FINAL REPORT

VOLUME VII OF VII
DIVERSION MODELING

MISSISSIPPI RIVER REINTRODUCTION INTO MAUREPAS SWAMP PROJECT PO-29

Louisiana Department of Natural Resources
U.S. Environmental Protection Agency

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URS Corporation is undertaking a Hydraulic Feasibility Study to evaluate hydrologic impacts for a proposed 1,500 cubic feet per second (cfs) diversion of freshwater from the Mississippi River to the Maurepas Swamp, near Garyville, Louisiana. This study is part of the Mississippi River Reintroduction into Maurepas Swamp Project (PO-29) sponsored by the U.S. Environmental Protection Agency and the Louisiana Department of Natural Resources under the federal Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA). URS has previously submitted five volumes addressing critical data collection and model development and calibration efforts in support of the feasibility study:

- *Volume II, Secondary Benchmark GPS Static Survey;*
- *Volume III, Topographic and Bathymetric Survey;*
- *Volume IV, Hydrologic Data;*
- *Volume V, One Dimensional (SWMM) Model; and*
- *Volume VI, Two Dimensional Hydrodynamic Swamp Area Model, Development and Calibration.*

The Maurepas Swamp is a generally freshwater cypress-tupelo forested landscape located at the upper tidal margin of the Lake Pontchartrain/Lake Maurepas estuary system (Figure 1). The swamp is threatened by episodic brackish water intrusion from Lake Maurepas, long-term subsidence, and the elimination of nutrient inputs, a consequence largely of the century-plus isolation of the swamp from the annual nourishment of Mississippi River overbank floods. The CWPPRA Phase 0 reconnaissance level study (Lee Wilson, 2001) of a reintroduction of Mississippi River water estimated the potential wetland landscape benefits to be among the most cost-effective identified to-date in Louisiana coastal restoration. The diversion concept is illustrated in Figure 2 and features a gated structure at the river, a sand/silt settling basin, a new banked diversion channel (taking the Hope Canal alignment north of US Highway 61), and outfall management structures in the swamp north of Interstate 10 to distribute diversion water within the 50,000 acre north of US Highway 61 (Airline Highway) between Reserve Relief Canal on the east and Blind River on the west.

The Hydraulic Feasibility Study focuses on the physical hydrodynamics of the diversion and the key question of “Will the water go where we want it to go?” This question reflects four important hydrologic objectives for the project:

1. Broad and uniform flow distribution should be achieved to deliver nutrients, fine sediments, and freshening throughout the declining forest, and to avoid exacerbating stagnant areas.

2. The diversion water should be retained in the swamp for a reasonable time and short-circuiting to Lake Maurepas should be avoided.

3. The planned diversion and associated outfall management features should have no adverse impact on the stormwater drainage systems for the Garyville/Reserve communities. [The existing gravity system has very mild slopes and is sensitive to tailwater conditions in the swamp.]

4. Diversion velocities should be modest to prevent scouring, particularly at sensitive bank locations, such as near Interstate 10.

In order to study these issues, URS has developed and calibrated a high resolution, two-dimensional (2D) physical hydrodynamic model of the swamp using the program ADCIRC—capable of assessing swamp water surface elevations (WSEs), circulation patterns, retention times, and channel velocities under various diversion scenarios. URS has also developed and calibrated a one-dimensional (1D) model of the Garyville/Reserve drainage system using Surface Water Management Model (SWMM) to enhance analysis of the relationship of tailwater conditions to the discharge capacity of the drainage network.

In this Volume URS presents the results of simulations to evaluate the effects of diversion on the project study area, including the following tasks:

- Planning for Diversion Modeling
- Evaluation of Outfall Management Requirements
- Evaluation of Alternative Diversion Flows
- Evaluation of Alternative Lake Conditions
- Assessment of Impacts to Garyville/Reserve Drainage System
- Examination of Velocity Scouring Impacts
- Development of Conclusions and Recommendations

This Volume describes methodologies and presents results for the diversion modeling tasks. Relevant model input files and output files and supporting information are given in Appendices A through E.

The model findings, taken together, show that all four of the diversion project objectives for the feasibility study can be achieved. The findings point toward eight diversion project design/operating requirements. Additional physical and water quality modeling needs have been defined for developing engineering, operating, and adaptive management plans.

Diversion modeling has been the subject of extensive discussion, planning, and cooperative decision-making among members of the Project Team. Participants in the planning have included:

- Ken Teague and Patty Taylor, USEPA;
- Brad Miller and Russ Joffrion, LDNR;
- Mike Patorno, Bob Jacobsen, Harry Harlan, Chris Reed, and Nathan Dill, URS Corporation; and
- Elizabeth Valenti and Ben Jelley (WorldWinds, Inc.), high performance computing.

In order to study the four objectives associated with the Maurepas diversion listed in the Introduction, URS developed and calibrated a 2D physical hydrodynamic model of the swamp, using the program ADCIRC, capable of assessing swamp WSEs, circulation patterns, retention times, and channel velocities under various diversion scenarios (see *Volume VI, Two Dimensional Hydrodynamic Swamp Area Model, Development and Calibration (ADCIRC Model*). The 2D ADCIRC finite element model provides very high resolution of project area features, with node spacing as close as 15 feet (see Figure 3). The model represents 2D physical hydrodynamics in the project area – including channel flow, propagation of tidal signals, overbank flow, flow through bank gaps, and swamp circulation – during a variety of conditions.

The large computational requirements of the model require execution on a parallel high performance computer cluster. Testing of the 2D model revealed limitations in simulating swamp resistance. Current 2D swamp modeling techniques are not capable of representing resistance under a wide range of turbulent conditions. Extensive parameter testing was conducted to improve the representation of swamp resistance. This limitation was addressed in part by artificially raising the elevation of the swamp floor. URS evaluated the performance of the model through calibration and validation and determined that the model supports a feasibility analysis of the four objectives.

In July 2006, following the development and calibration/validation of the 2D model, the Project Team agreed to proceed with diversion modeling. The results of the 2D model calibration and validations showed that application of the 2D model must carefully consider the swamp resistance limitation and implications for under-representing backwater and short-circuiting. The Project Team therefore agreed with a URS recommendation to use the 2D model for diversion evaluation primarily by comparing *relative* stage and flow differences for various scenarios under near *steady state* conditions. Diversion modeling was completed in November 2006.

In accordance with Project Team discussions, URS initially conducted a series of outfall management simulations with a 1,500 cfs diversion[1] and steady WSE in Lake Maurepas at mean level (1.1 ft NAVD-88 LDNR) to investigate the circulation and retention of diversion water in the Maurepas Swamp using the 2D ADCIRC model. To support the evaluation of diversion circulation URS developed a particle-tracking code for use in conjunction with the 2D steady-state flow field output. A description of the code and verification testing, along with a copy, are included in Appendix A. The code was used to define *selected representative* steady-state streamlines and estimate Median Swamp Retention Time (MSRT)[2]. During the course of simulations the results of outfall management alternatives were reviewed and modified in consultation between URS and the other members of the Project Team. The Project Team identified outfall management features for modeling in order to test a range of outfall management strategies. A comprehensive, systematic modeling of detailed outfall management design alternatives was beyond the scope of this phase of work.

Following the identification of basic outfall management requirements, the Project Team agreed to simulations of alternative diversion flows of 1,000 and 2,000 cfs[3]. A shut-down simulation of the 1,500 cfs diversion was performed to provide an indication of the time frame for re-establishing initial conditions. Simulations of 1,500 cfs diversion were also undertaken for alternative Lake WSEs (0.5, 2.0 and 3.0 ft NAVD-88 LDNR). A 1,500 cfs

[1] The 1,500 cfs flow rate was chosen based on the earlier results of the Phase 0 Report: *Diversion into the Maurepas Swamps, A Complex Project Under the CWPPRA Program*, Lee Wilson & Associates, June 2001.

[2] The program defines 199 streamlines such that the space between each streamline represents an equivalent 0.5 percent of the fully developed flow. Particle travel times through the swamp are computed for each streamline, from the diversion outlet to final exit into a major channel (Blind River, Hope Canal/Bayou Tent/Dutch Bayou, Mississippi Bayou, or Reserve Relief Canal) leading directly to Lake Maurepas. The 50th percentile travel time represents the MSRT. MSRT is a relative indication of circulation, with a longer MSRT generally indicating better circulation and less short-circuiting. The performance of swamp nutrient assimilation and prevention of downstream eutrophication are closely tied to MSRT. Development of project-specific design criteria for MSRT was deferred by the Project Team to the water quality modeling phase of work.

[3] These represented a reasonable range of flows targeted by the Phase 0 Report. Higher flow rates have been discussed by other researchers based on the needs to restore the larger complex of swamps south of Lake Maurepas, especially areas east of Reserve Relief Canal.

diversion simulation was also conducted using one unsteady Lake condition—the LSU Calibration Period.

The 2D simulations provided an indication of the potential impact of diversion on the WSE throughout the Maurepas Swamp. Based on these results the Project Team agreed to conduct a drainage impact simulation using the 2D ADCIRC model to provide tailwater conditions to the 1D SWMM model. URS had previously developed and calibrated a 1D SWMM model of the Garyville/Reserve drainage system to assess backwater impacts on the system (Figure 4). The 1D SWMM model simulates rainfall runoff and drainage discharges in the canals largely south of US Highway 61.

A comparison was made of existing drainage conditions for a 24-hour, 10-year return frequency rainfall event, versus a 1,500 cfs diversion with "Refined Outfall Management" and the Lake at 1.1 ft. Based on the results of this comparison, and the negligible stage impacts of the diversion at higher Lake WSEs, the Project Team agreed that no further drainage impact simulations were warranted for this phase of study.

The simulation of a 1,500 cfs at low Lake WSE (0.5 ft) and the simulation of a higher diversion rate (2,000 cfs) would be expected to exhibit the highest velocities and were used to identify potential scouring issues.

The Project Team gave extensive consideration to circulation issues related to the Central Swamp due to potentially affected private landowners, the current stagnation problems in this area, and the relationship of Central Swamp WSEs to upland drainage. Based on the initial evaluation of diversion impact on the Central Swamp during the outfall management simulations, the Project Team agreed that direct release of diversion water into the Central Swamp would need to be carefully controlled in order to minimize WSEs and drainage impacts. In practice such releases could be handled through controlling flow in the interstate culverts and using additional gated conduits along the east and west bank of the diversion channel between Airline Highway and Interstate 10. Because the amount and duration of controlled releases into the Central Swamp are likely to be small and short, these releases were not simulated during this phase of study.

URS conducted all simulations on the WorldWinds, Inc. parallel cluster, which includes 32 Xeon 64-bit processors (Intel 7520 dual-core 3.0GHz with 2GB DIMM). The dual core processors allow for the assignment of 64 sub-domains. The resulting run speed approached 10:1 using a 0.5 second time step and 5:1 for a 0.25 second time step.

URS undertook a total of 48 ADCIRC simulations over an 18 week period in order evaluate the diversion objectives. All diversion simulations were conducted with the basic "High Swamp" calibrated/validated model. The numeric and physical parameters for the diversion simulations were largely the same as those used for the "High Swamp" model and are summarized in Table 1. Appendix B provides a Simulation Log describing all the diversion runs.

URS prepared 1D SWMM and 2D ADCIRC (Version 45.09) simulation input files in accordance with model requirements (see calibration volumes). SWMM simulations were performed using XP-SWMM which includes its own user interface. ADCIRC input files were prepared using the Surface-water Modeling System (SMS) pre-processing program interface and by directly modifying previous simulation input files with the aid of data management software (SciLab). ADCIRC model output was post-processed using SMS, primarily to prepare plan view contour plots of WSE and velocity. Digital copies of the input and output files for simulations referenced in this Volume are included in Appendix C (1D SWMM simulations) and Appendix D (2D ADCIRC simulations).

Table 1
Summary of Numeric and Physical Parameters for ADCIRC Diversion Simulations

Parameter	Value
Numeric Parameter	
Time-step	0.5 seconds 0.25 seconds for Drainage Impact Simulations
Tau_0	0.03
Convergence criteria	1×10^{-8}
Maximum number of iterations	35
DRAMP	Typically 2 days with diversion
H_0	0.02 feet
VELMIN	0.02 feet/second
Horizontal eddy viscosity	10 $feet^2$/second
Physical Parameter	
Drag Coefficient based on …	
Bottom Elevation Range (feet)	Value for $C_{D\text{-}ADCIRC}$
z < -6	0.005
-6 < z < -3	0.01
-3 < z < -1	0.05
-1 < z <0	0.1
z > 0	0.5
Weir Coefficient	0.5
Simulation Duration	
Outfall Management	20 days to reach near steady-state
Alternative Diversion Flows	10 days hotstart from “Refined Outfall Management” simulation to reach near steady-state
Alternative Lake WSE	20 days to reach near steady-state
Alternative Lake WSE—LSU Period	18 days hotstart from “Refined Outfall Management” simulation
Drainage Impact	5 days

Alternative Outfall Management Scenarios

The evaluation of diversion circulation patterns was undertaken for a variety of outfall management scenarios for a 1,500 cubic feet per second (cfs) flow, under a simplifying condition of a steady water surface for Lake Maurepas at a mean WSE of 1.1 ft NAVD88-LDNR. Simulations were run for a period of 20 days to approach fully developed, i.e., steady-state, flow conditions. A description of the various mesh changes for five selected outfall management scenarios is provided in Table 2, with locations called out in Figure 5.

Table 2
Summary of Outfall Management Scenarios

Outfall Management Simulation	Description of Scenario Changes to Without Diversion Model
1. Baseline	4000 ft diversion channel replaced lower Hope Canal extending 1000 ft north of I-10; diversion channel has invert elevation -8 ft, top width 160 ft, side slope 4:1; existing cross section at I-10 overpass.
2. Closed Interstate Culverts and Degraded Railroad Embankment	Closed 7 culverts under I-10 west of Mississippi Bayou; lowered railroad bed and created symmetrical gaps on both sides of Hope Canal 1000 ft downstream of diversion channel mouth; pluged north ditch along I-10 west of Bayou Bougere; widened 2 gaps in east-west portion of railroad bed to 600 ft; converted “weir” boundaries to mesh elements on east bank of Hope Canal to Bayou Tent to eliminate small numerical instabilities caused by overtopping weirs.
3. Extended Outfall	Extended high banks on Hope Canal 9000 ft farther downstream with bank elevation stepping down 0.25 ft every 1000 ft from 3.5 ft to 1.2 ft; reduced conveyance at Bayou Bec Crochet; plugged heads of Bourgeois Canal and South Bayou; widened gaps in north-south portion of railroad bed and on east bank of lower Blind River north of railroad bed to 600 ft.
4. Perimeter Weirs	Placed weirs at mouth of Dutch Bayou, Bourgeois Canal, and Bayou Secret; raised elevation of bank gaps to 0.2 ft lower than bank elevation around swamp perimeter from Blind River at I-10 to Reserve Relief Canal at I-10; converted “weirs” to mesh elements along Bayou Tent to Dutch Bayou; reduced conveyance from Mississippi Bayou to South Oilfield Canal.
5. Refined Outfall Management	Reverted to “Closed Interstate Culverts” grid; placed weirs at mouths of Bourgeois Canal and Bayou Secret; closed gaps on east bank of Blind River between I-10 and Transmission Line ROW; widened gaps in north-south portion of railroad bed to 600 ft.

Results

Stage hydrographs and a comparison of the peak stages at various project area locations for these five simulations are given in Figure 6 and Table 3, respectively. Figures 7 and 8 depict the fully-developed WSE and flow streamlines for each simulation. The streamlines are color coded to illustrate the swamp travel time beginning near Interstate 10. Figure 9 presents the frequency distribution of swamp travel-time for each simulation at fully developed flow. Table 4 summarizes the MSRT for each of the outfall management scenarios. Animations for the simulations are provided in Appendix E.

Simulation of “Scenario 1, Baseline” indicated 1) that a high proportion of the flow was diverted to the east by the old railroad embankment along Hope Canal (Figures 7a and 8a), and 2) stage increases of over one-half foot in the Central Swamp (see results at S-25 and Airport in Table 3). These results are based on fully-developed flow under existing topographic and bathymetric conditions throughout the project area—i.e., no outfall management and with the equalizing culverts underneath Interstate 10 remaining open. Previous SWMM modeling showed that drainage of the Garyville/Reserve area is sensitive to tailwater increases (see *Volume V, One Dimensional Hydrodynamic Garyville/Reserve Drainage System Model, Development and Calibration (SWMM Model).*

“Scenario 2, Closed Interstate Culverts and Degraded Railroad Embankment” introduced outfall management features to address the two key findings in the “Scenario 1, Baseline.” This scenario improved westward flow balance, as illustrated in Figure 8b, and reduced the stage increase in the Central Swamp to about 0.1 ft (S-25 and Airport). However, the diversion flow did not fan out evenly toward the northern swamp. The smaller area of inundation compared to the “Baseline” scenario reduced the MSRT from 6.5 to 5.5 days.

“Scenario 3, Extended Outfall” included several modifications to improve northward circulation and MSRT, most notably moving the diversion outlet northward about 9,000 ft. However, the results, as indicated by the streamlines in Figure 8c, show that the “Extended Outfall” scenario produced a more direct eastward and westward gradient, increasing short-circuiting and reducing MSRT to 4.0 days.

Table 3
Comparison of Peak Stages, Outfall Management Simulations

Location	Outfall Management Simulation* Peak Stage (ft NAVD—LDNR)				
	1. Baseline	2. Closed Interstate Culverts & Degraded Railroad Embankment	3. Extended Outfall	4. Perimeter Weirs	5. Refined Outfall Managemen t
S-4, Dutch Bayou at Lake	1.12	1.12	1.13	1.56	1.12
S-7, Hope Canal at I-10	3.12	2.97	3.98	3.98	2.97
S-9, Dutch Bayou	1.47	1.46	1.72	1.83	1.47
S-10, Blind River	1.13	1.13	1.16	1.18	1.13
S-11, Mississippi Bayou at I-10	1.63	1.56	1.83	1.89	1.56
S-16, Blind River at I-10	1.20	1.23	1.37	1.40	1.23
S-23, North Swamp	1.81	1.77	2.15	2.19	1.78
S-24, Reserve Relief Canal at Airline Hwy	1.29	1.23	1.39	1.48	1.23
S-25, Central Swamp	2.03	1.18	1.22	1.26	1.18
Airport	1.90	Dry (1.4)	Dry (1.4)	Dry (1.4)	Dry (1.4)

* Lake WSE is 1.1 ft NAVD88-LDNR; results can be compared to a Without Diversion WSE throughout the area of 1.1 ft NAVD88-LDNR.

"Scenario 4, Perimeter Weirs" examined the effect of adding constrictions at the mouth of Dutch Bayou and several other major outflow locations to the "Extended Outfall" scenario. This scenario was intended to reduce channelized flow and short-circuiting, and to create a broader impounding and over-banking of the diversion flow. However, these modifications only increased MSRT slightly, to 4.2 days.

The "Extended Outfall" and "Perimeter Weirs" simulations noticeably raised stages at Reserve Relief Canal (0.39 ft at S-24) and Blind River (0.30 ft at S-16), which indicate a potential for significant drainage impacts.

"Scenario 5, Refined Outfall Management" incorporates features from the various scenarios that improved circulation and MSRT without significantly impacting drainage. Figures 8e and 9 show that this scenario achieved the best flow pattern of any of the outfall management simulations. However, circulation to the northern swamp was still limited. The MSRT was the longest, at 5.8 days, for scenarios that included closure of the interstate culverts.

Table 4
Summary of Outfall Management Median Swamp Retention Times

Outfall Management Scenario	MSRT (days)
Baseline	6.5
Closed Interstate Culverts	5.5
Extended Outfall	4.0
Perimeter Weirs	4.2
Refined Outfall Management	5.8

The various outfall management scenarios taken together indicate that circulation and MSRT could be further improved by reducing the eastward/westward surface water gradient, creating a better impounding of the diversion water. This might be accomplished with further upgrading of the integrity of the western bank of Reserve Relief Canal and the eastern bank of Blind River.

The hydrographs in Figure 6 for "Refined Outfall Management" show that the North Swamp stages begin to plateau around Day 10 (S-9, S-11, and S-23). The "Refined Outfall Management" animation clearly shows that diversion water fans out evenly throughout the North Swamp during flow development. Comparing the animation with the steady-state streamlines provides strong evidence for short-term pulsing of the diversion as a way to effectively distribute flow (and related benefits such as freshening, nutrients, and fine sediments) throughout the North Swamp. Gradients toward the northern swamp reaches are steeper during flow development, drawing higher relative amounts of flow and possibly extending MSRTs[4].

The circulation and retention time findings must be considered in light of the 2D ADCIRC model calibration/validation results, which showed that the model under-represents swamp resistance. This indicates that channelized flow and short-circuiting are likely to be greater than found in the model results, and that, while travel times within the swamp may be longer, the overall MSRTs may be shorter.

[4] A continuous dynamic particle tracking code is needed to evaluate the MSRT during a pulsing event.

Alternative Diversion Flow Scenarios

Following the outfall management simulations at the 1,500 cfs diversion rate, URS restarted the "Refined Outfall Management" simulation at Day 20 and conducted ten-day simulations of three alternative diversion flows of 1,000, 1,500, and 2,000 cfs. Stage hydrographs and a comparison of the peak stages (at Day 30) at various project area locations for these three simulations are given in Figure 10 and Table 5, respectively. Figures 11 and 12 depict the fully-developed WSE and flow streamlines for the two alternate simulations. Figure 13 presents the frequency distribution of particle-streamline travel times, and Table 6 summarizes the MSRTs, for the three diversion flows. Animations for the simulations are provided in Appendix E.

Table 5
Comparison of Peak Stages, Alternative Diversion Flows

Location	Peak Stages (ft NAVD88-LDNR) Alternative Diversion Flows		
	1,000 cfs	1,500 cfs	2,000 cfs
S-4, Dutch Bayou at Lake	1.11	1.12	1.12
S-7, Hope Canal at I-10	2.53	2.97	3.37
S-9, Dutch Bayou	1.36	1.47	1.57
S-10, Blind River	1.13	1.13	1.14
S-11, Mississippi Bayou at I-10	1.44	1.56	1.67
S-16, Blind River at I-10	1.19	1.23	1.27
S-23, North Swamp	1.60	1.78	1.93
S-24, Reserve Relief Canal at Airline Hwy	1.18	1.24	1.29
S-25, Central Swamp	1.24	1.24	1.24
Airport	Dry (1.4)	Dry (1.4)	Dry (1.4)

Results

Table 5 shows that the 33 percent decrease/increase in "Refined Outfall Management" diversion flow (versus 1,500 cfs) had little impact on peak stages near Lake Maurepas (S-4 and S-10), in the Central Swamp (S-25 and Airport), Reserve Relief Canal at Airline Highway (S-24), and Blind River (S-16). The effect of varying diversion flow was most noticeable in the North Swamp (S-23), but even then small, at about +/- 0.2 ft.

Table 6
Summary of Alternative Diversion Flow Median Swamp Retention Times

Alternative Diversion Flow	MSRT (days)
1,000 cfs	6.9
1,500 cfs	5.8
2,000 cfs	5.0

The overall effect of alternate diversion flows on streamline distribution was also minor, with the lower and high flows continuing to exhibit lower circulation toward the north. The 33 percent flow increase/decrease produced about a 14 to 19 percent reduction/increase in MSRT. These results indicate that the diversion circulation and MSRT are not highly sensitive to moderate changes in flow rate.

Shutdown Scenario

The results of the 1,500 cfs diversion shutdown simulation are presented in Figure 14 hydrographs. These hydrographs show that project area stages generally fall back to pre-diversion WSEs within 20 days. The combination of the "Refined Outfall Management" and "Shutdown" simulations suggest that 10 days of flow followed by a 20 day shutdown could be considered for a baseline pulsing scenario.

Alternative Lake Elevation Scenarios

URS has also undertaken simulations to assess the effect of a range of Lake Maurepas tailwater conditions during diversion on swamp stages, circulation, and MSRT. Twenty day simulations were performed to achieve fully-developed flow using steady Lake WSEs of 0.5, 2.0, and 3.0 ft NAVD88-LDNR using the "Refined Outfall Management Scenario" with a 1,500 cfs diversion flow. Results were compared to the Mean Lake WSE (1.1 ft). Stage hydrographs and a comparison of Day 20 peak stages at various project area locations for the four simulations are given in Figure 15 and Table 7, respectively. Figures 16 and 17 depict the fully-developed WSE and flow streamlines for the alternative Lake WSE simulations. Figure 18 presents the frequency distribution of particle-streamline travel times, and Table 8 summarizes the MSRTs. Animations for the simulations are provided in Appendix E.

Table 7
Comparison of Peak Stages, Alternative Lake WSEs

Location	Peak Stages (ft NAVD88-LDNR) Alternative Lake WSE			
	Low Lake 0.5 ft	Mean Lake 1.1 ft	High Lake 2.0 ft	Higher Lake 3.0 ft
S-4, Dutch Bayou at Lake	0.53	1.12	2.00	3.01
S-7, Hope Canal at I-10	2.97	2.97	3.06	3.55
S-9, Dutch Bayou	1.24	1.47	2.06	3.02
S-10, Blind River	0.54	1.13	2.03	3.02
S-11, Mississippi Bayou at I-10	1.50	1.56	2.08	3.03
S-16, Blind River at I-10	0.67	1.23	2.07	3.04
S-23, North Swamp	1.73	1.78	2.15	3.05
S-24, Reserve Relief Canal at Airline Hwy	0.70	1.23	2.06	3.02
S-25, Central Swamp	Dry	1.24	2.07	3.03
Airport	Dry	Dry	2.07	3.03

Elevations are in NAVD88-LDNR

Results

The hydrographs and Table 7 show that at Low Lake stage (0.5 ft) the diversion raises WSEs in the North Swamp interior (by 1.23 ft at S-23), Mississippi Bayou (1 ft at S-11), and upper Dutch Bayou (0.74 ft at S-9). At Low Lake WSEs diversion flow is more confined by the project area bank features, and thus has a greater impact on water stages, especially in the channels. On the other hand, at High Lake and Higher Lake the diversion model shows a very minor effect on project area stages. At High Lake and Higher Lake WSEs the diversion is overtopping many of the project area banks. Thus, the diversion circulation is not as confined to the channels.

Figure 17 and Table 8 show that the High Lake and Higher Lake stage dramatically impacts the diversion circulation and MSRT. At High Lake and Higher Lake stages, overbanking causes the diversion gradients to flatten out, significantly improving flow to the north and increasing the MSRT.

Table 8
Summary of Alternative Lake WSE Median Swamp Retention Times

Alternative Lake WSE (ft NAVD88-LDNR)	MSRT (days)
0.5	5.1
1.1 (Mean Lake Level)	5.8
2.0	10.1
3.0	>20

Unsteady Lake Simulation

URS also completed a diversion simulation using the 18-day Unsteady Lake condition from the LSU Period, used for the ADCIRC model calibration. This simulation was started from the end of the "Refine Outfall Management" simulation. Figure 19 presents a comparison of the Without-Diversion and With-Diversion hydrographs. The Without Diversion results are taken from the ADCIRC calibration volume. The diversion impact on the Unsteady Lake scenario is consistent with the fully developed flow results, with perimeter locations showing less impact than interior locations. The With-Diversion hydrographs closely duplicate the Without-Diversion high and low frequency Lake signals at perimeter, large conveyance locations (S-4, S-10, S-16, and S-24), but are shifted up a few tenths by the diversion. As with the fully developed flow results, the unsteady simulation shows that the stage impact is greater during lower Lake WSEs and less at higher Lake WSEs. This consistency of the Unsteady and fully-developed flow results is a further indication of the robustness of the ADCIRC model.

Taken together, the results of High Lake, Higher Lake, and the Unsteady LSU Period simulations seem to suggest that diversion flow would have a minor stage impact during occasional Lake setup, tropical storms, and Blind River floods. However, the under-representation of swamp resistance in the ADCIRC model needs to be further resolved in order to better determine the diversion impact on high stage conditions. Under-representation of swamp resistance allows for excess propagation of a Lake surge into the swamp and tends to attenuate the surge peak in the channels (as discussed in the *Volume VI, Two Dimensional Hydrodynamic Swamp Area Model, Development and Calibration*). Similarly, under-representation of swamp resistance also over estimates diversion flow through the swamp. Thus, the impact of diversion on channel WSEs during high Lake level events could be greater than suggested in the above results.

If future swamp resistance modeling does confirm that diversion performance is significantly improved at higher Lake WSEs, then sustained diversion operations could be targeted for seasonal periods of above mean Lake stage. [However, diversion during Blind River floods and tropical storms, while it may not have a significant impact on swamp stages, may not be advisable for operational reasons.]

Approach to Drainage Impact Evaluation

The results of a 1,500 cfs diversion at mean (1.1 ft), steady Lake WSE, with closed interstate culverts, revealed only a minimal impact—on the order of 0.1 ft—to Central Swamp WSEs. The higher diversion flow rate of 2,000 cfs increased this impact to about 0.2 ft. At High Lake and Higher Lake WSEs of 2.0 and 3.0 ft the impact of the 1,500 cfs diversion flow to the Central Swamp water stage was less than 0.1 ft. The developed and agricultural lands west of Louisiana Highway 54 and east of Dupont Road (including those north of Airline Highway) encompass about 7,500 acres, The Central Swamp just to the north of this area, between Hope and Reserve Relief Canals, has a roughly equivalent area. The combination of a low stage impact in the Central Swamp and relatively large Central Swamp storage area compared to the runoff area suggest a minimal impact of diversion on the gravity rainfall drainage from the Garyville/Reserve communities for moderate rainfall events, assuming the interstate culverts are closed.

In order to further assess the potential impact of diversion on the Garyville/Reserve drainage system URS undertook a simulation of a typical design storm—the 24-hour/10-year return frequency rainfall event—with a steady Lake boundary WSE of 1.1 ft[5]. Figure 20 presents the rainfall time-series (hyetograph), which reflects a cumulative 24-hour precipitation of 9.24 inches.

In order to simulate the rainfall event and take into account the combined transient response of both the drainage system and the swamp, URS developed an interactive link between the 1D SWMM model and the 2D ADCIRC model. This was accomplished by selecting a series of eight "handshake" locations at which a) the time-varying discharge values from the 1D SWMM model would be used as input to the 2D ADCIRC model, and b) the concurrent time-varying stage values from the ADCIRC model would be used as tailwater control input for the 1D SWMM model. Dynamic linking of the two models in simultaneous real-time operation was not practical so URS therefore adopted an iterative approach. The 1D SWMM model was run first with an initial (assumed) tailwater condition and the handshake discharge results were then used as input in the initial 2D ADCIRC model. The handshake stage results from 2D ADCIRC run were then used as a tailwater control for the second round of the 1D SWMM model, and so forth. Results after successive runs were compared visually to assess convergence. The handshake discharge results of the 4th SWMM run showed a

[5] The 2D ADCIRC model does not include an input for rainfall. Thus, the model Lake head boundary reflects the Lake Maurepas WSE and any accumulated swamp rainfall.

reasonable agreement with the 3rd SWMM run, and similarly the handshake stage results of the 3rd 2D ADCIRC run were in good agreement with the 2nd ADCIRC run.

This iterative approach to SWMM-ADCIRC linking was used to simulate both the Without- and With-Diversion scenarios. A key modification to the With-Diversion scenario is that the Hope Canal watershed, which can no longer drain to Hope Canal due to the diversion channel, is converted to a forced drainage system and served by a pump station. Final stage and discharge hydrographs comparing Without- versus With-Diversion for the handshake locations are presented in Figure 21, along with stage hydrographs for additional swamp locations. Table 9 provides a comparison of the peak stage and discharge for these locations, as well as several points south of Airline Highway. Figure 22 depicts the peak WSE throughout Central Swamp for Without- versus With-Diversion.

Results

The simulations show that a Hope Canal pump station replacing the gravity discharge with an equivalent peak flow of about 180 cfs had nearly identical stage results in Hope Canal south of Airline Highway. Furthermore, with this pump station in place, the event stages and discharges in the area east of Hope Canal are impacted to a minor degree by the diversion.

At the six handshake locations between Hope and Godchaux Canals, the peak stage impacts were 0.2 ft or less. For five of these points, the peak discharge impact was very small, 1 to 2 cfs, and at the sixth (Guidry Canal) the impact was a 10 cfs (8 percent) increase. The Godchaux Canal stage increased 0.36 ft (from 3.54 to 3.90 ft, or 10 percent) and the discharge was 26 cfs (8 percent) lower with the diversion. The Godchaux Canal result may reflect the downstream diversion impact to Mississippi Bayou, north of Interstate 10, which drains the western end of Godchaux Canal. The peak swamp stage result at S-11 (Mississippi Bayou at Interstate 10) showed a 0.38 ft (30 percent) impact from diversion.

The Reserve Relief Canal handshake location showed a 0.1 ft (3 percent) increase in stage, and an 89 cfs (30 percent) increase in discharge. This increase in Reserve Relief Canal may be caused by the reduced flow in Godchaux Canal. The larger increase in Reserve Relief Canal flow compared with the flow reduction in Godchaux Canal may be attributable to time of concentration.

Table 9
Comparison of Peak Stages and Discharges
24-Hour/10-Year Return Frequency Rainfall Event
Without- versus With-Diversion

Location	Peak Stage (ft NAVD88-LDNR)		Peak Discharge (cfs)	
	Without Diversion	With Diversion	Without Diversion	With Diversion
Handshake Points				
Hope Canal	1.97	NA	178	179 Pump
Bougeree Canal	1.81	1.83	92	92
Dolson Canal	2.22	2.23	469	467
Lions Canal	1.64	1.67	13	13
Guidry Canal	1.50	1.60	122	132
Pump Station	Dry (1.4)	1.59	23	21
Godchaux Canal	3.54	3.90	308	282
Reserve Relief Canal	3.19	3.29	293	382
Swamp Points				
S-4, Dutch Bayou at Lake	1.10	1.12		
S-7, Hope Canal at I-10	1.27	3.11		
S-9, Dutch Bayou	1.14	1.50		
S-10, Blind River	1.11	1.13		
S-11, Mississippi Bayou at I-10	1.27	1.65		
S-16, Blind River at I-10	1.12	1.23		
S-23, North Swamp	1.23	1.82		
S-24, Reserve Relief Canal at Airline Hwy	3.29	3.42		
S-25, Central Swamp	1.35	1.59		
Airport	1.53	1.61		
South of Airline Hwy				
Hope Canal	4.0	4.0	41	42
Doslon Canal	6.3	6.3	35	35
Godchaux Canal	4.3	4.5	139	136
Reserve Relief Canal	4.6	4.5	517	533

The results at three points south of Airline Highway and east of Hope Canal reflect lower impact than the handshake locations. Upstream on Godchaux Canal the peak stage impact is reduced to 0.2 ft.

Overall, the diversion impact to the Central Swamp area east of Hope Canal, particularly in terms of stage, appears to be minor for a 24-hour/10-year return frequency rainfall. As shown in Figure 22, peak stage increases of about 0.2 ft may affect property between the Reserve Airport and Godchaux Canal, north of the protection levee, and about 0.3 ft in an isolated area just east of Godchaux Canal and north of Airline Highway.

The combined results of the High Lake and Higher Lake and Drainage Impact simulations suggest that drainage impacts associated with diversion would lessen as the Lake stage (plus accumulated rainfall) exceeds a WSE of 1.1 ft.

As with other findings, the under-representation of swamp resistance in the model should be considered in interpreting the drainage impact results. The diversion may have a higher than estimated impact on key channel stages, such as Mississippi Bayou, which in turn could mean that the drainage impact on upstream channels, such as Godchaux Canal, could be higher than estimated. The drainage impact modeling also reflects a condition of near-steady mean Lake WSE. Thus, the drainage impact to peak channel stages could be greater during a simultaneous propagation of Lake surge into the channels.

The “2,000 cfs Diversion Flow” and “Low Lake” simulations were used to identify locations of high velocity and potential scouring. Modeled velocities throughout the diversion area were typically mild, with only two locations exhibiting velocities greater than 1 fps. The Hope Canal channel experienced a peak velocity of 3.8 fps during the 2,000 cfs diversion at the Interstate 10 overpass. Figure 23 illustrates the areal distribution of peak velocities at the crossing. The peak velocity at the same location was 3.0 fps during the “Low Lake” simulation. The ADCIRC model does not incorporate the reduced channel cross-section and drag forces associated with the interstate overpass support piers. Also, the model velocity is depth averaged. Therefore, these results provide only a general indication of the level of scour potential at the interstate overpass. Velocities consistent with these values are readily addressed through conventional channel armoring techniques.

The “Low Lake” simulation indicated a peak velocity of 1.2 fps at the mouth of Bourgeois Canal at Blind River. This location was partially constricted in the Refined Outfall Management (see Figure 5e). In the 2,000 cfs alternate flow simulations the peak velocity at the mouth of Bourgeois Canal was lower, at 0.9 fps. Some isolated bank sections and bank gap locations may also experience temporary velocities above 1 fps during diversion, although none were seen in the simulations. The velocities at these locations can be re-evaluated based on final diversion flow and outfall management design, and addressed as needed with conventional stabilization techniques.

Minimum diversion velocities are also a critical factor in order to effectively transport suspended sediments and nutrients from the diversion channel into the swamp. The ADCIRC model shows that diversion velocities in Hope Canal typically drop below 0.5 fps within 5,000 feet of the outlet north of Interstate 10, and continue to decline through Bayou Tent. The model also shows a dramatic fall in velocity in the swamp just outside the diversion channel. These areas may experience significant deposition of suspended sediment and aquatic vegetation growth, which could in turn alter diversion circulation. Diversion and outfall management design and operation plans should address the control of diversion velocities and maintenance of proper circulation. One important consideration is the optimization of the sand/silt settling basin.

As with the other results, the findings on scouring and sediment deposition can be affected by the ADCIRC model limitations. In particular, modeled channel velocities may be under-estimated and the modeled swamp velocities over-estimated.

CONCLUSIONS

The findings from the physical hydrodynamic modeling support that the reintroduction of the Mississippi River into the Maurepas Swamp via Hope Canal is technically feasible. Specifically,

- The diversion simulations showed that several outfall modifications, together with pulsing, are critical to broadening the distribution of flow in the North Swamp area (north of Interstate 10). The modifications include degrading and opening the old railroad embankment along the west bank of Hope Canal, reducing the interception of diversion by Bourgeois Canal and Bayou Secret, and the closure of gaps along Blind River and Reserve Relief Canal.

- In addition, simulations showed that the culverts under Interstate 10 between Louisiana Highway 641and Mississippi Bayou needed to be closed during full flow to prevent excessive inundation of the Central Swamp area between US Highway 61 (Airline Highway) and the interstate. Previous SWMM modeling demonstrated that increasing WSEs in the Central Swamp would likely impact drainage for the Garyville/Reserve area.

- Simulations show that once fully developed flow is reached, the diversion flow field contracts into a pattern dominated by more direct eastward and westward flow (toward Reserve Relief Canal and Blind River, respectively). This contraction is the result of the steeper water surface gradient along these two direct outward paths that is developed as the diversion approaches steady state. At fully developed flow MSRT is on the order of 6 days.

- Diversion animations exhibit a good fanning pattern during the initial 10 days of flow, prior to stages plateauing, providing strong evidence for the effectiveness of pulsing. During flow development MSRT may be longer than at steady-state.

- Simulations of 1,000 cfs and 2,000 cfs diversion at mean, steady Lake WSE showed minimal changes in distribution patterns at fully developed flow, compared to the 1,500 cfs diversion, and less than a 20 percent change in MSRT. While these results indicate some response of distribution to flow rate they imply that distribution is not highly sensitive to flow rate.

- A diversion shutdown simulation shows that stages recover within 20 days, suggesting an overall pulsing cycle of 10 days on/20 days off.

- At lower Lake WSEs (0.5 ft) the short-circuiting of flow to the east and west was more pronounced, due to the greater confinement of flow to the swamp channels and steeper gradients. At higher Lake WSEs circulation improved and retention times increased to 10 and 20 days, for Lake WSEs of 2.0 and 3.0 ft, respectively. As Lake WSEs rise the diversion flow overtops channel banks, circulation is less confined to the channels, and gradients flatten. These findings suggest that better diversion flow may be achieved during prolonged periods of above average Lake WSE.

- Simulations coupling the swamp 2D ADCIRC model and Garyville/Reserve drainage network 1D SWMM model—for a fully-developed 1,500 cfs diversion at mean Lake WSE during a 24-hour duration, 10-year return frequency rainfall event—showed a minimal impact to the Garyville/Reserve drainage network The With-diversion simulation included a Hope Canal watershed pump station operating at a peak flow of 179 cfs. The simulations showed that the gravity drainage network east of Hope Canal experiences a slight change in storage and discharge capacity as a consequence of the fully-developed 1,500 cfs diversion.

- Modeling of the 2,000 cfs flow showed that the existing Interstate 10 overpass at Hope Canal, which has a reduced cross-sectional area, has peak depth-averaged velocities of nearly 4 feet per second (fps), which can be addressed through conventional armoring techniques.

- Channels and swamp areas are likely to experience sharp drops in velocity, creating significant potential for sediment deposition, aquatic vegetation growth, and alteration of circulation patterns.

All model findings must be considered in light of the 2D ADCIRC model calibration/validation results, which showed that the model under-represents swamp resistance. This indicates that while swamp velocities are likely to be lower, diversion flow through channels (i.e., short-circuiting) is likely to be greater than found in the model results. Thus, MSRTs may be shorter. Also, drainage impacts could be slightly higher than estimated, particularly during Lake surge events.

With regard to the four objectives for this study:

1. Flow distribution throughout the North Swamp (between Blind River and Reserve Relief Canal) can be improved by including the identified outfall management features in combination with pulsing the diversion flow. Targeting sustained flow for prolonged periods of above mean Lake Maurepas WSE, and controlling minimum diversion velocities, will also aid in diversion distribution.

2. Pulsing and control of diversion flow in response to Lake WSE should aid in extending MSRT and reducing short-circuiting to Lake Maurepas. Control of sediment deposition is crucial to long-term circulation maintenance.

3. The planned diversion and associated outfall management features will not adversely impact the stormwater drainage systems for the Hope Canal watershed provided that a forced drainage system of adequate capacity replaces the gravity Hope Canal drainage system. The impact on the Garyville/Reserve gravity drainage system east of Hope Canal is minimal for a 24-hour/10-year return frequency rainfall event and can be mitigated.

4. Diversion velocities at Interstate 10 are in a moderate range and can be readily addressed to prevent scouring. Isolated locations of minimal bank and gap scouring potential can also be addressed.

RECOMMENDATIONS

The simulation findings provide the basis for eight specific project design and operating requirements:

1. The major features included in the "Refined Outfall Management" simulation, and additional features indicated by the results, to provide improved circulation and MSRT.

2. The diversion structure maximum design flow at least 2,000 cfs, with controls to manage flow, circulation, and retention time in response to forecasted Lake WSE conditions.

3. Flow control features to regulate flow through the culverts under Interstate 10 between Louisiana Highway 641 and Mississippi Bayou.

4. Additional flow control features to provide limited introduction of water into the Central Swamp from the diversion channel. Occasional introduction of low rates of diversion water is needed to prevent exacerbating the stagnation of the Central Swamp and to improve the swamp nourishment in this area.

5. Replacement of the Hope Canal watershed system gravity drainage by forced drainage, including a pump station of adequate capacity.

6. Increased drainage or pumping capacity for the eastern Garyville and Reserve drainage systems to address mitigation of minor impacts. This could include several options: a) increasing drainage capacity from Godchaux Canal to Reserve Relief Canal via the Cross-Over Canal; b) increased capacity of the above Hope Canal pump station (and drainage system), or c) increased capacity for the Reserve Airport and/or Reserve Relief Canal pump stations. The Reserve Airport and Reserve Relief pump stations currently provide limited augmentation to the gravity drainage system[6].

7. Upgraded armoring of the Diversion Channel at the current Interstate 10 overpass over Hope Canal and additional erosion controls at locations where diversion velocities may exceed scouring thresholds (e.g., 1 to 2 fps).

8. Design and operating measures to prevent sediment deposition and aquatic vegetation growth that would adversely affect circulation, including optimization of the sand/silt settling basin.

These requirements are refinements of, and in some cases additions to, the Phase 0 Report conceptual diversion plan. Preliminary engineering plans, cost estimates, and construction schedules, along with revised assessments of project benefits, are expected to be developed for the conceptual diversion plan by the Project Team during the subsequent phase of work.

[6] It is important to note that the drainage systems for the Garyville/Reserve watersheds are open to intrusion from Lake Maurepas. Thus, further improvements to pump stations augmenting this gravity system are of minimal benefit during Lake surge events. Comprehensive upgrades to the levees north of Airline Highway and a total conversion of the Garyville/Reserve area to forced drainage are not indicated by the diversion project impacts. Such a conversion could be undertaken in the future in conjunction with a hurricane levee project to protect Garyville and Reserve from Lake Maurepas storm surge.

In order to finalize project designs, support detailed assessments of project environmental benefits and impacts, and develop project operation and adaptive management plans, URS recommends that further hydrodynamic physical and water quality modeling be conducted to:

1. Assess circulation patterns and MSRT under dynamic conditions, such as during diversion pulsing and unsteady Lake conditions.

2. Evaluate additional outfall management features to reduce the eastward and westward diversion gradient, such as improving the bounding Reserve Relief Canal and Blind River banks for some distance north of Interstate 10.

3. Develop high resolution spatial-temporal estimates of diversion freshening, nitrate, and fine sediment distribution throughout the Central and North Swamp under various operating scenarios. High resolution modeling of nitrate loading and assimilation is important to assessing project benefits and possible eutrophication impacts to Blind River and Lake Maurepas. Modeling of fine sediment transport through the swamp is critical to the design of the sand/silt settling basin and preventing the plugging of diversion flow paths.

4. Simulate a more complete suite of rainfall events, such as longer duration (48- and 72-hour) and less frequent/more intense (50– and 100-year) rainfalls for the Garyville/Reserve drainage system and estimates of the impacts of diversion. This will allow for refining estimates of forced drainage improvements.

5. Simulate higher (500-year) flows at overpass locations to refine scour evaluation and armor requirements.

To support this additional hydrodynamic modeling, URS recommends three efforts:

1. Improving parameterization of swamp resistance in the 2D ADCIRC physical hydrodynamic model as described in the calibration/validation volume. This is needed to more properly represent diversion circulation, short-circuiting, MSRT, and velocities. Improving swamp resistance parameterization in the ADCIRC model will require additional field data and modification to the ADCIRC code.

2. Develop a high resolution 2D water quality model—for salinity, nitrate, and suspended sediment—that is compatible with an improved 2D ADCIRC model.

3. Conduct site-specific investigations of nitrate assimilation within the Central and North Swamp to evaluate project-specific denitrification kinetics. This will determine project specific MSRT design criteria for achieving adequate swamp nitrate assimilation and protecting Blind River and Lake Maurepas water quality.

The project-specific MSRT design criteria can then be coupled with the high-resolution water quality model of Maurepas Swamp to refine the project design, operating, and adaptive management requirements.

Incorporation of the design/operating recommendations into the project will require extensive coordination with federal, state, and local agencies, as well as local land owners. Modifications to inundation and circulation patterns within the Central and North Swamps must be reviewed with the Louisiana Department of Wildlife and Fisheries (a large portion of the swamp lies with a state Wildlife Management Area) and private land owners.

The Blind River is currently listed by the Louisiana Department of Environmental Quality (LDEQ) as not meeting water quality criteria for nutrients and is currently subject to development of a nutrient Total Maximum Daily Load limitation under order from the U. S. Fifth Circuit Court of Appeals. The LDEQ is currently proposing to revise state nutrient (including nitrate) water quality criteria based on studies of nutrient assimilation and Blind River water quality could be re-evaluated. Water quality impacts to Blind River and Lake Maurepas are subject to review by both the LDEQ and the US Environmental Protection Agency under non-point source programs.

The control of flow through the interstate culverts must be vetted with the Louisiana Department of Transportation and Development and federal Department of Transportation. The mitigation alternatives for impacts to the Garyville/Reserve drainage must be accepted by St. John the Baptist Parish. Depending on timing, diversion project drainage mitigation components could be integrated with a more comprehensive hurricane protection levee and drainage project. Any approach to integrating the diversion project with hurricane protection and drainage improvements must be coordinated with the Louisiana Coastal Protection and Restoration Authority, the Pontchartrain Levee District, and the U. S. Army Corps of Engineers.

FIGURES

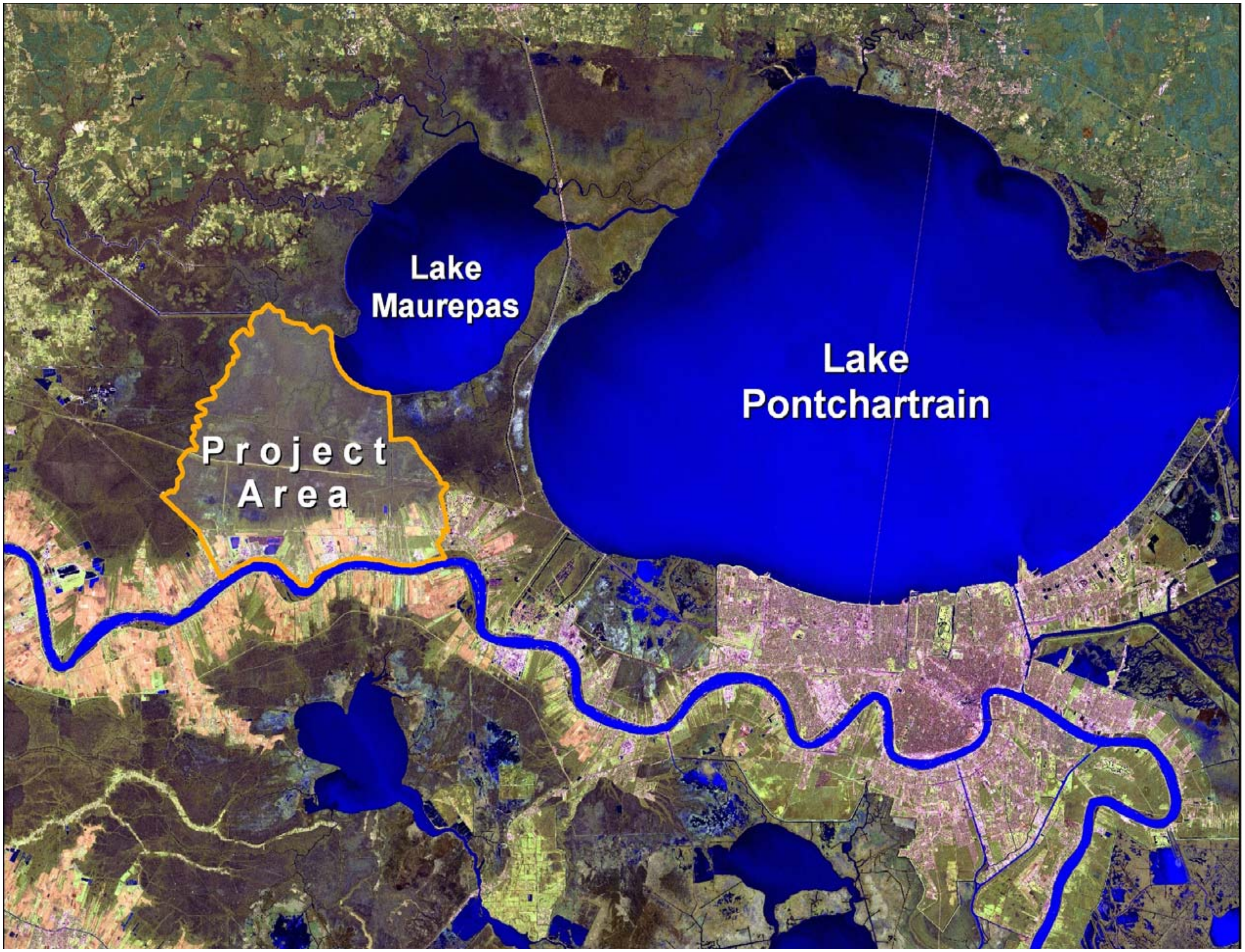

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Figure 1. Project Location

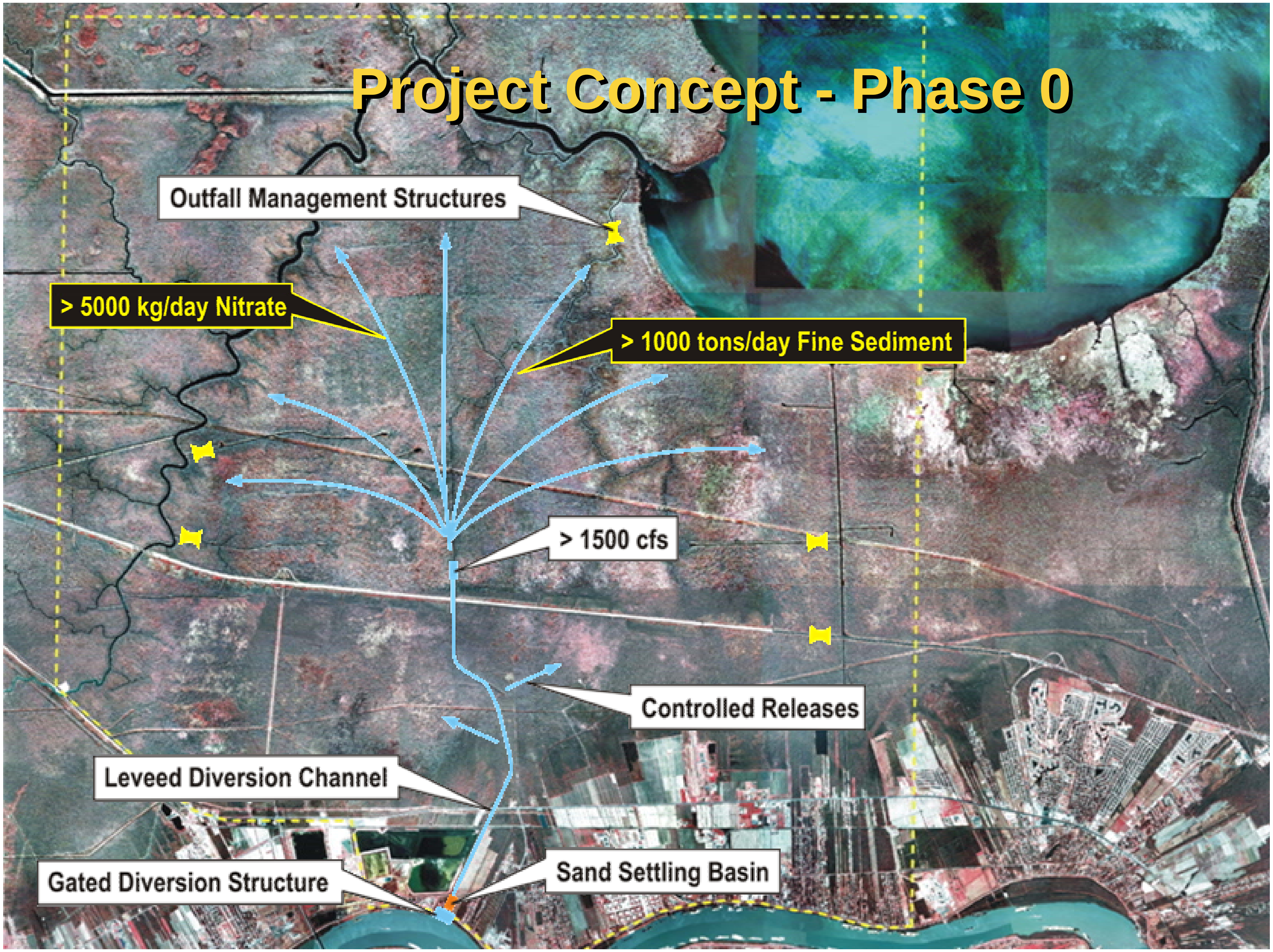

Figure 2. Diversion Schematic

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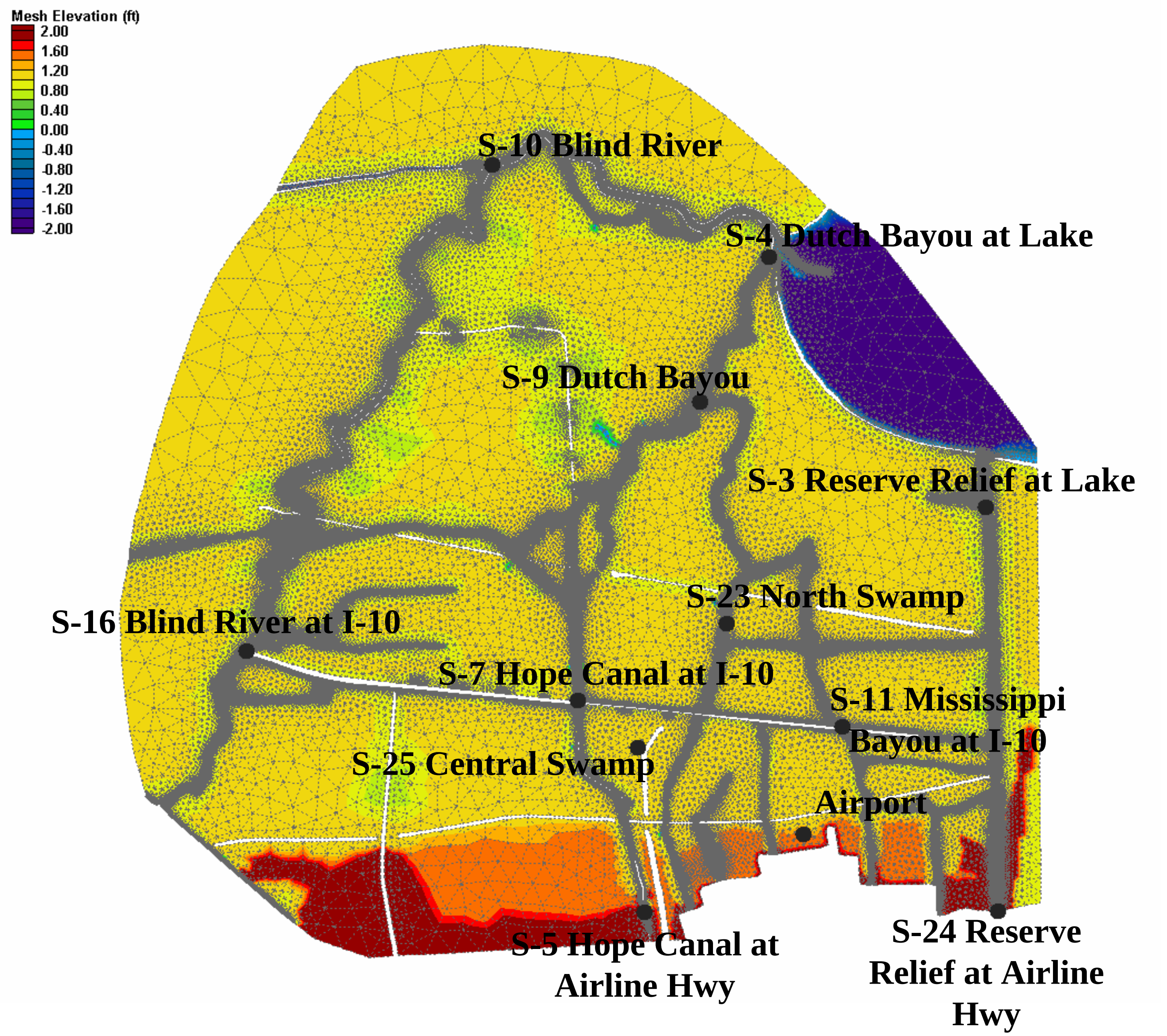
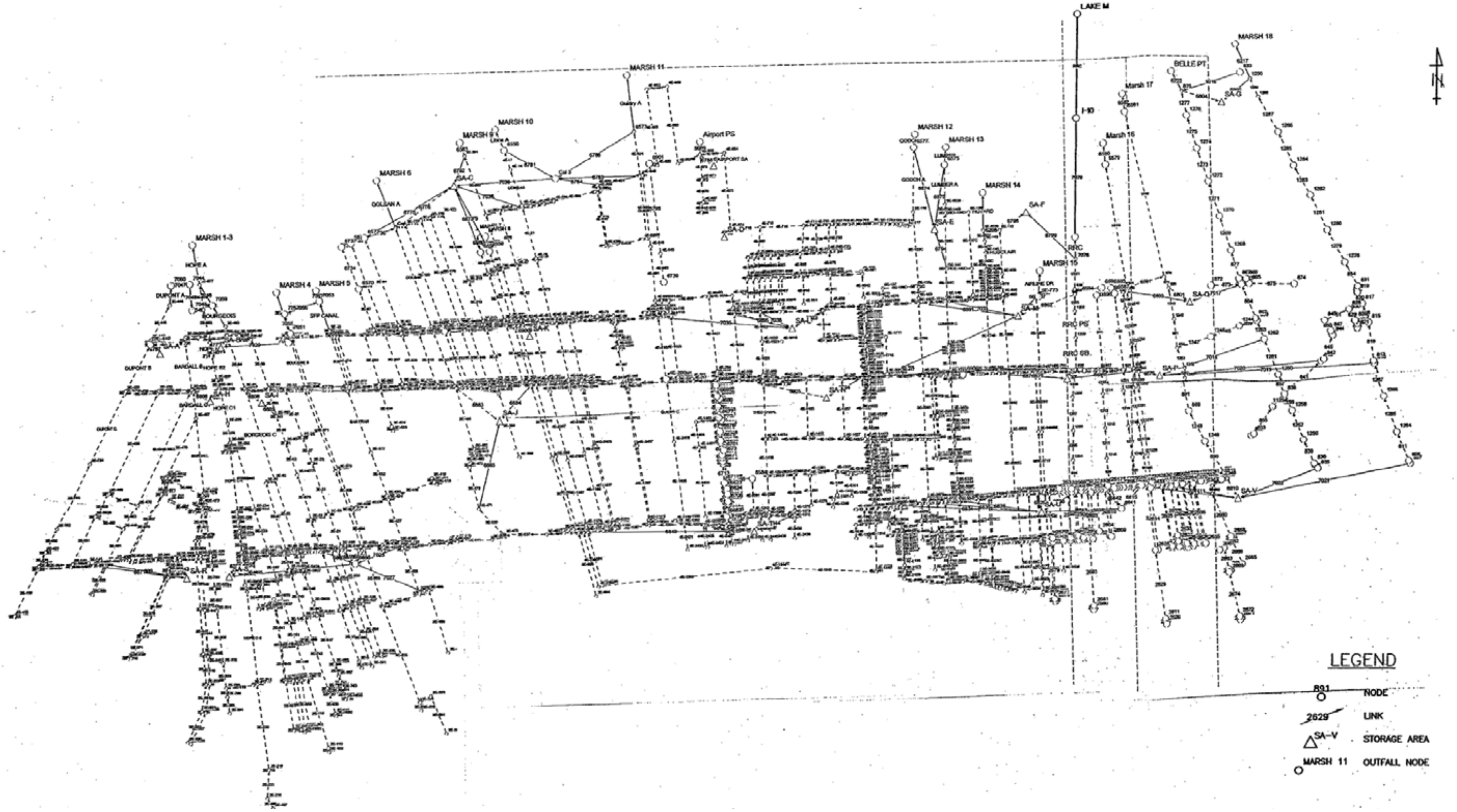


Figure 3. 2D ADCIRC Model Mesh



a) 1D SWMM Model Geometry

Figure 4. 1D SWMM Model Geometry and Handshake Locations

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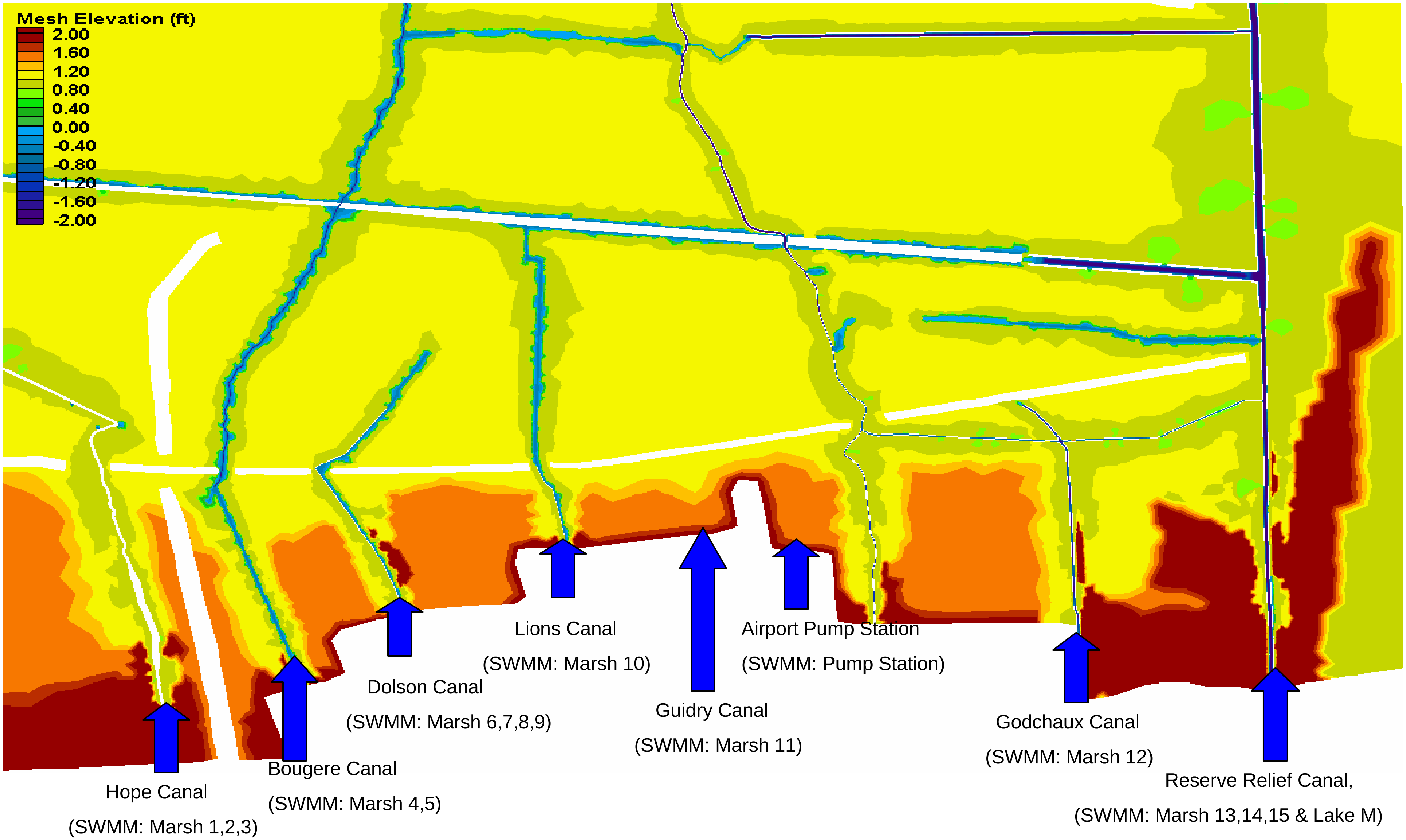

b) Handshake Locations

Figure 4. 1D SWMM Model Geometry and Handshake Locations

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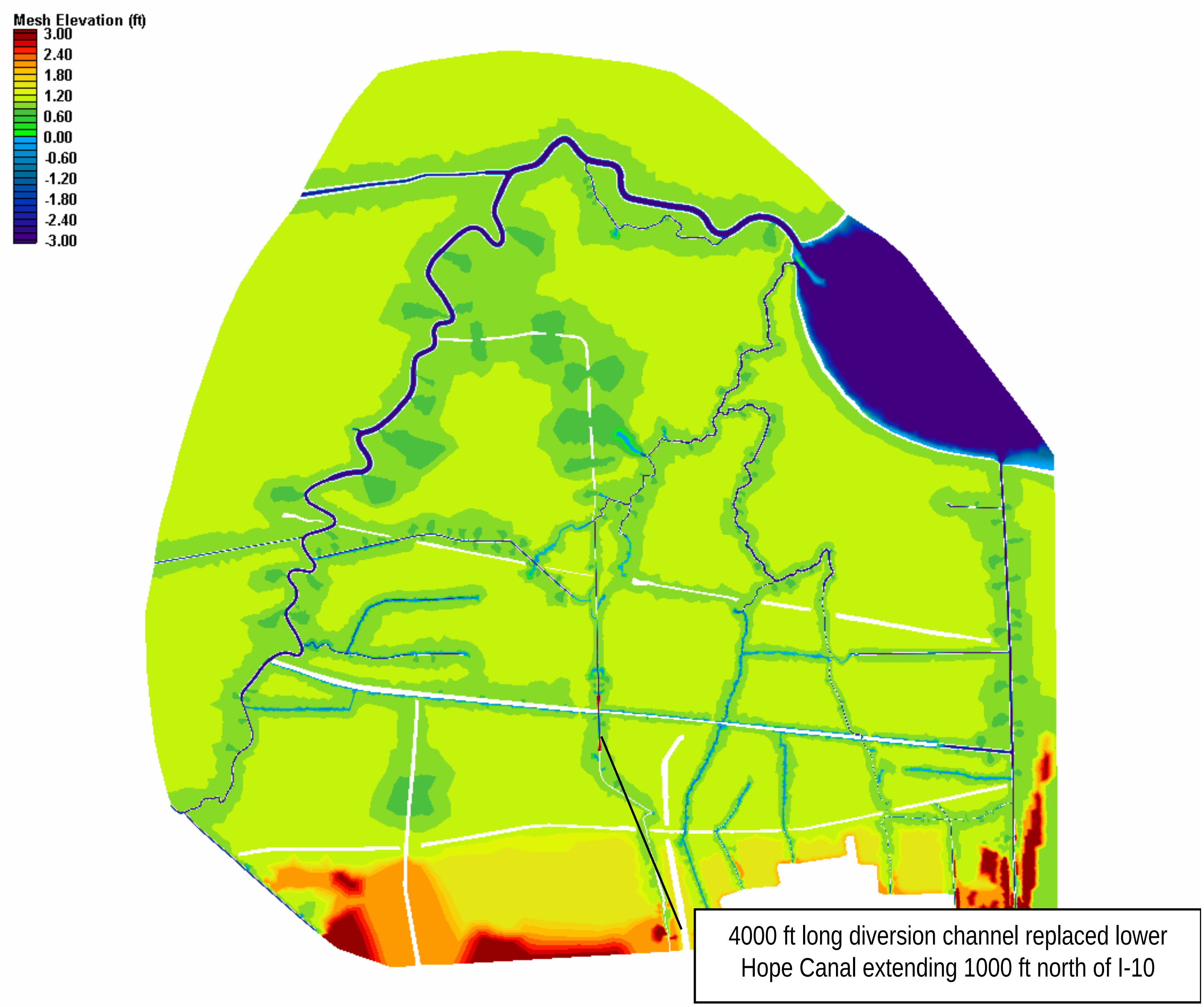
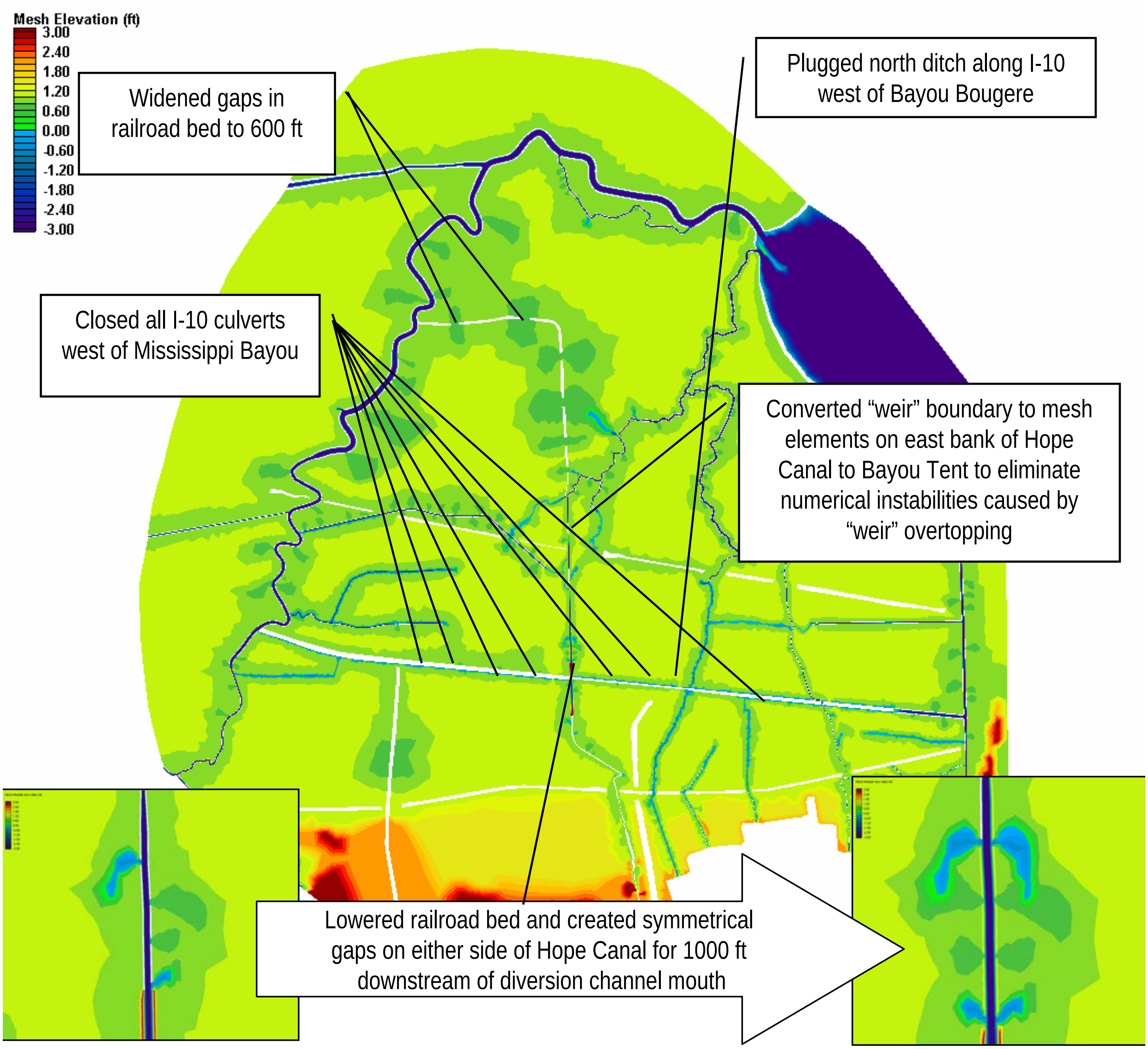


a) Baseline

Figure 5. Outfall Management Mesh Changes

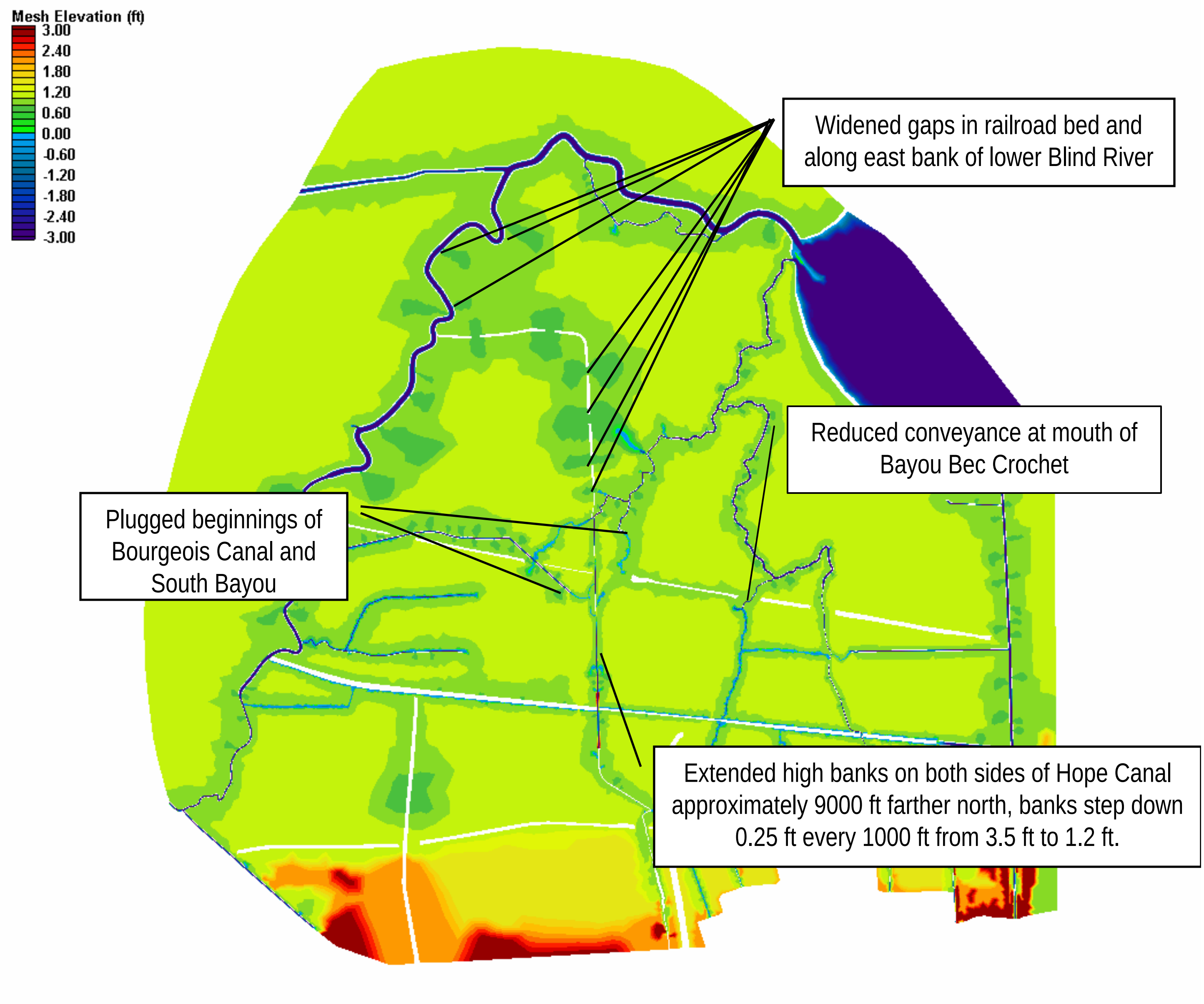
URS



b) Closed Interstate Culverts and Degraded Railroad Embankment

Figure 5. Outfall Management Mesh Changes

URS



c) Extended Outfall

Figure 5. Outfall Management Mesh Changes

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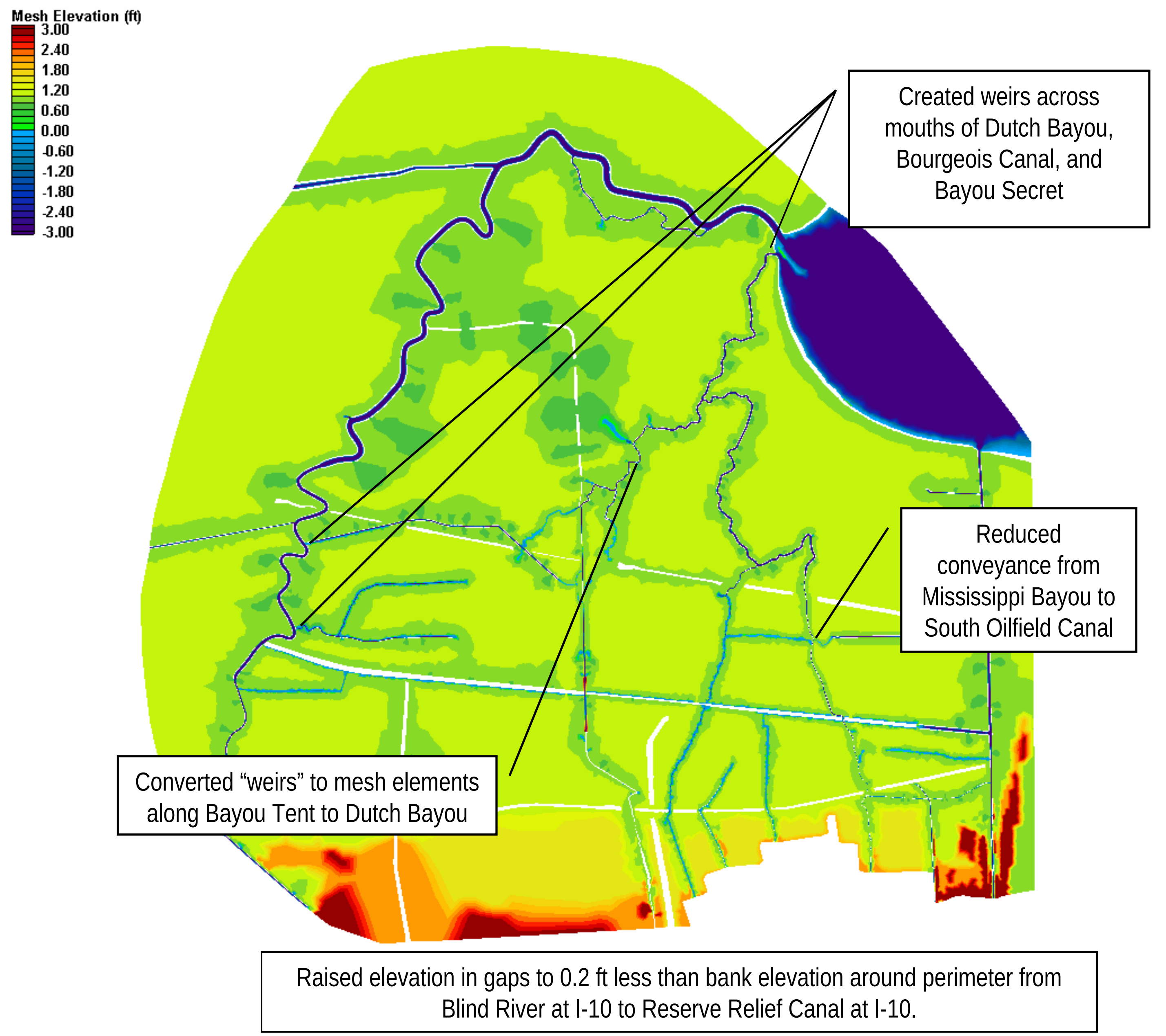
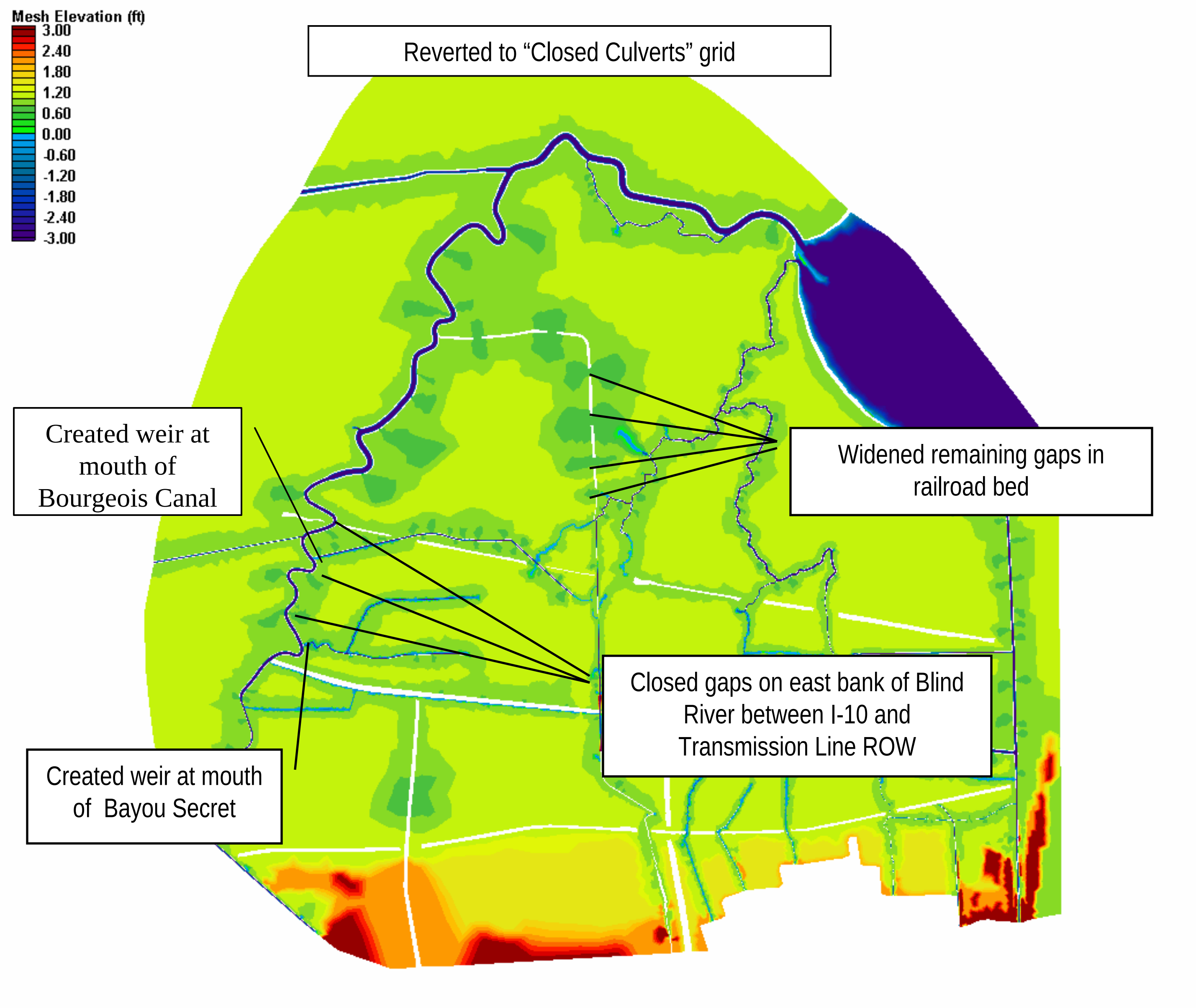


d) Perimeter Weirs

Figure 5. Outfall Management Mesh Changes

URS



e) Refined Outfall Management

Figure 5. Outfall Management Mesh Changes

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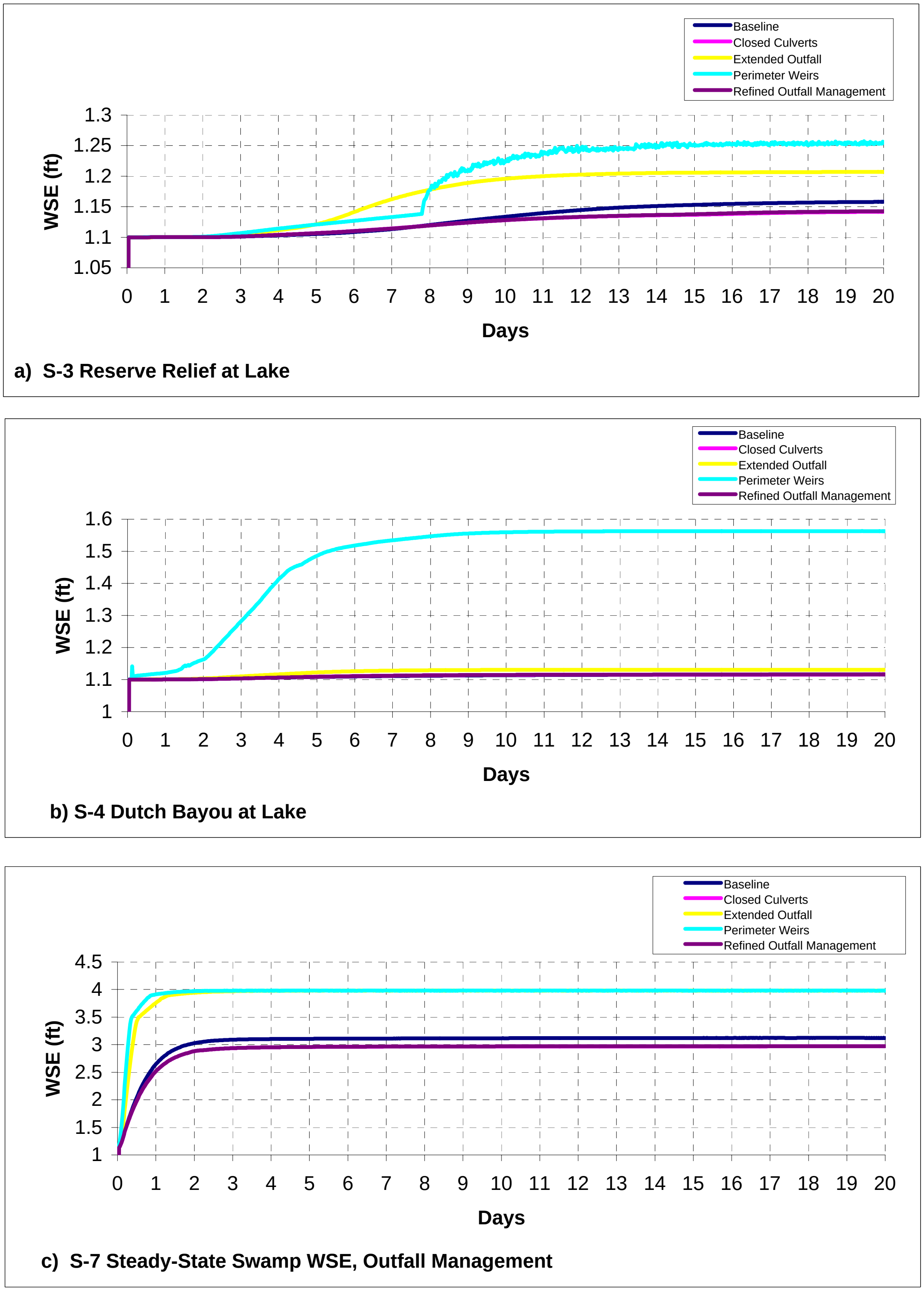


Figure 6. Stage Hydrographs, Outfall Management (a - c)

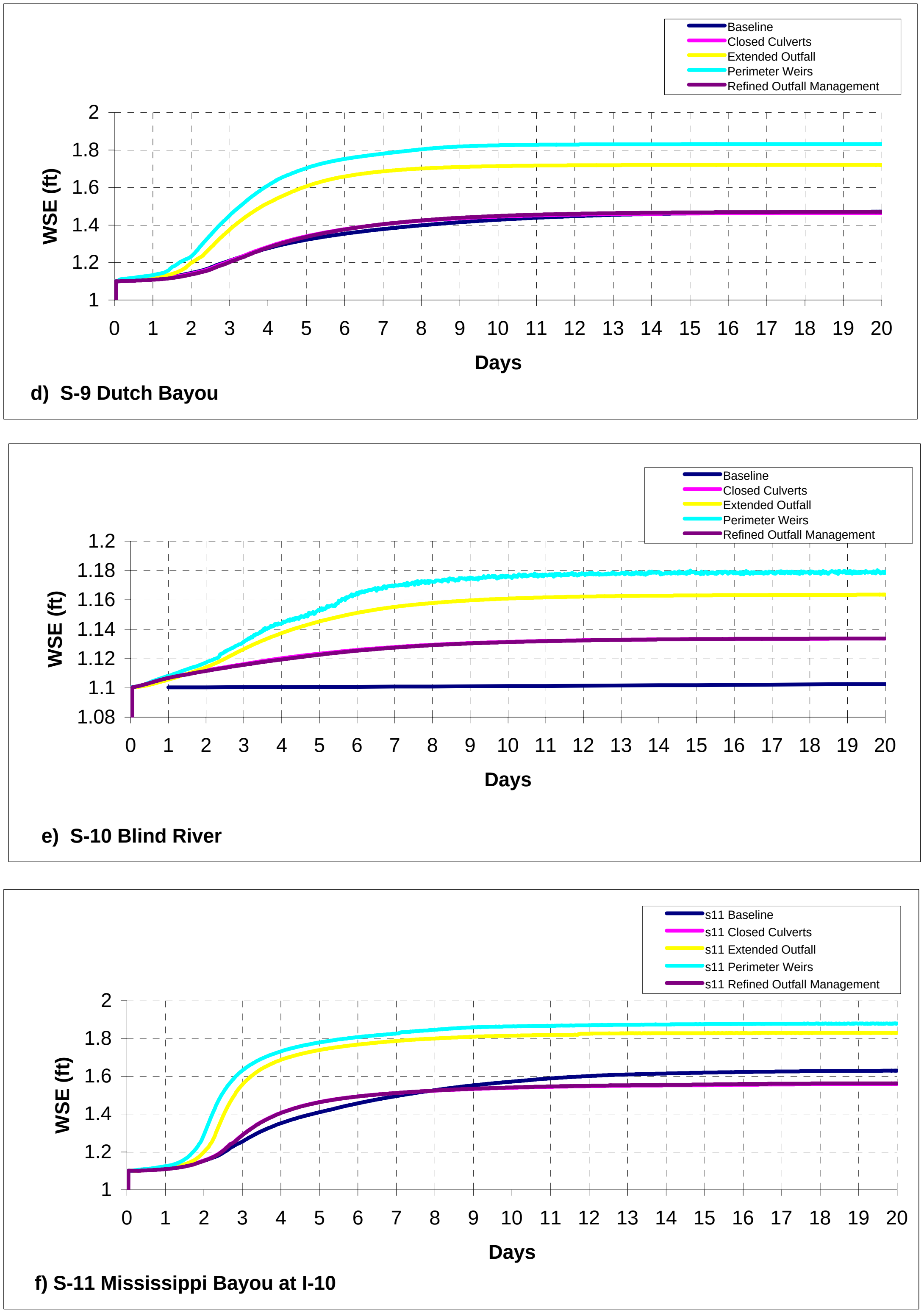
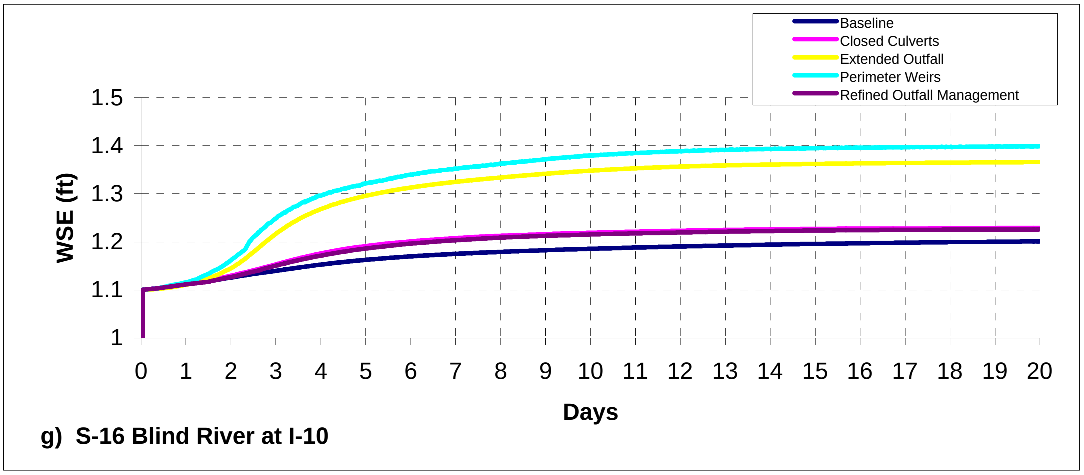
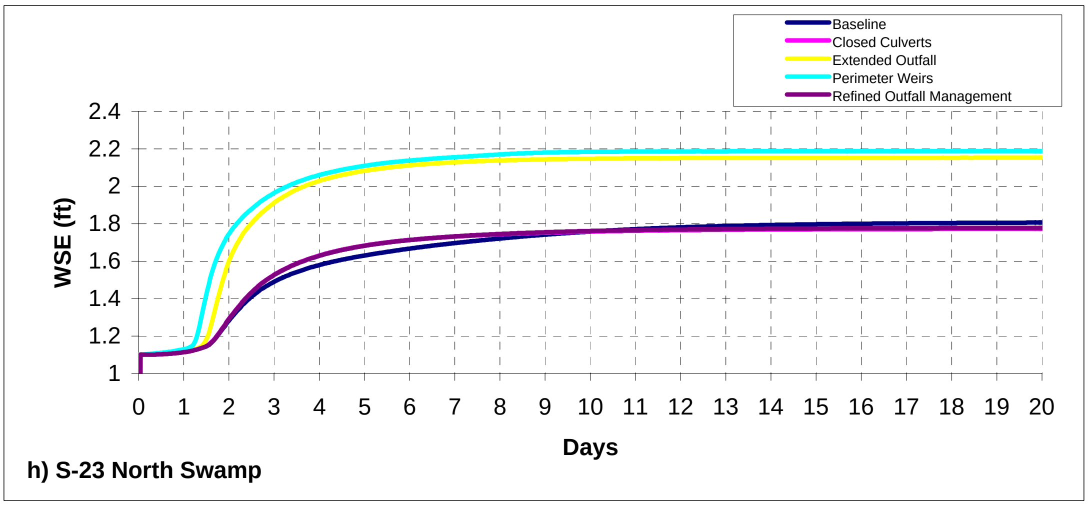


Figure 6. Stage Hydrographs, Outfall Management (d - f)





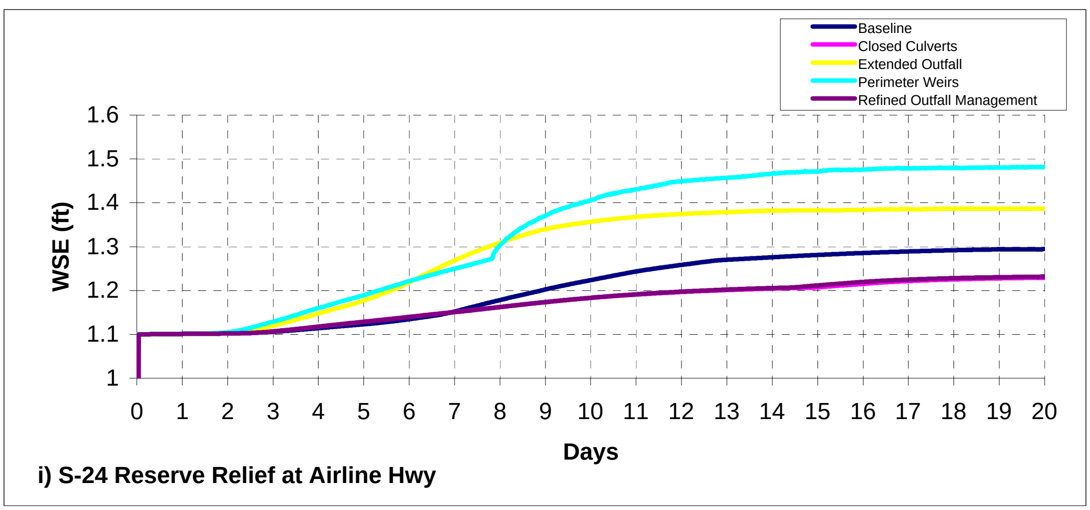


Figure 6. Stage Hydrographs, Outfall Management (g - i)

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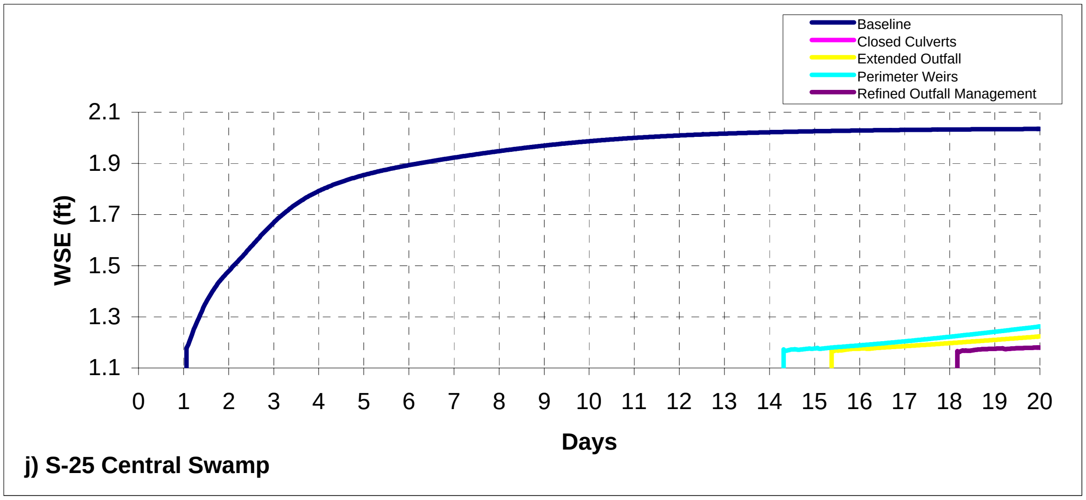

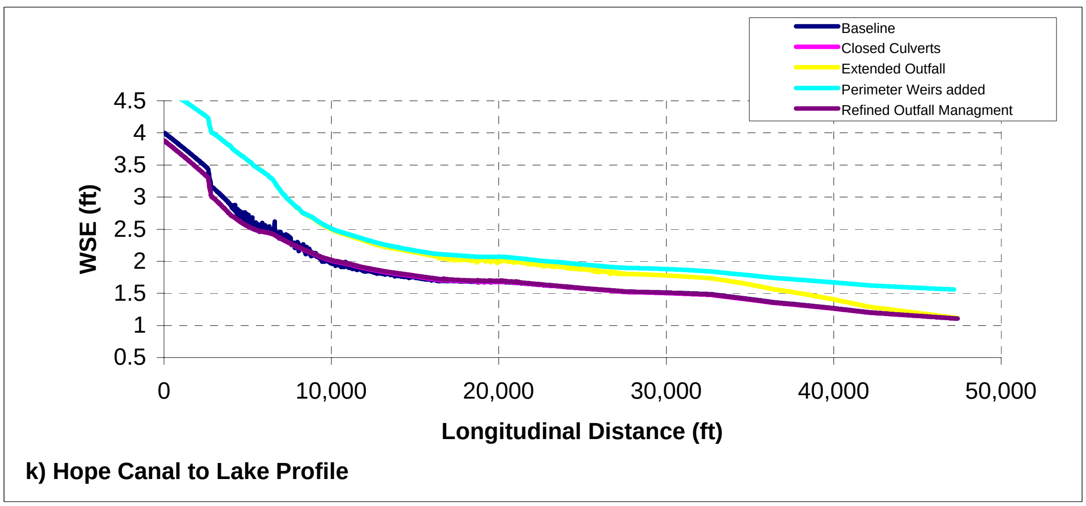

Figure 6. Stage Hydrographs, Outfall Management (j - k)

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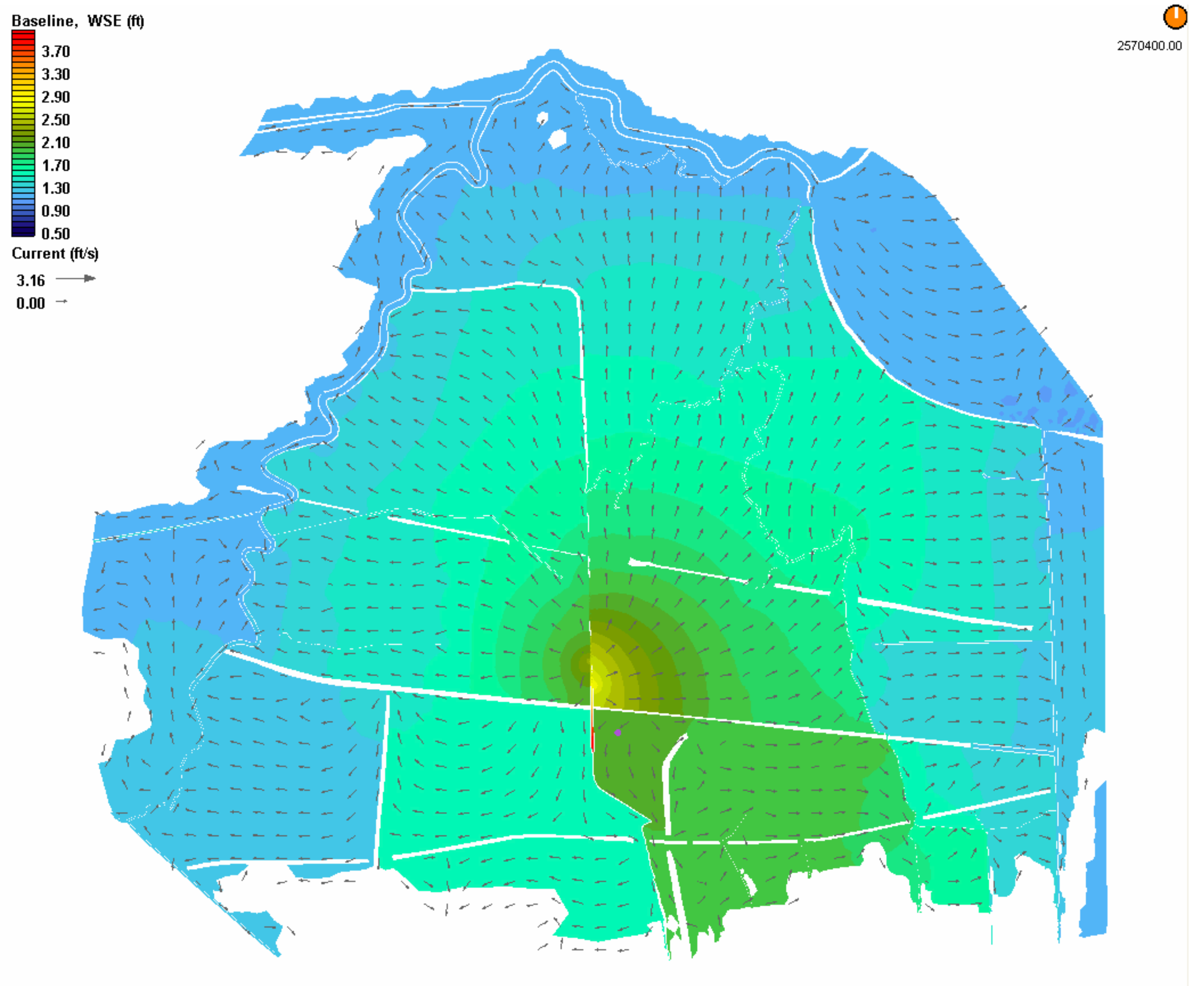

a) Baseline

Figure 7. Steady-State Swamp WSE, Outfall Management

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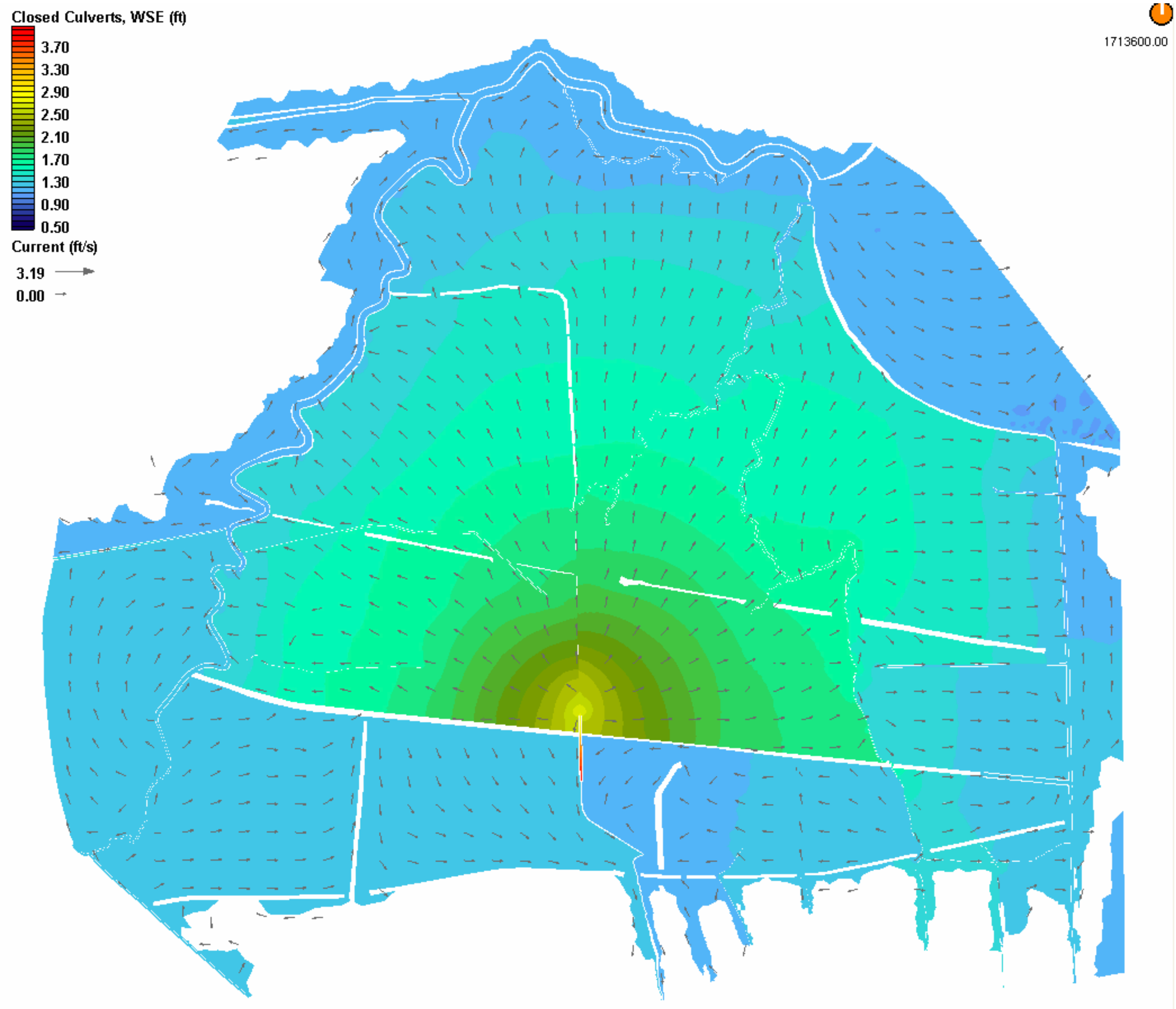
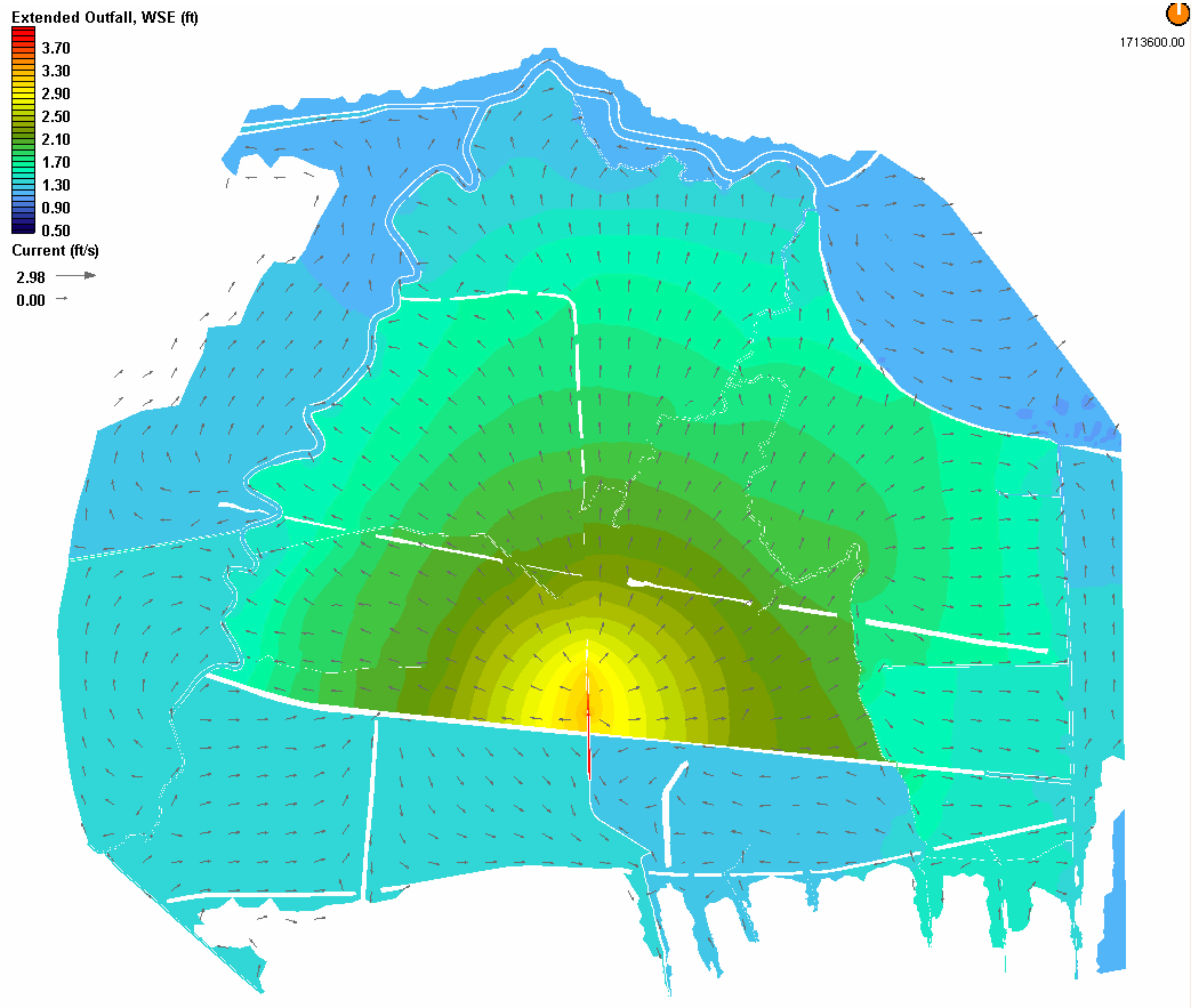


b) Closed Interstate Culverts

Figure 7. Steady-State Swamp WSE, Outfall Management

URS



c) Extended Outfall

Figure 7. Steady-State Swamp WSE, Outfall Management

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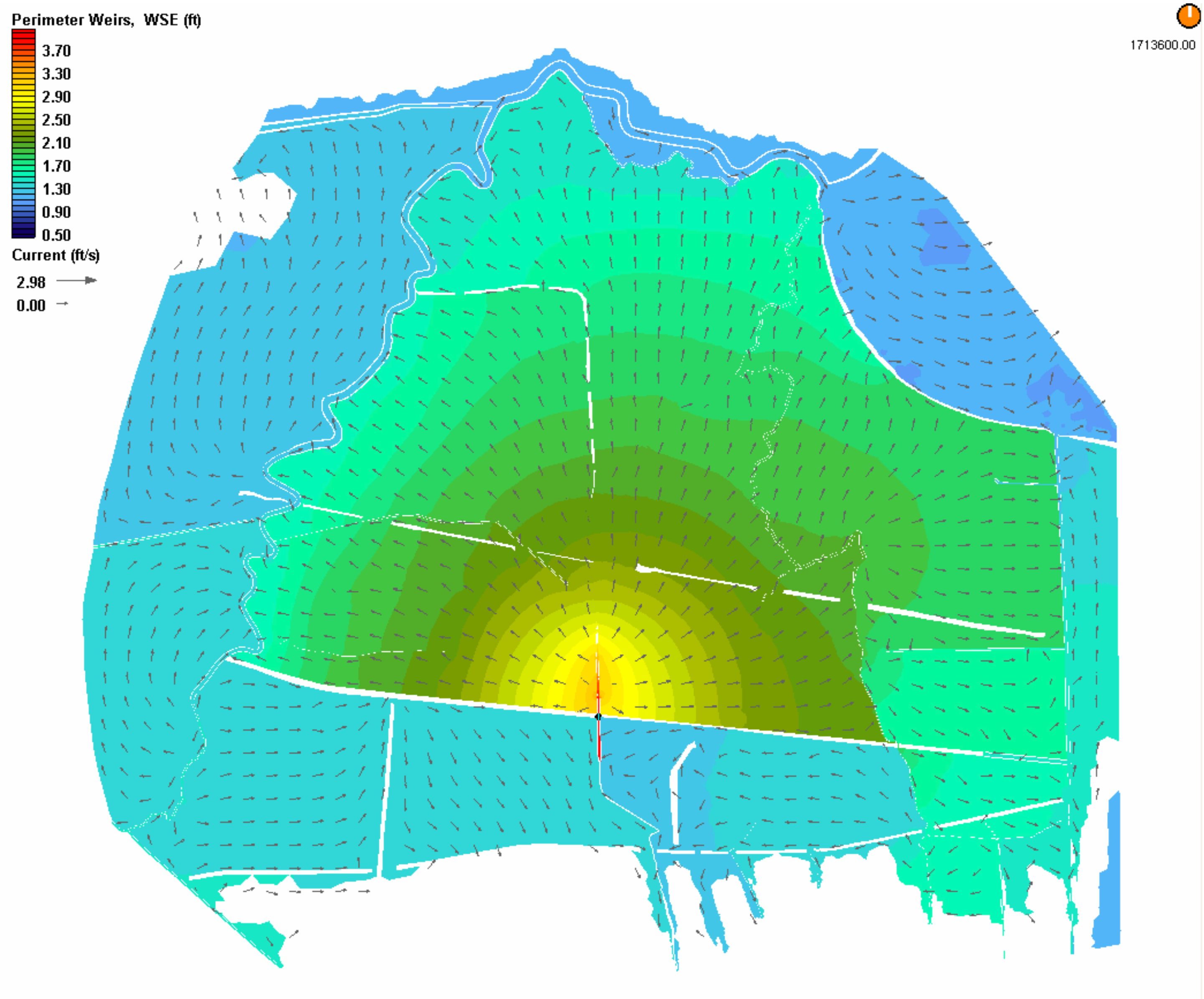

d) Perimeter Weirs

Figure 7. Steady-State Swamp WSE, Outfall Management

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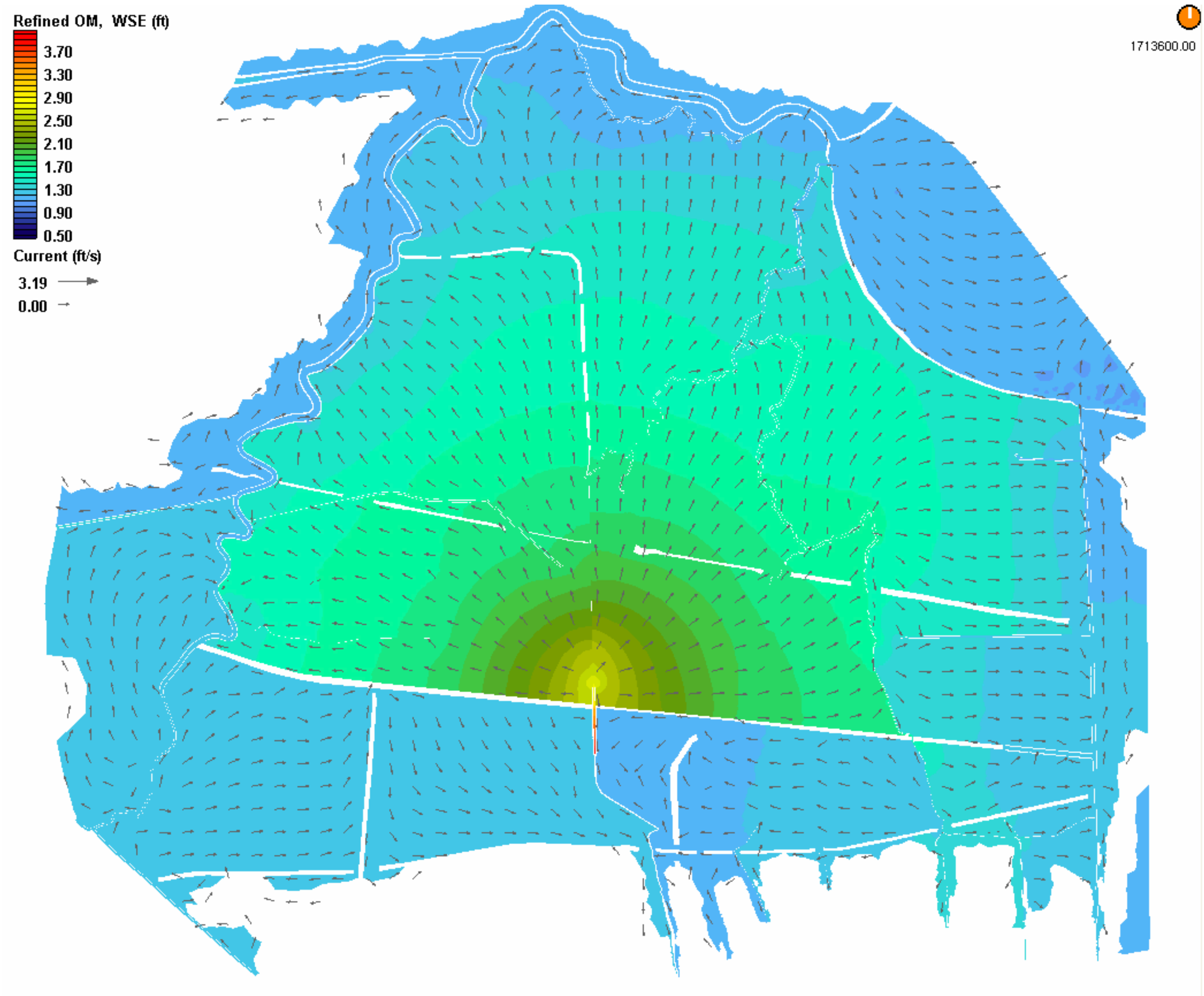
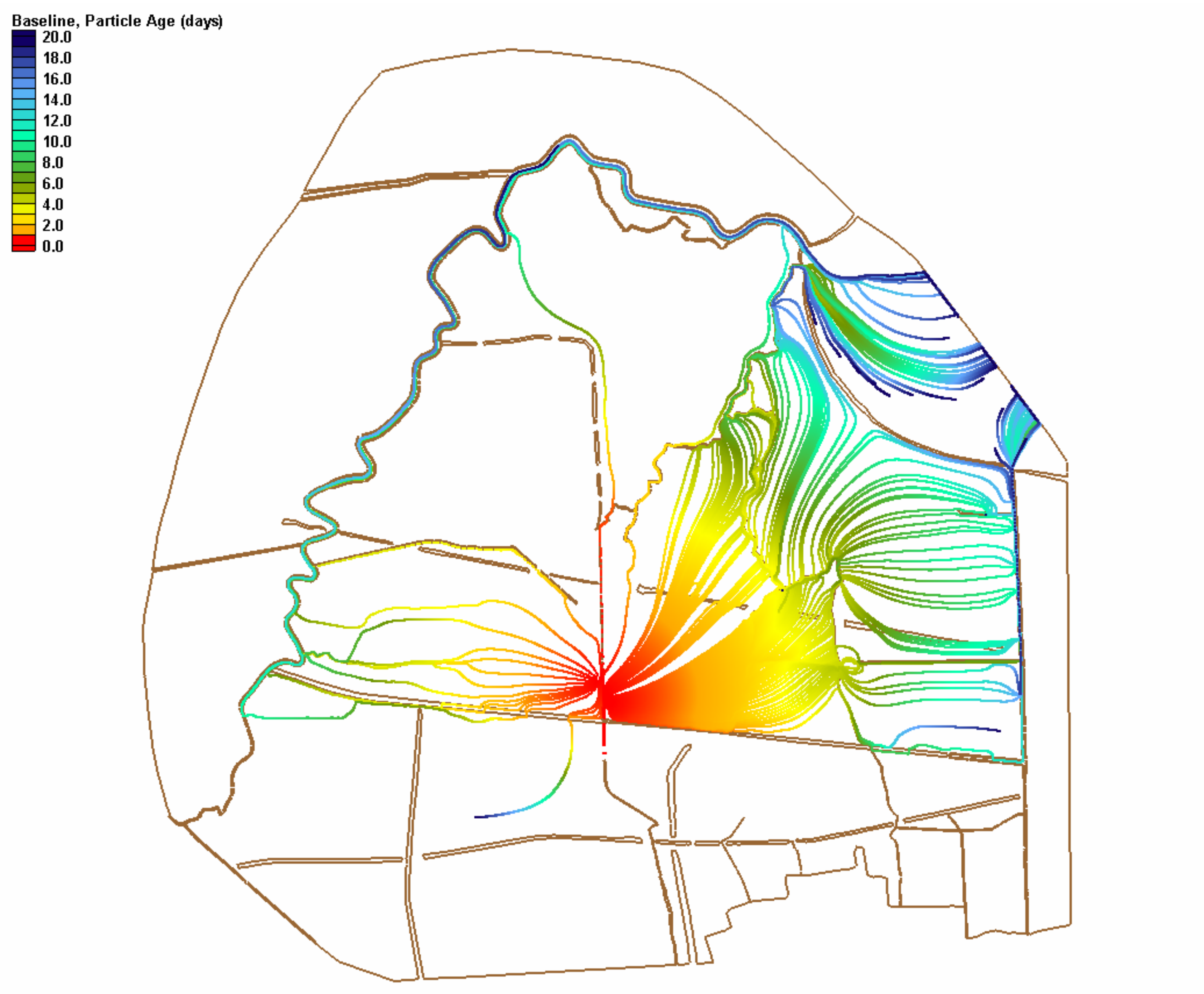


e) Refined Outfall Management

Figure 7. Steady-State Swamp WSE, Outfall Management

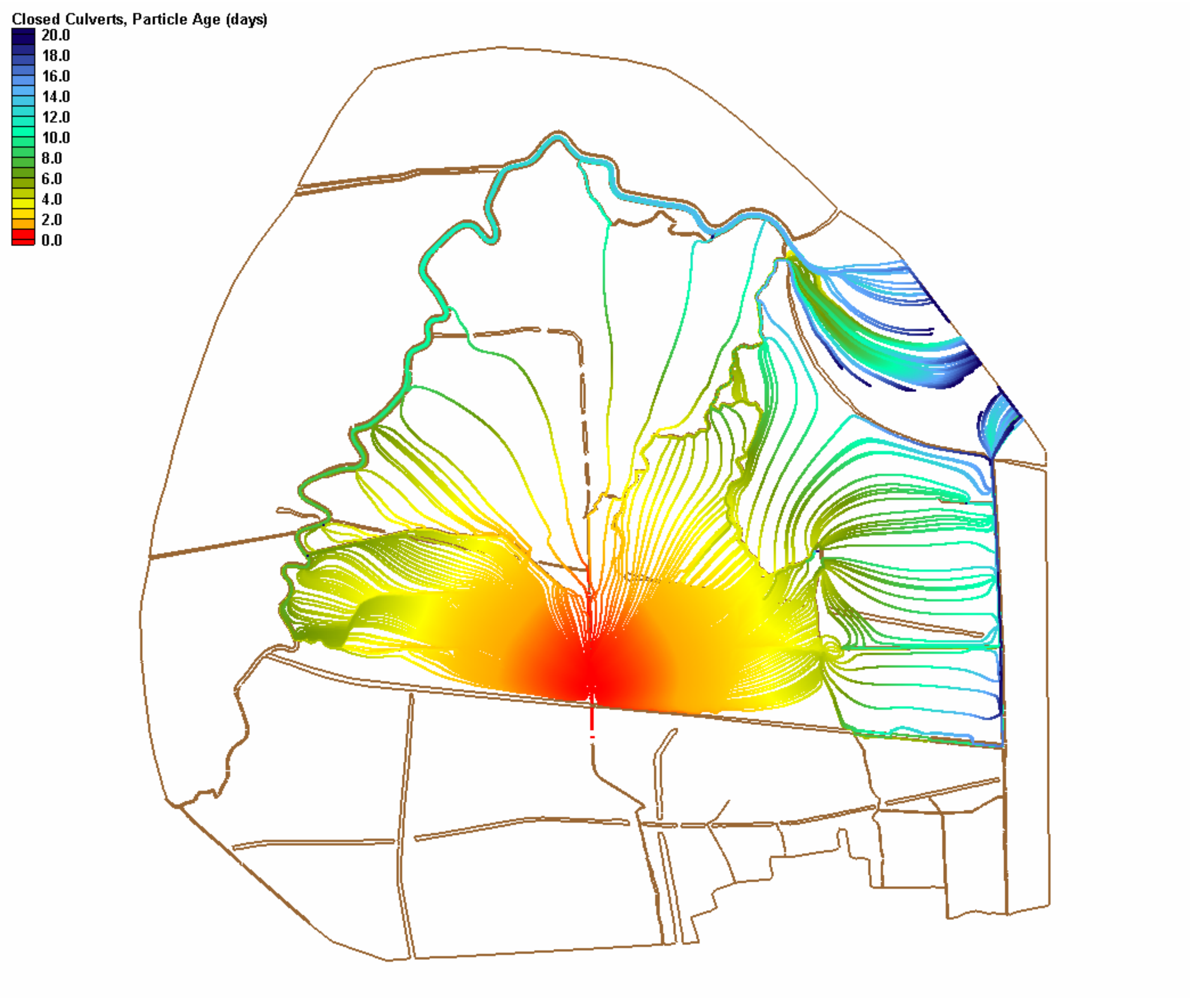
URS



a) Baseline

Figure 8. Steady-State Streamlines, Outfall Management

URS

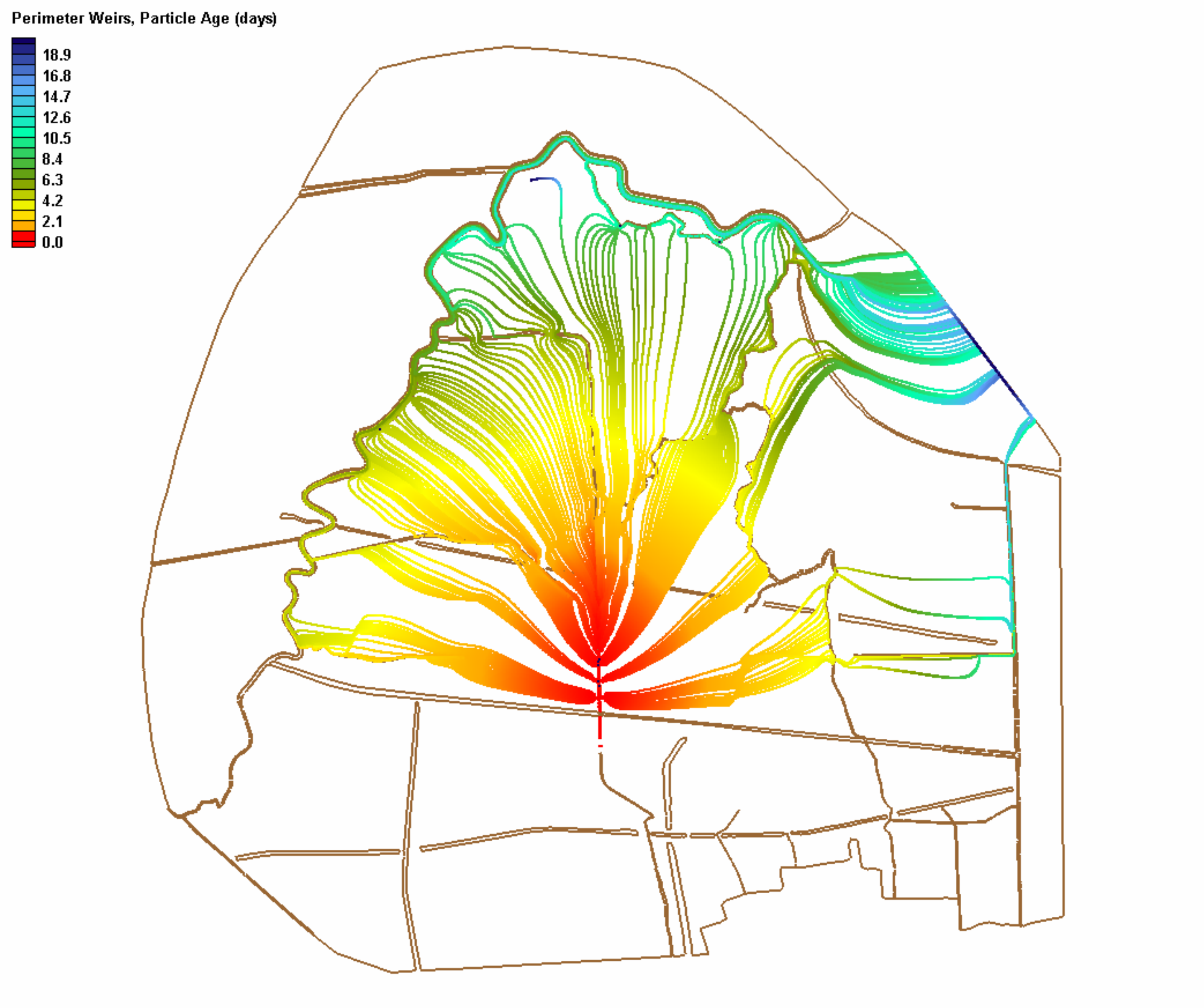


b) Closed Interstate Culverts

Figure 8. Steady-State Streamlines, Outfall Management

c) Extended Outfall

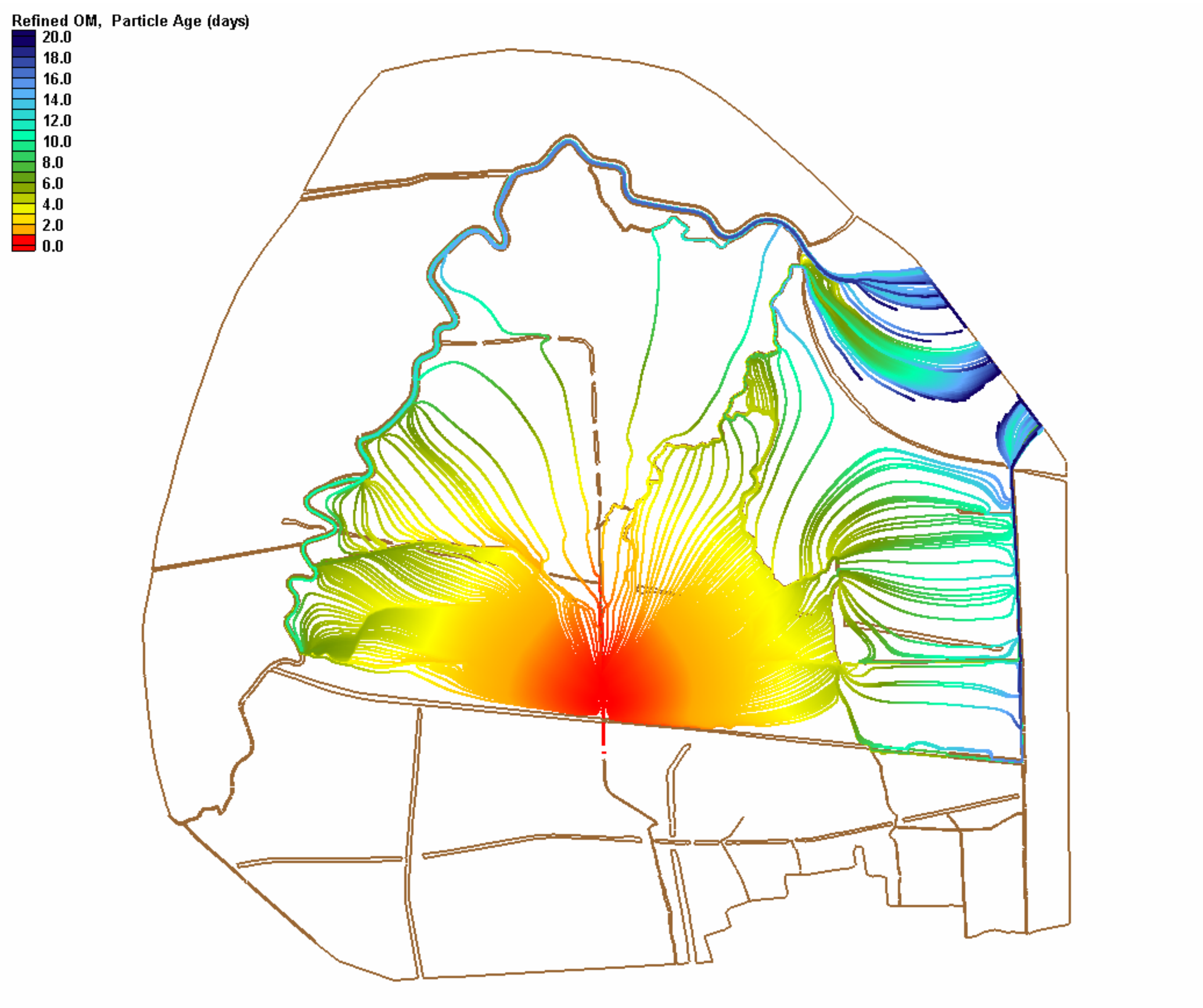
Figure 8. Steady-State Streamlines, Outfall Management



d) Perimeter Weirs

Figure 8. Steady-State Streamlines, Outfall Management

URS



e) Refined Outfall Management

Figure 8. Steady-State Streamlines, Outfall Management

URS

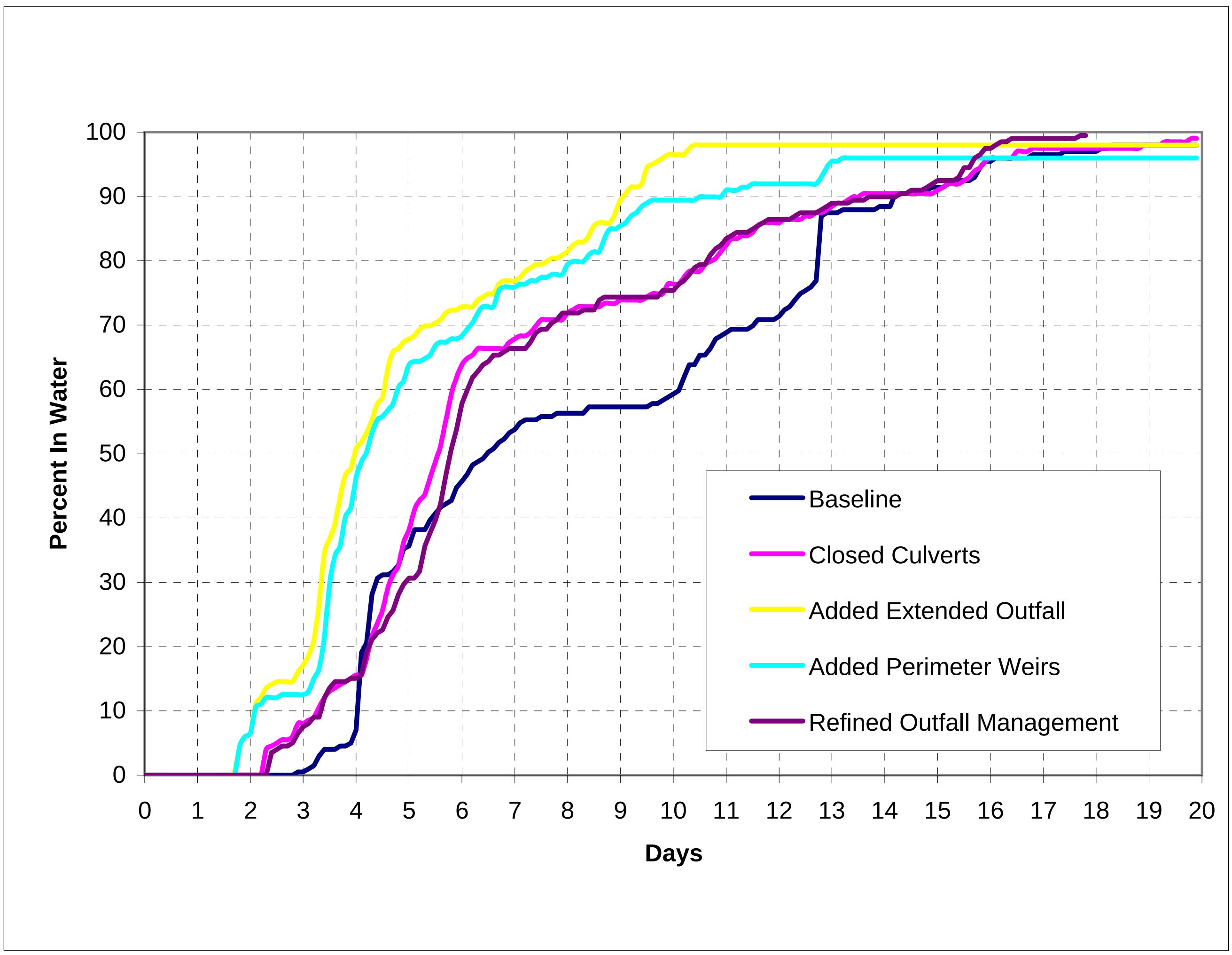


Figure 9. Steady State Flow Retention Time, Outfall Management

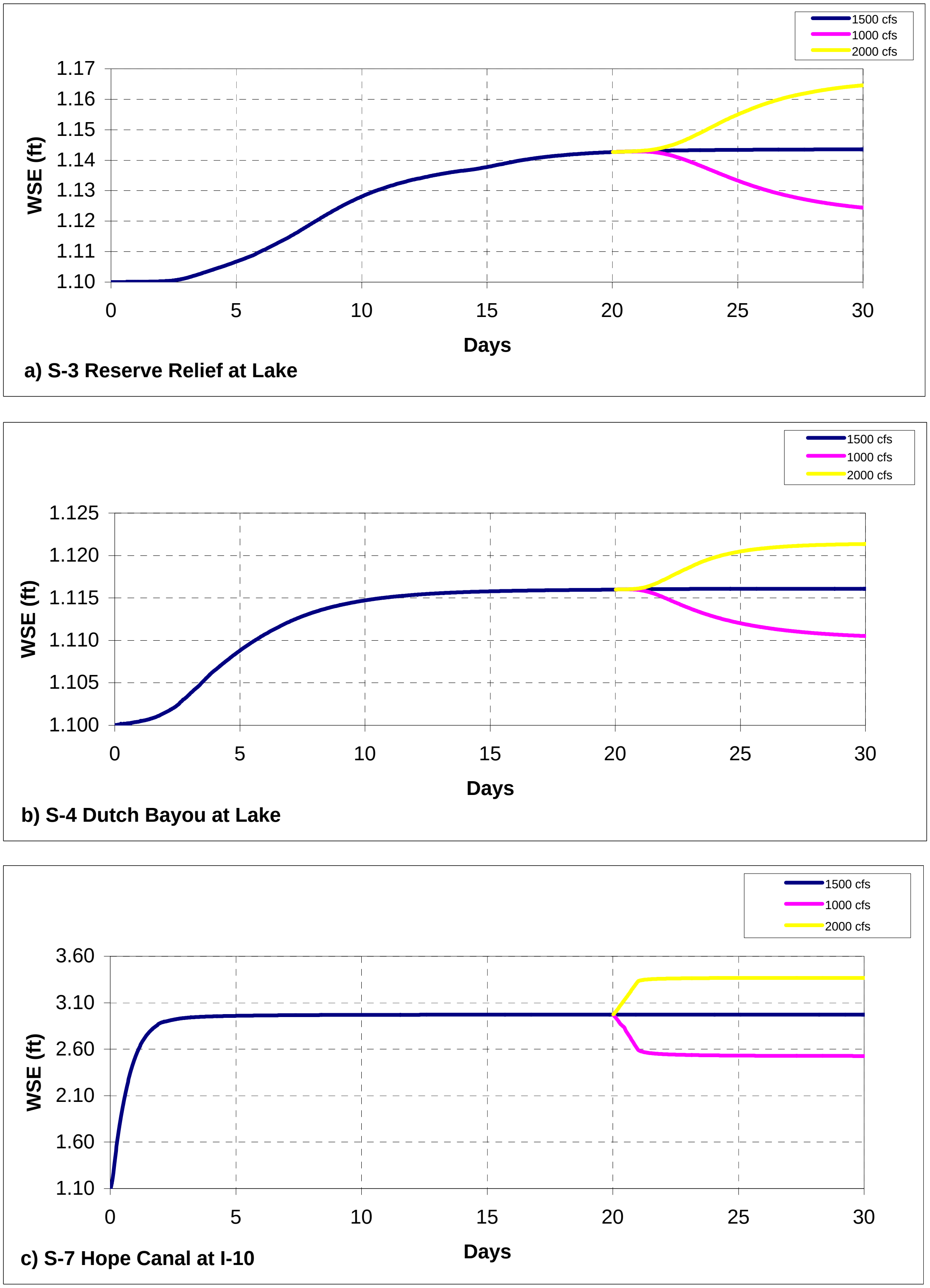
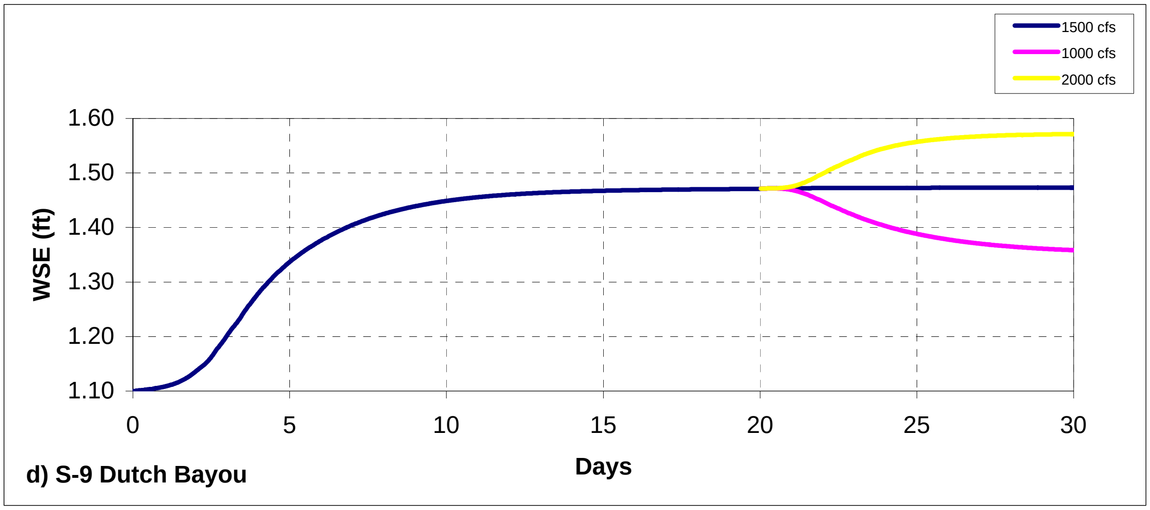
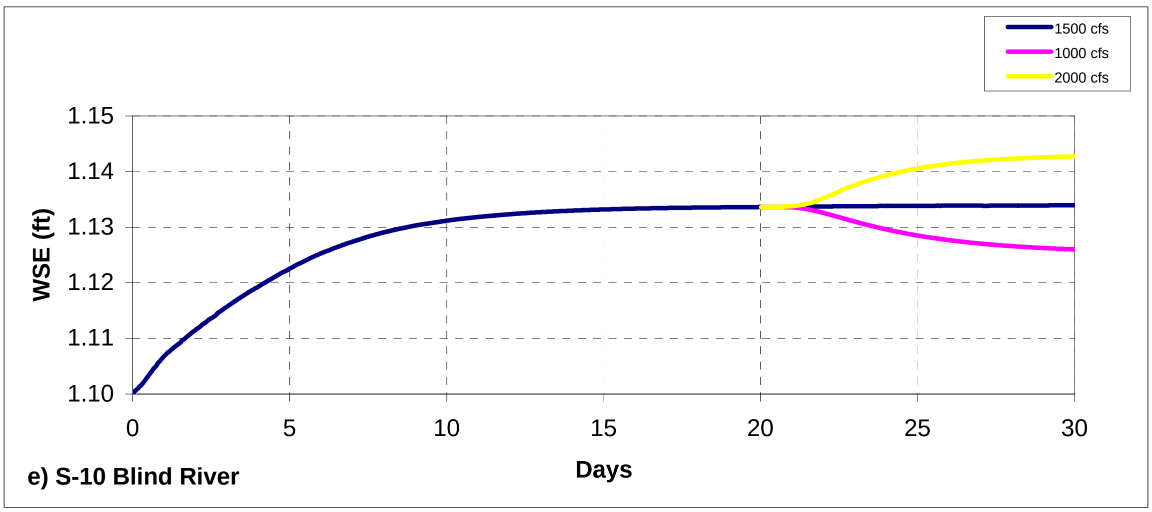


Figure 10. Stage Hydrographs, Alternative Diversion Flows (a - c)





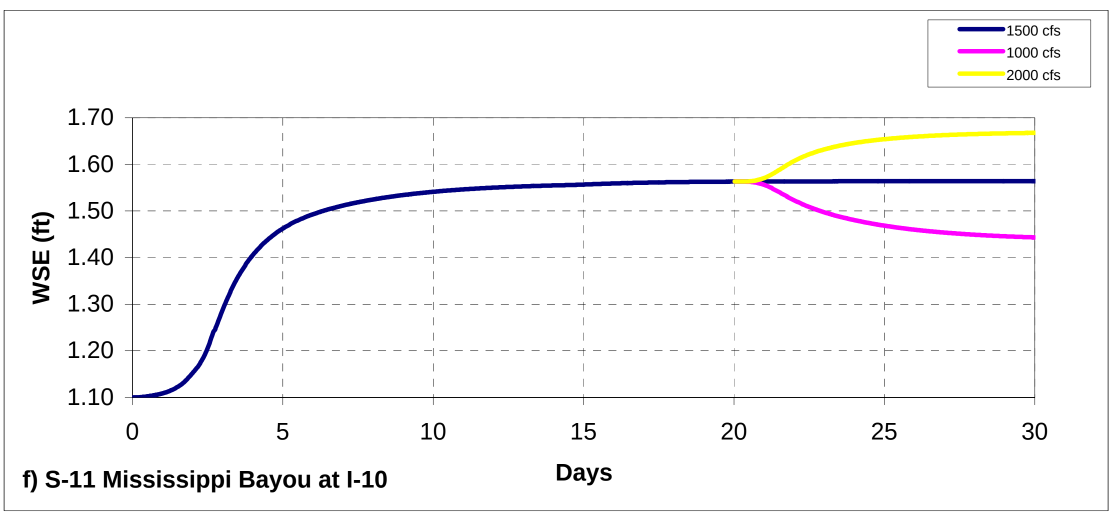
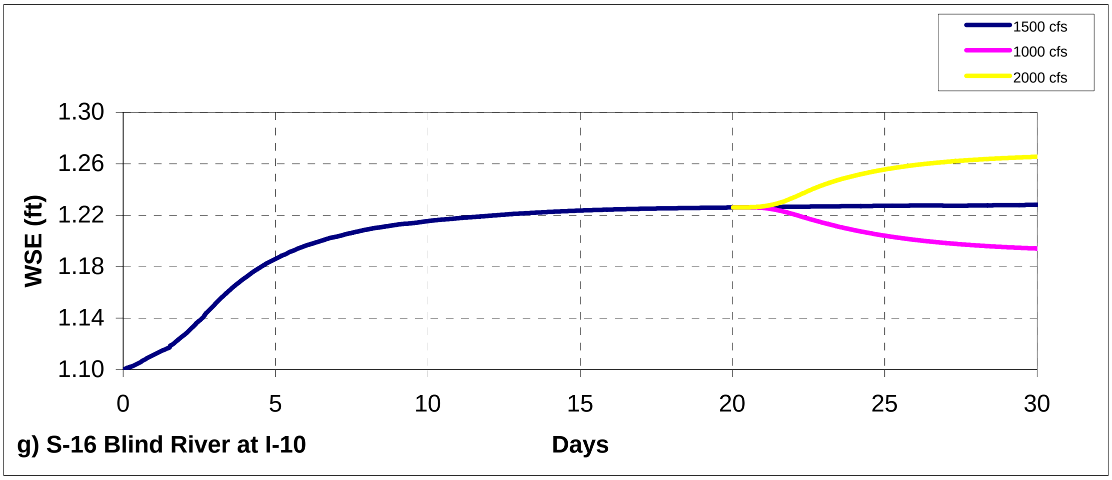
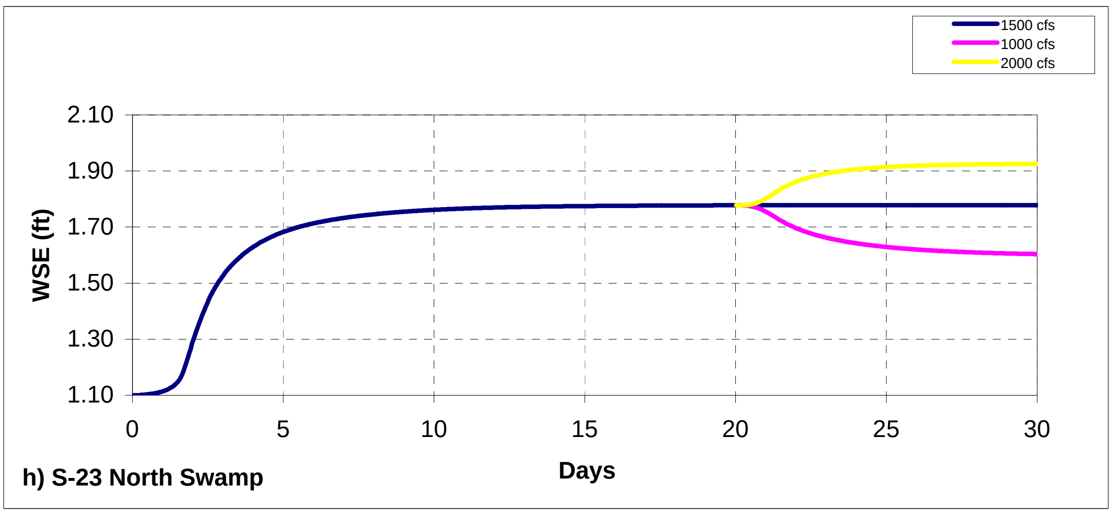


Figure 10. Stage Hydrographs, Alternative Diversion Flows (d - f)





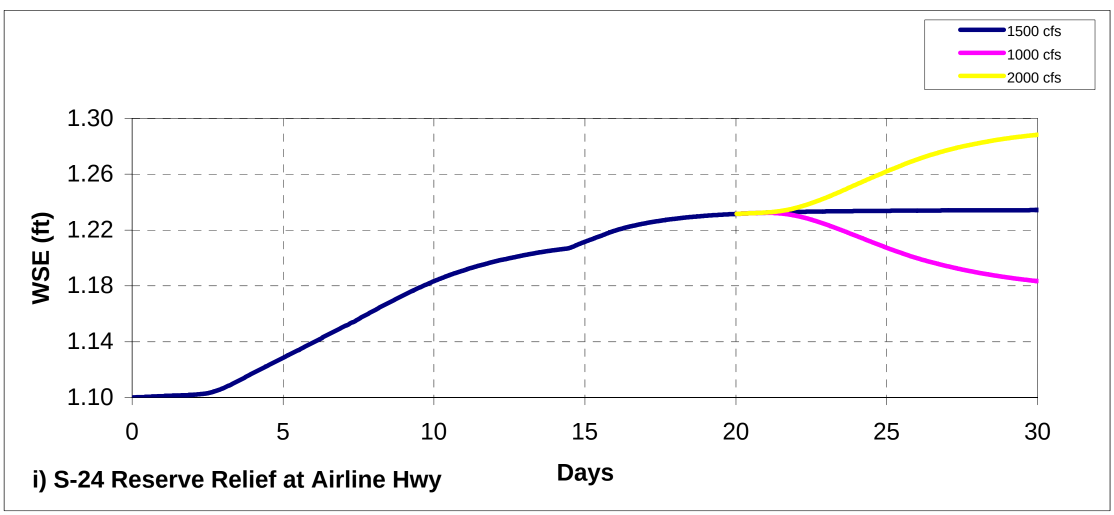
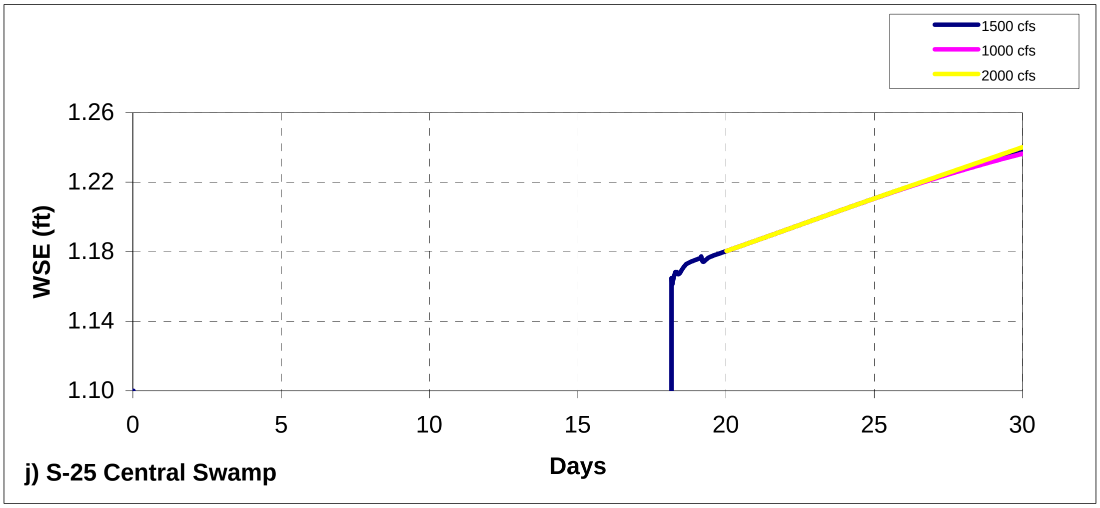


Figure 10. Stage Hydrographs, Alternative Diversion Flows (g - i)



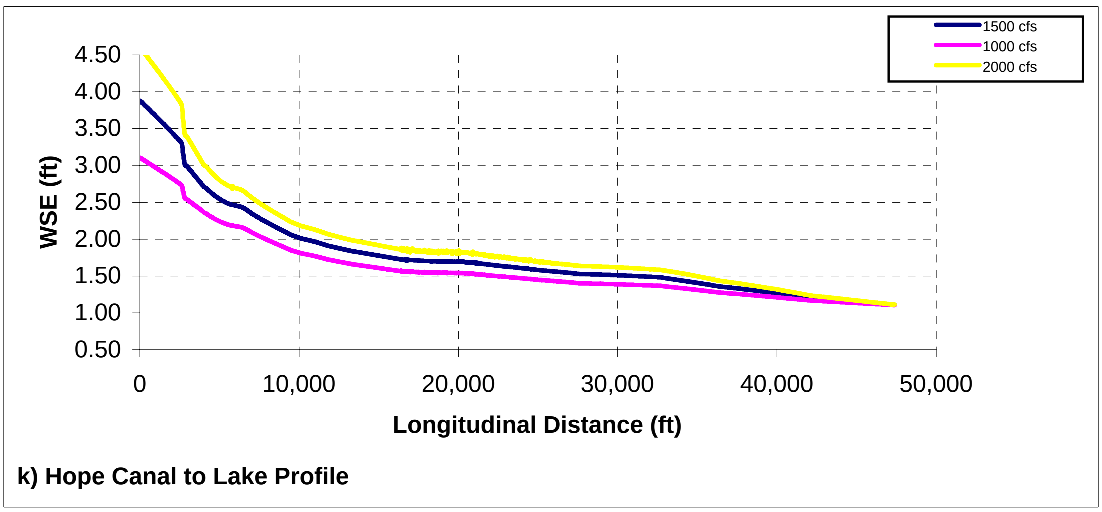
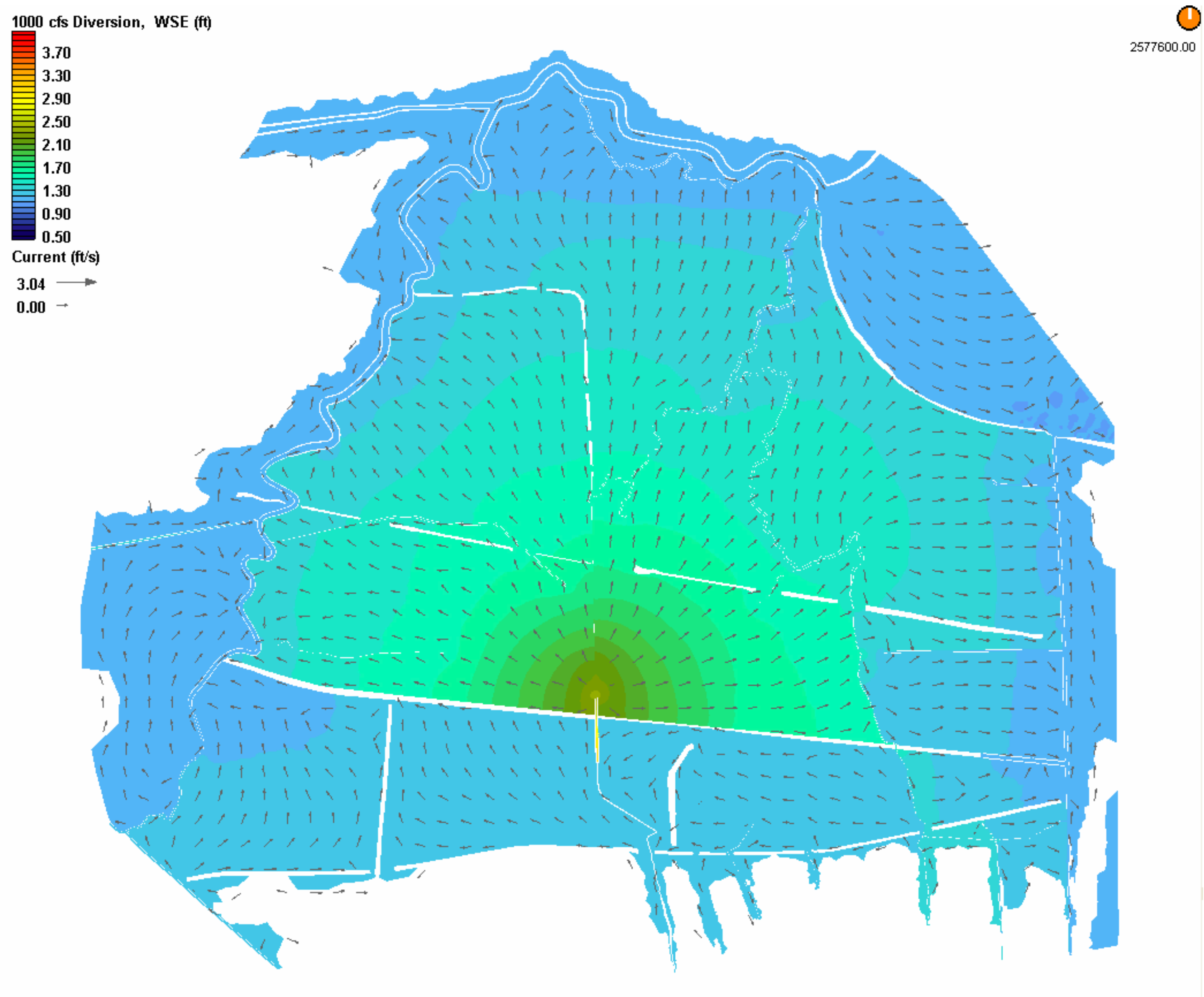


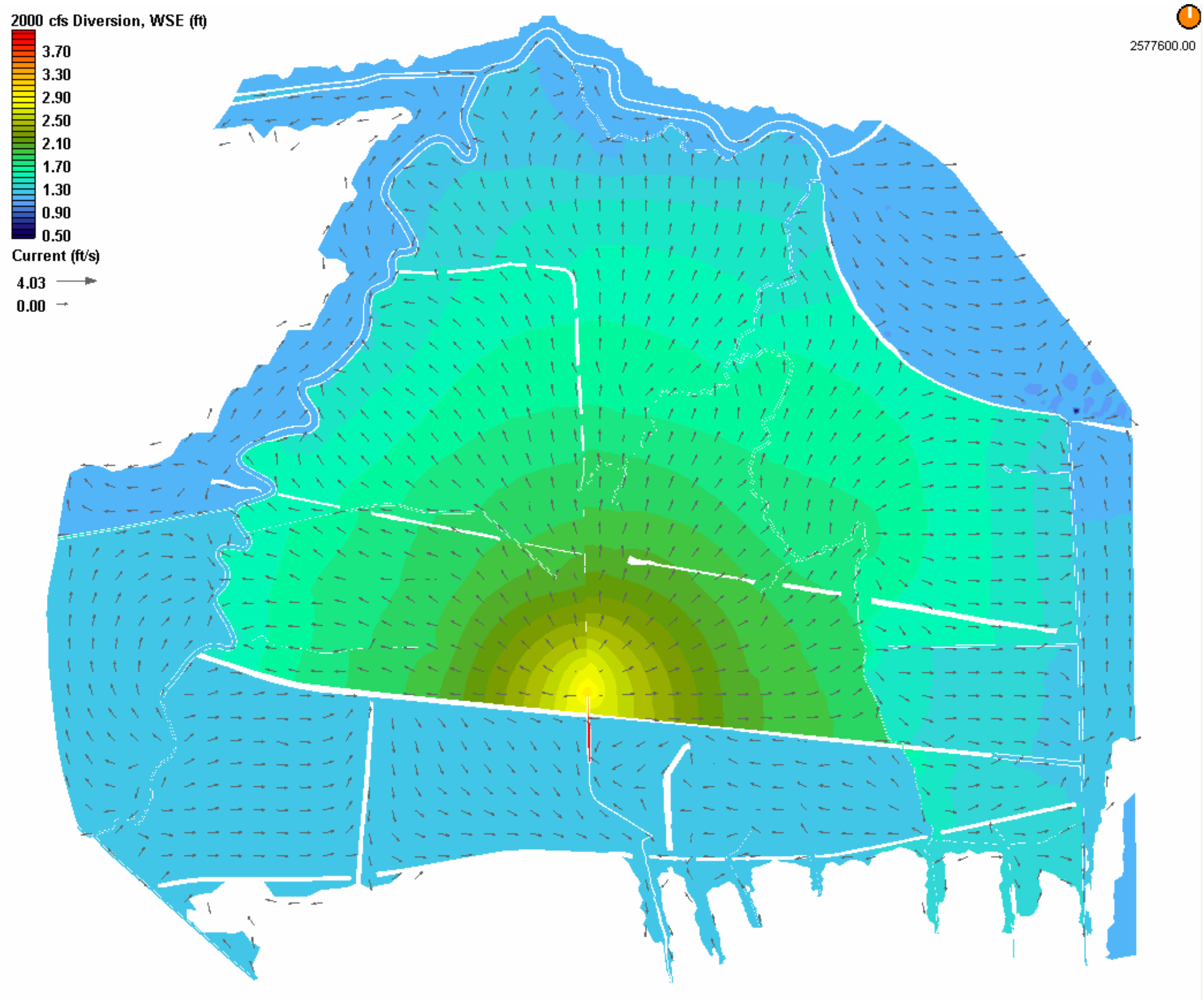
Figure 10. Stage Hydrographs, Alternative Diversion Flows (j - k)



a) 1000 cfs Diversion

Figure 11. Steady-State Swamp WSE, Alternative Diversion Flows

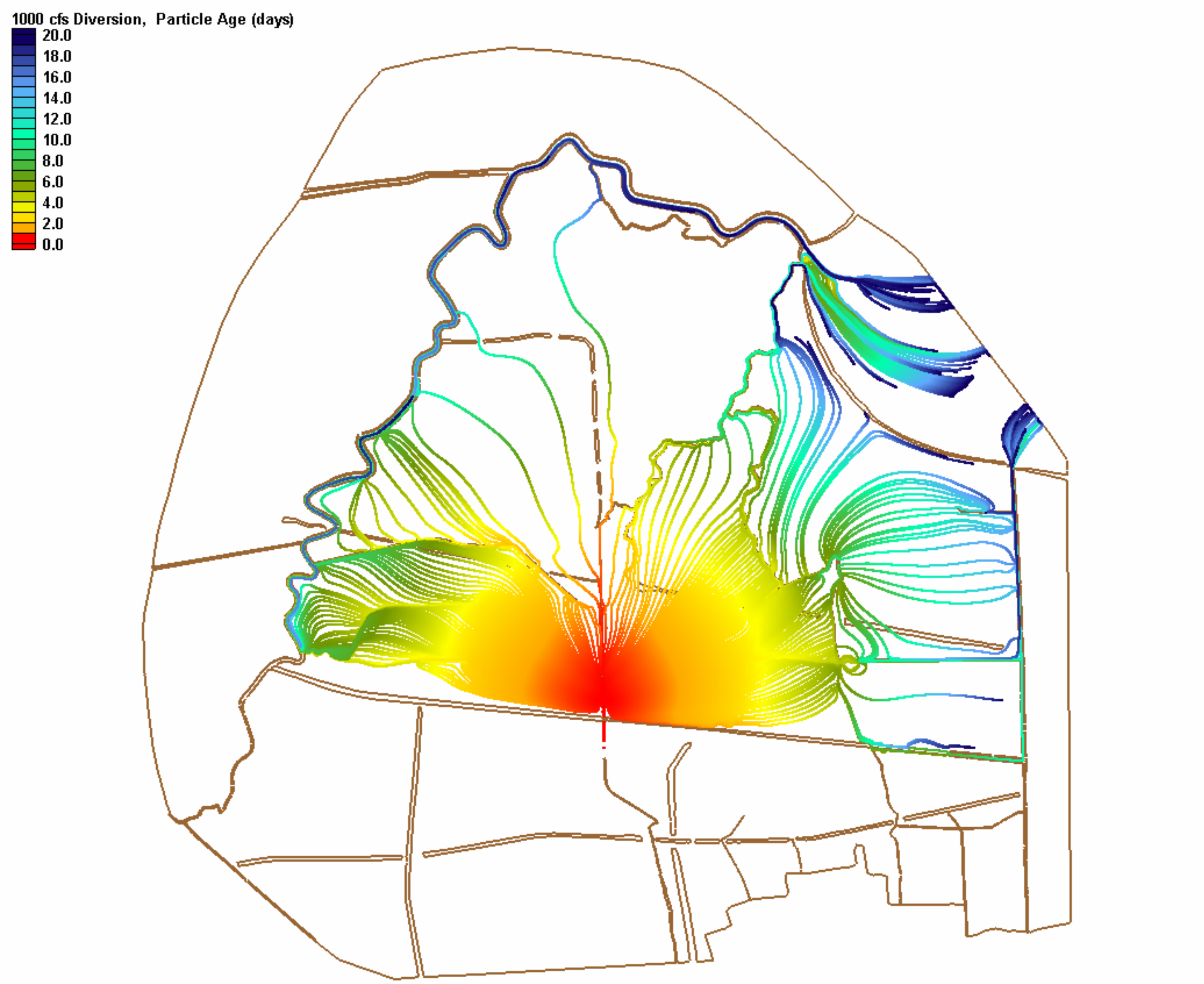
URS



b) 2000 cfs Diversion

Figure 11. Steady-State Swamp WSE, Alternative Diversion Flows

URS



a) 1000 cfs Diversion

Figure 12. Steady-State Streamlines, Alternative Diversion Flows

URS

b) 2000 cfs Diversion

Figure 12. Steady-State Streamlines, Alternative Diversion Flows

URS

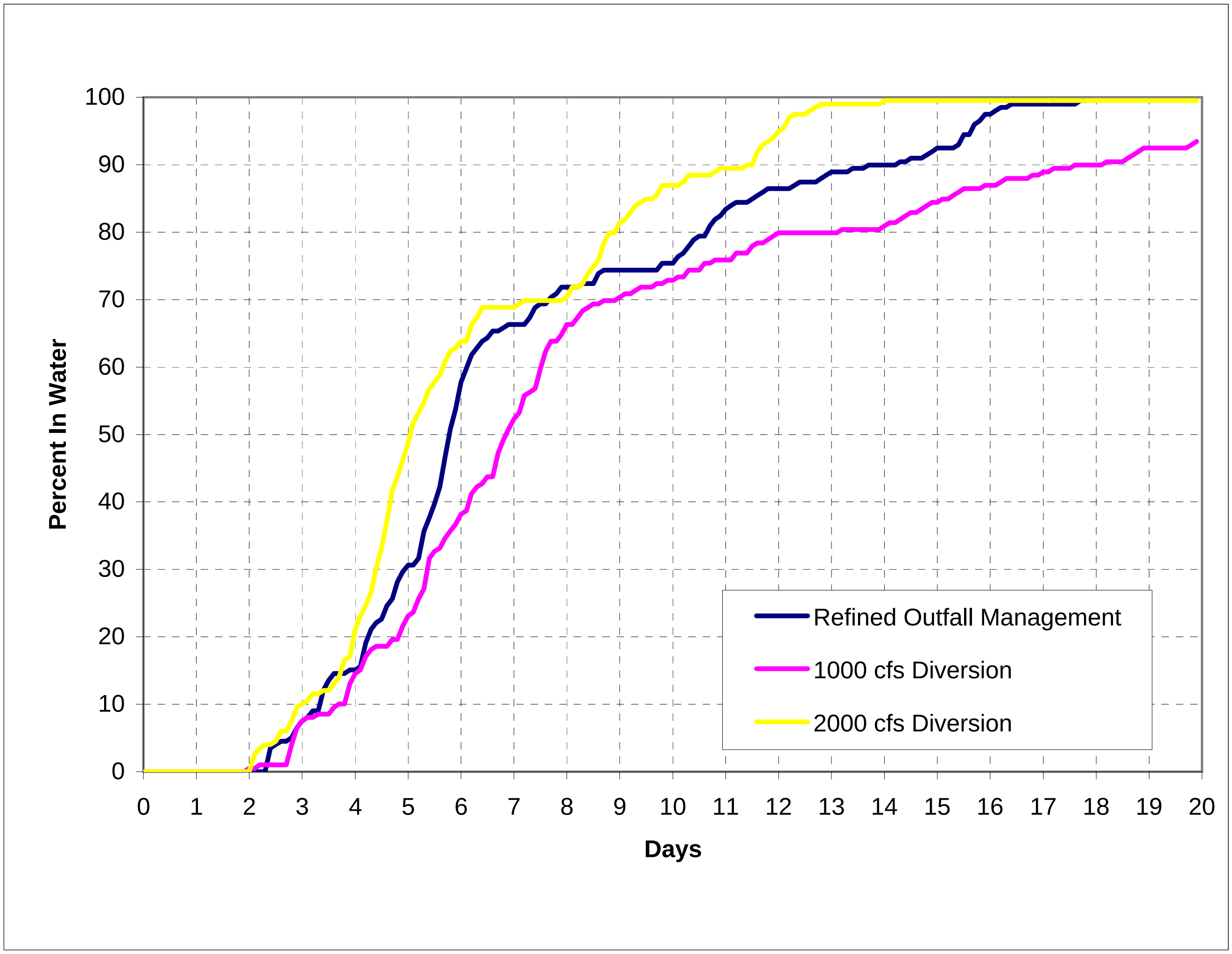


Figure 13. Steady State Flow Retention Time, Alternative Diversion Flows

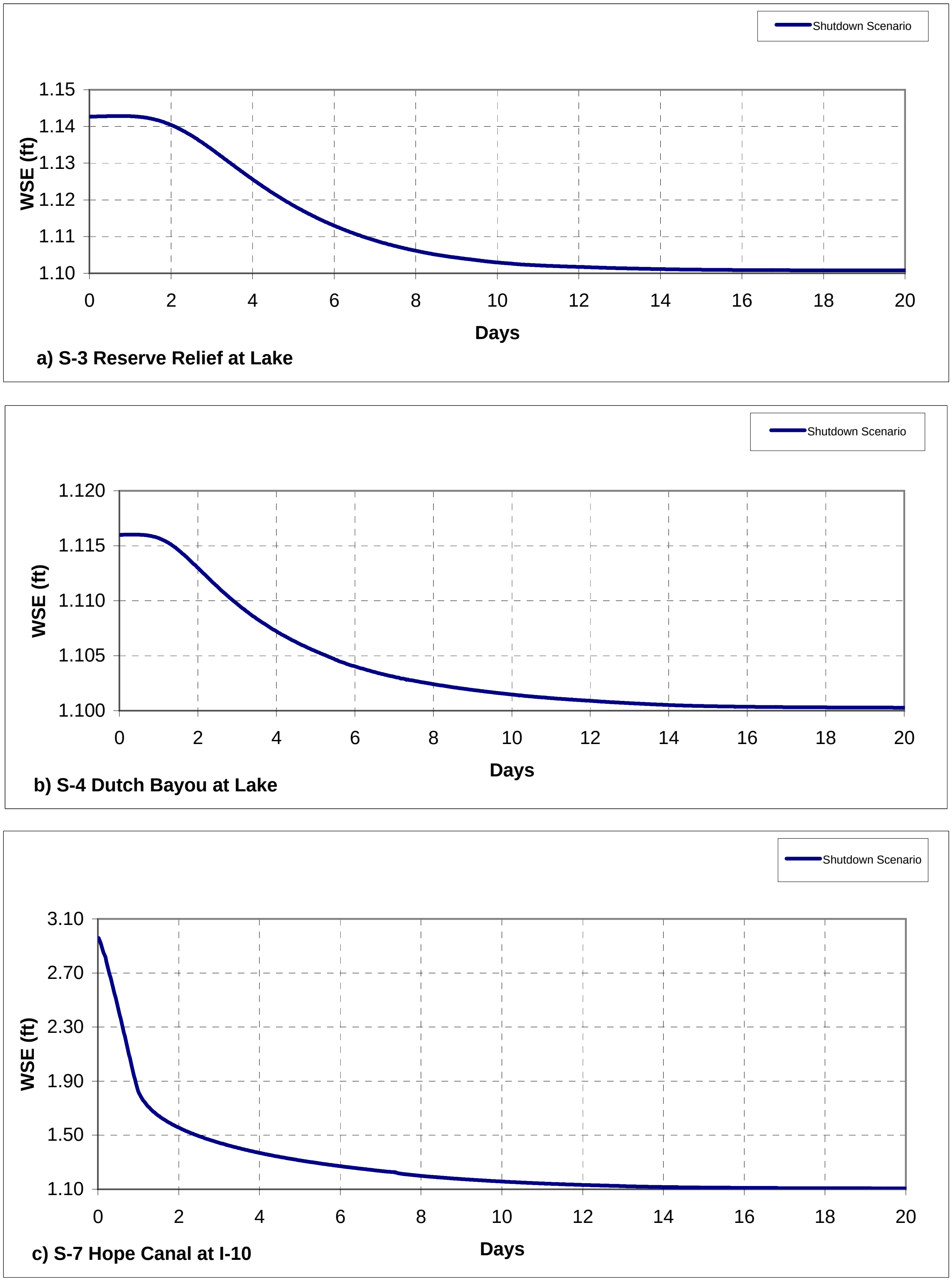
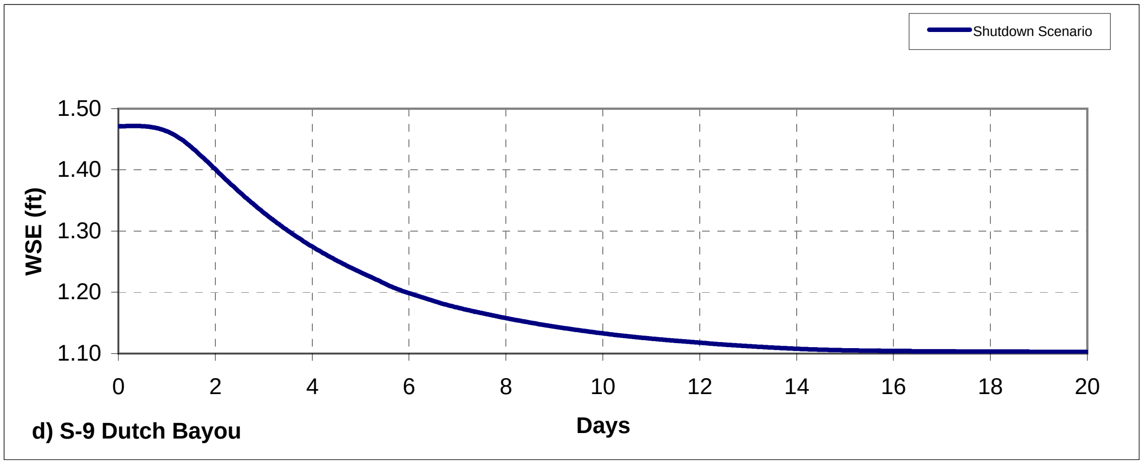
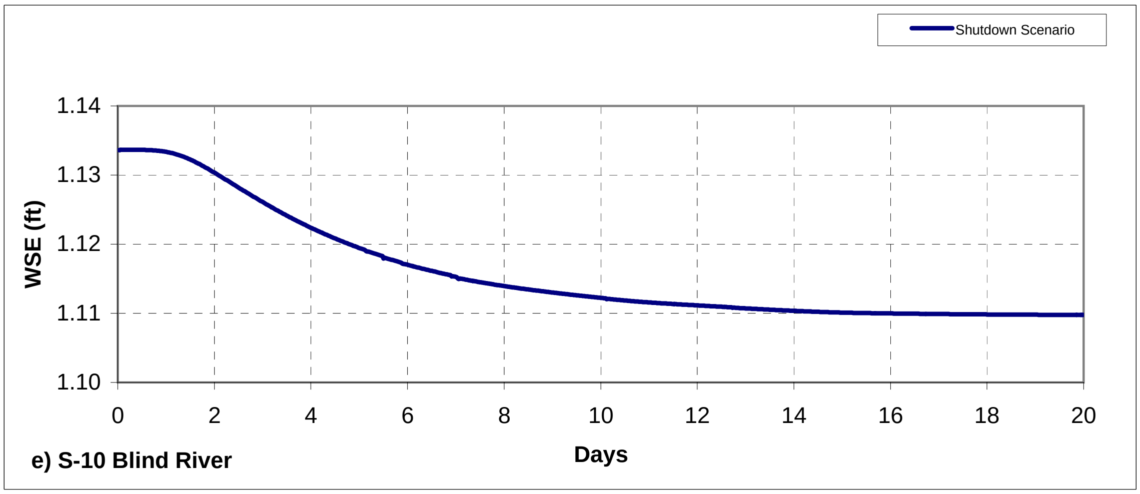


Figure 14. Stage Hydrographs, Shutdown Simulation (a - c)





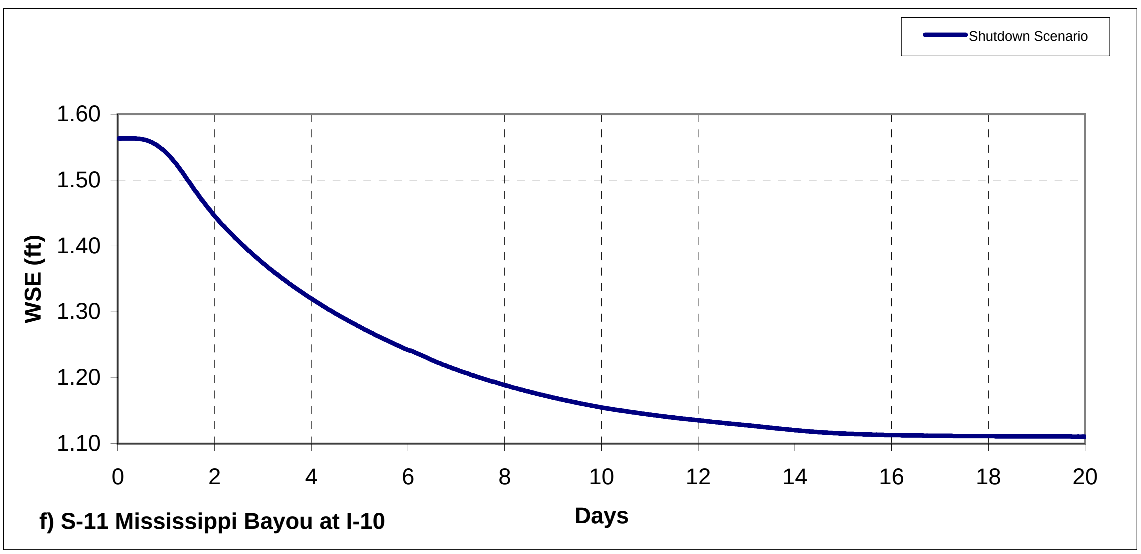
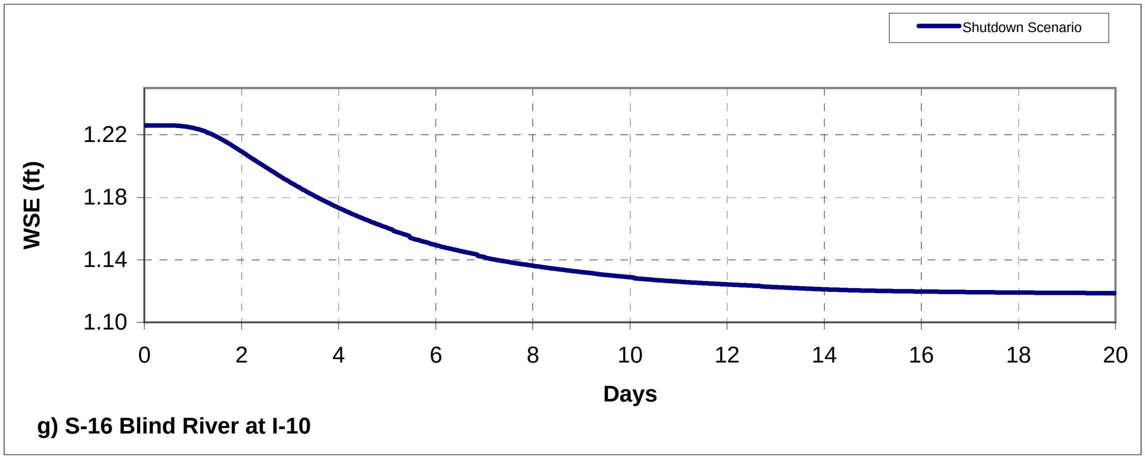
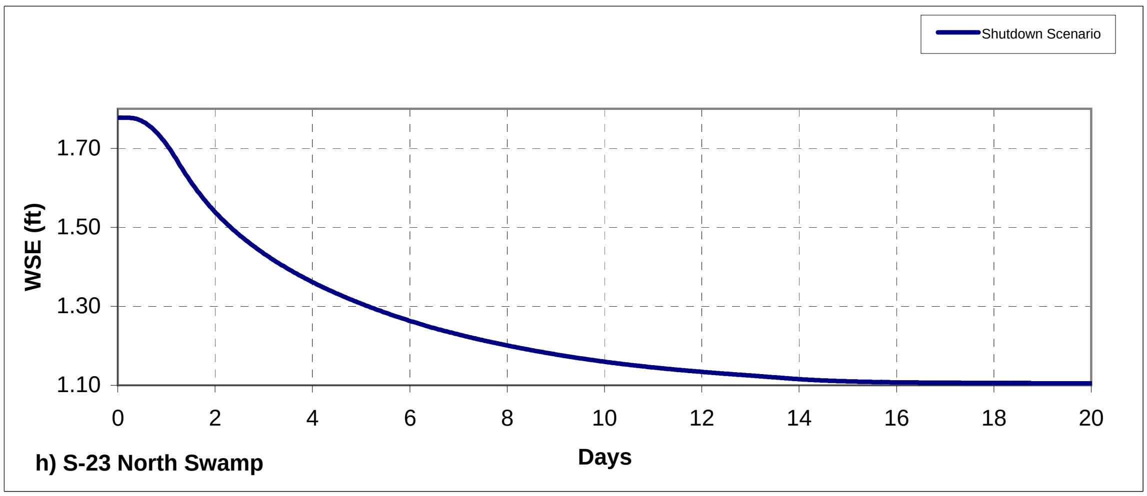


Figure 14. Stage Hydrographs, Shutdown Simulation (d - f)

URS





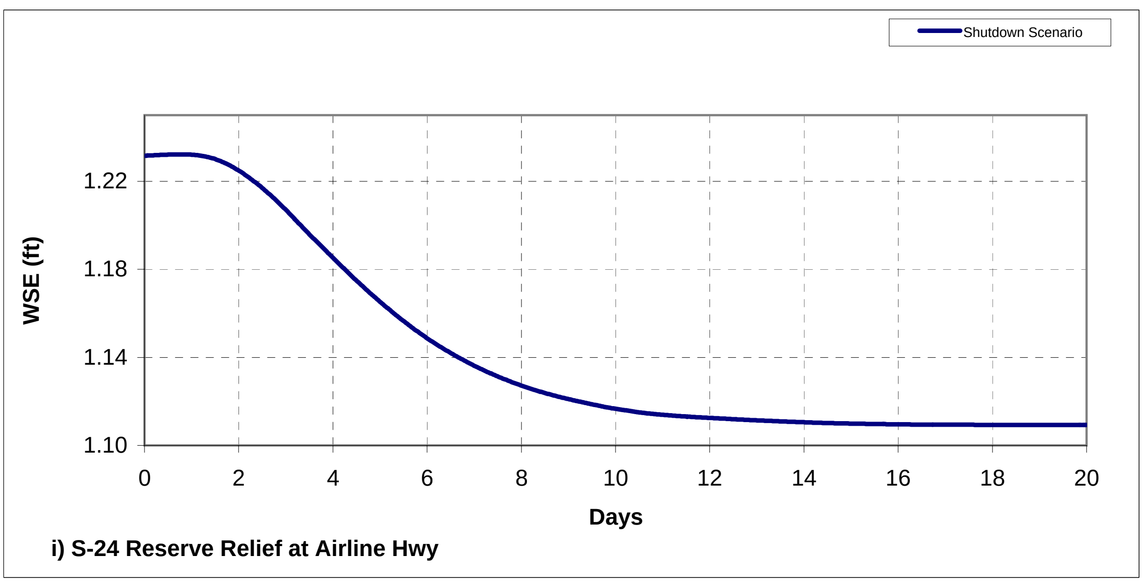


Figure 14. Stage Hydrographs, Shutdown Simulation (g - i)

URS

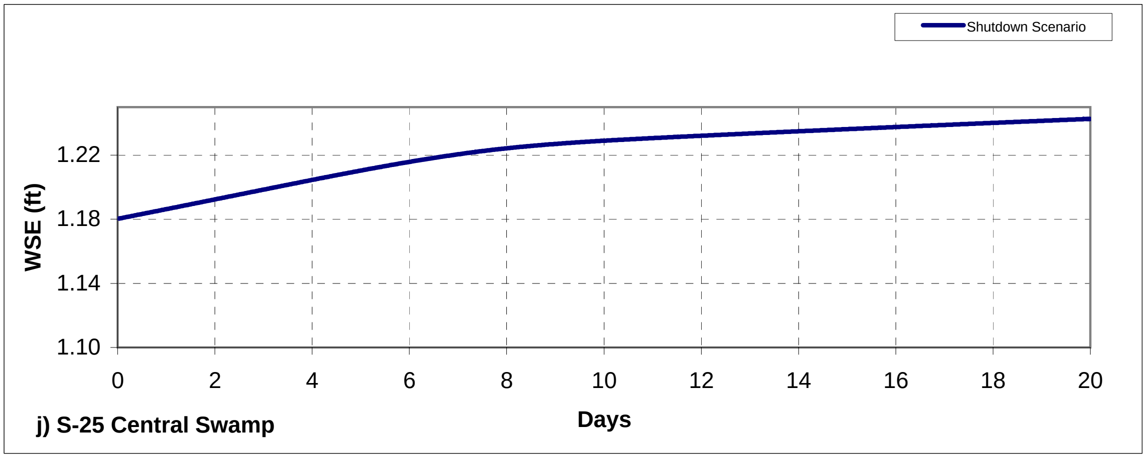
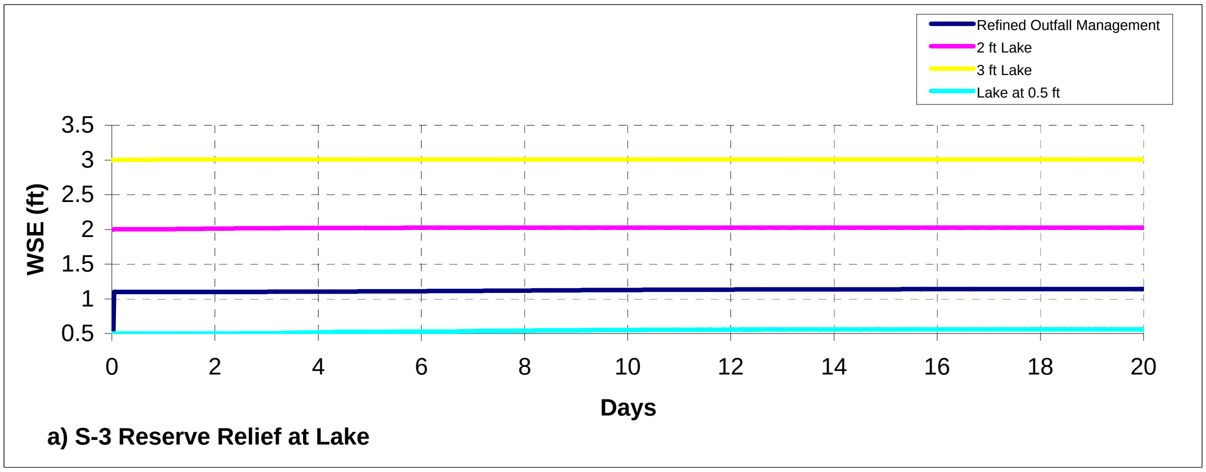
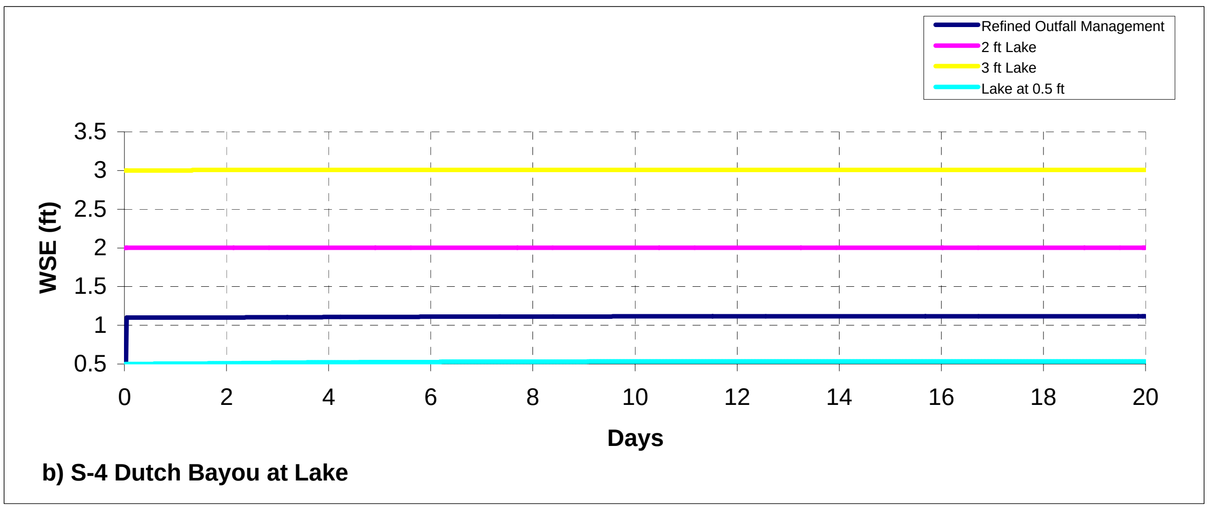


Figure 14. Stage Hydrographs, Shutdown Simulation (j)





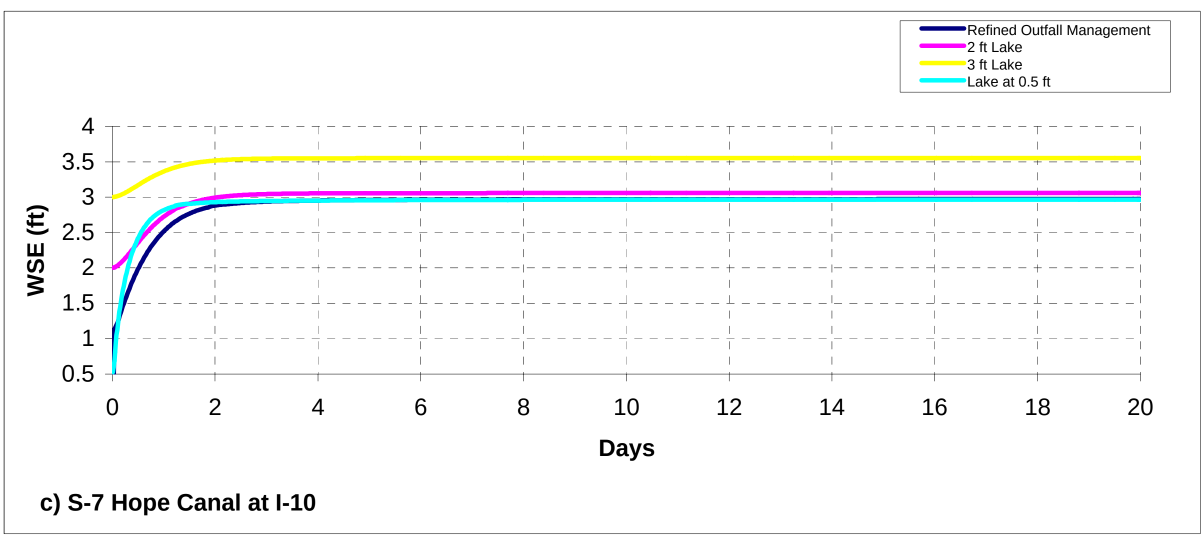


Figure 15. Stage Hydrographs, Alternative Lake WSEs (a - c)

URS

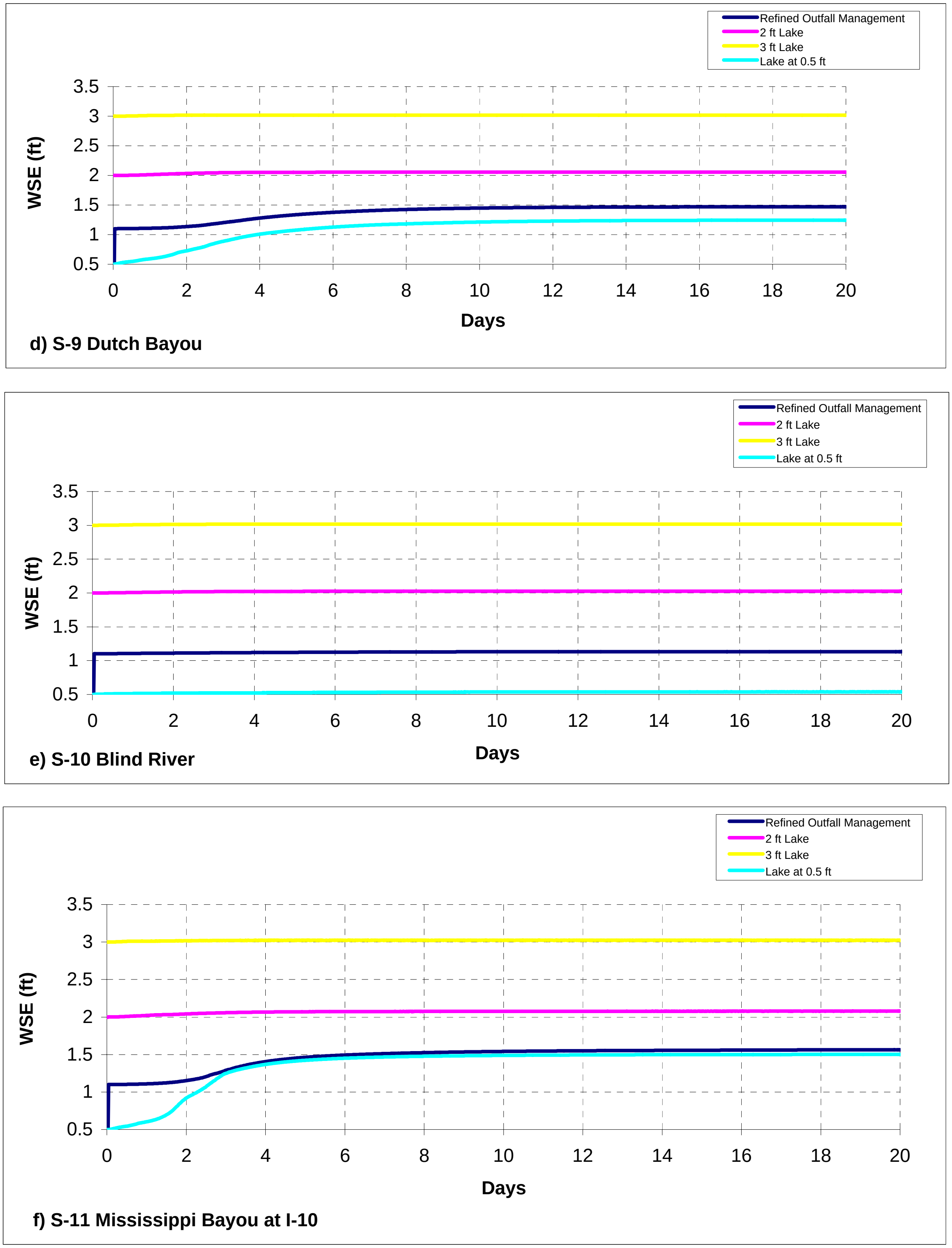
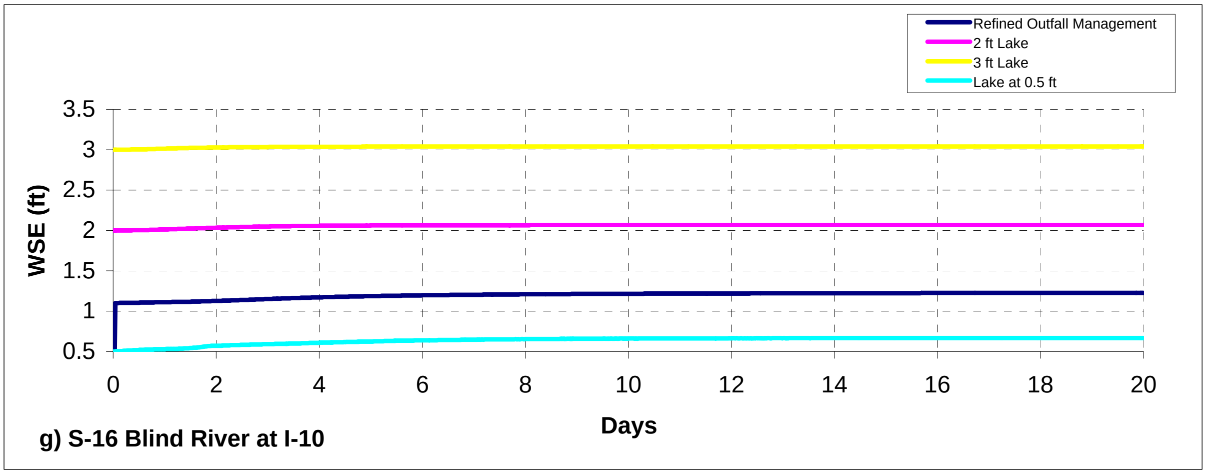
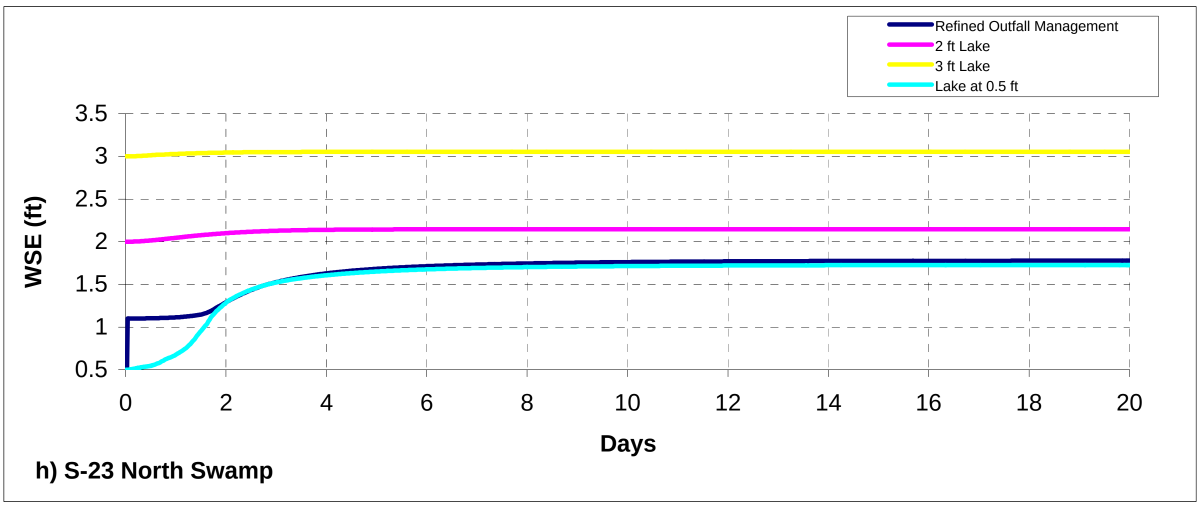


Figure 15. Stage Hydrographs, Alternative Lake WSEs (d - f)





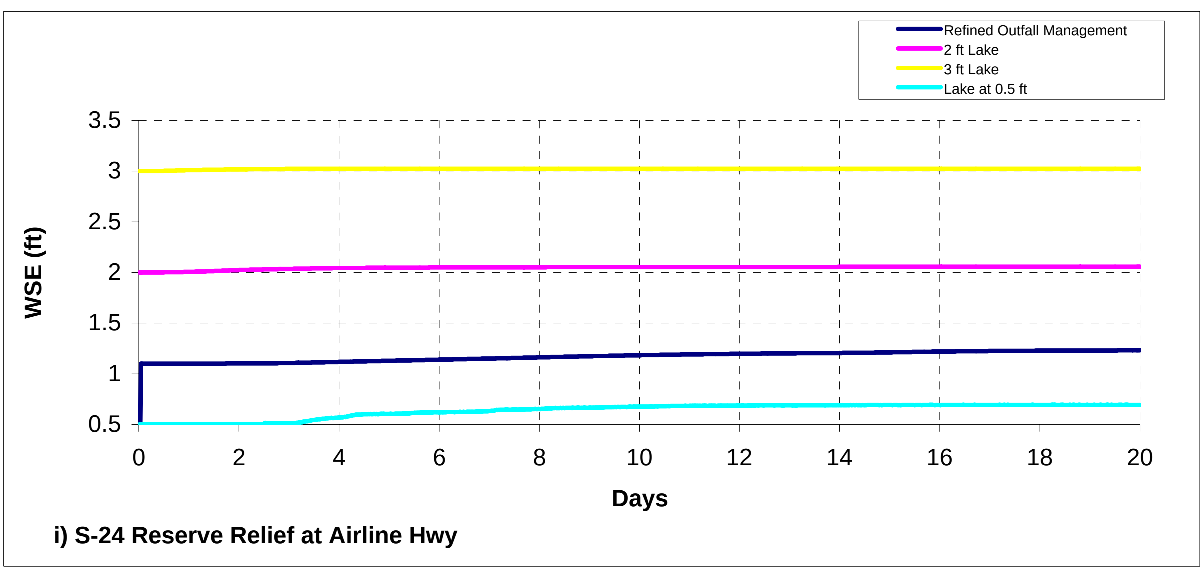
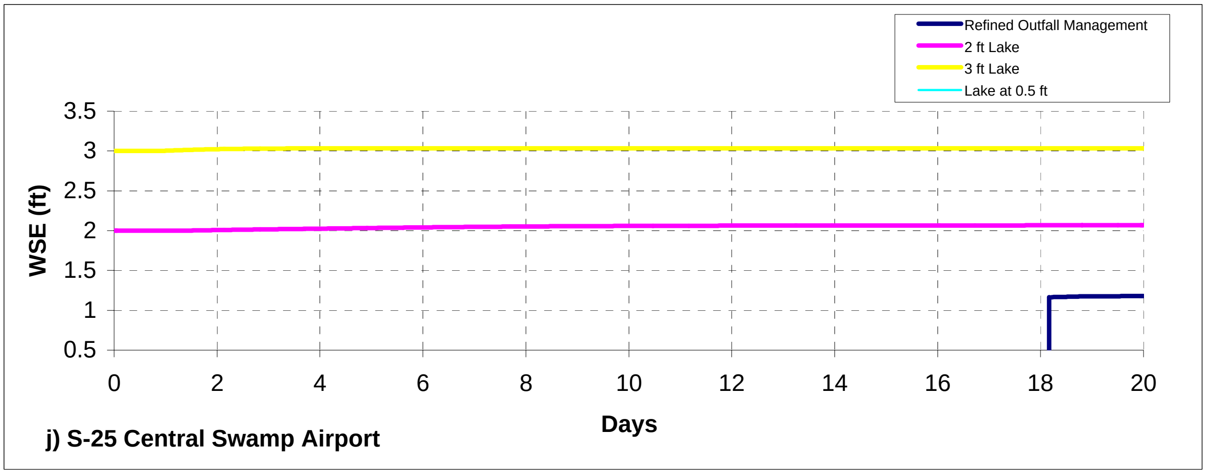
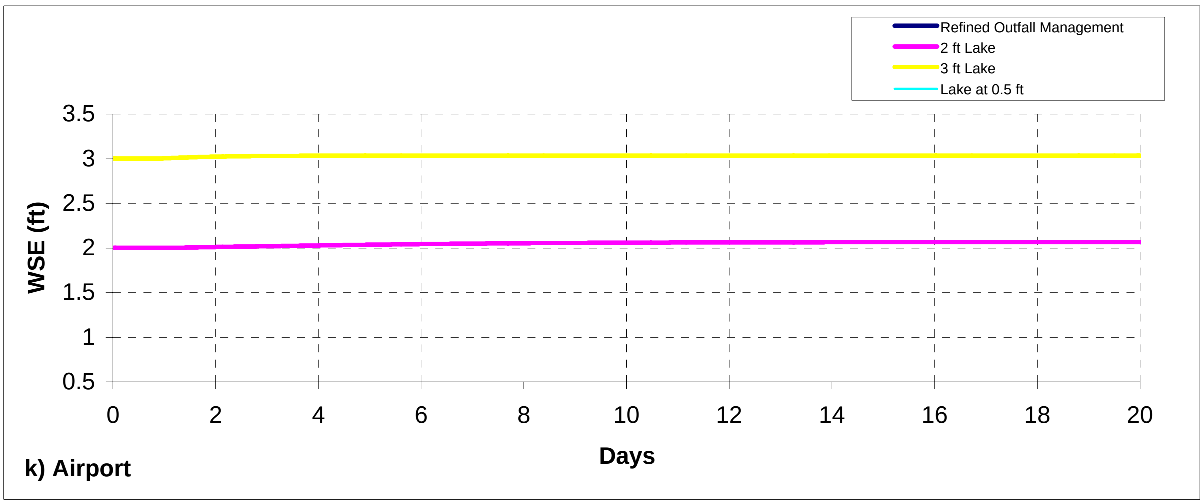


Figure 15. Stage Hydrographs, Alternative Lake WSEs (g - i)

URS





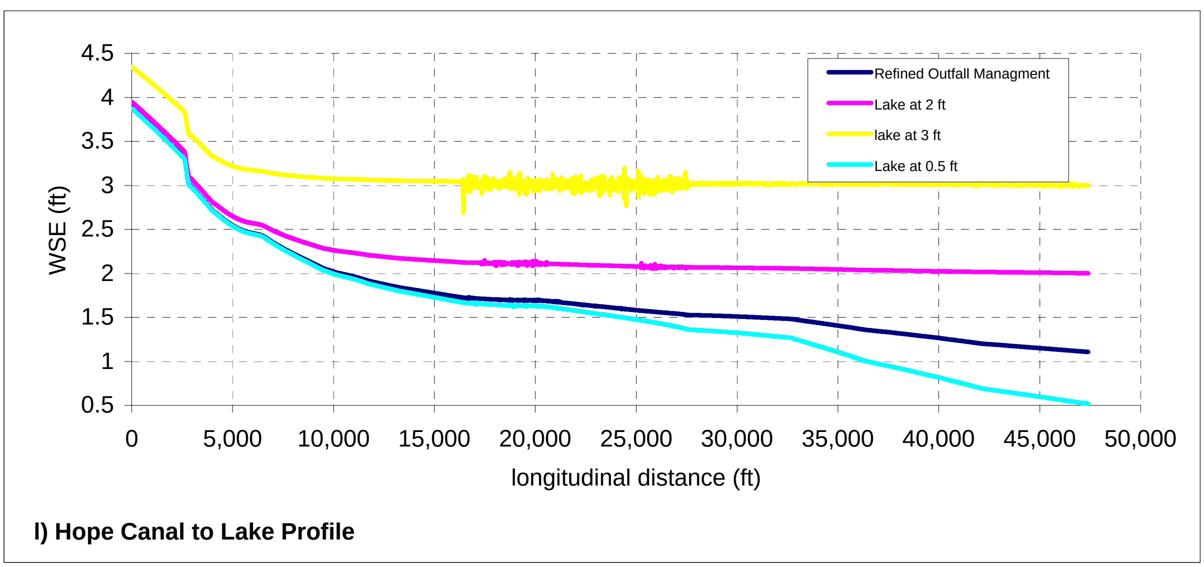
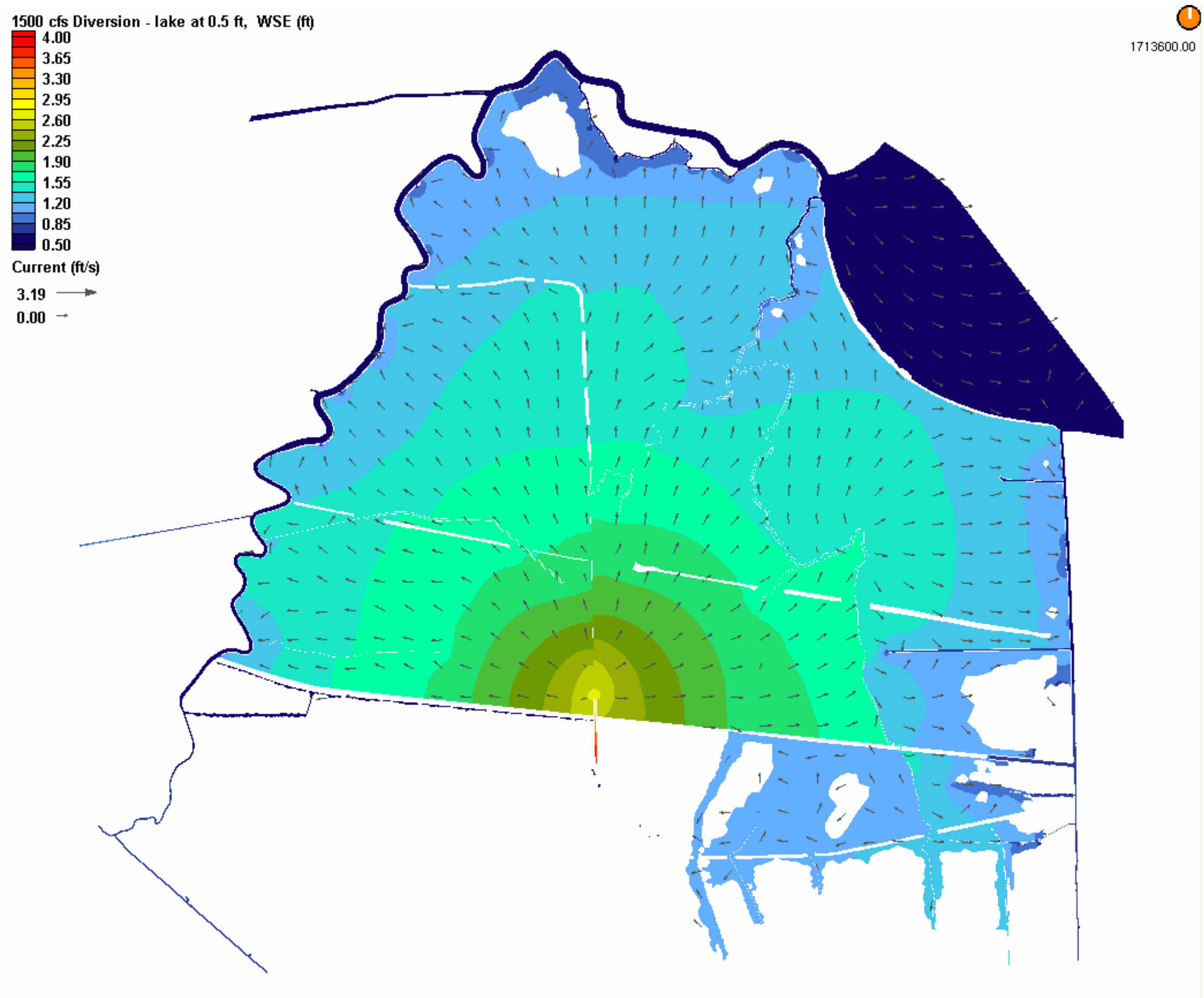


Figure 15. Stage Hydrographs, Alternative Lake WSEs (j - l)

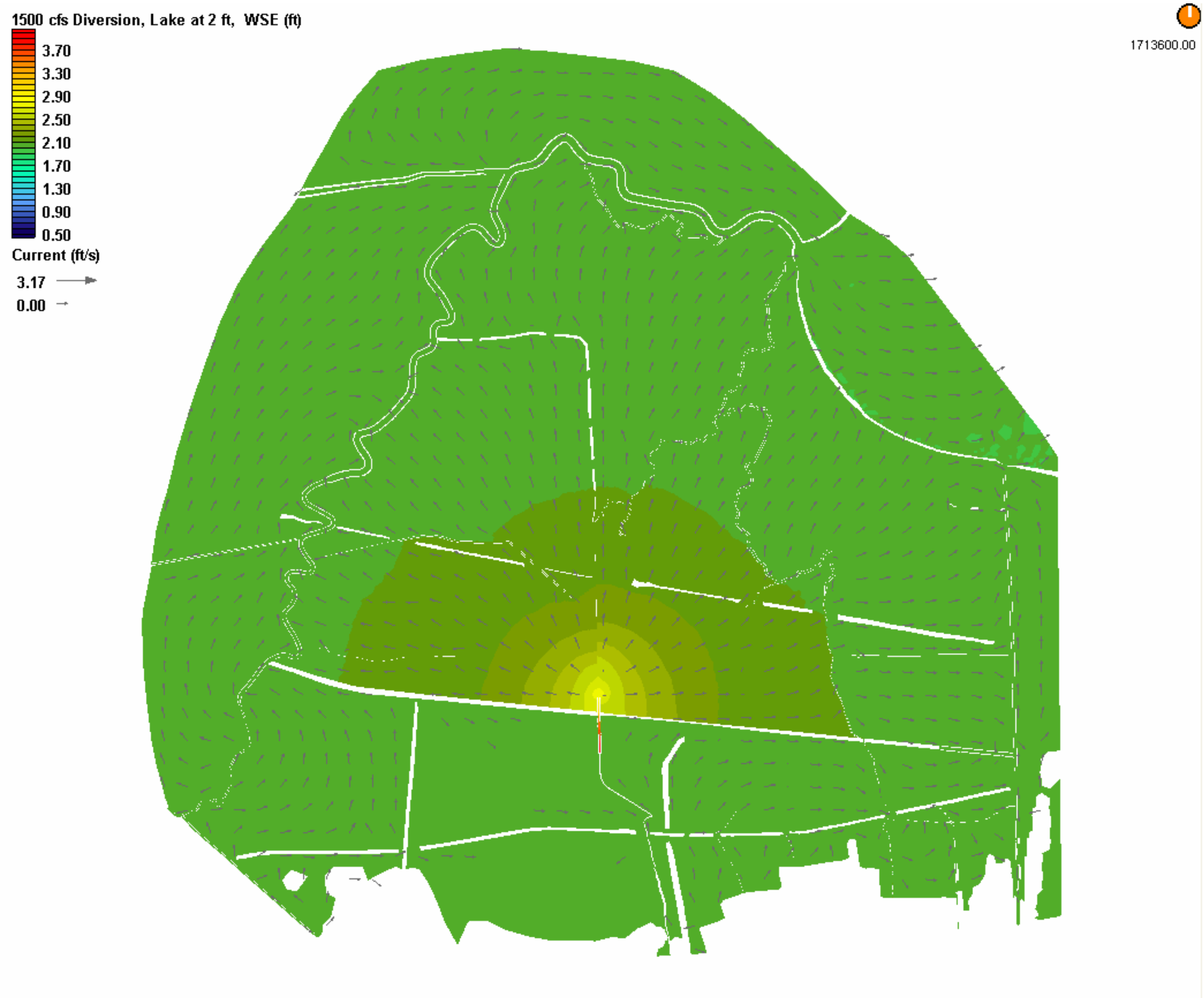
URS



a) Lake at 0.5 ft

Figure 16. Steady-State Swamp WSE, Alternative Lake WSEs

URS



b) Lake at 2.0 ft

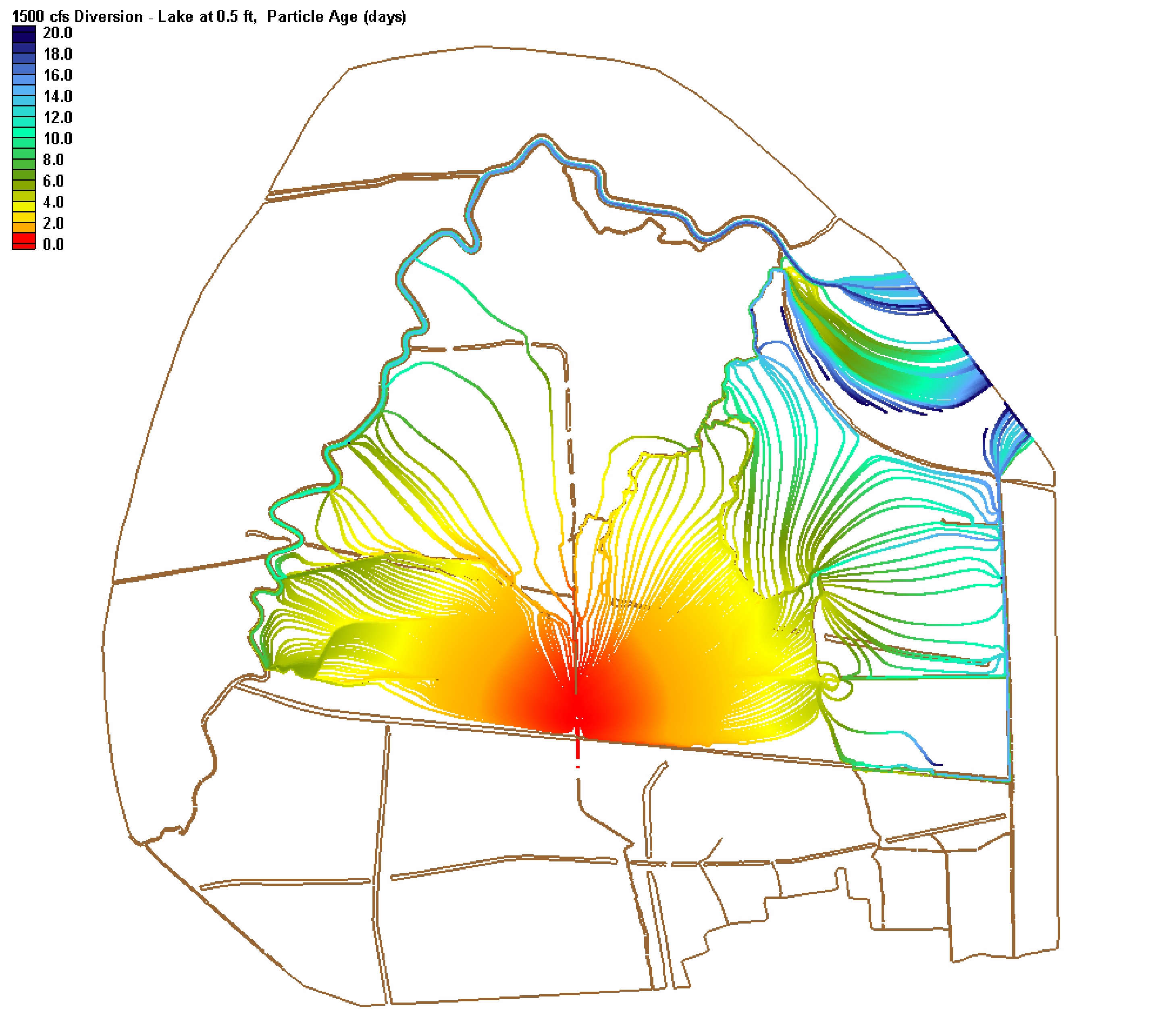
Figure 16. Steady-State Swamp WSE, Alternative Lake WSEs

URS

c) Lake at 3.0 ft

Figure 16. Steady-State Swamp WSE, Alternative Lake WSEs

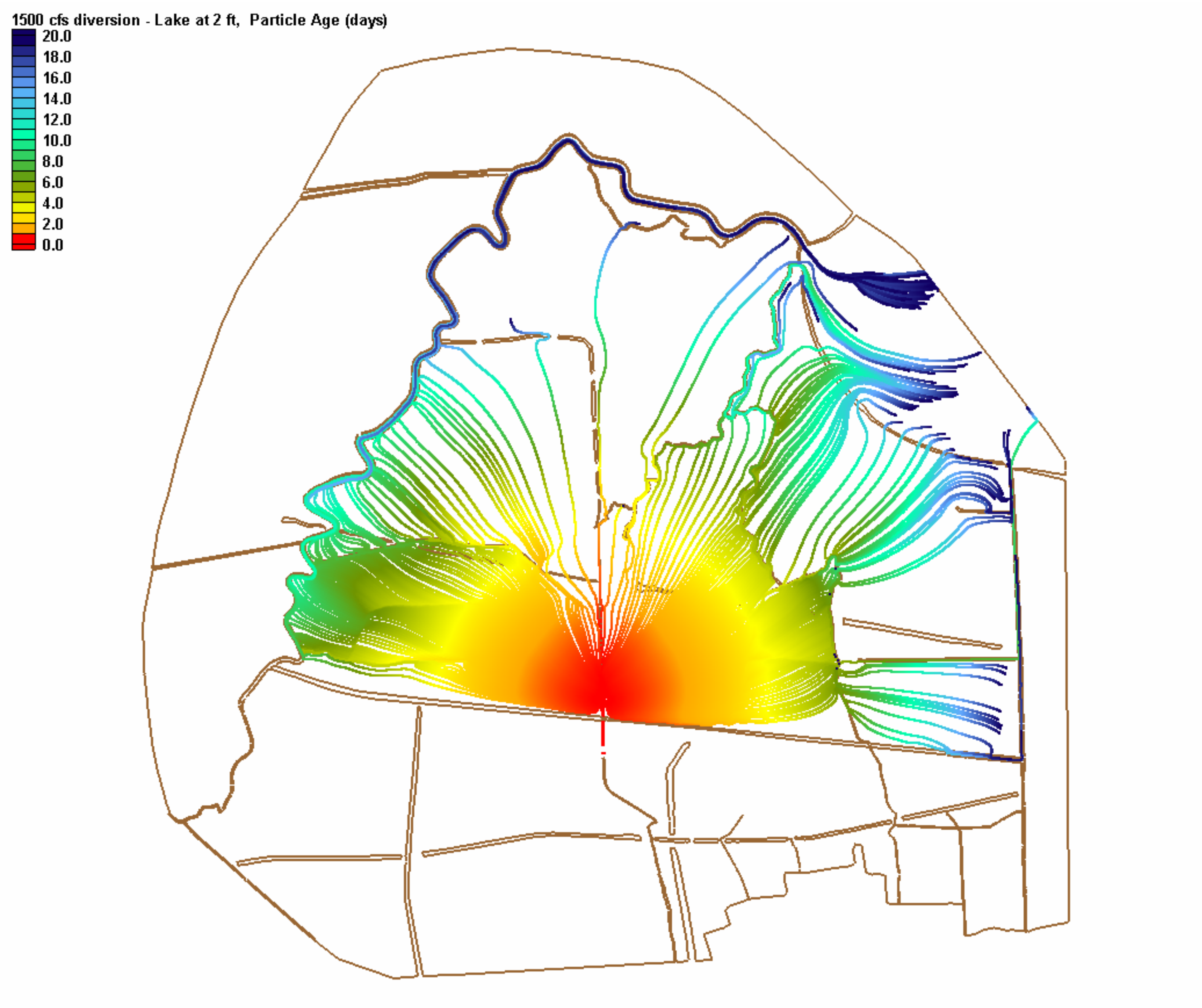
URS



a) Lake at 0.5 ft

Figure 17. Steady-State Streamlines, Alternative Lake WSEs

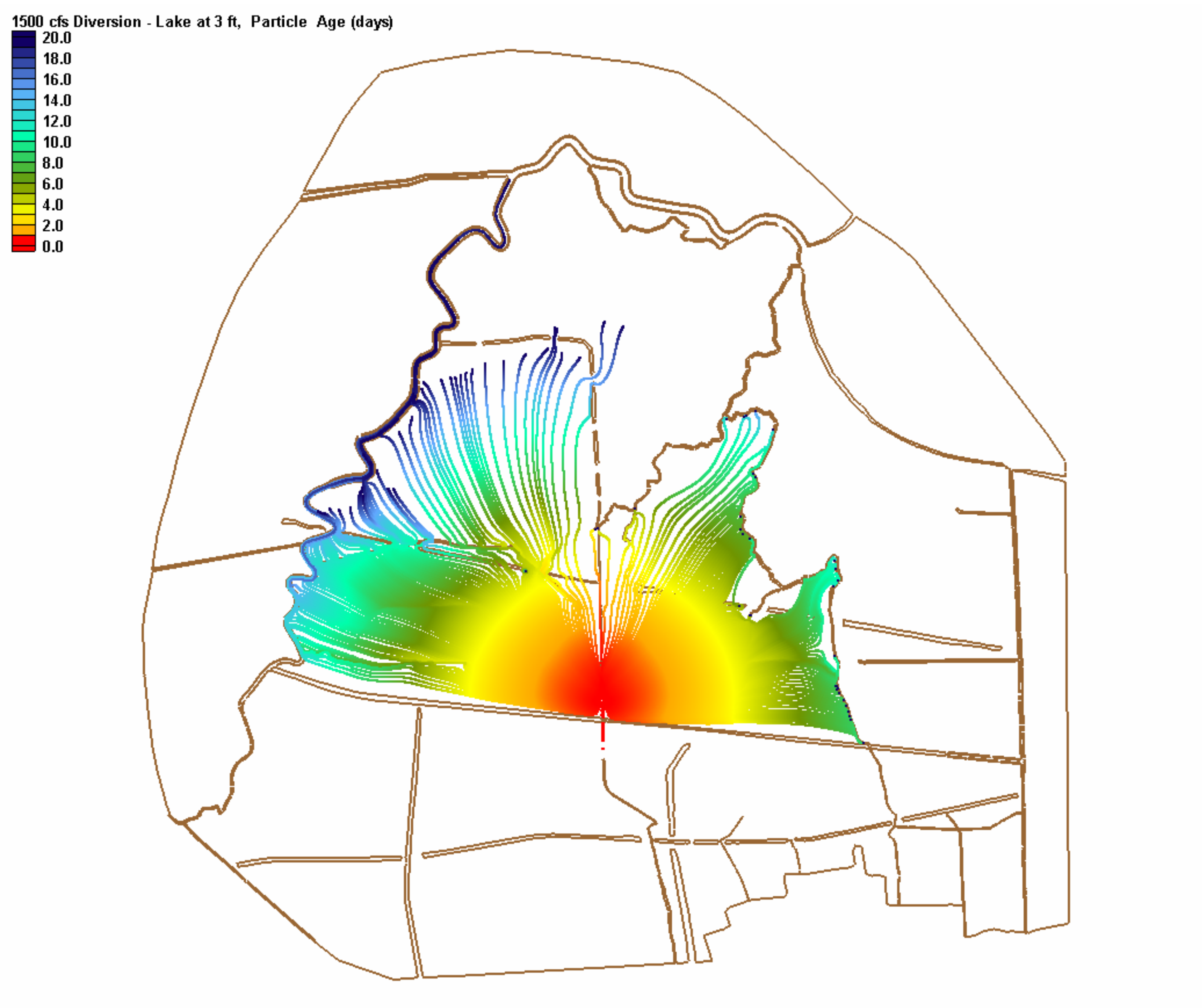
URS



b) Lake at 2.0 ft

Figure 17. Steady-State Streamlines, Alternative Lake WSEs

URS



c) Lake at 3.0 ft

Figure 17. Steady-State Streamlines, Alternative Lake WSEs

URS

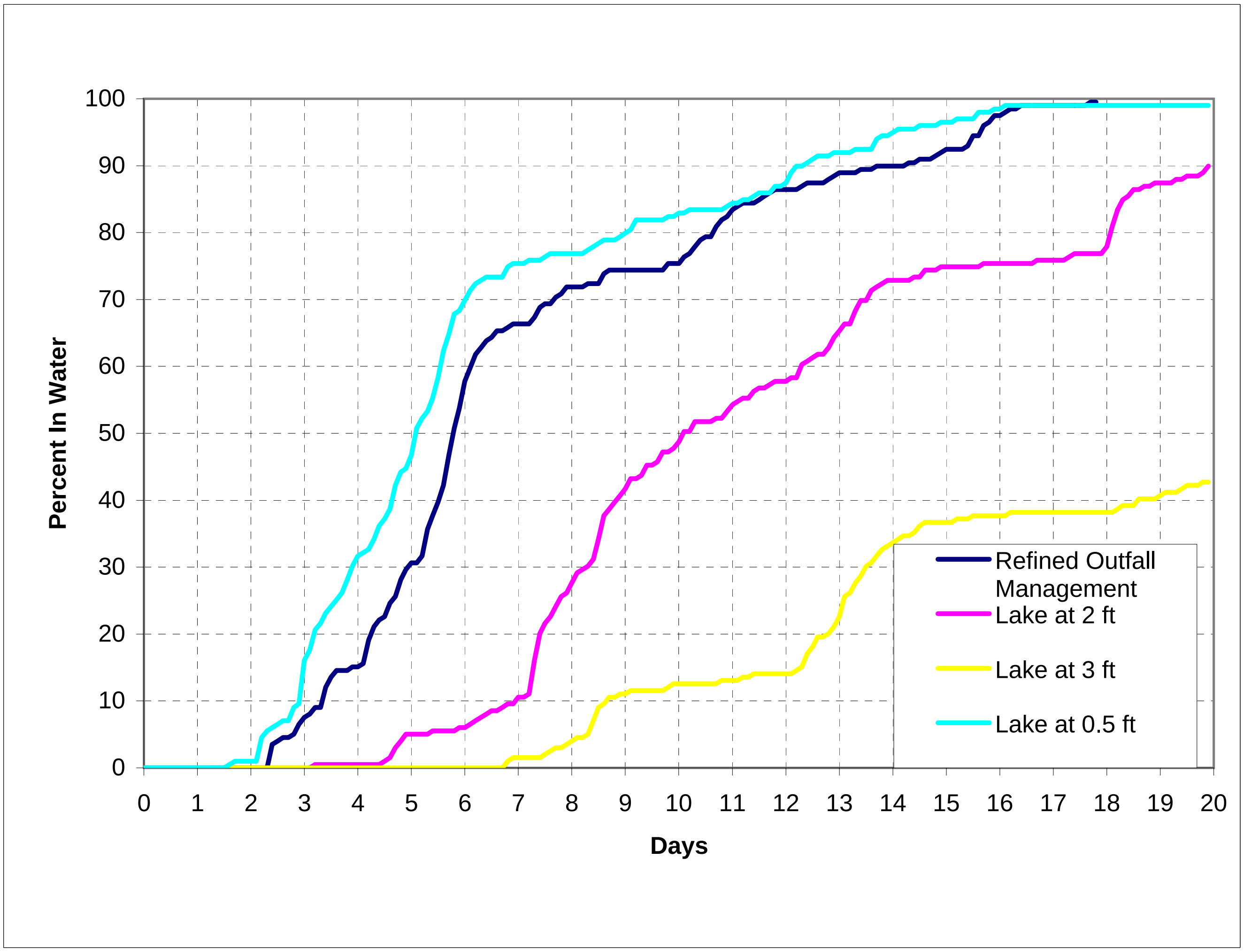
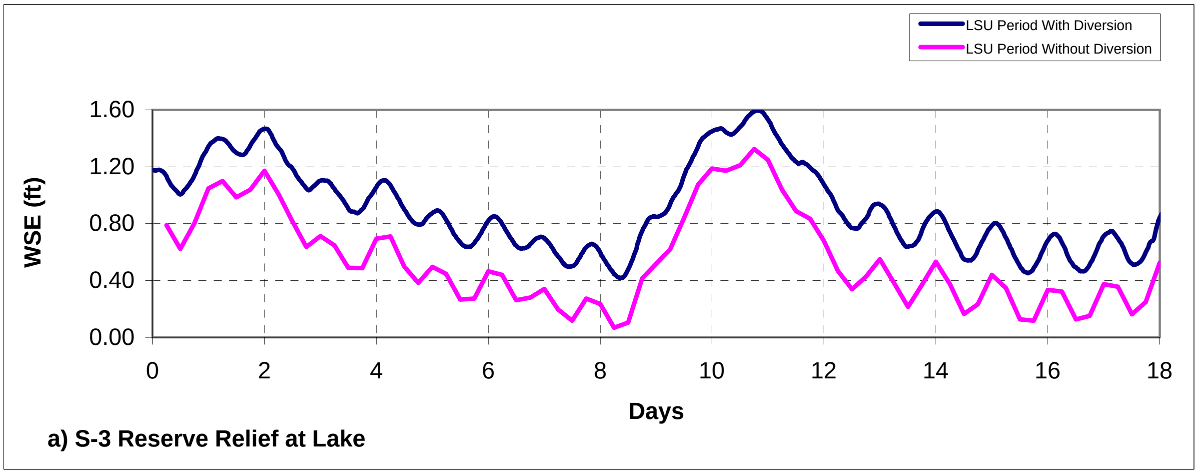
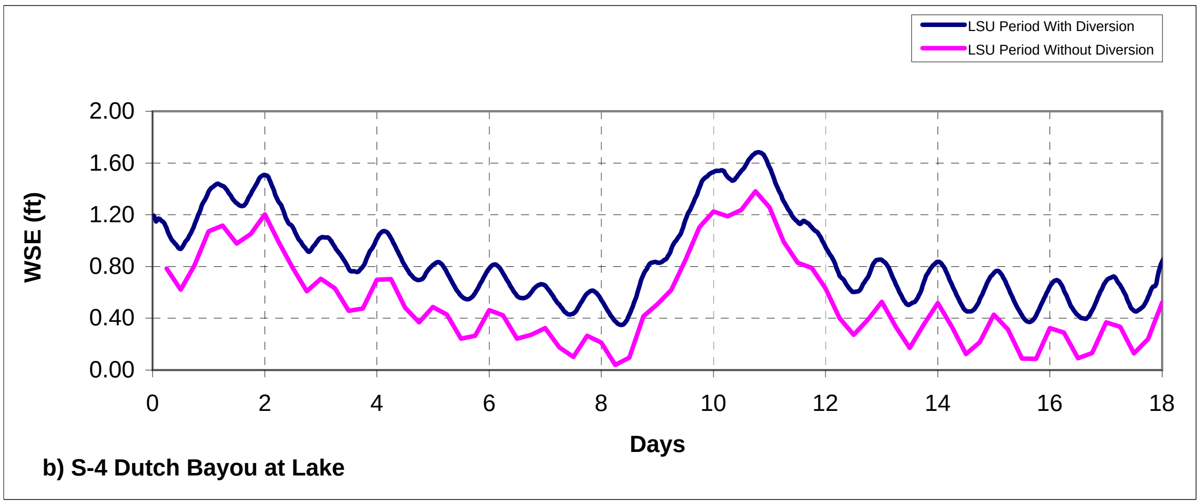


Figure 18. Steady State Flow Retention Time, Altenative Lake WSEs





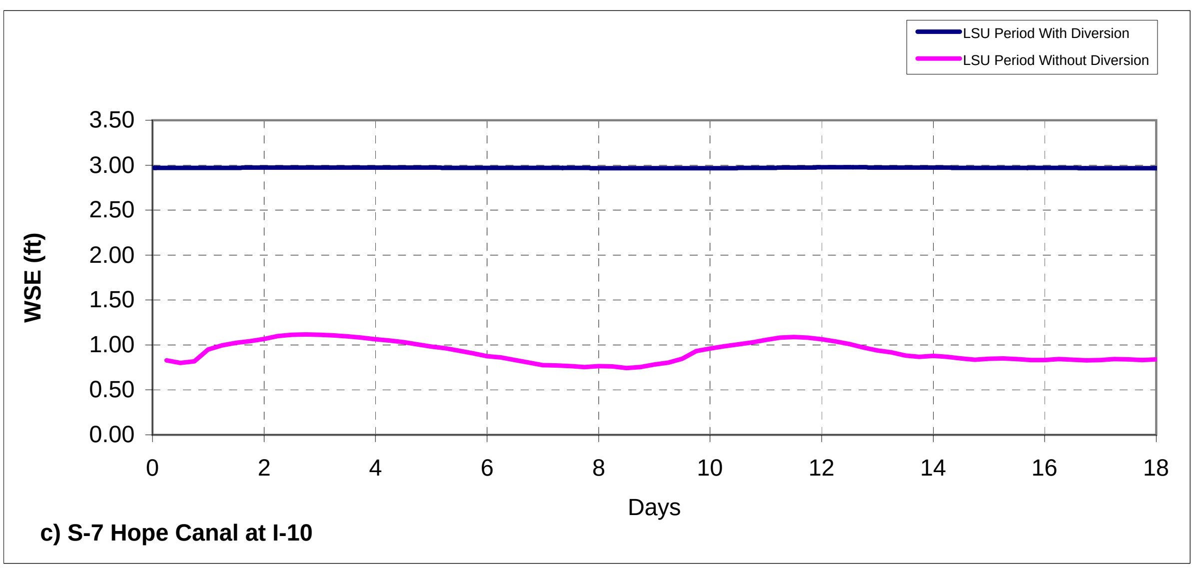
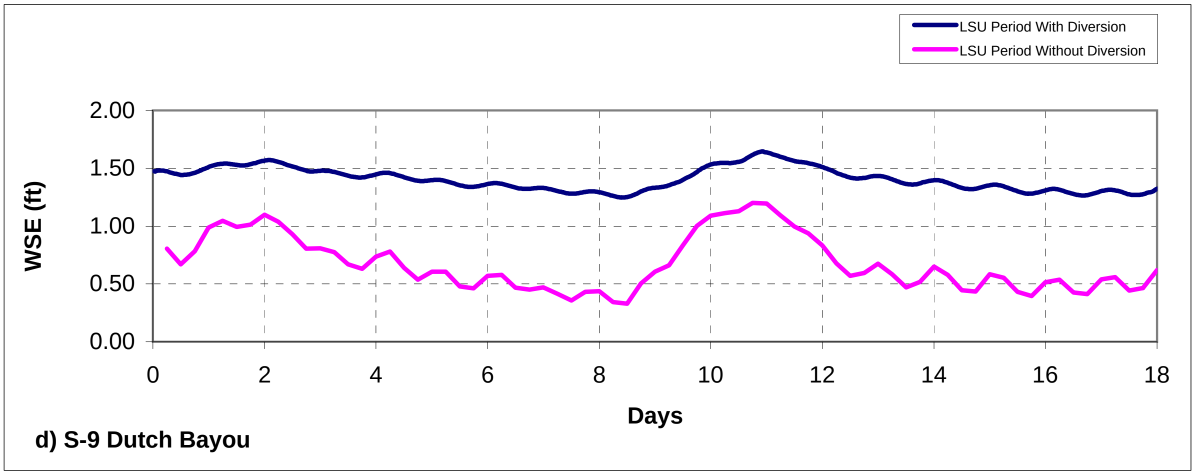
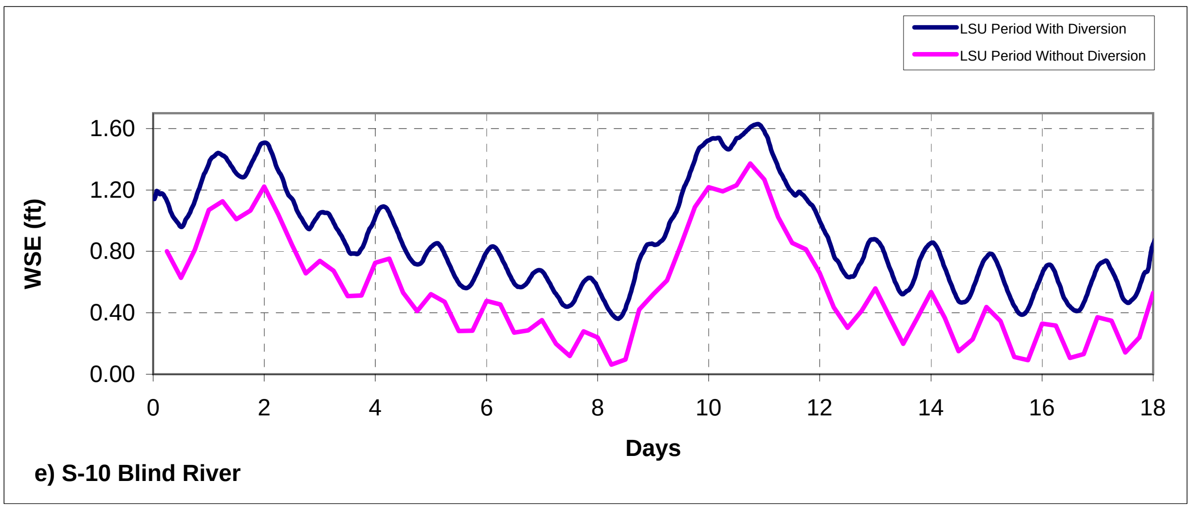


Figure 19. Stage Hydrographs, LSU Period, Without versus With Diversion (a - c)





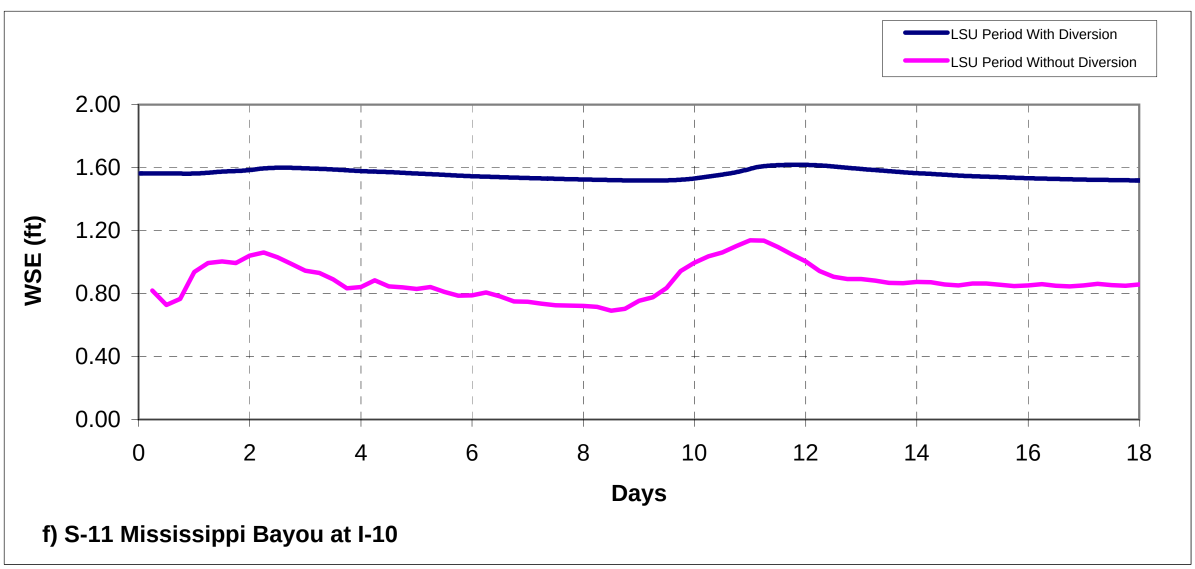
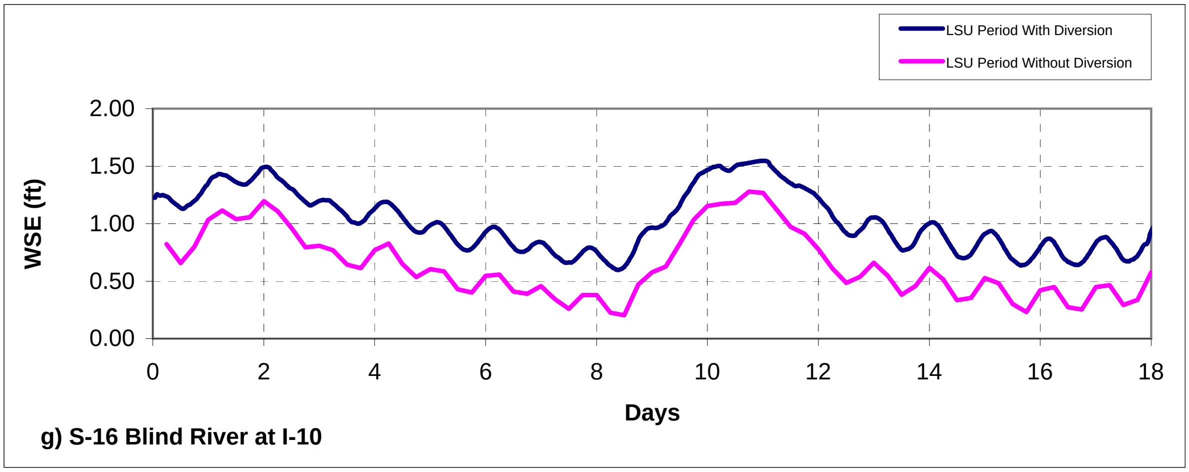
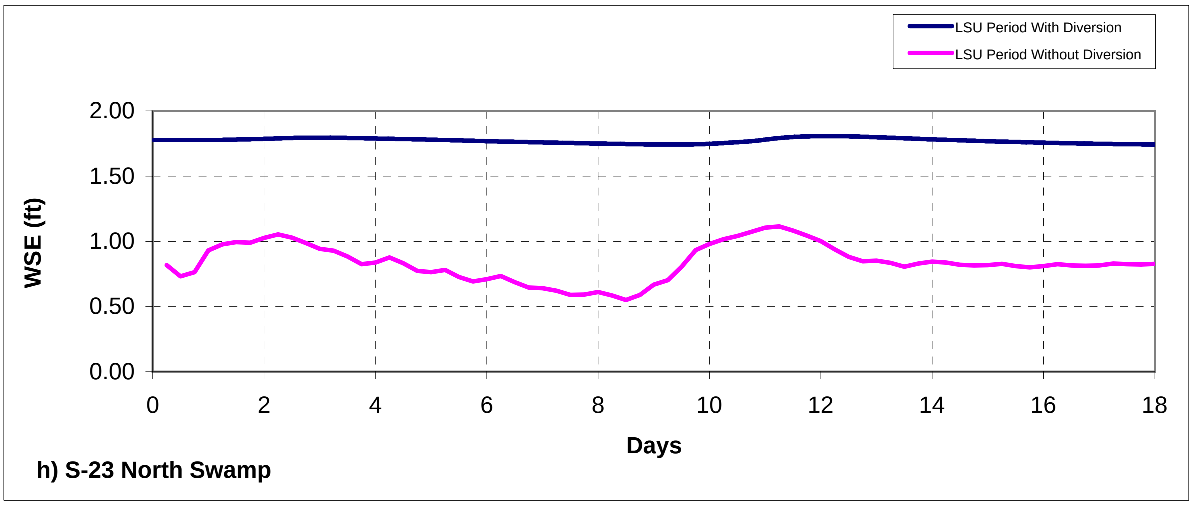


Figure 19. Stage Hydrographs, LSU Period, Without versus With Diversion (d - f)

URS





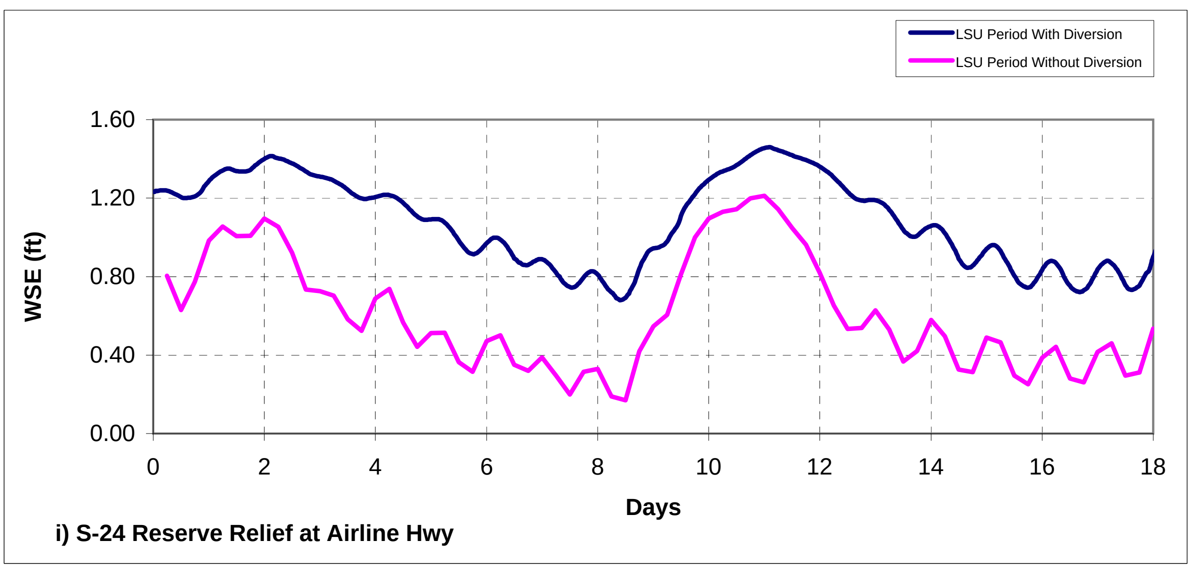


Figure 19. Stage Hydrographs, LSU Period, Without versus With Diversion (g - i)

URS

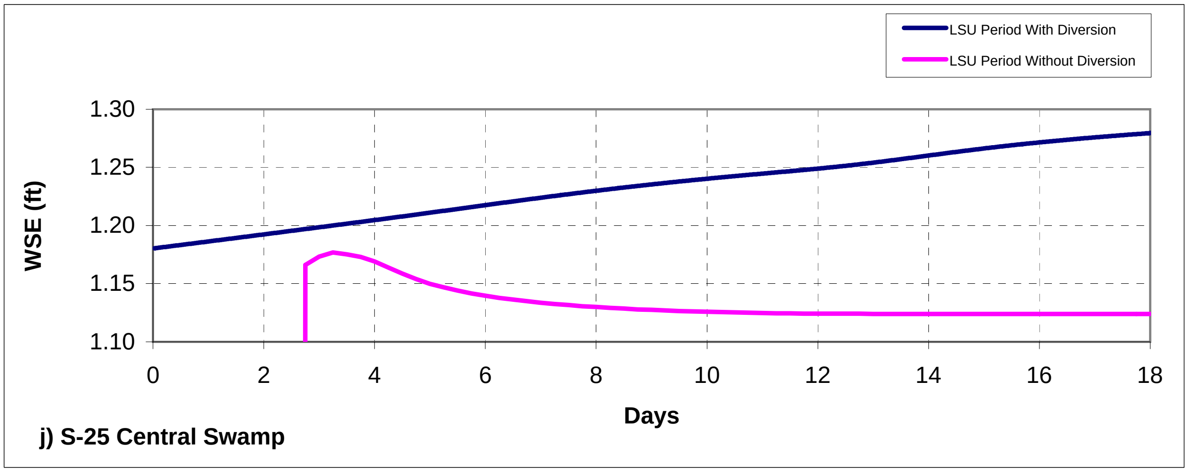


Figure 19. Stage Hydrographs, LSU Period, Without versus With Diversion (j)

URS

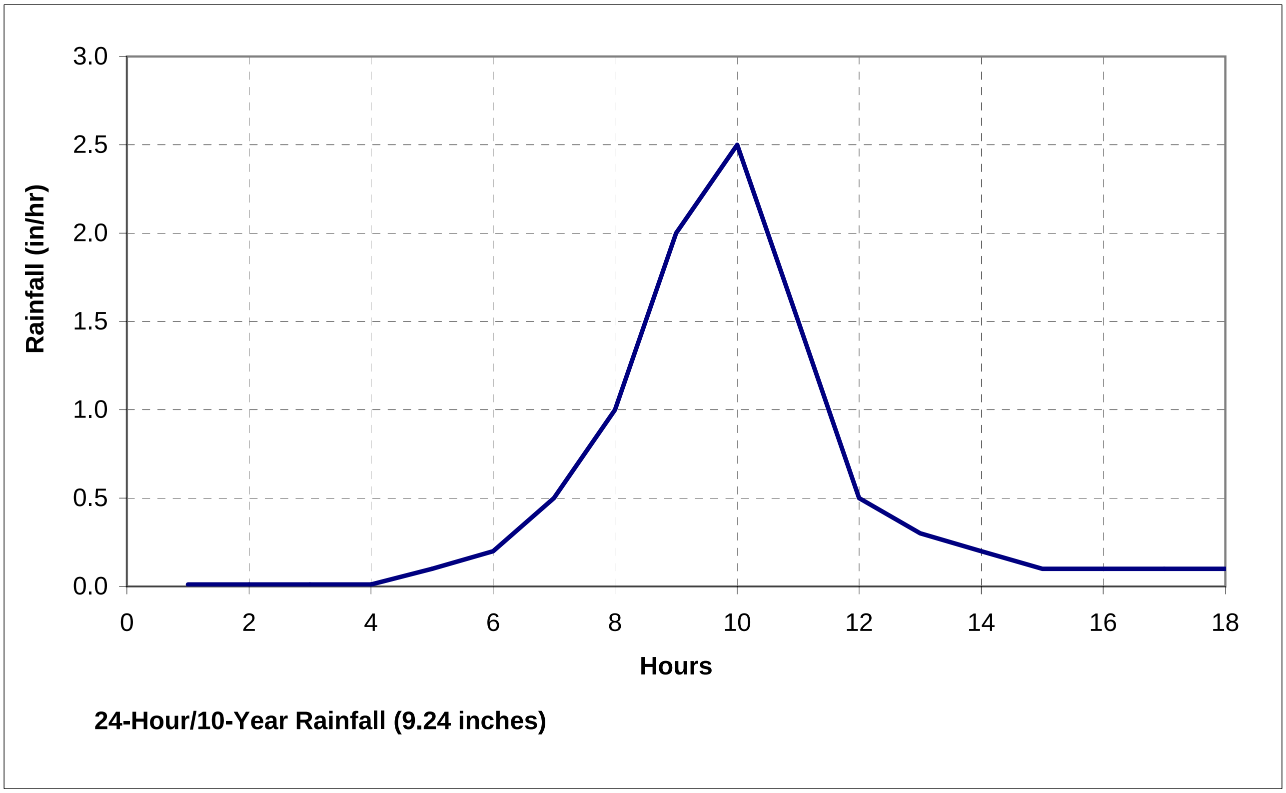


Figure 20. 24-Hour/10-Year Return Frequency Rainfall Event Hyetograph

URS

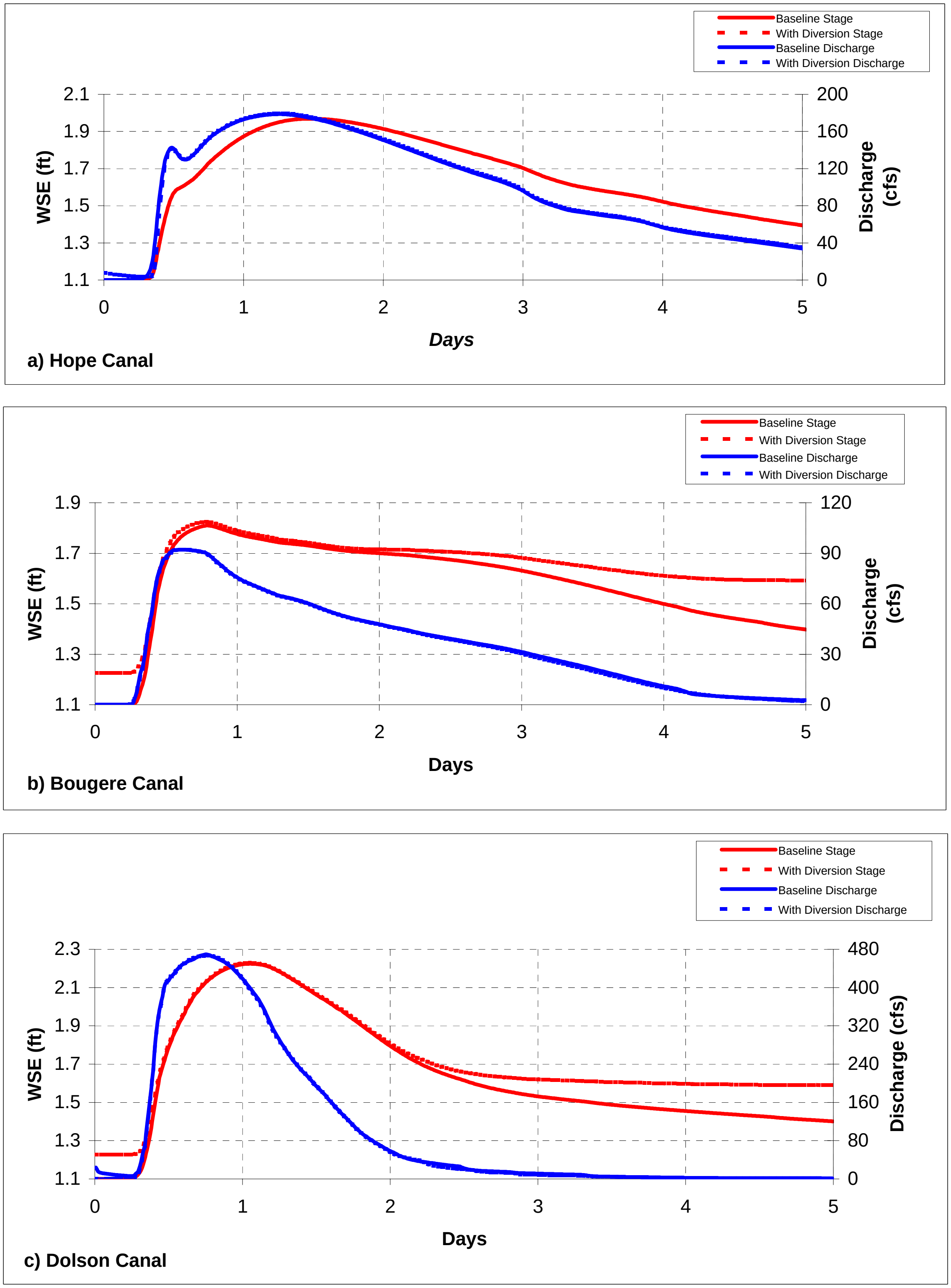


Figure 21. Stage and Discharge Hydrographs, 24-Hour/10-Year Return Frequency Rainfall Event, With and Without Diversion (a - c)

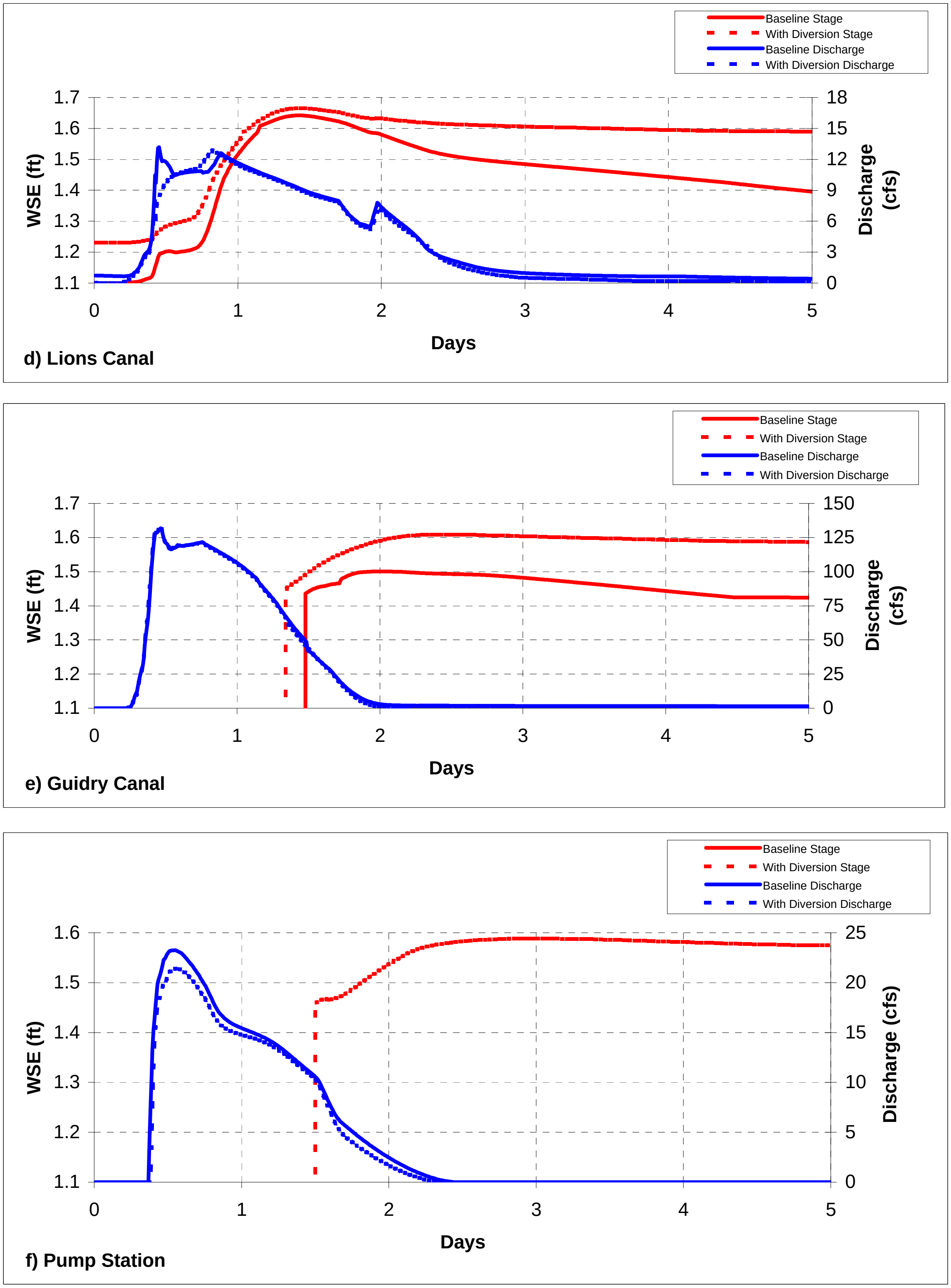
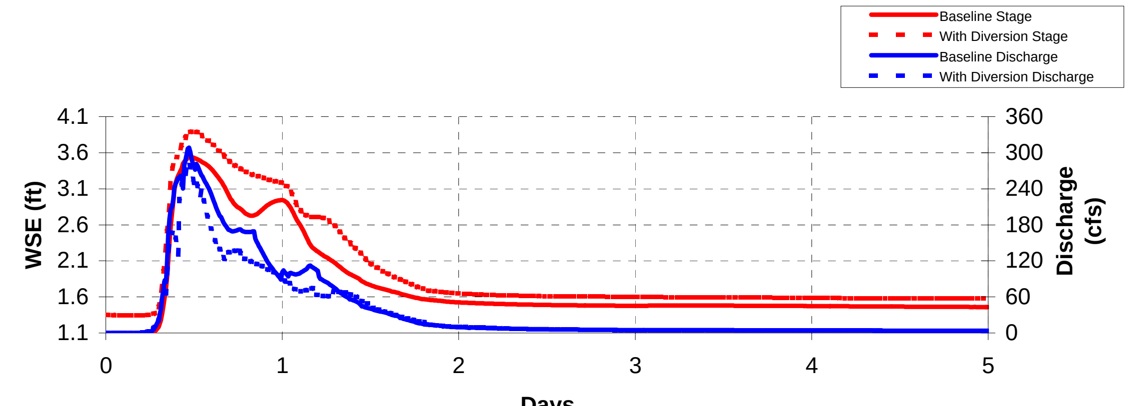
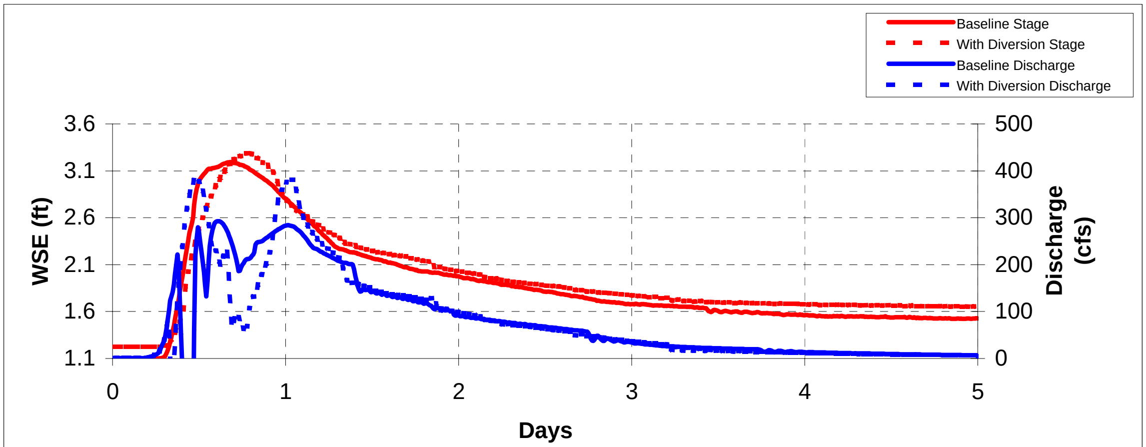


Figure 21. Stage and Discharge Hydrographs, 24-Hour/10-Year Return Frequency Rainfall Event, With and Without Diversion (d - f)



g) Godchaux Canal



h) Reserve Relief Canal

Figure 21. Stage and Discharge Hydrographs, 24-Hour/10-Year Return Frequency Rainfall Event, With and Without Diversion (g - h)

URS

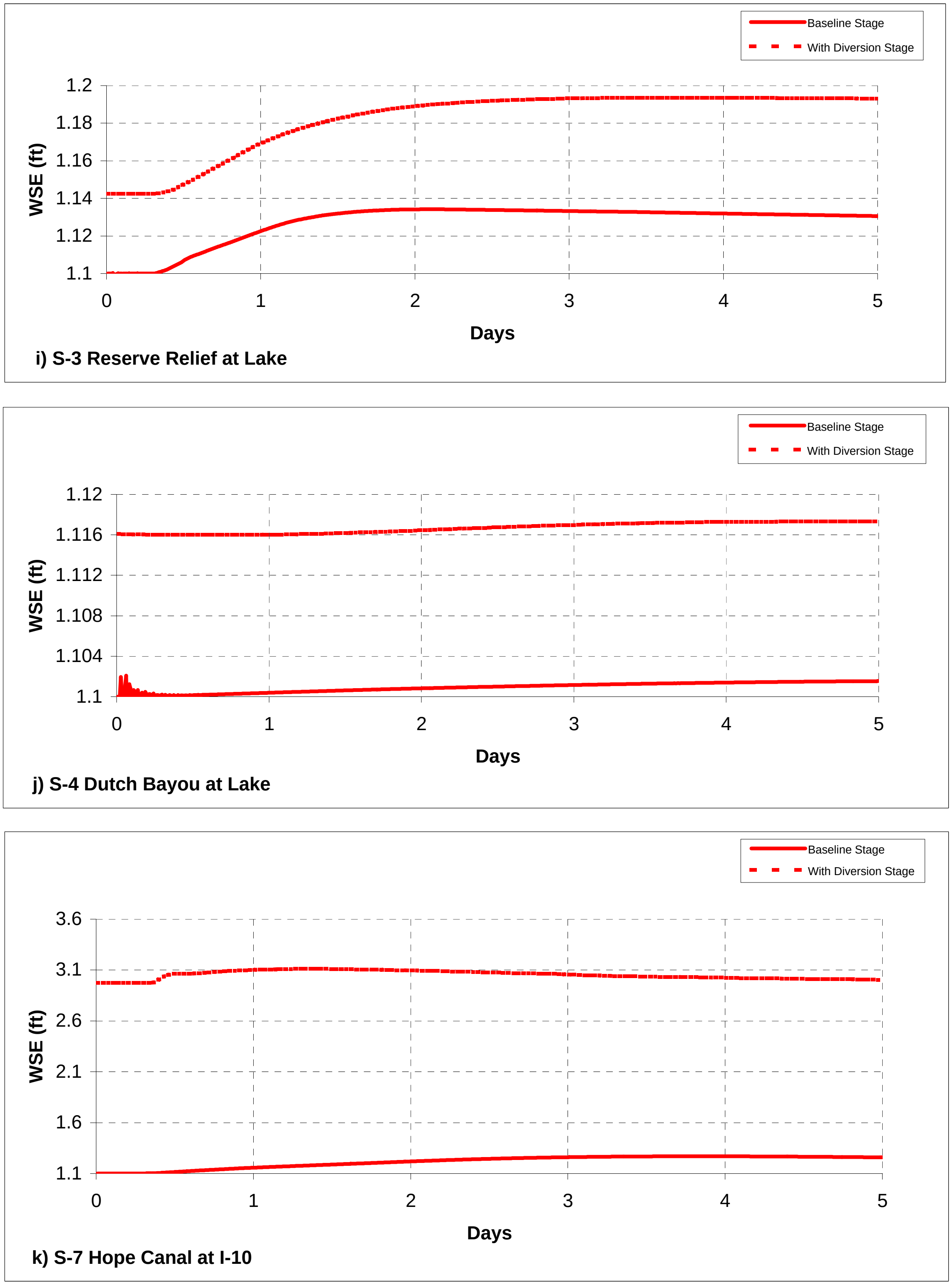
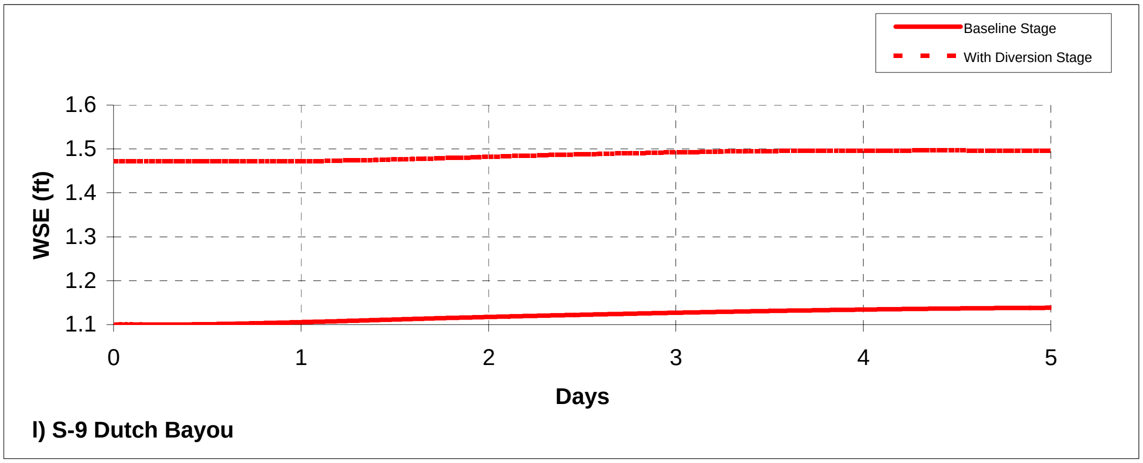
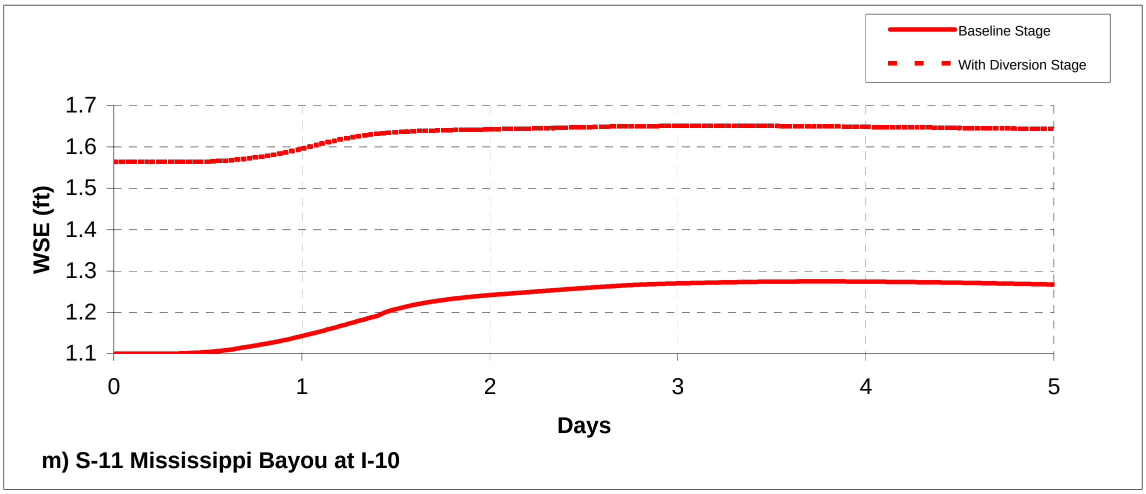


Figure 21. Stage and Discharge Hydrographs, 24-Hour/10-Year Return Frequency Rainfall Event, With and Without Diversion (i - k)





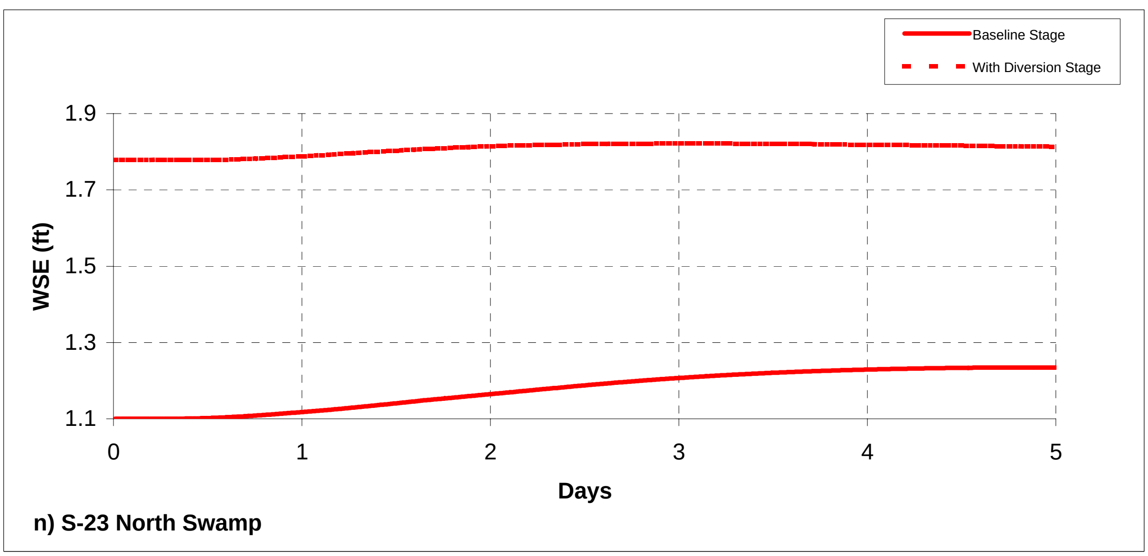


Figure 21. Stage and Discharge Hydrographs, 24-Hour/10-Year Return Frequency Rainfall Event, With and Without Diversion (l - n)

URS

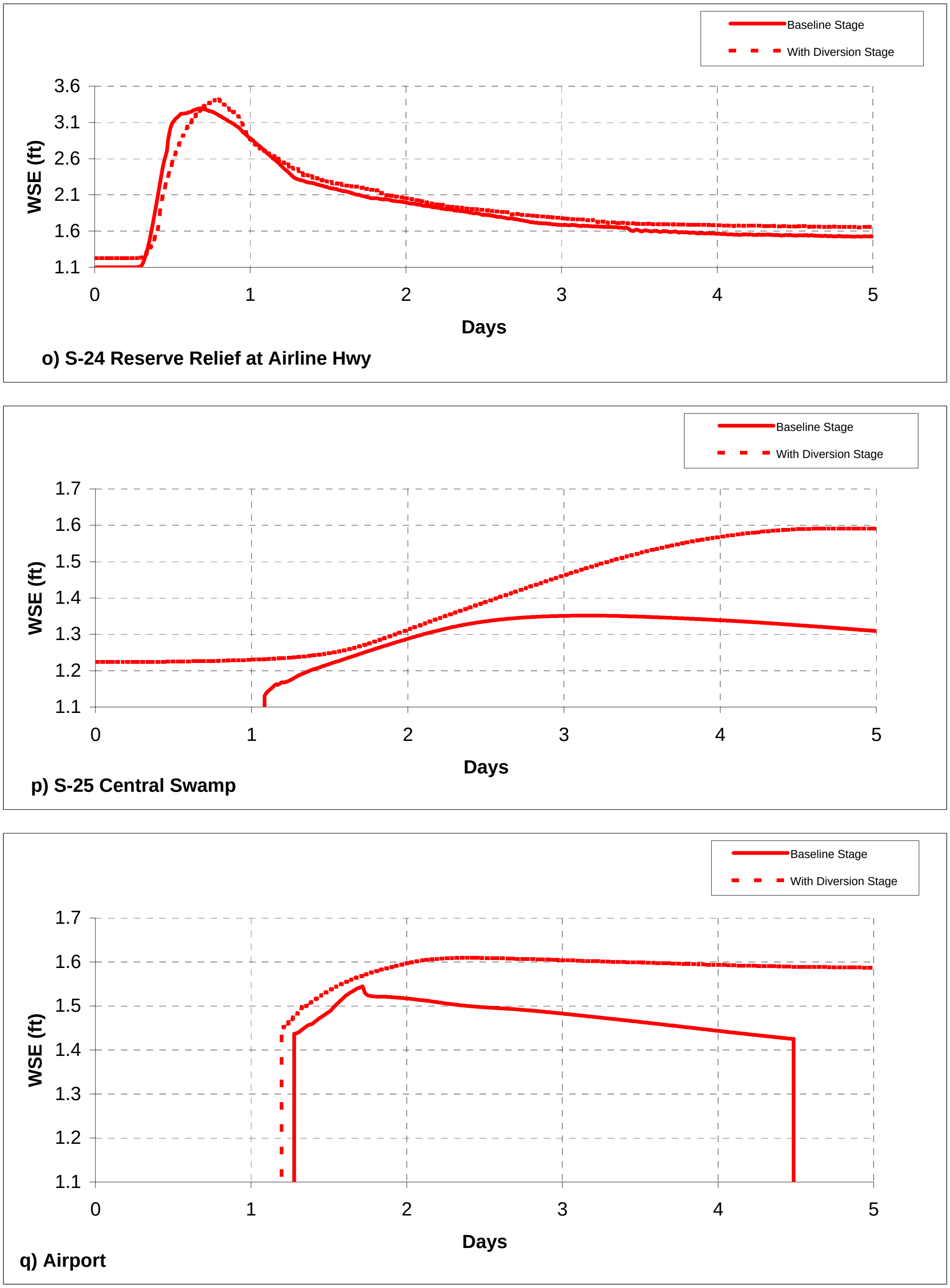
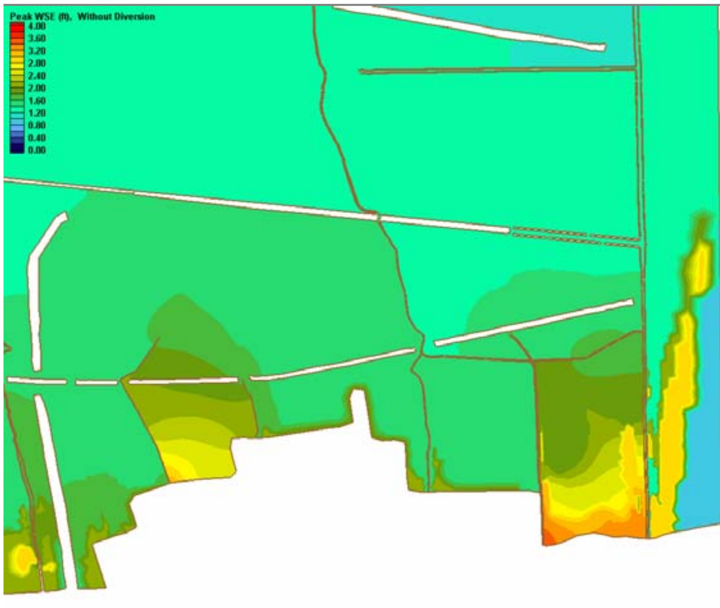
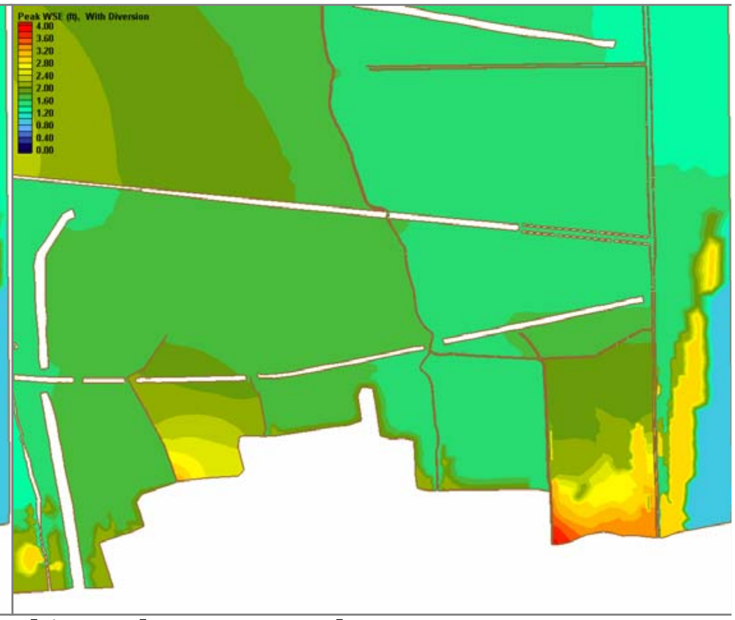


Figure 21. Stage and Discharge Hydrographs, 24-Hour/10-Year Return Frequency Rainfall Event, With and Without Diversion (o - q)

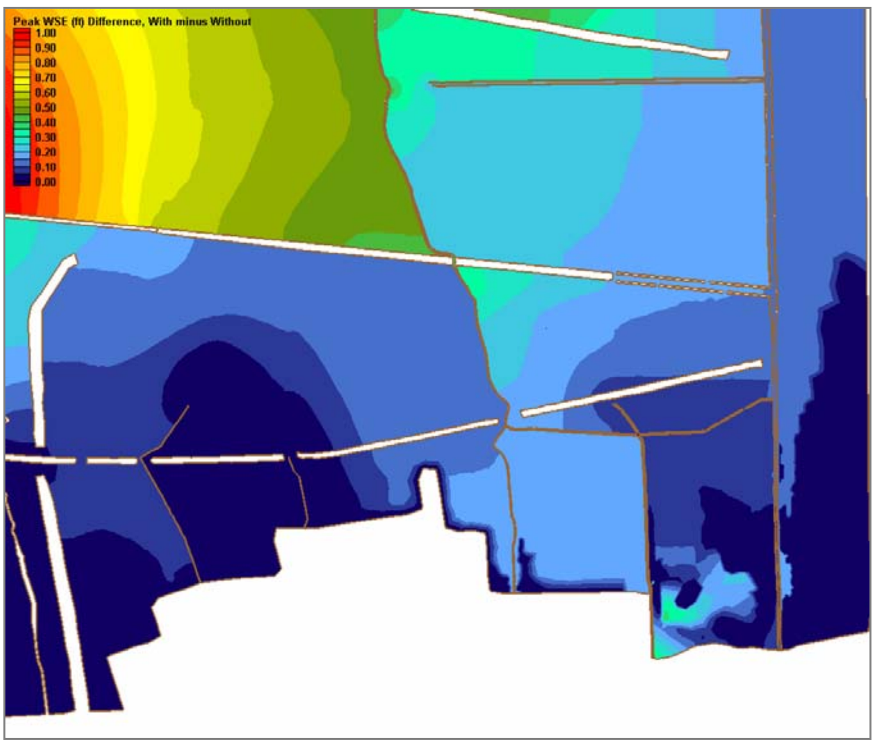
URS



a) Peak WSE Without Diversion



b) Peak WSE With Diversion



c) Peak WSE Difference, With Minus Without

Figure 22. Peak Central Swamp WSE,
24-Hour/10-Year Return Frequency Rainfall Event,
Comparison of Without- Versus With- Diversion (a-c)

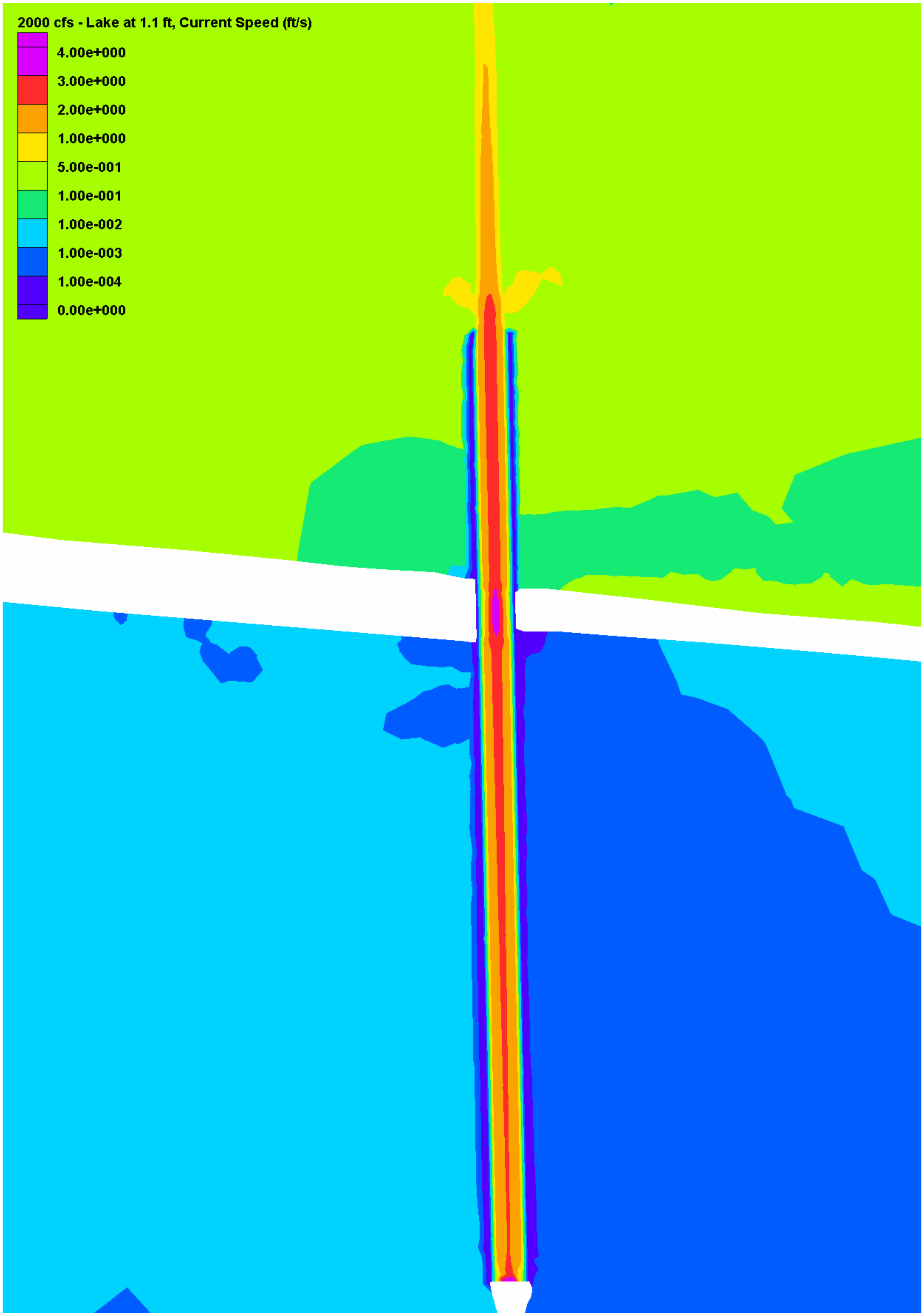


Figure 23. Maximum Velocity Distribution,
Hope Canal at Interstate 10

APPENDIX A

PARTICLE TRACKING CODE

APPENDIX A

Particle Tracking Code

PURPOSE

In order to properly analyze the fully developed steady-state diversion results generated by the 2D ADCIRC model throughout the Maurepas Swamp, URS required techniques for visualizing the flow pattern and estimating retention time. Both of these requirements, in turn, necessitated the development of a particle tracking code to calculate the position and time of massless fluid "particles" as they move through the model domain. Particles are initially placed across the diversion channel at equal increments of discharge (rather than equal increments of distance), producing particle trajectories that represent boundaries of stream-tubes containing equal fractions of the total diversion flow. The streamlines generated in this manner thus depict the overall distribution of the diversion flow. Also the time of travel along particle paths allows estimation the Median Swamp Retention Time (MSRT).

Initially a version of the commercial particle tracking code DROG3DDT, adapted for use with ADCIRC input and output files, was examined as a candidate for computing the particle tracks. DROG3DDT and its associated mesh pre-processing code CONNECT2D, proved unable to track particles over the numerous weir boundaries within the ADCIRC Maurepas Swamp model mesh. Therefore, a new simpler code was developed to track the particles through a steady-state flow field and over weir boundaries when necessary.

The URS particle tracking code includes a pair of scripts written in the Scilab language. The first script is essentially a mesh pre-processor which builds an element-to-element (e2e) table relating each element to its three neighboring elements and a node-to-element (n2e) table relating each node to the elements that share it. In addition to building these tables this script also creates a "weirless mesh" to allow tracking particles over weirs. New "pseudo" elements are created in the "empty" space between ADCIRC node-strings representing weirs. These "pseudo" elements effectively allow particles to be located and tracked as they move across ADCIRC weirs. The "weirless mesh" and the e2e and n2e tables are all written out as files. Once the script has been run for a particular mesh it is not necessary to do it again.

The second script uses the ADCIRC velocity output file (fort.64 depth-averaged x and y velocity at all nodes in the model grid field) for the near-steady-state condition (i.e., the final time step) in combination with the files generated by the first script to perform the actual tracking. The second script requires an input file specifying

- The tracking time-step,
- Duration of the tracking simulation,
- The number of particles, and
- Particle starting positions.

The second script moves each particle in a series of time-steps as function of its position and the interpolated velocity at that point. [The particle tracking time-step is totally independent of the ADCIRC time-step and is modified depending on tracking accuracy and processing time considerations.] The second script provides an output of each particle's particles' position at each tracking time-step.

The Scilab software is required for execution of the code. Scilab is a free open-source scientific and engineering software for numerical computations originally developed by the French Institut National De Recherche En Informatique Et En Autmatique(INRIA) in cooperation with the French Engineering school Ecole Nationale Des Ponts et Chaussees(ENPC), and now maintained by the Scilab Consortium. It is quite similar to the more popular software Matlab, but it is free and open source.

CODE DESCRIPTION

A Particle tracking code for use on an unstructured 2D triangular mesh must address three main issues:

1. A particle must be initially located within a particular mesh element and subsequently relocated in neighboring elements as it moves through the mesh.

2. The velocity at the particle's position must be interpolated from the known velocities at the three nodes of the element in which the particle is located.

3. The particle's displacement must be found by integrating the velocity over a discrete particle time-step.

Particle Location:

The location of a particle refers to the element in which the particle resides, this is in contrast to the position of a particle which is it's precise (x, y) coordinates. To test if a particle is located within a particular element, as shown in Figure B-1, three counterclockwise cross products of the displacement vectors from the particle's position to the nodes of the element are calculated. If they are all positive, then the particle lies within the element. A particle is initially located by looping over all the elements and calculating the cross products until it is found. This process is extremely time consuming for large meshes and/or a large number of particles. Fortunately, once a particle's initial elemental location is known a much smaller group of elements can be searched when the particle moves to a neighboring element.

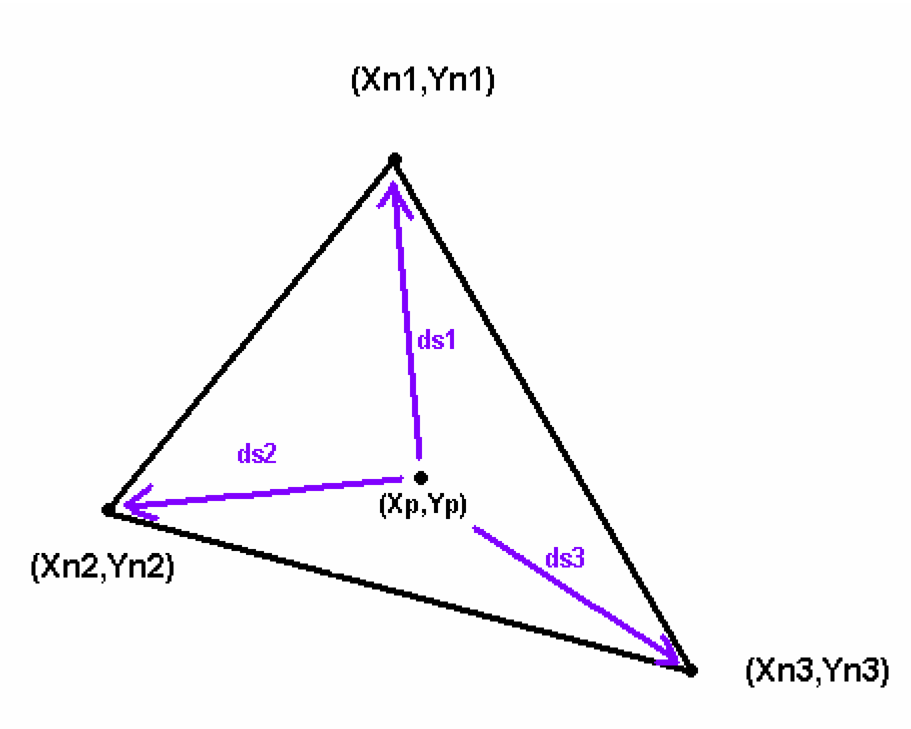


Figure B-1. Particle Element Vectors

Figure B-2 demonstrates how the element-to-element e2e) and node-to-element (n2e) tables are referred to when tracking a particle from one element to the next. Particle e2e displacements may be found by referring to the element-to-element table. An n2e displacement may be found by referring to the node-to-element table. An out of bounds particle may be brought back to boundary. Finally, a lost particle causes the script to crash and requires a reduction in time-step. (Particles should typically not travel more than halfway across an element in a single time-step.)

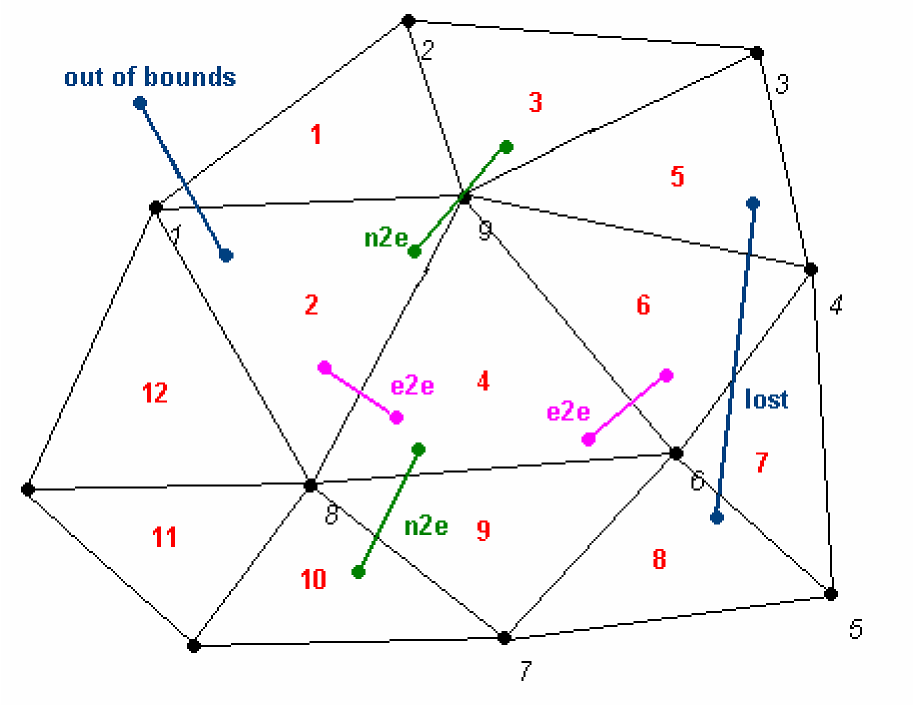


Figure B-2, Example Particle Displacements

Velocity Interpolation:

Once the elemental location of a particle is known, the velocity is found by linear interpolation between the three nodes of the element. Each component of velocity is found separately as the elevation on a plane at point (xp,yp) intersecting the three points (xn1,yn1,un1), (xn2,yn2,un2), (xn3,yn3,un3) defined by the element and velocity field. For example, the x component of velocity at point p, is found by:

$$u_p = \frac{-1 \times (Ax_p + By_p + D)}{C} \qquad \text{(B-1)}$$

$$A = y_{n1}(u_{n2} - u_{n3}) + y_{n2}(u_{n3} - u_{n1}) + y_{n3}(u_{n1} - u_{n2}) \qquad \text{(B-1.1)}$$

$$B = u_{n1}(x_{n2} - x_{n3}) + u_{n2}(x_{n3} - x_{n1}) + u_{n3}(x_{n1} - x_{n2}) \qquad \text{(B-1.2)}$$

$$C = x_{n1}(y_{n2} - y_{n3}) + x_{n2}(y_{n3} - y_{n1}) + x_{n3}(y_{n1} - y_{n2}) \qquad \text{(B-1.3)}$$

$$D = -Ax_{n1} - By_{n1} - Cu_{n1} \qquad \text{(B-1.4)}$$

Here, x, y are Cartesian coordinates; u is the x component of velocity. The subscripts n1, n2, n3 denotes the nodes of the element and p the particle.

Particle Displacement:

The ADCIRC Maurepas Swamp model generates a fully-developed, near-steady-state 2D (depth-averaged) velocity field. Particle trajectories through this field are estimated by numerically solving the equation for the particle position, $\vec{r}$, as a function of time, *t*, The position change for each time step is a function of the velocity vector field, $\vec{q}$:

$$\frac{d\vec{r}}{dt} = \vec{q} \qquad \text{(B-2)}$$

Equation B-2 is integrated in the simplest way using the method the Forward Euler Method. Considering that the velocity field does not depend on time, a particle's new position at time t is found from:

$$\vec{r}_t = \vec{r}_{t-\Delta t} + \vec{q}(\vec{r}_{t-\Delta t})\Delta t \qquad \text{(B-3)}$$

The particle tracking model writes out the position of each particle at each time during a simulation which is later plotted to visualize streamlines and analyzed to calculate MSRT.

ERROR ANALYSIS

Forward Euler integration can produce significant error when the gradient of the velocity field is large. The error can be reduced by reducing the tracking step size. Alternatively, higher order methods of numerical integration can be used to improve results, but they require more displacement and velocity interpolation calculations, and therefore more processing time. Figure B-3 shows a comparison particle tracks generated using both the Forward Euler method and the 2nd order Runge-Kutta method (RK2), also known as the midpoint method.

In the RK2 method an initial guess is made at the particle's new position using a Forward Euler step, then the velocity is interpolated at the midpoint of that step, and a second and final step is made using the original position and the new velocity.

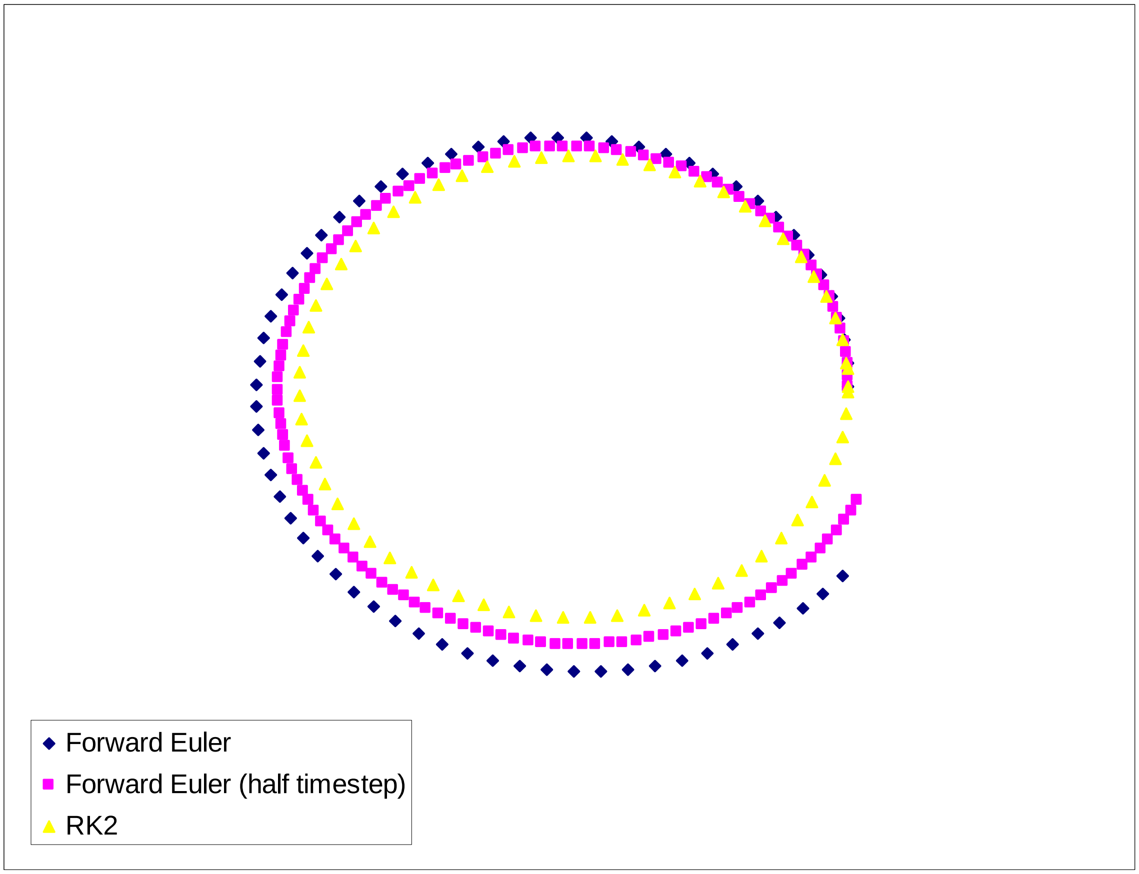


Figure B-3 Comparison of Particle Tracks Using the Forward Euler and RK2 Methods. (R/ds = 10)

For example the x component of a particle's new position is calculated by:

$$x_t = x_{t-\Delta t} + k_2 \qquad \text{(B-4)}$$

$$k_1 = u\left(\vec{r}_{t-\Delta t}, t - \Delta t\right)\Delta t \qquad \text{(B-4.1)}$$

$$k_2 = u\left(\frac{k_1}{2}, t - \frac{\Delta t}{2}\right)\Delta t \qquad \text{(B-4.2)}$$

The velocity field used in Figure B-3 is an irrotational vortex with circular streamlines, and the particle was initially placed so that the ratio of the radius of curvature of the field, R, to the step size, ds, was 10:1. The particles were tracked just long enough to allow them to travel a distance equal to one circumference. For a given time step, RK2 requires twice as many displacement calculations and velocity interpolations as the Forward Euler method. Therefore the RK2 track and the Forward Euler track with half the time-step, take roughly the same CPU time. Clearly, when the velocity field is significantly curved, i.e. R/ds is small, the RK2 method gives much more accurate results. However, as Figure B-4 shows, the error in position for a particle step decreases as the radius of curvature of the velocity field increases.

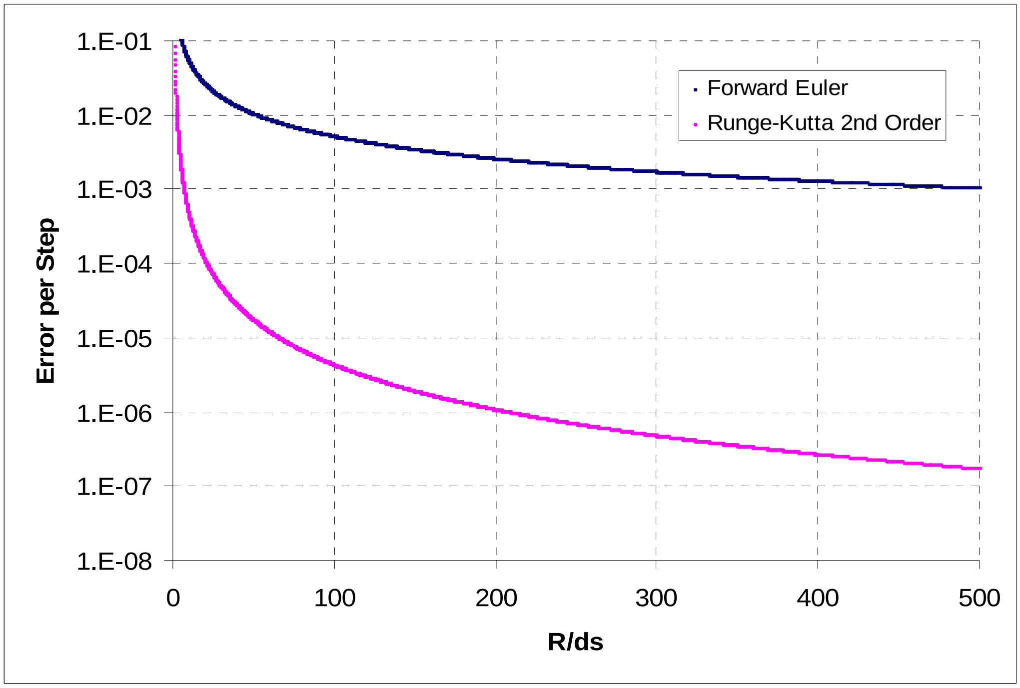
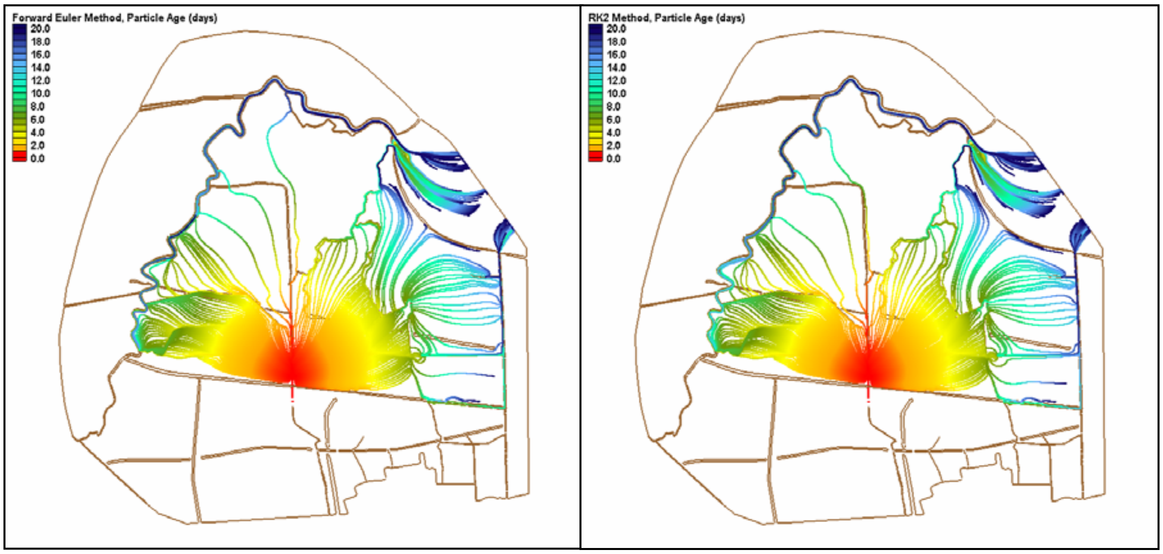


Figure B-4 Error Versus Non-Dimensional Radius of Curvature for a Forward Euler versus RK2 on an Irrotational Vortex.

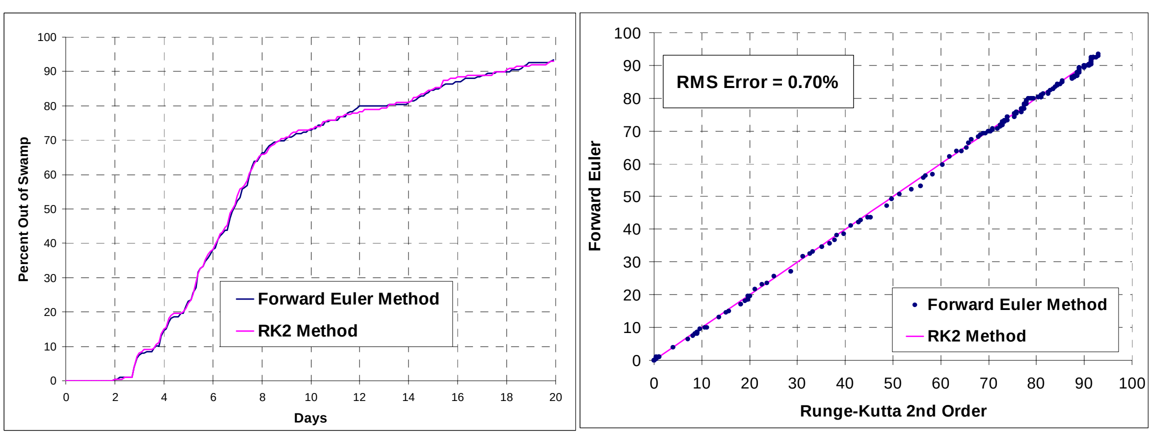
When the R/ds is greater than 500, the error will be less than 0.1% of the step length even for the Forward Euler method. Thus, assuming minimal change in step length from one step to the next, for relatively straight velocity fields, Forward Euler integration may give acceptable results in less time than RK2. For simulations requiring the tracking of a large number of particles over long durations, the required CPU time can become a limiting factor and the use of higher order methods may not be practical.

In order to better quantify the error resulting from the use of the Forward Euler Method particle tracking for the 2D ADCIRC Maurepas swamp model. An additional particle tracking simulation of the 1000cfs Alternative Diversion Discharge case was done using the RK2 method. Both the Forward Euler simulation and the RK2 simulation were done with 199 particles over a 20 day period using a 5 second timestep. While there are a few individual particle tracks that are significantly different, the overall flow distribution shown in Figure B-5 is similar in both cases. The difference in MSRT, Figure B-6a, was less than 0.1 days. And the RMS difference between the values for "percent of particles out of swamp" was only about 0.7%. Thus the Forward Euler Method based particle tracking simulations appear to be acceptable for visualizing flow patterns and calculating MSRT for the 2D Maurepas Swamp ADCDIRC model.



a) Forward Euler Method b) RK2 method

Figure B-5. Comparison of Forward Euler and RK2 Method Generated Steady-State Streamlines



a) Forward Euler vs RK2 MSRT b) Forward Euler vs RK2

Figure B-6. Comparison of Forward Euler and RK2 Method MSRT

Particle Tracking Code

```
////////////////////////////////////////////////////////////////////////
////
//  by: Nathan Dill,
//  URS corp.
//  July 13, 2006
//
//  This is PART 1 of the maureparticle particle tracking script
//
//  part 1 reads a fort.14 file and will write a file newfort.14 with
//  space between weir boundaries converted to elements.  It then makes a node to element
//  connection table and an element neighbor table. and saves them as files
//  node2el.txt and el2el.txt
//
//  you need to have the fort.14 file in SCILAB's current directory. and
//  the files will be written to the same directory, or just use the chdir command below
//  then Copy and past this entire test file into the SCILAB command line.
//////////////////////////////////////////////////////////////////////////////////////

//chdir('path to directory where fort.14 file is');

stacksize(10000000)
format('v',18);

//read nodes
fd=mopen('fort.14','r');
fd2=mopen('newfort.14','w');
[n,s1,s2]=mfscanf(1,fd,'%s %s');   // see how many words are on first line of fort.14
mfprintf(fd2,'%s %s\n',[s1 s2]);   // you may need to read more strings

[n,ne,nn]=mfscanf(1,fd,'%f %f');
[n,nid,x,y,z]=mfscanf(nn,fd,'%i%f%f%f');

//read elements
[n,eid,three,N1,N2,N3]=mfscanf(ne,fd,'%i%i%i%i%i');
elements=[];
elements=[N1, N2, N3];

//read open boundries
[n,nopen,j1,j2,j3,j4,j5]=mfscanf(1,fd,'%i%s%s%s%s%s');   //read strings for " = number of open boundaries"
[n,nopenn,j1,j2,j3,j4,j5,j6,j7]=mfscanf(1,fd,'%i%s%s%s%s%s%s%s');

for i=1:nopen
[n,nobn,j1,j2,j3,j4,j5,j6,j7,lb]=mfscanf(1,fd,'%i%s%s%s%s%s%s%s%i');
[n,nobid]=mfscanf(nobn,fd,'%i');
end

//  read land boundaries        create new elements from weirs

[n,nland,j1,j2,j3,j4,j5]=mfscanf(1,fd,'%i%s%s%s%s%s');
[n,nlandn,j1,j2,j3,j4,j5,j6,j7]=mfscanf(1,fd,'%i%s%s%s%s%s%s%s');
```

```
for q=1:nland
[n,nnp,typ]=mfscanf(1,fd,'%i%i');

   if typ==24 | typ==4
   [n,s1,s2,s3,s4,s5,s6,s7,s8,s9,s10]=mfscanf(1,fd,'%s%s%s%s%s%s%s%s%s%s');
   [n,N1,N2,elev,Wc1,Wc2]=mfscanf(nnp,fd,'%i%i%f%f%f');

   //create elements from nodestring pairs

         z1=z(N1);  z2=z(N2);
         x1=x(N1);  x2=x(N2);
         y1=y(N1);  y2=y(N2);

         ds1=[(x1(2)-x1(1)),(y1(2)-y1(1))];      //determine which way is counter clockwise
         ds2=[(x2(1)-x1(1)),(y2(1)-y1(1))];

         cross=ds1(1)*ds2(2)-ds1(2)*ds2(1);

         if cross>0        // N2 is on N1's left
            EE=[];
            ee=[];
            for i=1:nnp-1
               ee=[N1(i) N1(i+1) N2(i); N2(i) N1(i+1) N2(i+1)];
               EE=[EE;ee];
            end
         else              //  N2 on right
            EE=[];
            ee=[];
            for i=1:nnp-1
               ee=[N2(i) N2(i+1) N1(i); N1(i) N2(i+1) N1(i+1)];
               EE=[EE;ee];
            end
         end
  elements=[elements;EE];

   elseif typ==3 | typ==13 | typ==23
   [n,j1,j2,j3,j4,j5,j6,j7,i1]=mfscanf(1,fd,'%s%s%s%s%s%s%s%s');
   [n,NID1,elev,Wc1]=mfscanf(nnp,fd,'%i%f%f');

   else
   [n,j1,j2,j3,j4,j5,j6,j7,i1]=mfscanf(1,fd,'%s%s%s%s%s%s%s%s');
   [n,NID1]=mfscanf(nnp,fd,'%i');
   end
end
mclose(fd);

ne=length(elements(:,1));

mfprintf(fd2,'%i %i\n',[ne nn]);
```

```
mfprintf(fd2,'%i %18.10f %18.10f %12.10f\n',nid,x,y,z);

eid=[1:ne]';
three=zeros(ne,1);
three(:,:)=3;
mfprintf(fd2,'%i %i %i %i %i\n',[eid three elements]);
mclose(fd2);

/// make node to element table

fd4=mopen('node2el.txt','w');
  node2el=zeros(nn,12);
  for i=1:nn
    k=find(elements(:,1)==i | elements(:,2)==i | elements(:,3)==i);
    node2el(i,1:length(k))=k;
    mfprintf(fd4,'%i %i %i %i %i %i %i %i %i %i %i %i\n',node2el(i,:));
  end
  mclose(fd4);

////// use find command to make element to element table !this may take some time!

  fd3=mopen('el2el.txt','w');
  el2el=zeros(ne,3);
  for i=1:ne
     kk=[];
     for j=1:3
       k=find(elements(i,j)==elements(:,1));
       kk=[kk k];
       k=find(elements(i,j)==elements(:,2));
       kk=[kk k];
       k=find(elements(i,j)==elements(:,3));
       kk=[kk k];
     end
     q=find(kk==i);
     kk(q)=[];

     w=[];
     for m=1:length(kk)
       n=find(kk==kk(m));
       if length(n)==1
          w=[w n];
       end
       if length(n)==2
          w=[w n(1)];
       end
     end
     kk(w)=[];
     el2el(i,1:length(kk))=kk;
     mfprintf(fd3,'%i %i %i\n',el2el(i,:));
  end
  mclose(fd3)
```

```
////////////////////////////////////////////////////////////////////
//////
////
//  by: Nathan Dill,
//  URS corp.
//  July 13, 2006
//
//  This is PART 2 of the Maureparticle particle tracking script
//
//  It tracks particles through an assumed steady-state velocity field
//  which is read from a specific time in the fort.64 file. the velocity
//  is linearly interpolated between the three nodes of the element which
//  contains the particle.
//
//  PART 2 reads the files generated by PART I (newfort.14, node2el.txt, el2el.txt)
//  and also reads the fort.64 file and a file containing the starting positions
//  of the particles called particles.inp .  It outputs files:  position.out
//  and scatter.xyz .  position.out contains the x,y location and the element ID location
//  of each particle at each timestep.  scatter.xyz has the time for its z value and
//  is handy for looking at the tracks in SMS
//
//  you need to have a file "particles.inp" which describes the timestep,
//  and the starting locations of the particles. like this:
//  the timestep(ts) must be exactly equal to a time(seconds) at which there
//  a global velocity output in the fort.64 file.  particles will be tracked
//  assuming this velocity field is steady.  tts is the tracking time step,
//  totaltime is the duration of the tracking.  all times in seconds.  locat is the
//  element id location of the particle.  if this is unknown initially use zero.  If you
//  do know the element id location, perhaps from the positon.out of a previous run,
//  it will save some time to put the values in locat (especially if you've got lots of particles)
//
//  particles.inp:

//  ts 0 0
//  n 0 0
//  tts totaltime 0
//  Xi Yi locat(i)
//  '  '  '
//  '  '  '
//  Xn Yn locat(n)
/////////////////////////////////////////////////////////

// fixed bug in find in el2el 8/10/06. was only looking in first element
// of in el2el table then going on to search node2el if not foung
// in first element.  this caused particle to think they were
// lost in come cases when they weren't

// read in results from part 1
stacksize(100000000);

format('v',18);
```

```
//read nodes
fd=mopen('newfort.14','r');
[n,s1,s2]=mfscanf(1,fd,'%s %s');

[n,ne,nn]=mfscanf(1,fd,'%f %f');

[n,nid,x,y,z]=mfscanf(nn,fd,'%i%f%f%f');

// read elements
[n,eid,three,N1,N2,N3]=mfscanf(ne,fd,'%i%i%i%i%i');
mclose(fd);

// read el2el table
fd1=mopen('el2el.txt','r');
[n,E1,E2,E3]=mfscanf(ne,fd1,'%i%i%i');
el2el=[E1,E2,E3];
clear E1 E2 E3;
mclose(fd1);

// read node2el table
fd2=mopen('node2el.txt','r');
[n,e1,e2,e3,e4,e5,e6,e7,e8,e9,e10,e11,e12]=mfscanf(nn,fd2,'%i%i%i%i%i%i%i%i%i%i%i%i');
node2el=[e1,e2,e3,e4,e5,e6,e7,e8,e9,e10,e11,e12];
clear e1 e2 e3 e4 e5 e6 e7 e8 e9 e10 e11 e12;
mclose(fd2);

// read particle input
fd3=mopen('particles.inp','r');
[n,TS,j1,j2]=mfscanf(1,fd3,'%i%i%i');          // this is the timestep(seconds) for steady veloity field
[n,numpart,j1,j2]=mfscanf(1,fd3,'%i%i%i');     // number of particles to track
[n,tts,tot,j1]=mfscanf(1,fd3,'%f%f%i');        // time step for tracking and total tracking time(seconds)
[gg]=read('particles.inp',numpart+3,3);
gg(1:3,:)=[];
px=gg(:,1);
py=gg(:,2);
locat=gg(:,3);

//[px,py,locat]=fscanf('particles.inp','%14f %14f %i');
//[n,px,py,locat]=mfscanf(numpart,fd3,'%14f %14f %i');      // starting x,y coordinates for particles
mclose(fd3);

// find starting element for particles
if locat(1)==0
disp 'locating particles'
for i=1:numpart

  for j=1:ne               // clculate cross product to find what element particle is in
  locat(i)=j;
  ds1=[x(N1(j))-px(i) y(N1(j))-py(i)];
  ds2=[x(N2(j))-px(i) y(N2(j))-py(i)];
```

```
   ds3=[x(N3(j))-px(i) y(N3(j))-py(i)];

   cros1=det([ds1; ds2]);
   cros2=det([ds2; ds3]);
   cros3=det([ds3; ds1]);
      if cros1>=0 & cros2>=0 & cros3>=0
      break
      end
   end
end
end

// begin writing output
out=mopen('position.out','w');
time=0;
mfprintf(out,'%i\n',time);
mfprintf(out,'%f %f %i\n',px,py,locat);

// read velocity field

fd4=mopen('fort.64','r');
[n,s1,s2,s3,s4,s5,s6]=mfscanf(1,fd4,'%s%s%s%s%s%s');
clear s1 s2 s3 s4 s5 s6
[n,nts,j2,j3,j4,j5]=mfscanf(1,fd4,'%f%f%f%f%f');
clear j2 j3 j4 j5

for i=1:nts
[n,secs,j1]=mfscanf(1,fd4,'%f%f');
[n,NID,vx,vy]=mfscanf(nn,fd4,'%i%f%f');
clear NID
  if secs==TS
  break
  end
end
mclose(fd4);

///////////////////
////////////////////////
/////////////////////////////////// loop to track particles

stp=tot/tts;
for iii=1:stp

//  linear interpolate particle velicity from elements nodal velocities
vxp=[];
vyp=[];
for i=1:numpart

    nod1=N1(locat(i));
    nod2=N2(locat(i));
    nod3=N3(locat(i));
```

```
    // x-velocity
    AA=y(nod1)*(vx(nod2)-vx(nod3))+y(nod2)*(vx(nod3)-vx(nod1))+y(nod3)*(vx(nod1)-vx(nod2));
    BB=vx(nod1)*(x(nod2)-x(nod3))+vx(nod2)*(x(nod3)-x(nod1))+vx(nod3)*(x(nod1)-x(nod2));
    CC=x(nod1)*(y(nod2)-y(nod3))+x(nod2)*(y(nod3)-y(nod1))+x(nod3)*(y(nod1)-y(nod2));
    DD=-AA*x(nod1)-BB*y(nod1)-CC*vx(nod1);
    vxp(i)=-1*(AA*px(i)+BB*py(i)+DD)/CC;

    // y-velocity
    AA=y(nod1)*(vy(nod2)-vy(nod3))+y(nod2)*(vy(nod3)-vy(nod1))+y(nod3)*(vy(nod1)-vy(nod2));
    BB=vy(nod1)*(x(nod2)-x(nod3))+vy(nod2)*(x(nod3)-x(nod1))+vy(nod3)*(x(nod1)-x(nod2));
    CC=x(nod1)*(y(nod2)-y(nod3))+x(nod2)*(y(nod3)-y(nod1))+x(nod3)*(y(nod1)-y(nod2));
    DD=-AA*x(nod1)-BB*y(nod1)-CC*vy(nod1);
    vyp(i)=-1*(AA*px(i)+BB*py(i)+DD)/CC;
end

//  find new positions

px=px+tts*vxp;
py=py+tts*vyp;
time=time+tts;

//  what elements are they in now?
// check if still in same element

for i=1:numpart

j=locat(i);
ds1=[x(N1(j))-px(i) y(N1(j))-py(i)];
ds2=[x(N2(j))-px(i) y(N2(j))-py(i)];
ds3=[x(N3(j))-px(i) y(N3(j))-py(i)];

cros1=det([ds1; ds2]);
cros2=det([ds2; ds3]);
cros3=det([ds3; ds1]);

   if cros1<=0 | cros2<=0 | cros3<=0

      for q=1:3                              // refer to element to element table to look for particle
      jjj=el2el(j,q);

         if jjj==0
         break
         end

      ds1=[x(N1(jjj))-px(i) y(N1(jjj))-py(i)];
      ds2=[x(N2(jjj))-px(i) y(N2(jjj))-py(i)];
      ds3=[x(N3(jjj))-px(i) y(N3(jjj))-py(i)];

      cros1=det([ds1; ds2]);
      cros2=det([ds2; ds3]);
      cros3=det([ds3; ds1]);
```

```
      if cros1>0 & cros2>0 & cros3>0
      //disp 'found el2el'
      j=jjj;
      locat(i)=j;
      break
      end
    end

    if locat(i)~=jjj                    // find the closest node and refer to node to element table
    j=locat(i);                         // and look in those elements
    ds1=[x(N1(j))-px(i) y(N1(j))-py(i)];
    ds2=[x(N2(j))-px(i) y(N2(j))-py(i)];
    ds3=[x(N3(j))-px(i) y(N3(j))-py(i)];

    mag1=sqrt(ds1(1)^2+ds1(2)^2);
    mag2=sqrt(ds2(1)^2+ds2(2)^2);
    mag3=sqrt(ds3(1)^2+ds3(2)^2);
    mag=[mag1 mag2 mag3];
    corners=[N1(j) N2(j) N3(j)];
    k=find(mag==min(mag));
    closest=corners(k);
    search=node2el(closest,:);
    k=find(search==0);,  search(k)=[];
    k=find(search==j);, search(k)=[];
      for q=1:length(search)

      j=search(q);

      ds1=[x(N1(j))-px(i) y(N1(j))-py(i)];
      ds2=[x(N2(j))-px(i) y(N2(j))-py(i)];
      ds3=[x(N3(j))-px(i) y(N3(j))-py(i)];

      cros1=det([ds1; ds2]);
      cros2=det([ds2; ds3]);
      cros3=det([ds3; ds1]);

        if cros1>0 & cros2>0 & cros3>0
        //disp 'found node2el'
        locat(i)=j;
        break

        end
      end
    end
end

if locat(i)~=j                          // the particle has left the domain, change its position

//disp 'lost particle, move to boundary'     // it may have skipped over a node-element group
j=locat(i);                             // in which case you need to make the timestep smaller
```

```
  ds1=[x(N1(j))-px(i) y(N1(j))-py(i)];       // displacement vectors to nodes of element j
  ds2=[x(N2(j))-px(i) y(N2(j))-py(i)];
  ds3=[x(N3(j))-px(i) y(N3(j))-py(i)];

  mag1=sqrt(ds1(1)^2+ds1(2)^2);
  mag2=sqrt(ds2(1)^2+ds2(2)^2);            // find the nearest node and all elements around it
  mag3=sqrt(ds3(1)^2+ds3(2)^2);
  mag=[mag1 mag2 mag3];
  corners=[N1(j) N2(j) N3(j)];
  k=find(mag==min(mag));
  closest=corners(k);
  search=node2el(closest,:);
  k=find(search==0);,  search(k)=[];

    ell=[search', el2el(search,:)];

    k=find(ell(:,4)==0);                  // this should be the two elements on the boundary
    bel=ell(k,1);
    k=find(bel==j);, bel(k)=[];           // remove element j from k, bel is the next boundary element
      if length(bel)>1
      bel=bel(1);
      end

  cros1=det([ds1; ds2]);                   // where cross is negative nodes are on boundary
  cros2=det([ds2; ds3]);
  cros3=det([ds3; ds1]);

    if cros1*cros2*cros3<=0        // one negtive cross prodcut,  case 1 or case 3
    crosx=[cros1 cros2 cros3];      // bring particle to boundary perpendicular to its position
    k=find(crosx<=0);

      if k==1
      nods=[N1(j) N2(j)];
      elseif k==2
      nods=[N2(j) N3(j)];
      else
      nods=[N3(j) N1(j)];
      end


      if nods==[N2(bel) N1(bel)] | nods==[N3(bel) N2(bel)] | nods==[N1(bel) N3(bel)]    // case 3  use next
element along boundary
      //disp 'case3'
      j=bel;
      locat(i)=j;

      ds1=[x(N1(j))-px(i) y(N1(j))-py(i)];       // displacement vectors to nodes of element j
      ds2=[x(N2(j))-px(i) y(N2(j))-py(i)];
      ds3=[x(N3(j))-px(i) y(N3(j))-py(i)];
```

```
  cros1=det([ds1; ds2]);                    // where cross is negative nodes are on boundary
  cros2=det([ds2; ds3]);
  cros3=det([ds3; ds1]);

    if cros1<0
    xn1=x(N1(j));, yn1=y(N1(j));            // find  coordinates of two nodes on bounary
    xn2=x(N2(j));, yn2=y(N2(j));
    elseif cros2<0
    xn1=x(N2(j));, yn1=y(N2(j));
    xn2=x(N3(j));, yn2=y(N3(j));
    else
    xn1=x(N3(j));, yn1=y(N3(j));
    xn2=x(N1(j));, yn2=y(N1(j));
    end

  slope=(yn2-yn1)/(xn2-xn1);                // calculate new position on boundary
  newx=(slope*(py(i)-yn1+slope*xn1)+px(i))/(slope^2+1);
  newy=py(i)-(newx-px(i))/slope;
  px(i)=newx;, py(i)=newy;

  else                                      // case 1  use nodes of orignnal element
     //disp 'case1'                         // and bring to boundary perpendicular to current position
    if cros1<0
    xn1=x(N1(j));, yn1=y(N1(j));            // find  coordinates of two nodes on bounary
    xn2=x(N2(j));, yn2=y(N2(j));
    elseif cros2<0
    xn1=x(N2(j));, yn1=y(N2(j));
    xn2=x(N3(j));, yn2=y(N3(j));
    else
    xn1=x(N3(j));, yn1=y(N3(j));
    xn2=x(N1(j));, yn2=y(N1(j));
    end


  thetas=atan((yn2-yn1),(xn2-xn1));
  slope=tan(thetas);
   if slope==0
     slope=0.000000001  ;
   end                             // oops divide by zero is no no
  newx=(slope*(py(i)-yn1+slope*xn1)+px(i))/(slope^2+1);
  newy=py(i)-(newx-px(i))/slope;
  px(i)=newx;, py(i)=newy;

  end

else                               // case 2  two negative cross products
   //   disp 'case2'                         // move to nearest node, and next element along boundary
px(i)=x(closest);
py(i)=y(closest);
locat(i)=bel;
```

```
      end
   end
end

mfprintf(out,'%i\n',time);
mfprintf(out,'%f %f %i\n',px,py,locat);

end              // for iii
mclose(out);
///

////  this makes a scatter point file of the tracks which can be easily examined with SMS

//ffd=mopen('position.out','r');
//ffd2=mopen('scatter.xyz','w');
//for iiii=1:stp
//[n,time]=mfscanf(1,ffd,'%i');
//ttme=zeros(numpart,1);
//ttme(:,:)=time;
//[n,xxx,yyy,junk]=mfscanf(numpart,ffd,'%f %f %i');
//mfprintf(ffd2,'%f %f %f\n',xxx,yyy,ttme);
//end
//mclose(ffd);
//mclose(ffd2);
```

APPENDIX B

SIMULATION LOG

Appendix B
Simulation Log

Outfall Management and Alternative Lake and Flows

6/28/06	BRgrid_B01_ss, Base case with typical inflows, original Hope canal, same mesh as C04_6
6/29/06	BRgrid_D07, Diversion run with new Hope canal and datum shift of 1.l ft.
7/01/06	BRgrid_D08, approximately 1000 ft of railroad bed lowered on west side of Hope canal
7/03/06	BRgrid_B01_ss_hot. Hotstart of previous run to get last 10 days.
7/5/06	BRgrid_D09 made symmetrical gaps after mouth of hope. And modification to bathymetry near pipline and road. Same as D08
7/7/06	BRgrid_D10, removed first culvert west of Hope and first two east of hope, also extended mound to I-10 increasing embankment along bayou Bougere
7/14/06	BRgrid_D11, corrected inflows used D07 grid and fixed bathy by pipeline
7/17/06	BRgrid_B02_ss, some as B01 with corrected inflows
7/18/06	Brgrid_D12, same D10 w/ corrected inflows all culverts west of Miss bayou removed. Gaps in east –west part of railroad bed widen to ~600ft.
7/26/06	BRgrid_B03_ss, same as B02 with correct inflows (switched AMRDC and Conway)
8/4/06	BRgrid_D13, removed weir just after mouth of diversion channel to eliminate instiabilities cause by weirs. Initial run had bad fort.21, D13_2 has good fort.21 file
8/8/06	BRgrid_D14, made consistent 1.2 ft banks along hope canal to transmission line, opened up rest of gaps in railroad bed to ~600 ft. put plugs in beginning of bayou, Bourgeouis(also plugged first gap on south side), and south boyou ; reduced conveyance at mouth of bayou bec crochet. Also widened 3 gaps on east bank of Blind north of railroad.
8/11/06	BRgrid_D15, put in sloping banks (3.5 ft → 1.2 ft over 9000 ft past mouth of diversion channel), reduced conveyande in two places near Miss Bayou , branch tenth, and south oilfield canal. CRASH!! 0.25 days (wetting front problem)
8/11-8/12	BRgrid_D15_2 and D15_3, increased DRAMP to 3 days and fixed some relatively thin triangles that resulted from converting weirs along Hope into mesh. CRASHED at 0.33 and 0.36 days respectively
8/12/06	BRgrid_D15_4, used stairsteps 0.25 ft every 1000 ft along bank instead of continous straignt line slope like in previous runs. STABLE!!!
8/26/09	BRgrid_D16, put weirs in mouth of Dutch Bayou(model -1.5 ft), Bayou Secret(#12 canal), and Bourgeois canal(model -1 ft), fill gaps up to elevations 0.2 ft. < banks along swamp boundary from Blind/I-10 intersection all the way around to RR canal. Raised gap from Mississippi Bayou into oilfield canal to reduce conveyance to RR. Removed weirs on B. Tent up to Dutch/Mississippi bayous
9/8/06	BRgrid_D17, used D13 grid, closed gaps on east side of blind between I10 and Transmission line, put weirs across B. Secret and Bourgeois canal, open gaps on N-S section of railroad to ~600ft. open conveyance from third gap on west side of B.Tent toward railroad.
9/22/06	BRgrid_D18, 10 day hot start from end of D17 with Q linearly ramped over 1 day to 1000 cfs into hope
9/23/06	Brgrid_D19, 10 day hot start from end of D17 with Q linearly ramped over 1 day 2000 cfs
9/24/06	Brgrid_D20, hotstart form end of D17 with LSU period lake boundary added.
9/26/06	BRgrid_D21, hotstart from D17, extend 10 days with one day ramp down to zero inflow at handshake inflow baoundary location for SWMM. This is a priming run to help sinc initial head and discharge conditions for drainage impact runs with diversion.(DI04)
10/17/06	BRgrid_D22, 10 day hotstart of D21 bring lake level up to 2 ft and try to achieve steady velocity field. Did not achieve steaday state after only 10 days
10/19/06	BRgrid_D23, hotstart of D22 to bring lake level to 3ft. saw instability at Godchaux due to low nodes along east side of east weir once water level got above weirs there. Need to use

	corrected grid of DI08.
10/22/06	BRgrid_D24, 10 day hotstart of D22, used grid with fixed elevations on east weir of godcheaux. DI08 Grid
10/23/06	BRgrid_D25, 20 day hotstart of D24, with lake ramped up to 3 ft.
10/25/06	Brgrid_D26, D24 grid modified by dropping bathy and weir heights by 0.9 ft to simulate initial condition of swamp WSE at 2ft. lake held constant at 2ft while diversion is ramped up to 1500 cfs over 2 day DRAMP. Datum shift =2 ft
10/27/06	BRgrid_D27, similar to D26 but with bathy dropped another foot to simulate 3ft constant lake level. datum shift=3ft
10/30/06	BRgrid_D28, similar to D26 but with bathy raised 0.6 ft from D17 level, to simulate constant lake level of 0.5 ft. datum shift = 0.5, run went unstable at 0.63 days seems to be wetting problem along hope canal just upstream of Tent Bayou.
11/02/06	BRgrid_D29, hotstart of D17 with shutdown of diversion.

Drainage Impact

8/16/06	DI01, Same mesh used as calibration C04_6. used data generated by WPSWMM at 600 second intervals to make fort.20 file. Repeated first 10 Minute SWMM output for 12 hours and applied 0.5 day DRAMP in adcirc to prevent shock from intital high disharges. Used 0.5 second timestep and lake level held constant at 1.1ft(model 0ft)Run went unstable near godchaux at 0.81 days.
8/18/06	DI01_2, made some minor geometry changes to mesh just on east side of weir on east side of Godchaux. Run blew up with no results.
8/18/06	DI02_1, same as DI01_2 with 0.25 second time step. Run ran to completion and results were sent to Harry for next round SWMM run.
8/29/06	DI02_2, Used SWMM output to generate fort.20 file. Run blew up at Dolson possibly due to negative flow. Made series of 2 mort fort.20 filesWhich successively reduced negative flows in Dolson: DI02_2-2 (9/01); DI02_2-3(9/02); now solution was blowing up at Godchaux. On a final attempt, DI02_2-4 (9/03), zeroed out all negative flows on tail of hydrograph at godchaux. DI02_2-4 ran successfully.
9/06/06	got results form DI02_2 and sent to harry for another SWMM run. Initial SWMM results did not look good, so Harry ran another run which Did not give good results even with artifical delays in some of the stage Hydrographs. WE decided to make some changes to mesh and also SWMM model and begin again at round 1
9/15/06	DI03_1, moved dolson and RR handshake points north a slightly, deepened beginning of godchaux canal making the invert 6 ft (model) all the way down. For these attempts we made sure Initial condition was the same for both models by removing ramp period from adcirc simulations and using a SWMM hotstart from in initial “priming” run with minimum rainfall to draw down the WSE to 1.1 ft. at all gages.
9/21/06	DI03_2, ran 16 point running mean through RRC SWMM output to to smooth wiggles in back side of hydrograph, Also zeroed out intial negative flows before rise of hydrograph. Used RRC output instead of RRC handshake. Removed two point downward spike in Godchaux SWMM output. Zeroed intial points on all imput where there were small “wiggles” befor rise of hydrographs.
9/29/06	Di03_3, smoothed RRC ADCIRC imput considerabley by connecting peaks to remove a number of downward spikes. Also ran 5 point running mean to smoothe “wiggles” on RRC’s hydrograph tail. Zeroed intial points on all imput where there were small “wiggles” befor rise of hydrographs
9/30/06	DI04_1, this is hotstart of D21(10 day extention of D17 to shut down inflows and achieve intital condition at handshake boundaries priming run with inflows derived from SWMM output. First iteration with inflows given from third SWMM round of DI03_3. flow at hope canal is added to diversion flow of ~1500cfs. Due to change in timestep from 0.5 sec(D21) to 0.25 sec(DI04), ADCIRC began simulation at day 15 instead of day 30, therefore it was necessary to only put 15 days of “unused” input in the fort.20 file prior to the 5 days of

	runoff discharge generated by SWMM. This does not seem to be the case for the fort.19 file though(infact if the fort.19 didn't have 35 days of input adcprep will not prep, changing runday from 35 to 20 might have fixed this, but did not try this).
10/3/06	Received SWMM output from SWMM DI03_4. it was found that the the imput used for this run was incorrect. Harry will run it again with proper input.
10/5/06	DI05_1, mesh was modified at three nodes just east of godchaux. One in particular along mesh boundary had low elevation and seems to have causing "simmering" instability when banks of Godcaux got over topped. Used "best guess" output from most recent SWMM run DI03_4 with some Smoothing. Did some other smoothing of grid geometry in area b/w RRC Godchaux. Still seeing instabilities but not further north right along east Nodestring of east weir along Godchaux. Believe this is due to low node Elevation along that nodestring (ditch along bank).
10/6/06	DI06_1, similar to DI04_1, with corrected mesh(DI05_1). Used same same flow discharge inputs at DI05_1. adcprep would not prep with fort.14 from DI05_1 perhaps due to too much mesh modification. It seems that some nodes were lowered to elevations where they would been wet, but there was no information in the fort.68 for those nodes b/c those nodes were dry at end of D21 run. Tried a new fort2.14 without mesh modifications that would make dry nodes become wet. <u>Did not run this one</u> because DI05 showed instabilities due to poor geometry along east bank of Godchaux
10/7/06	DI07_1, Base case run , raised elevations of nodes along east bank of Godchaux to remove "ditch". Used same flow inputs as DI05_1. Got rid Of "geyser instabilities' and results look useable, although there is a lot of High requency fluctuations in godchaux WSE.
10/9/06	DI08_1, made same modifications to Diversion grid as in DI07_1, hotstart off end of D21, similar to DI04_1. inflows same as DI07_1. We were effectively able to raise elevations of nodes that were wet at end Of coldstart(D21) to elevations that would make them dry at beginning of Hotstart.
10/10/06	DI07_1_2nd_attempt After more close examination of DI07_1, discovered that inflow boundary at Godchaux was not working properly and seems to have only been causing the wiggles seen in the hydrograph, while the overall average hydrograph was caused by overall increase in level in swamp. This was noticeable as a ~5 hour delay from the onset of runoff to the onset of stage. Made new fort.20 file with 10cfs initial discharge at godchaux instead of 0 cfs in hope to prevent instability. Results of DI08_1 did not show same instability and look useable for 1st round SWMM input.
10/11/06	DI07_1 attempts 3-5, flow input going into godchaux still not working properly, attempt three: moved normal flow boundary nodestring to side of canal instead of head(did not work and same problem occurred). Attempt 4. properly ordered normal flow boundaries in fort.14, (did not work), Attempt 5: added two nodes to head of godchaux so canal would be three elements wide for three rows at head.(partial results showed success).
10/12/06	Got results from DI07_1 attempt 5, They looked good instabilities are not evident, sent off to Harry for 1st round SWMM run. Also began DI08_2 run using SWMM 1st round output. Did considerable Smoothing of RRC input completely removing second discharge peak in Hydrograph which we believe was an artifact of if the initial "best guess" Used for first round ADCIRC runs in which we now know Godchaux was Behaving badly.
10/13/06	got results from ADCIRC DI08_2 and sent off to harry for next round SWMM. Began DI07_2, also did considerable smoothing of RRC discharge Removing 2nd peak as in DI08.
10/16/06	began DI08_3 using 2nd round SWMM input, again some smoothing of RRC hydrograph was done but overall shape of hydrograph was preserved. Examined results of DI07_2 and sent off to Harry for 2nd round SWMM.
10/17/06	Began ADCIRC DI07_3 using 2nd round SWMM output. did some smoothing of RRC discharge hydrograph, and minor smoothing of Godchaux discharge. Also got results of DI08_3 ADCIRC run and sent to harry for next SWMM round.

APPENDIX C

1D SWMM SIMULATION INPUT/OUTPUT FILES

SWMM Drainage Impact Simulations Input/Output Files

Due to the large file sizes, the SWMM Input/Output files for the Drainage Impact simulations have been provided separately.

APPENDIX D

2D ADCIRC SIMULATION INPUT/OUTPUT FILES

ADCIRC Diversion Simulations Input/Output Files

Including:

1. Outfall Management
2. Alternative Diversion Flows
3. Shutdown
4. Alternative Lake Elevations
5. Drainage Impact

Due to the large file sizes, the ADCIRC Input/Output files for the Diversion simulations have been provided separately.

APPENDIX E

ANIMATION FILES

LIST of ANIMATIONS