that lies between the South Florida Water Management Model (SFWMM), which represents restoration scenarios for the South Florida inland areas, and the Florida Bay hydrodynamic model.

A total of 157 seven-year TIME application runs were made for calibration and sensitivity analyses. Model output values used to evaluate calibration included: (1) wetlands water levels; (2) river stages and flows; (3) wetland surface-water depths, flows, and salinities; and (4) ground-water heads and salinities. Evaluations were made using statistics (mean bias, correlation, and percentage of explained variance), which indicated that the calibration fit is within the allowable error. This finding supports the use of the TIME application as a suitable tool to utilize input of boundary conditions developed from the regional SFWMM ecosystem restoration scenarios to determine the effects of these proposed changes to the hydrologic system.

Sensitivity studies of the TIME application were conducted by comparing output statistics between the calibrated application and a simulation with: (1) the model-code version used for SICS, (2) local adjustment of frictional resistance, (3) no leakage, (4) a road barrier removed, and (5) lowered land surface. The following were observed:

- The TIME application has improved capabilities compared to SICS, particularly in the representation of coastal flows. This result probably is due to a more computationally stable representation of the coastal creek outlets.

- Empirically manipulating frictional resistance values in inland areas improved water-level representation locally, but had a negligible effect on area-wide values. Because these changes have only local effects and are not physically based, they are not considered a valid representation of frictional resistance in the model.

- Neglecting leakage caused ground-water heads to differ substantially from measured values and reduced the overall accuracy of the model simulations. Surface-water stages changed slightly at most sites, indicating minimal ground-water influence, although substantial differences occurred occasionally.

- The incorporation of a major road as a complete barrier to flow influenced the local distribution and timing of flow; however, the differences in total flow and individual creekflows were negligible compared to simulations without the road barrier.

- Lowering the model land-surface altitude by 0.1 m produced mixed results; overall, the stage representation did not improve definitively.

These sensitivity tests led to a final calibration to improve the model fit at several locations. Incorporating the topography of Turner River and reporting computed stage in the river for comparison improved the fit in the northwestern corner of the TIME domain. An improved water-level fit was achieved by reducing the friction coefficient at the Taylor Slough Bridge boundary inflow point and increasing the coefficient just south of C-111 Canal. The ET extinction function was modified to improve the ground-water head response of the model during the dry season. Additional data were used for the ground-water head boundary along the southeastern part of C-111 Canal and the frictional resistance of Trout Creek outlet was increased; both steps improved the model fit to measured data for the total flow to Florida Bay and coastal salinities. Improved agreements also were obtained at the majority of water-level sites throughout the model domain. This final calibration also supports the use of the TIME application as a suitable tool for representing restoration scenarios.

5 - References Cited

Abtew, W., 1996, Evapotranspiration measurements and modeling for three wetland systems in South Florida: Water Resources Bulletin, v. 32, no. 3, p. 465-473.

Abtew, W., and Obeysekera, Jayantha, 1995, Lysimeter study of evapotranspiration of cattails and comparison of three estimation methods: Transactions of the American Society of Agricultural Engineers, v. 38, no. 1, p. 121-129.

Abtew, W., Obeysekera, Jayantha, Irizarry-Ortiz, M., Lyons, D., and Reardon, A., 2003, Evapotranspiration estimation for South Florida, *in* Bizier P., and DeBarry P.A., eds., World water environmental resources congress 2003: American Society of Civil Engineers and Environmental Water Resources Institute, Philadelphia, Pennsylvania, June 23-26, 2003.

Cohen, A.D., and Spackman, Jr., William, 1984, The petrology of peats from the Everglades and coastal swamps of southern Florida, *in* Gleason, P.J., ed., Environments of South Florida, present and past II: Miami Geological Society, p. 352-374.

Desmond, Greg, 2003, Measuring and mapping the topography of the Florida Everglades for ecosystem restoration: U.S. Geological Survey Greater Everglades science program: 2002 biennial report: U.S. Geological Survey Open-File Report 03-54, p. 31-32.

Eagleson, P.S., 1970, Dynamic Hydrology: New York, McGraw-Hill, 462 p.

Fish, J.E., and Stewart, M.T., 1991, Hydrogeology of the surficial aquifer system, Dade County, Florida: U.S. Geological Survey Water-Resources Investigations Report 90-4108, 53 p.

Fitterman, D.V., and Deszcz-Pan, M., 1998, Helicopter EM mapping of saltwater intrusion in Everglades National Park, Florida: Exploration Geophysics, v. 29, p. 240-243.

Fitterman, D.V., and Deszcz-Pan, M., 2002, Helicopter electromagnetic data from Everglades National Park and surrounding areas, Florida: Collected 9-14 December 1994: U.S. Geological Survey Open-File Report 02-101, 38 p.

Fitterman, D.V., Deszcz-Pan, Maria, and Stoddard, C.E., 1999, Results of time-domain electromagnetic soundings in Everglades National Park, Florida: U.S. Geological Survey Open-File Report 99-426.

German, E.R., 2000, Regional evaluation of evapotranspiration in the Everglades: U.S. Geological Survey Water-Resources Investigations Report 00-4217, 48 p.

Guo, Weixing, and Langevin, C.D., 2002, User's guide to SEAWAT: A computer program for simulation of three-dimensional variable-density ground-water flow: U.S. Geological Survey Techniques of Water-Resources Investigations, book 6, chap. A7, 77 p.

Hamrick, J.M., and Moustafa, M.Z., 2003, Florida Bay hydrodynamic and salinity model analysis: Joint Conference on the Science and Restoration of the Greater Everglades and Florida Bay Ecosystem "From Kissimmee to the Keys", April 13-18, 2003, Palm Harbor, Florida.

Hansen, M., and DeWitt, N.T., 1999, Modern and historical bathymetry of Florida Bay *in* Proceedings of the 1999 Florida Bay and Adjacent Marine Systems Science Conference, November 1-5 1999, Key Largo, Fla.

Harvey, J.W., Jackson, J.M., Mooney, R.H., and Choi, J., 2000, Interaction between ground water and surface water in Taylor Slough and vicinity, Everglades National Park, South Florida: Study methods and appendixes: U.S. Geological Survey Open-File Report 00-483, 67 p.

Holmes, C.W., Robbins, John, Halley, R.B., Bothner, Michael, Tenbrink, Marilyn, and Marot, M., 2000, Sediment dynamics of Florida Bay mud banks on a decadal time scale: U.S. Geological Survey Program on the South Florida Ecosystem: 2000 Proceedings of the Greater Everglades Ecosystem Restoration (GEER) Conference, December 11-15, 2000: U.S. Geological Survey Open-File Report 00-449.

Intergovernmental Panel on Climate Change, 2001, Climate change 2001: The scientific basis: United Kingdom and New York, Cambridge University Press, 881 p.

Jacobs, J.M., and Sudheer, R.S., 2001, Evaluation of reference evapotranspiration methodologies and AFSIRS crop water use simulation model. Final report John M. Fitzgerald, Water Use Data Manager Division of Water Supply Management St. Johns River Water Management District Palatka, Florida. Department of Civil and Coastal Engineering University of Florida Gainesville, Florida. SJRWMD Contract Number: SD325AA. UF Contract Number: 4504771, April 2001.

Langevin, C.D., Swain, E.D., and Wolfert, M.A., 2004, Simulation of integrated surface-water/ground-water flow and salinity for a coastal wetland and adjacent estuary: U.S. Geological Survey Open-File Report 2004-1097, 30 p.

Langevin, C.D., Swain, E.D., and Wolfert, M.A., 2005, Simulation of integrated surface-water/ground-water flow and salinity for a coastal wetland and adjacent estuary: Journal of Hydrology v. 314, p. 212-234.

Large, W.G., and Pond, S., 1981, Open ocean momentum flux measurements in moderate to strong winds: Journal of Physical Oceanography, v. 11, p. 324-336.

Lee, J.K., and Carter, Virginia, 1999, Field measurement of flow resistance in the Florida Everglades: Proceedings of the South Florida Restoration Science Forum: May 17-19, 1999, Boca Raton, Florida: U.S. Geological Survey Open File Report 99-181.

Linsley, R.K. Jr., Kohler, M.A., and Paulhus, J.L.H., 1982, Hydrology for Engineers: New York, McGraw-Hill, p. 162-163.

Nemeth, M.S., Wilcox, W.M., and Solo-Gabriele, H.M., 2000, Evaluation of the use of reach transmissivity to quantify leakage beneath Levee 31N, Miami-Dade County, Florida: U.S. Geological Survey Water-Resources Investigations Report 00-4066.

Oke, T.R., 1978, Boundary Layer Climates: London, Methuen, 350 p.

Perrier A., and Tuzet A., 1991, Land surface processes: description, theoretical approaches, and physical laws underlying their measurements, *in* Schmugge. J., and Andre, J-C., eds., Land surface evaporation: Measurement and parameterization: New York, Springer, p. 145-155.

Prager, E.J., and Halley, R.B., 1997, Florida Bay bottom types: U.S. Geological Survey Open-File Report 97-526, 1 sheet.

Reese, R.S., and Cunningham, K.J., 2000, Hydrogeology of the gray limestone aquifer in southern Florida: U.S. Geological Survey Water-Resources Investigations Report 99-4213, 244 p.

Schaffranek, R.W., 2004, Simulation of surface-water integrated flow and transport in two dimensions: SWIFT2D user's manual: U.S. Geological Survey Techniques and Methods, book 6, chap B-1, 115 p.

Scheidt, D., Stober, J., Jones, R., and Thorton, K., 2000, South Florida Ecosystem Assessment: Everglades Water Management, Soil Loss, Eutrophication, and Habitat: U.S. Environmental Protection Agency Report 904-R-00-003.

Shoemaker, W.B., Sumner, D.M., Castillo, A., 2005, Estimating changes in heat energy stored within a column of wetland surface water and factors controlling their importance in the surface energy budget: Water Resources Research, v. 41, W10411.

Stannard, D.I., 1993, Comparison of Penman-Monteith, Shuttleworth-Wallace, and modified Preistley-Taylor evapotranspiration models for wildland vegetation in semiarid rangeland: Water Resources Research, v. 29, no. 5, p. 1379-1392.

Stewart, M.A., Bhatt, T.N., Fennema, R.J., and Fitterman, D.V., 2002, The road to flamingo: An evaluation of flow pattern alterations and salinity intrusion in the lower glades, Everglades National Park: U.S. Geological Survey Open-File Report 02-0059, 36 p.

Swain, E.D., 2005, A model for simulation of Surface-Water Integrated Flow and Transport in Two Dimensions: User's guide for application to coastal wetlands: U.S. Geological Survey Open-File Report 2005-1033, 88 p.

Swain, E.D., Wolfert, M.A., Bales, J.D., and Goodwin, C.R., 2004, Two-dimensional hydrodynamic simulation of surface-water flow and transport to Florida Bay through the Southern Inland and Coastal Systems (SICS): U.S. Geological Survey Water-Resources Investigations Report 03-4287, 56 p., 6 pls.

U.S. Army Corps of Engineers, 1999, CORPSCON v4.1 Technical documentation and operating instructions: Accessed on Nov. 2, 2006, at *http://www.iep.ca.gov/pub/corpscon/corpscon.doc*

U.S. Army Corps of Engineers and South Florida Water Management District, 2003, A Vision Statement for the Comprehensive Everglades Restoration Plan: accessed on Oct. 1, 2006, at *http://www.evergladesplan.org/pm/program_docs/cerp_vision_statement.cfm*

Wolfert, M.A., Langevin, C.D., and Swain, E.D., 2004, Assigning boundary conditions to the Southern Inland and Coastal Systems (SICS) model using results from the South Florida Water Management Model (SFWMM): U.S. Geological Survey Open-File Report 2004-1195, 30 p.

Worth, Dewey, Weaver, Cecella, and Trulock, Shelly, 2002, Florida Bay and Florida Keys Feasibility Study Overview: Accessed on Oct. 1, 2006, at *http://www.evergladesplan.org/docs/fs_fl_bay_feas_hires.pdf*