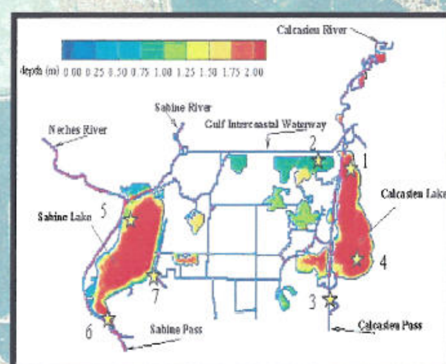
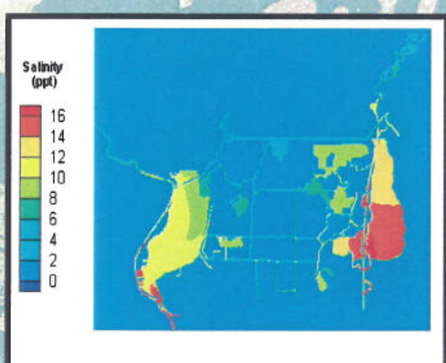
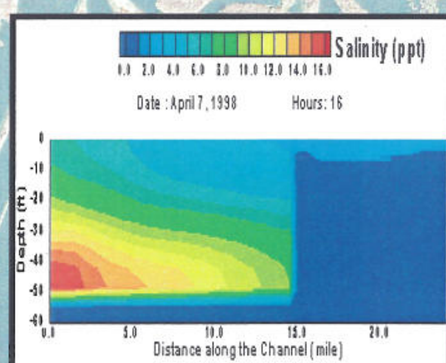
Hydrodynamic Modeling
Of The
Brown Lake Restoration Project
(CS-09)







Submitted by

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EXECUTIVE SUMMARY

The Brown Lake Hydrologic Restoration Project (CS-09) is located within the Calcasieu/Sabine Basin in Cameron Parish, Louisiana (See Figure 1). This project is a result of the Coastal Wetlands Planning Protection and Restoration Act (CWPPRA), and is federally sponsored by the United States Department of Agriculture- Natural Resources Conservation Service (NRCS) and locally by the Louisiana Department of Natural Resources (LADNR). The project area contains approximately 2,800 acres of wetlands, consisting of vegetated marsh and open water. The project area is bounded on the north by the Gulf Intracoastal Waterway (GIWW), on the south by oil well canals and spoil banks, on the east by LA Hwy 27, and on the west by the Alkali Ditch. The purpose of the project is to reduce the rate of loss of emergent wetlands by reducing salinity and water level variations with the proposed project components.

The proposed project components that are intended to reduce salinity and water level variations include:

1) **Site 14:** A variable crest weir with a boat bay and flap gate. The structure will consist of approximately 172' of steel sheet piling with a 7'wide box structure with a flap gate attached on the outside of the project area and a variable crest weir on the marsh side with adjustable weir boards.

2) **Site 15:** 5-48" x 64' corrugated metal pipes with 2-4' variable crest weirs and a 6" slot on the inside and a flap gate on the outside of each pipe.

3) **Site 18:** 2-36" x 72' corrugated metal pipes with a screw gate on the outside and a flap gate on the inside of each pipe.

4) **Site 8A:** 1-36" x 60' corrugated metal pipe with a screw gate on the outside and a flap gate on the inside.

5) Approximately 20,500 linear feet of earthen terraces constructed to an elevation of +2.0 NAVD 88', with two on one side slopes.

6) Approximately 30,000 linear feet of boundary embankment construction and repair.

Before completion of the design of this project by the federal sponsor, it was the intention of both agencies to predict the results of the above listed project components by preparing a hydrodynamic model that can predict water level variations, and salinity fluctuations with and without the project components.

There are numerous computer models available for studying estuaries and lakes, however, the selection of the most appropriate model depends on the type and resolution of the information needed, the purpose of the study, and the level of accuracy desired. Accordingly, the following factors were used to dictate the basis for the model selection for the Brown Lake Modeling Project:

- Computational efficiency
- Capability of modeling hydraulic structures
- Capability to model stratified flows
- Capability to model "wetting" and "drying" effects
- Previous applications that demonstrated model reliability

It is crucial to utilize a model that provides detailed information about the flow velocity and salinity not only over the horizontal plane, but also over the water column. Accordingly, to properly analyze this system, a three-dimensional model should be used in order to achieve a higher degree of accuracy that can best reflect existing and proposed conditions for this project.

A three (3) dimensional model was selected because of the topography and bathymetry of the project. Since the project area is predominantly a lake, hydraulic parameters in all three dimensions would be important in adequately accessing the existing as well as proposed conditions produced by the project components. By having a hydraulic model that can predict these conditions, it can be used as a tool to determine the efficiency of having each of these structures and address whether or not the design of these components are producing effects that are within acceptable means.

A complete three (3) dimensional hydrodynamic and advection dispersion model named H3D was selected to be used to access the impacts of the proposed project components as well as model the impacts of these components through various operational schemes. This modeled area was coupled with an existing three (3) dimensional model previously performed utilizing the H3D software, which encompassed the entire Calcasieu-Sabine Basin. The reason for this was that because the hydrodynamics of this area is affected greatly by tidal influence and global wind patterns, it is important to extend the model outward to capture these effects. It is also important to note that this modeling software has the capability to couple two models with two different resolutions, which was the case with this project. This practice is known as "nested" modeling.

Important hydraulic elements that influence the project area included in the hydraulic model are:

- The Calcasieu estuarine system, including the Calcasieu Ship Channel and Calcasieu Lake, and Calcasieu River
- The Gulf Intracoastal Waterway (GIWW) that connects the Sabine and Calcasieu estuarine systems
- The Sabine estuarine system, including the Sabine and Neches Rivers, the Sabine Lake, and the Port Arthur (or Sabine-Neches) Ship Channel
- Alkali Ditch bordering the western side of the project
- Kelso Bayou bordering the southern side of the project

Existing data within the model area and vicinity (water level, salinity, discharges, wind, and bathymetry) was collected from different sources. These sources include information from the Louisiana Department of Natural Resources, United States Geological Survey, the Lake Charles Airport, the US Corps of Engineers, and the National Oceanic and Atmospheric Administration (NOAA).

INTRODUCTION

The Calcasieu-Sabine Basin is located in the southwest corner of the state of Louisiana and extends into the State of Texas as shown in Figure (1). The basin receives fresh water from the Calcasieu, Sabine, and Neches Rivers, and it is connected to the Gulf of Mexico through two narrow channels, namely, the Calcasieu and the Sabine Passes. Brown Lake is located east of the Calcasieu ship channel, and south of the Gulf Intracoastal Waterway (GIWW). It is connected to Calcasieu Lake through two deep channels, Kelso Bayou and Alkali Ditch. In addition to submerged regions, the Brown Lake wetlands comprise of approximately 2,800 acres of emergent marsh that has lost over 1,800 marsh acres since 1952. This loss appears to be due to the elevated salinities and water levels in the Calcasieu basin resulting from construction and maintenance of the Calcasieu Ship Channel and the GIWW. The basin was also subjected to changes, such as dredging deep navigational channels and constructing water-control structures that impacted its hydrologic characteristics. The Natural Resources Conservation Service (NRCS) and Louisiana Department of Natural Resources (LADNR) are proposing to surround the perimeter of Brown Lake with a levee system with three water-control structures in an attempt to restore the hydrologic characteristics of Brown Lake close to its historical patterns. The purpose of the hydraulic structures is to control draining and filling of the lake based on a detailed operational schedule. The proposed restoration project also includes constructing a system of earthen terraces in an arranged pattern within the lake area. These terraces are intended to cause sediment buildup, which will eventually lead to vegetation growth within the lake.

Figure 1: General map of the project area

APPROACH

Hydrodynamics of the Calcasieu-Sabine Basin involve a combination of estuarine processes, such as saltwater intrusion, response to water level fluctuations at open boundaries, lake dynamics (such as strong response to wind forcing particularly in the water level setup), and the development of high velocity currents in near-shore shallow regions. Ship channels that are strongly salinity stratified effect the basin, therefore, creating the need for a three-dimensional model to analyze this complex hydrodynamic system. A robust, flexible and efficient numerical model is required to incorporate all of these processes in an operational program. A nested modeling approach, where a large-scale basin wide model was linked to a high-resolution local model for Brown Lake, was believed to be effective to accurately assess the impact of the proposed restoration project and possibly refine its design, if needed.

The three-dimensional finite-difference hydrodynamic model, H3D (Stronach et. al, 1993), was used to simulate the hydrodynamic characteristics of the Calcasieu-Sabine estuarine system. H3D provides the three components of velocity as well as scalar quantities, such as water levels, temperature and salinity distribution, on a Cartesian three-dimensional grid. The model is fully unsteady, meaning it responds to time-varying salinity and water level forcing at open boundaries, time-varying river inputs, and time-varying wind stress.

The H3D model was used to assess the impact of the proposed restoration project and possibly refine its design. The model was used to reproduce the existing water level and salinity conditions of the project area for a wet year (1998) and a drought year (1999). Since the H3D system is a physically based model, and the resulting hydrodynamics are based on solving the three dimensional mass, momentum and density conservation equations, it can be used to simulate flow and salinity patterns for different hydrologic conditions. Therefore, after the model has been carefully calibrated and validated, it was used to simulate the effects of both natural and human induced hydrologic changes in the basin. The model's geometric mesh can be modified to simulate changes in salinity, water level, flow pattern, and velocities induced by the addition of hydraulic structures, widening or deepening of navigation channels, or changing the volumes of freshwater inflow to the basin. The model proved to be a useful planning and adaptive management tool.

The model was used to calculate the water level and salinity patterns pre and post project construction. Direct comparison between the water level and salinity patterns with and without the project was used to evaluate the feasibility of the project.

CALCASIEU-SABINE BASIN-WIDE MODEL SETUP

A three-dimensional model for the entire Calcasieu-Sabine Basin was developed and validated (Meselhe and Noshi, 2001). This large-scale model was used to provide boundary conditions for a high-resolution model for the project area.

Geographic and Topographic Data

The United States Geological Survey (USGS) Quad maps and Digital Orthogonal Quarter Quadrangles (DOQQs) were used to digitize the shorelines of the rivers, channels, and lakes within the Calcasieu-Sabine Basin. The geometric properties of the flow cross-sections of the different streams, i.e. flow width and depth, were also collected and incorporated in the digitized map. In addition, National Oceanic and Atmospheric Administration (NOAA) maps were acquired and used to extract bathymetry information for the Calcasieu and Sabine Lakes. The layout of the basin-wide model is shown in Figure (2). Selection of the boundaries for the computational model is a complex matter, and often creates a tradeoff between factors such as the model objectives, the desired resolution of the flow field, the computational time and effort, and the locations where sufficient boundary condition data are available. In general, extending the model boundaries as far as possible from the region of interest is required.

Since the main intent of the study is to determine the flow patterns within the Calcasieu and Sabine Lakes and their interconnecting channels, and having sufficient water level and salinity data, the Calcasieu and Sabine Passes were a suitable location for the model's southern boundary. Further extension of the model's boundaries into the Gulf of Mexico, although beneficial, would have required the specification of salinity profiles and water levels at the edges of this open boundary. Such data was not available at the time of this study. The model's northern boundaries were extended to the first available reliable freshwater discharge gauge stations on the Calcasieu, Sabine and Neches Rivers.

The model's grid resolution is 250 x 250 meters (820.2' x 820.2'). The flow patterns in channels and streams with cross sections smaller than the 250 x 250 meter model resolution can still be represented in the H3D model through defining the specific ratios of these cross sections with respect to the full grid cell.

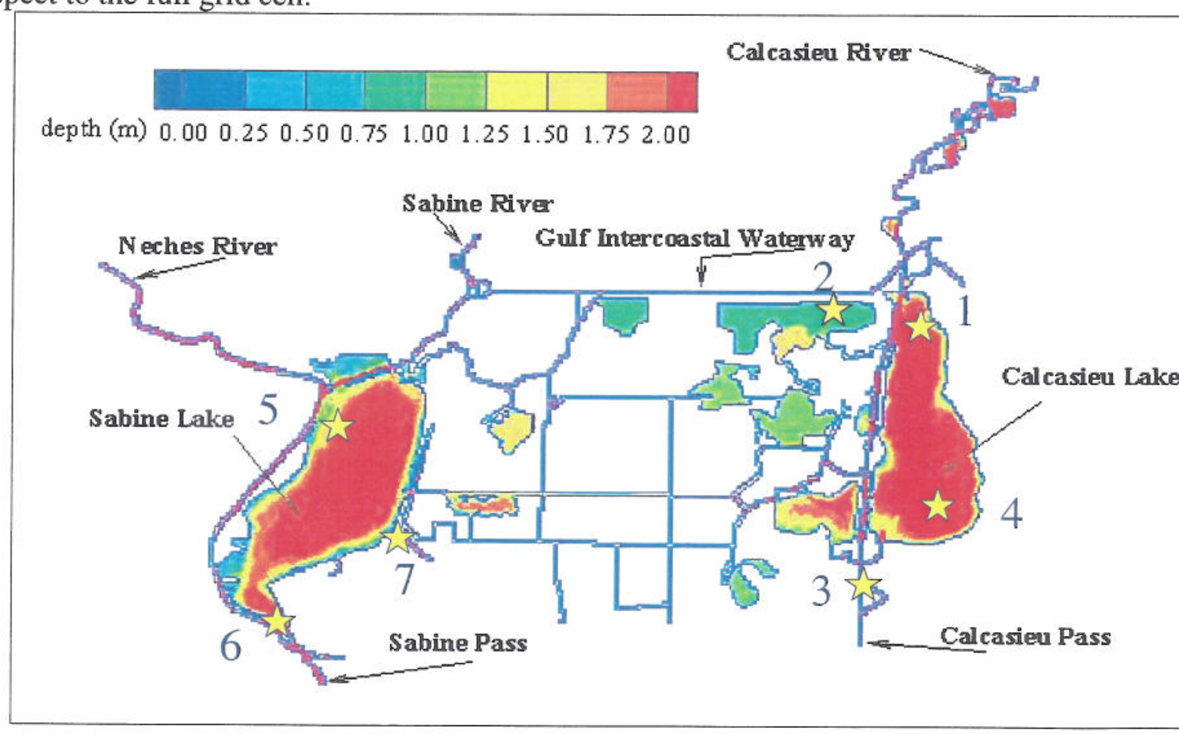

Figure 2: General layout of the boundaries used to describe the Calcasieu-Sabine Basin, showing the location of the seven gauge stations used for model calibration.

Boundary Conditions

Daily values for the freshwater discharges collected by USGS were used for the Calcasieu, Sabine and Neches Rivers. Hourly wind speed, wind direction, water level (tide), and salinity records at the Calcasieu and Sabine passes were used as the forcing function for the model (* It should be noted that the hourly salinity data is collected at a point near the water surface). Therefore, a vertical profile was constructed based on the point measurements guided by complete salinity profiles of the Calcasieu ship channel collected by James A. Duke, Jr. (see references) The data for the years of 1998 and 1999 were used to calibrate and validate the model. Existing data availability is shown in Table 2 attached at the end of this document.

Model Calibration and Validation:

The H3D model was calibrated using hourly water level and salinity records collected at seven gauge stations (shown in Figure 2) within the Calcasieu-Sabine Basin. The model results were compared with their corresponding water level and salinity records at the different gauge stations. The model calibration was a continuous process of data analysis and physically based model adjustments to achieve a reasonable match between the field measurements and the model results. It should be noted that during the calibration process, no adjustments to a particular local variable took place. Only global variables such as the shear/viscosity coefficients were adjusted and tuned. The H3D model successfully reproduced the water level and salinity patterns within the basin.

Calibration and Validation Results

The location of the stations used to calibrate and validate the model is shown in Figure (2). As can be seen in the figure, the stations were properly spread over the modeled area providing a good measure of the model's accuracy and ability to reproduce the flow field throughout the basin. A complete discussion of the basin-wide model calibration and validation can be found in the report by Meselhe and Noshi (2001). Only a sample of the model results is shown herein in Figures (3) through (9). Figure (10) represents a sample comparison between modeled and recorded water levels plotted for a short period. The figures illustrate the capability of the H3D model in simulating seasonal as well as hourly variations of water level and salinity.

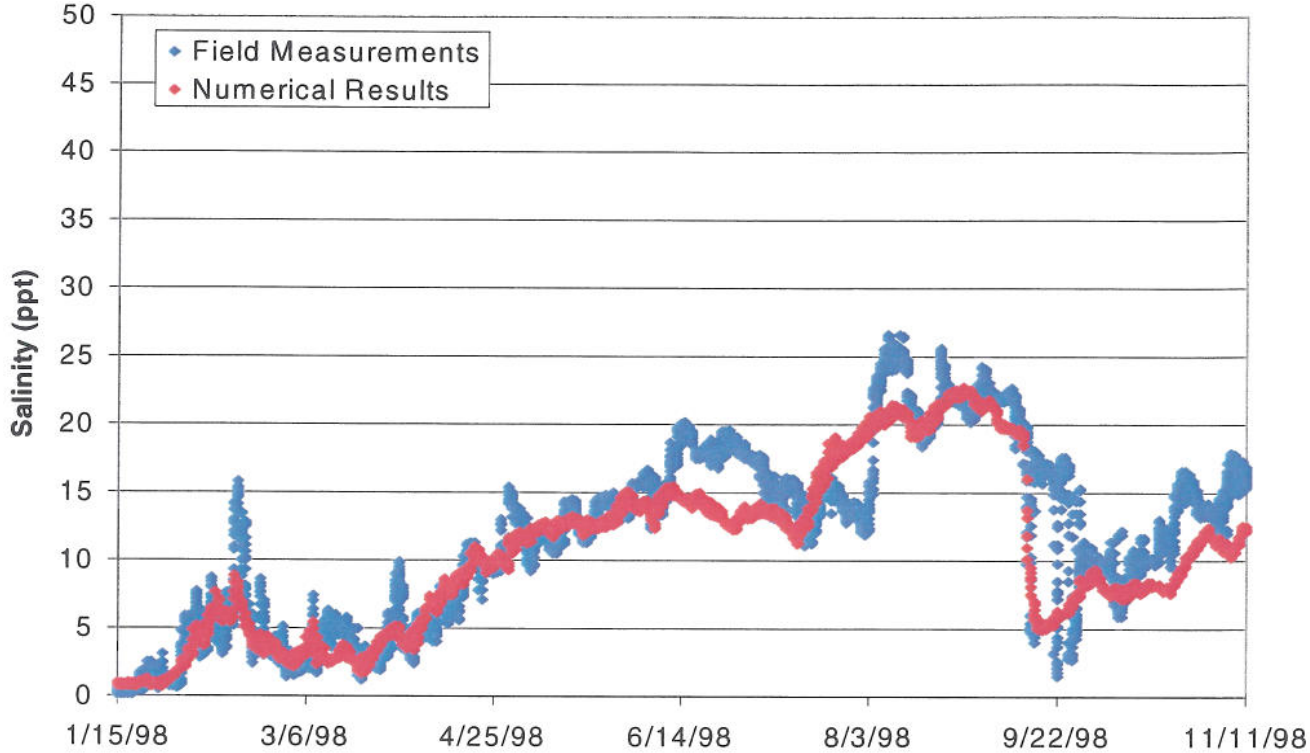

Figure 3a: Comparison between measured and modeled salinity values at North Calcasieu Lake Near Hackberry (USGS Gauge Station 08017095) (No. 1, Figure 2)

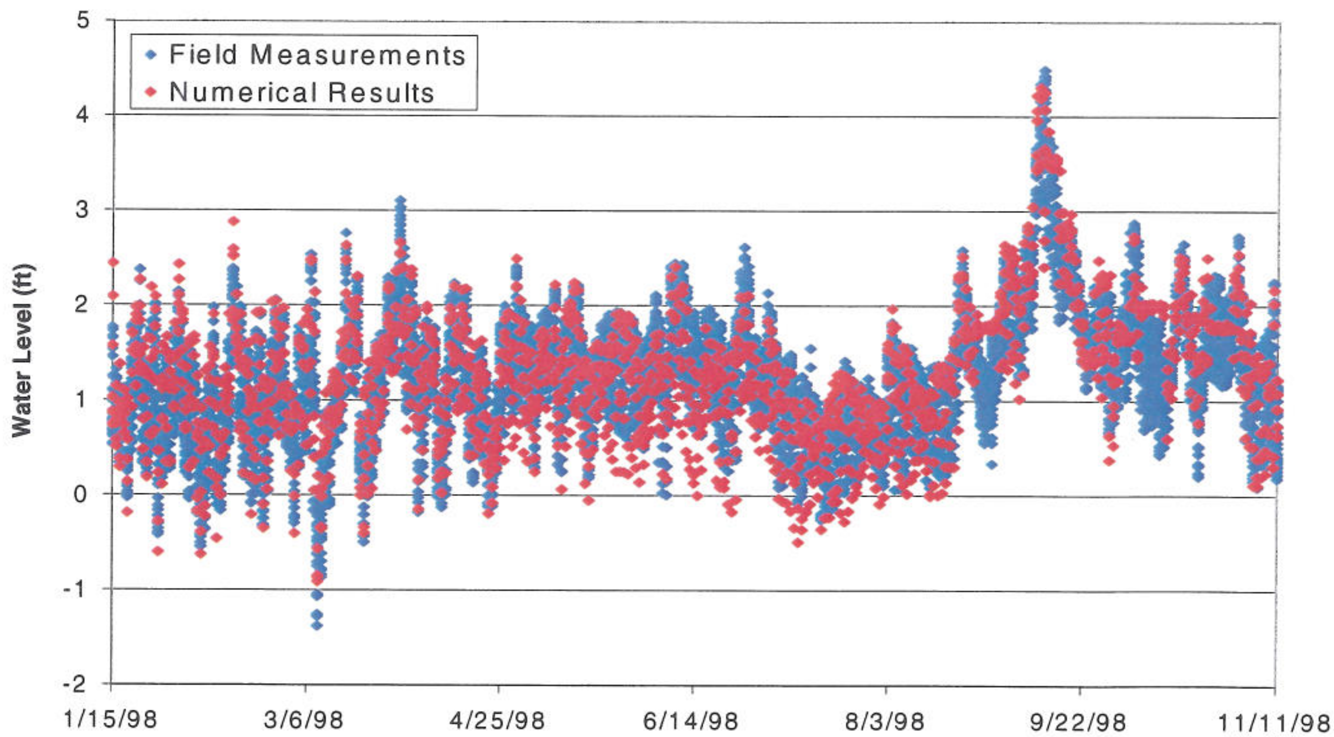

Figure 3b: Comparison between measured and modeled water level values at North Calcasieu Lake Near Hackberry (USGS Gauge Station 08017095) (No. 1, Figure 2)

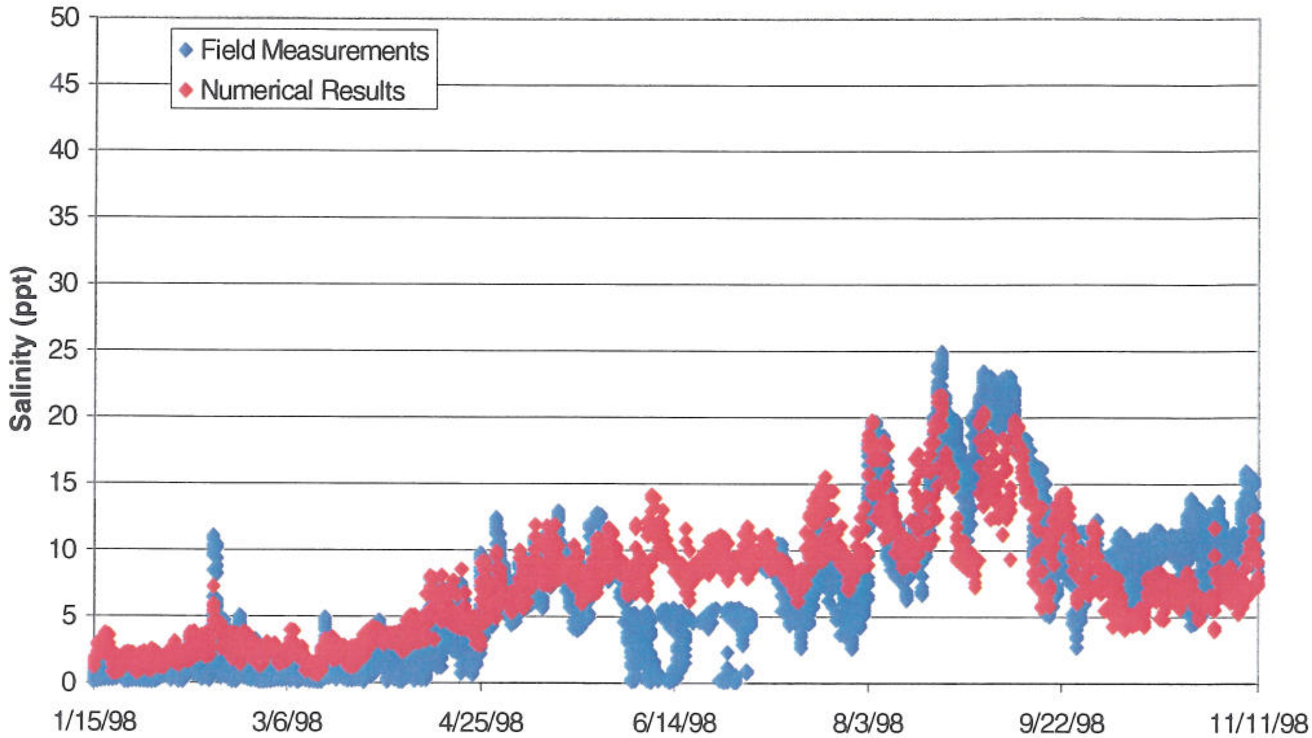

Figure 4a: Comparison between measured and modeled salinity values at Brown Lake (Station CS09-2R) (No. 2, Figure 2)

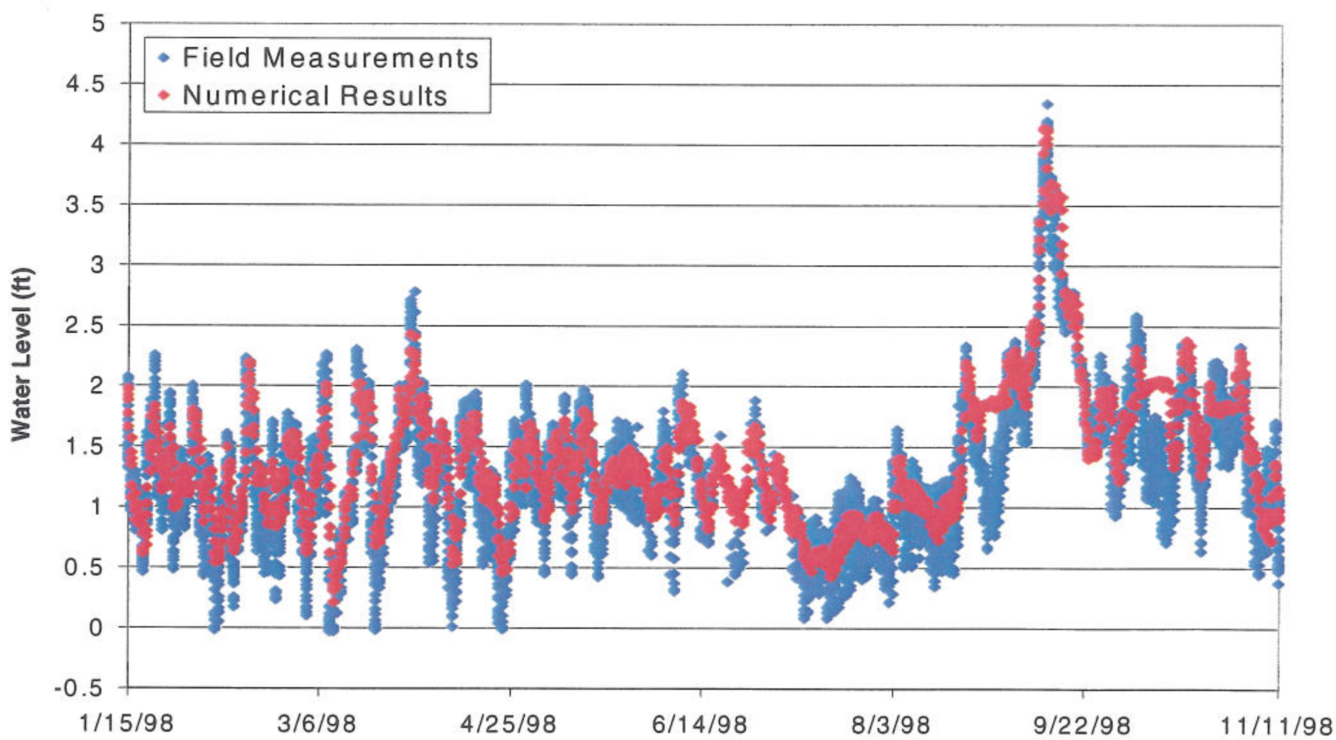

Figure 4b: Comparison between measured and modeled water level values at Brown Lake (Station CS09-2R) (No. 2, Figure 2)

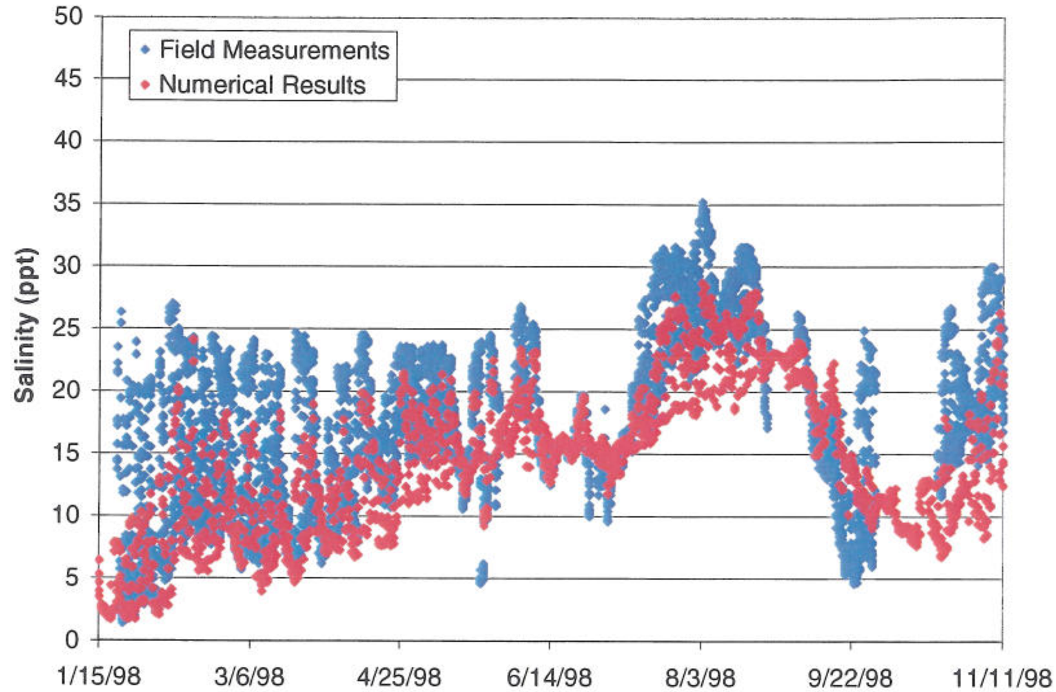

Figure 5a: Comparison between measured and modeled salinity values at Calcasieu River at Cameron (USGS Gauge Station 08017118) (No. 3, Figure 2)

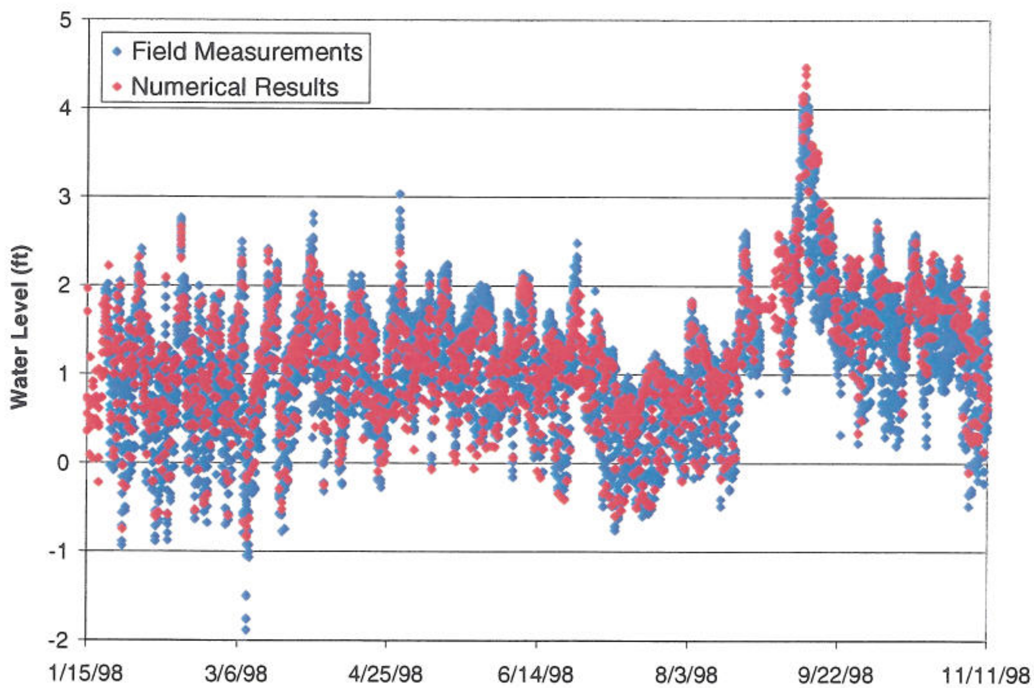

Figure 5b: Comparison between measured and modeled water level values at Calcasieu River at Cameron (USGS Gauge Station 08017118) (No. 3, Figure 2)

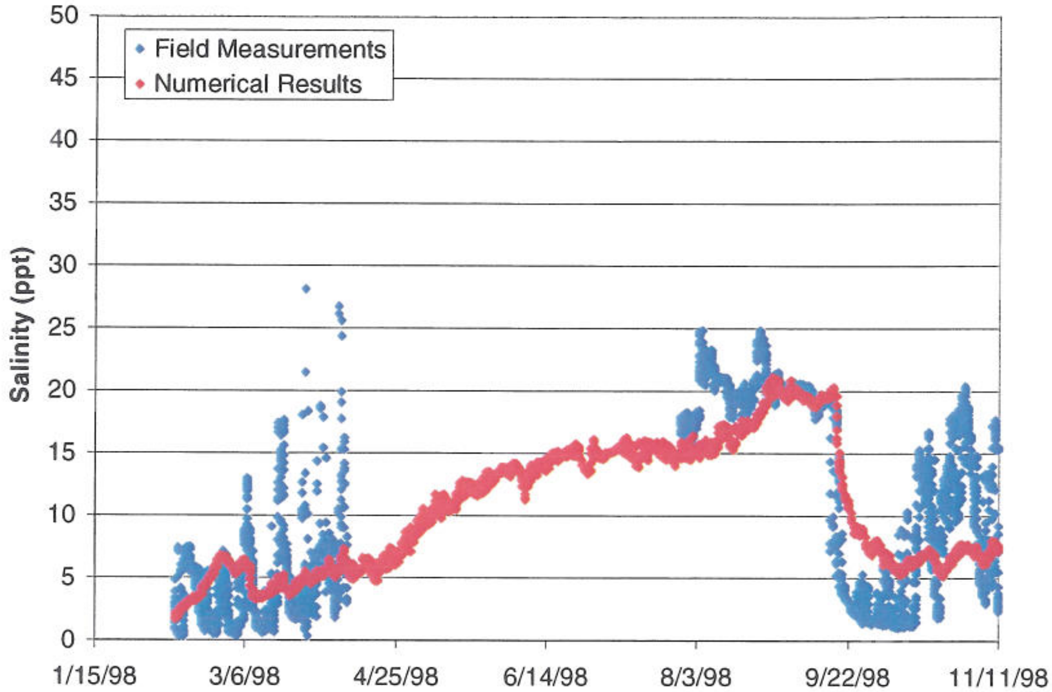

Figure 6a: Comparison between measured and modeled salinity values at South Calcasieu Lake (Station CS17-1R) (No. 4, Figure 2)

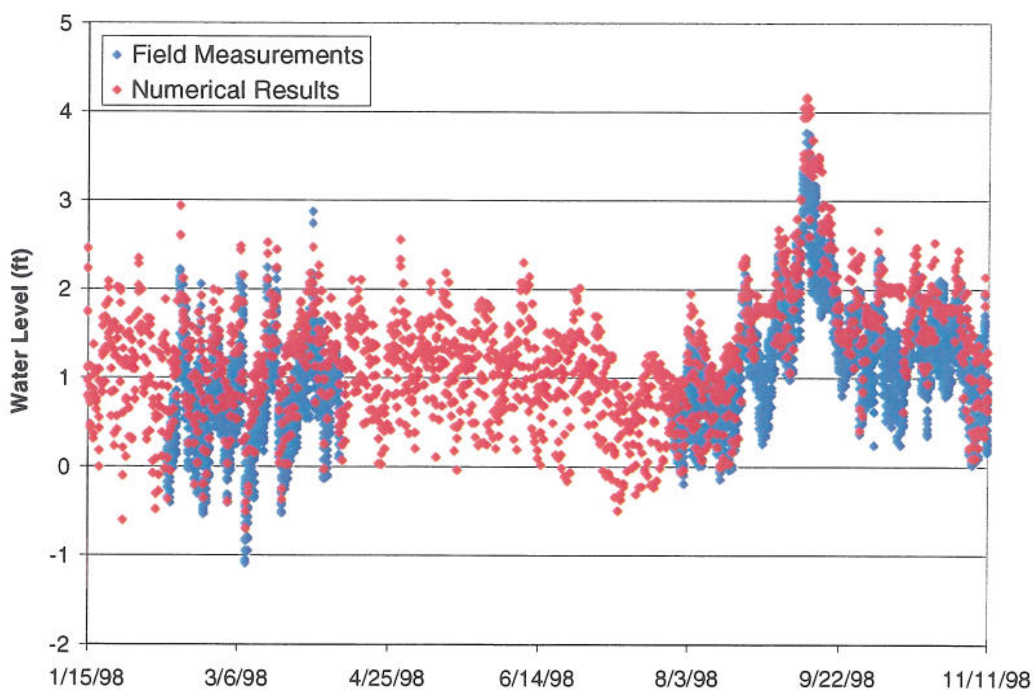

Figure 6b: Comparison between measured and modeled water level values at South Calcasieu Lake (Station CS17-1R) (No. 4, Figure 2)

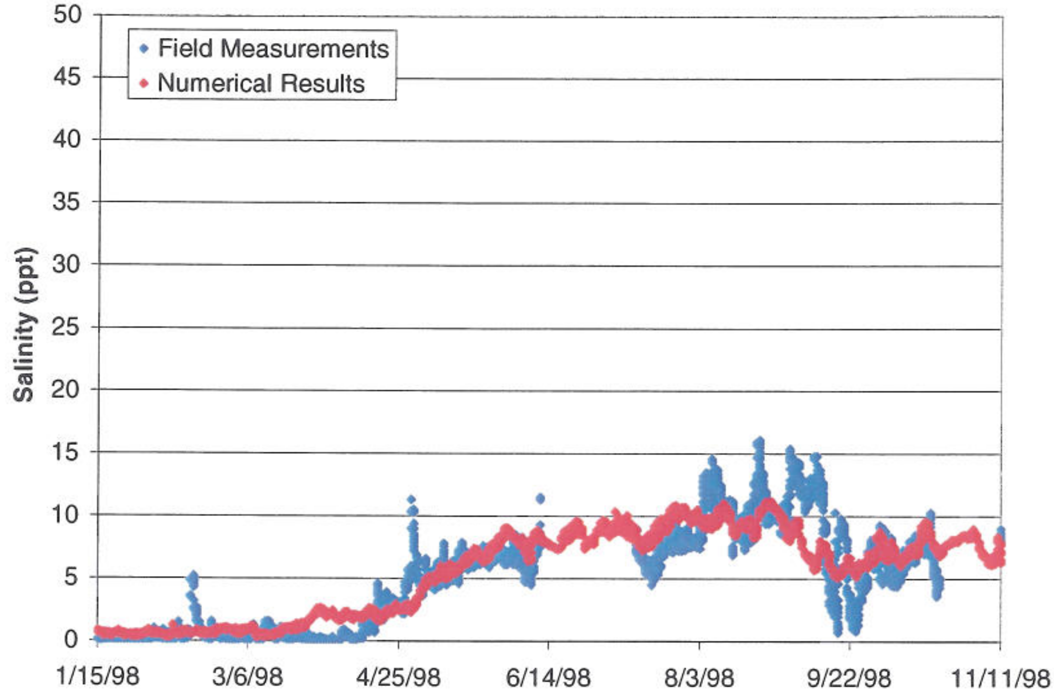

Figure 7a: Comparison between measured and modeled salinity values at Upper Sabine Lake at Platform "A" (No. 5, Figure 2)

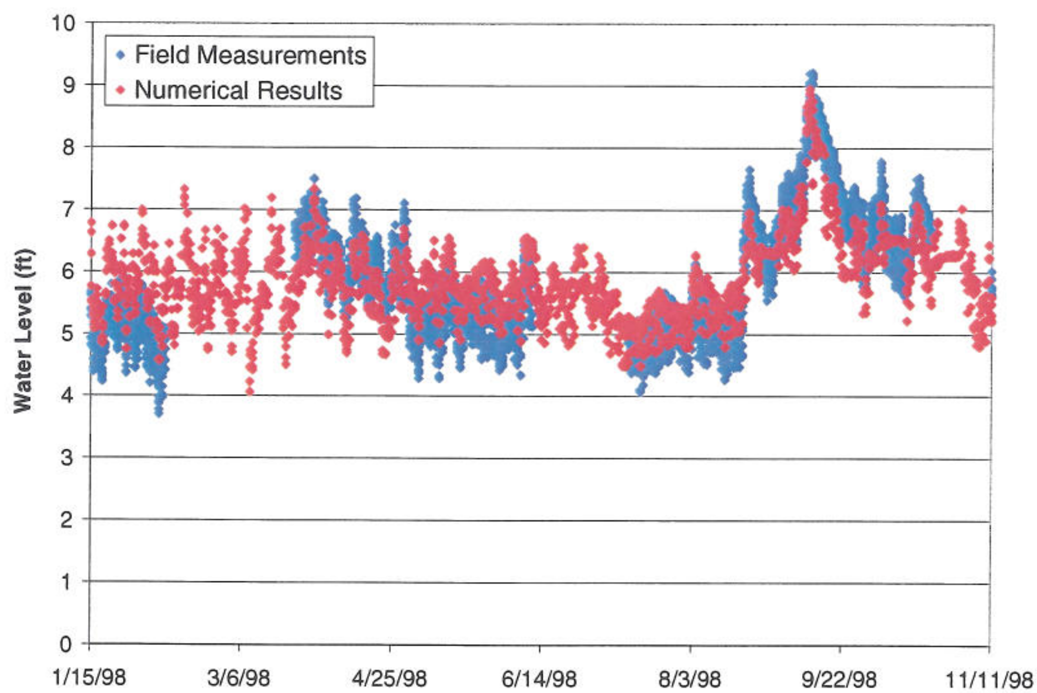

Figure 7b: Comparison between measured and modeled water level values at Upper Sabine Lake at Platform "A" (No. 5, Figure 2)

Note: Numerical results for figures 7b-9b were adjusted to match the local gauge datums.

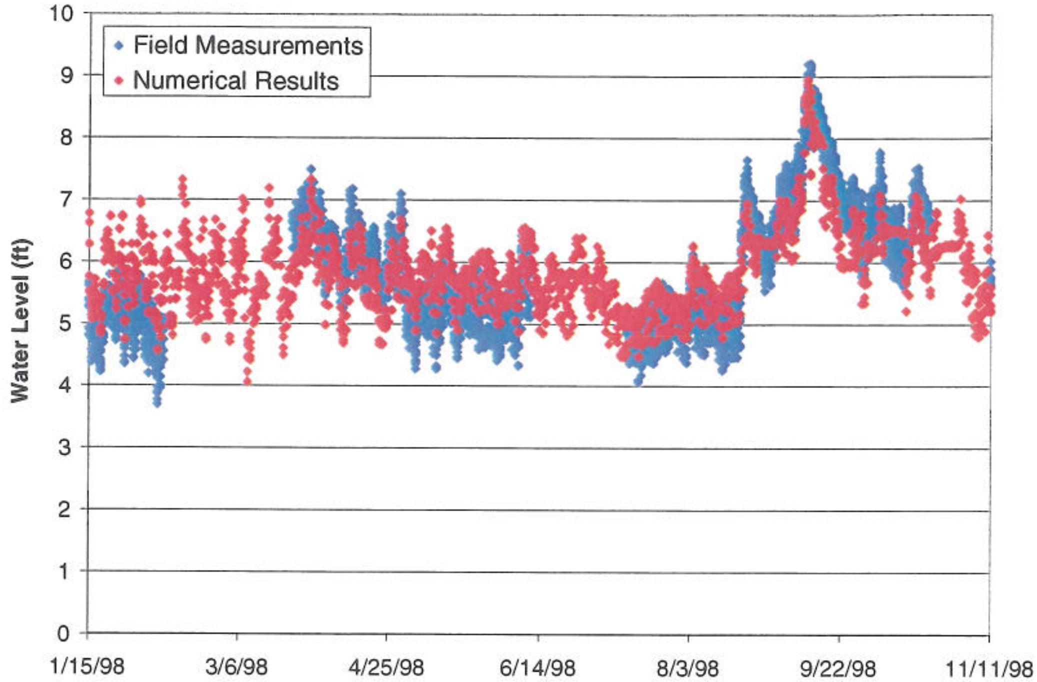

Figure 8a: Comparison between measured and modeled salinity values at Lower Sabine Lake (No. 6, Figure 2)

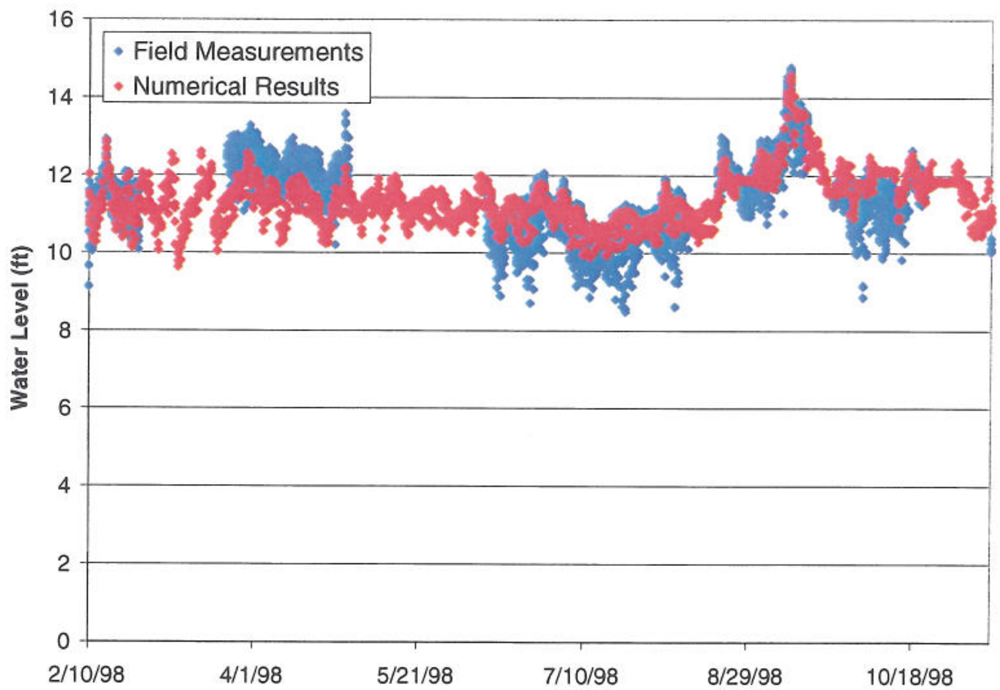

Figure 8b: Comparison between measured and modeled water level values at Lower Sabine Lake (No. 6, Figure 2)

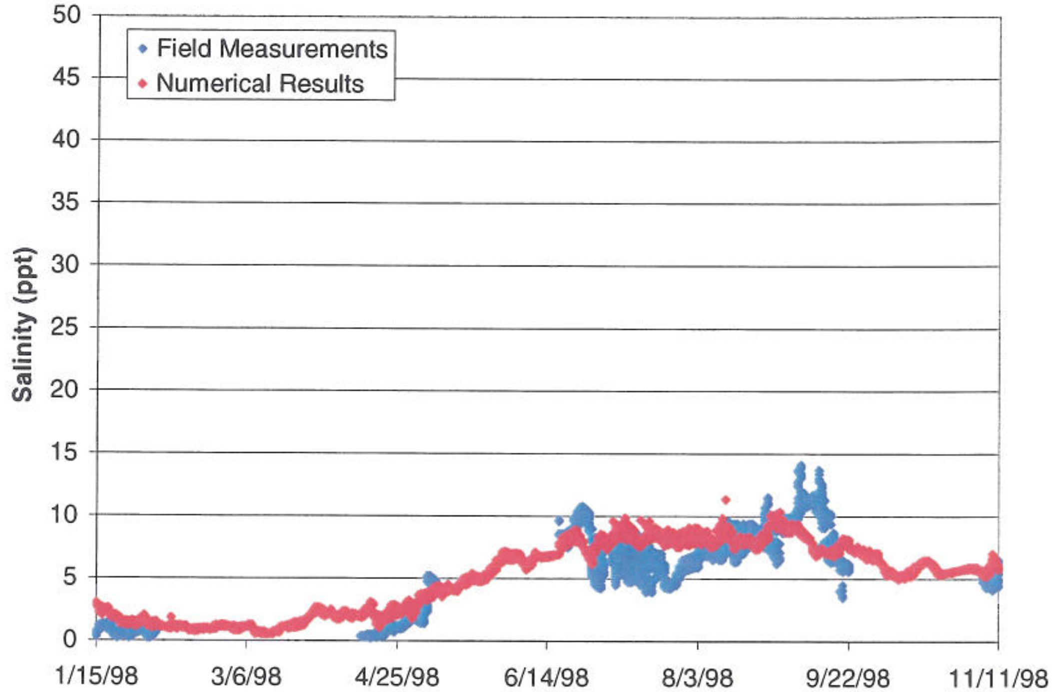

Figure 9a: Comparison between measured and modeled salinity values at Johnson Bayou (No. 7, Figure 2)

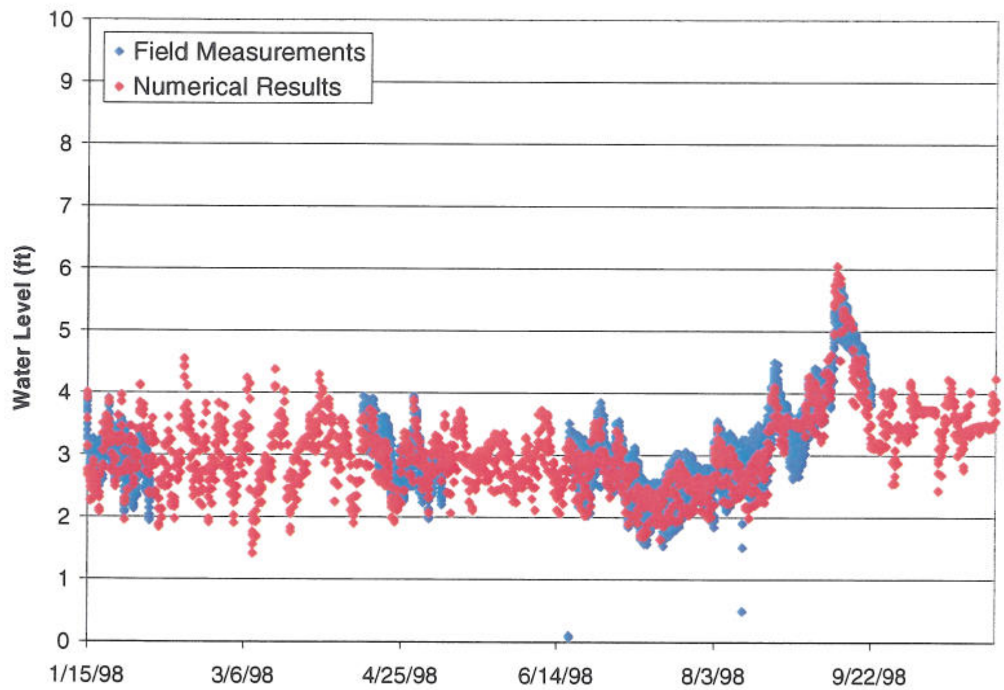

Figure 9b: Comparison between measured and modeled water level values at Johnson Bayou (No. 7, Figure 2)

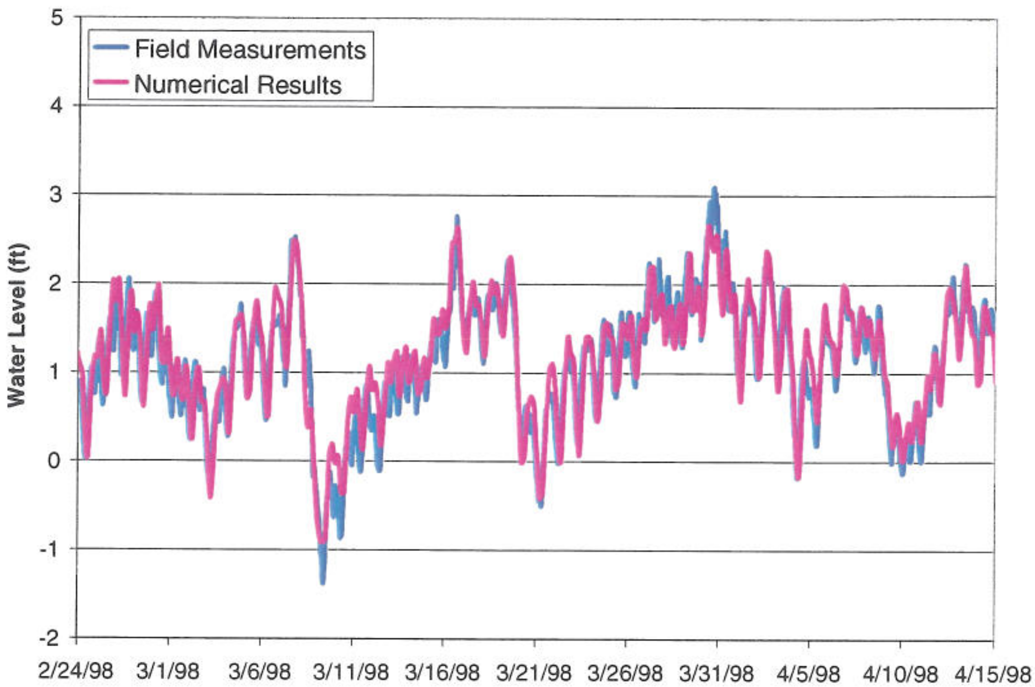

Figure 10: Comparison between short-term measured and modeled water level values at North Calcasieu Lake Near Hackberry (USGS Gauge Station 08017095) (No. 1, Figure 2)

The data shown in Figures (3) through (10) are for the year of 1998. Sample results for the year of 1999 are shown in Figures (11) through (17).

In order to quantitatively assess the accuracy of the H3D model, the root mean square errors between the modeled and measured values of water levels and salinities were computed. Table 1 shows a summary of the results of the error analysis between the modeled and recorded values. The table illustrates the Root Mean Square (RMS) error values and percentages for each station, defined as follows:

$$\text{Root Mean Square Error} = \sqrt{\frac{(Measured - Simulated\ Values)^2}{No. of\ Observations}}$$

$$\text{Root Mean Square Error\%} = \frac{Root\ Mean\ Square\ Error}{(Maximum - Minimum\ measured\ values)} x100$$

As shown in Table 1, the RMS error percentage ranged between 5.59-10.88% and 12.39-17.47% for the water levels and salinities, respectively. Given that these error values also account for the sometimes-inherited inconsistency of the measured values due to human errors or equipment malfunction, these results illustrate a reasonable agreement between the recorded and modeled values for all the stations.

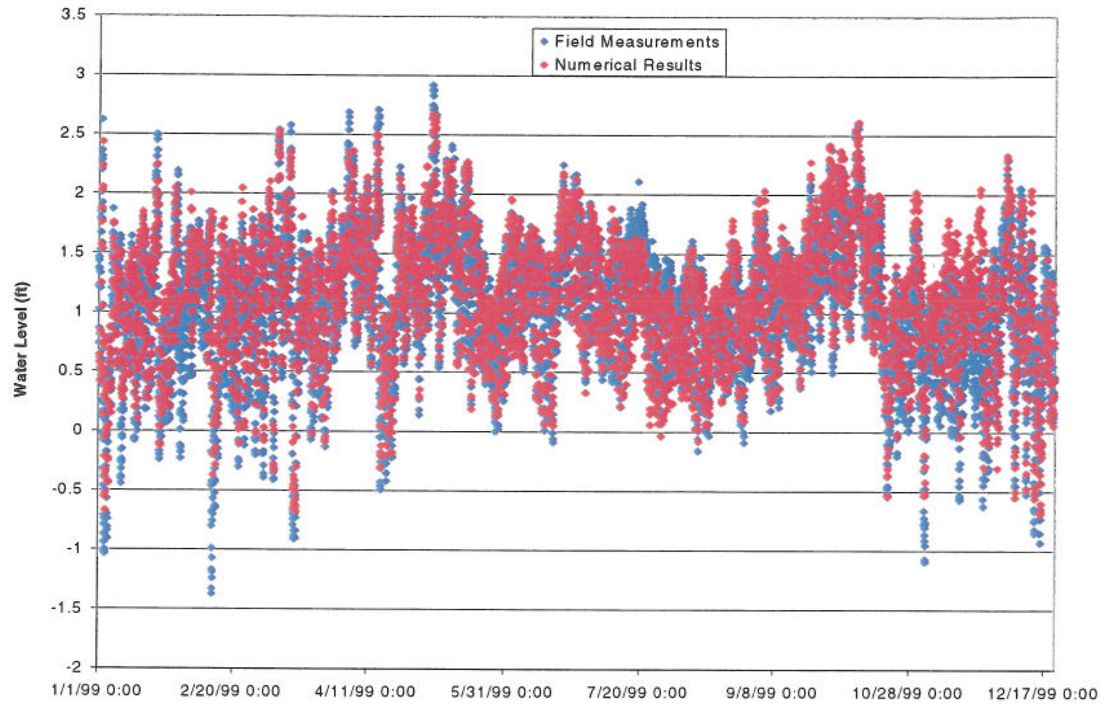

Figure 11: 1999 existing water level results of North Calcasieu Lake near Hackberry, LA (Gauge 08017095)

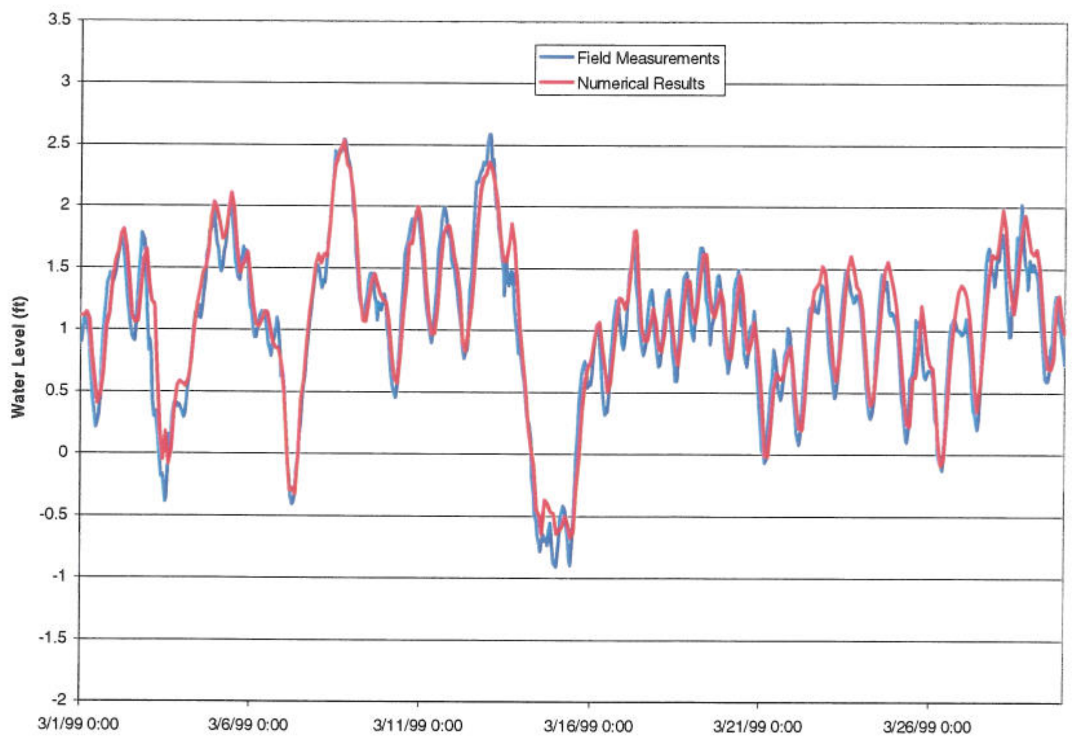

Figure 12: View of March 1999 for North Calcasieu Lake near Hackberry, LA (Gauge 08017095).

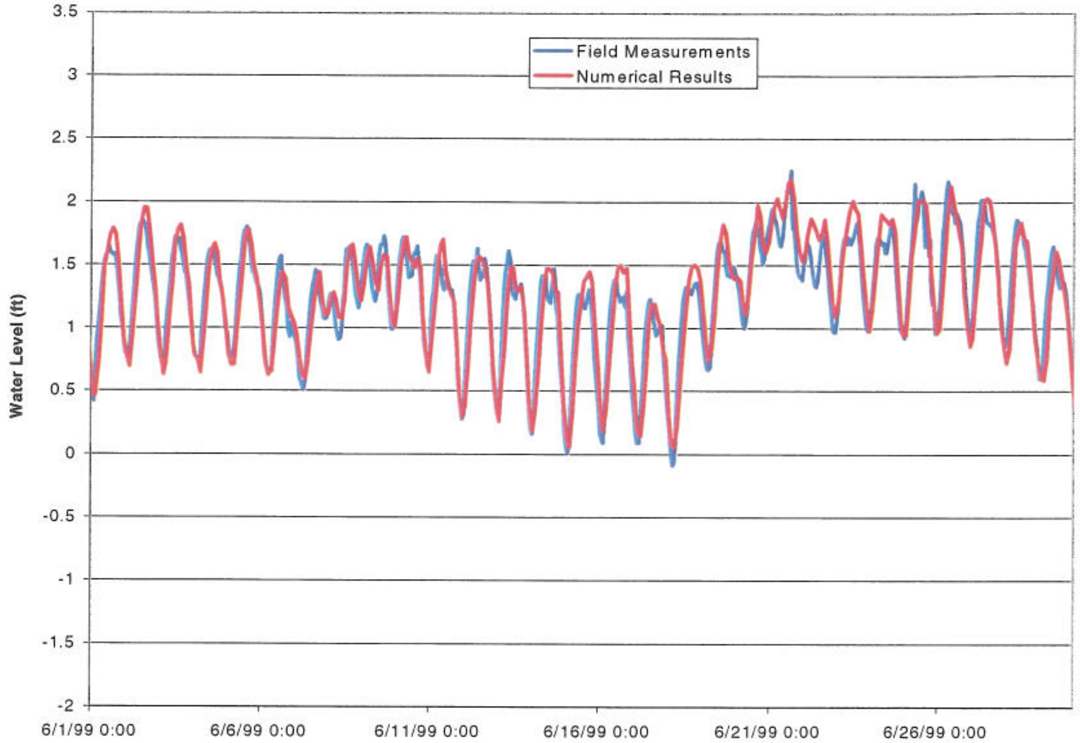

Figure 13: View of June 1999 for North Calcasieu Lake near Hackberry, LA (Gauge 08017095).

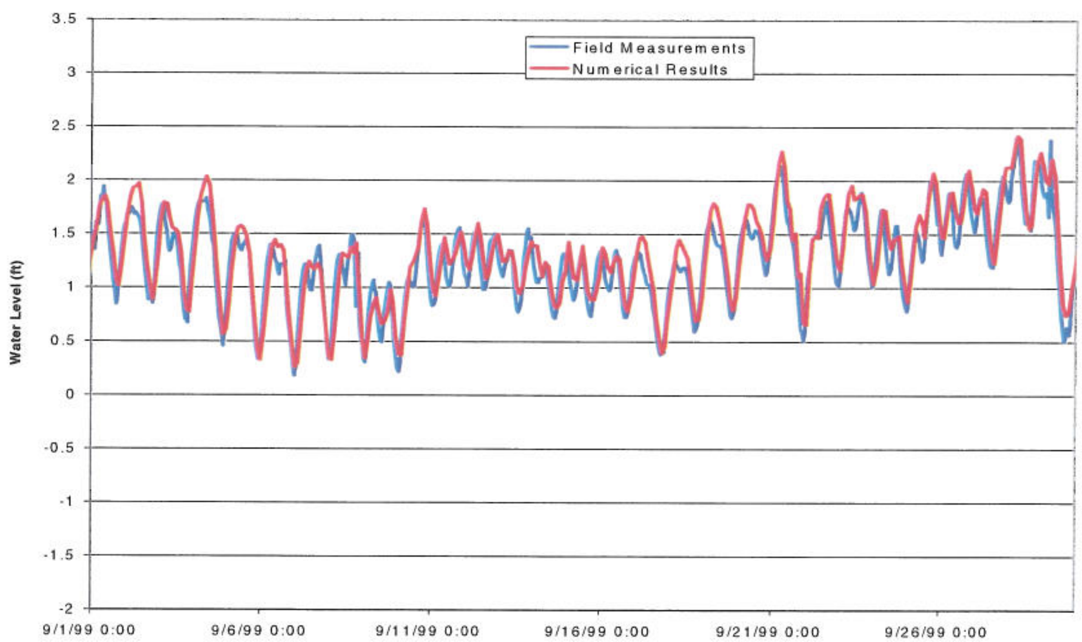

Figure 14: View of September 1999 for North Calcasieu Lake near Hackberry, LA (Gauge 08017095).

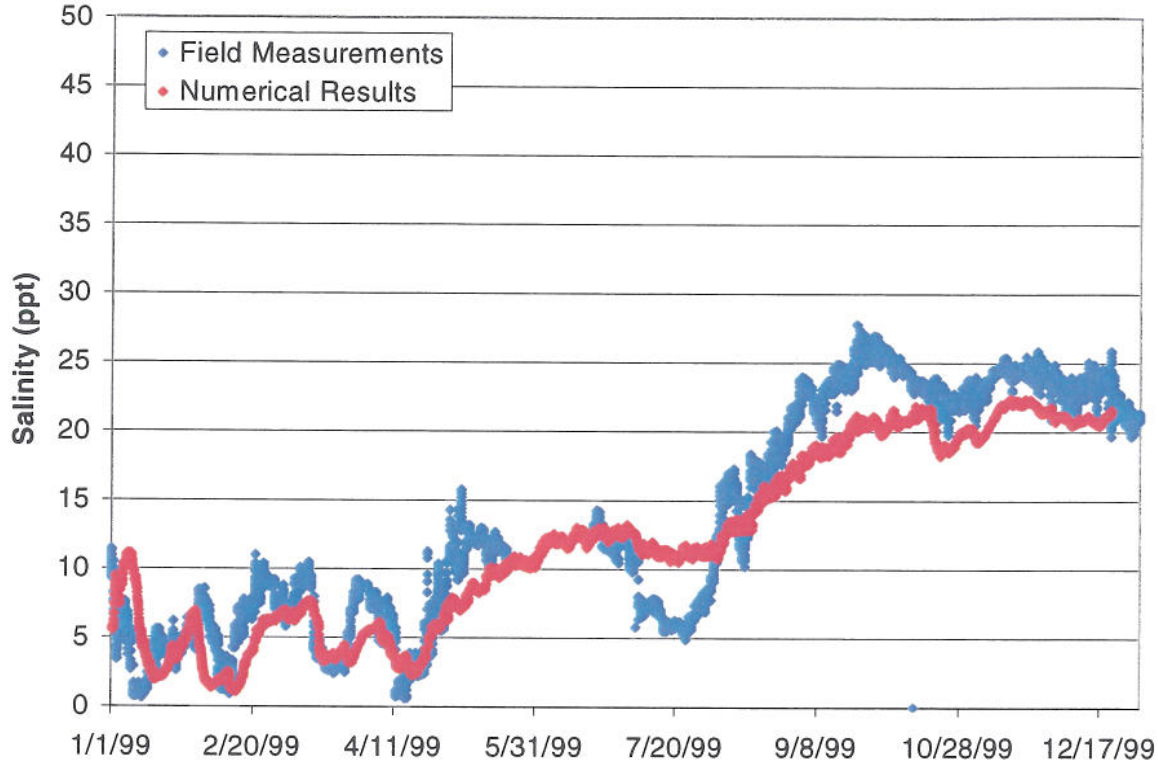

Figure 15: 1999 Salinity results of North Calcasieu Lake near Hackberry, LA (Gauge 08017095)

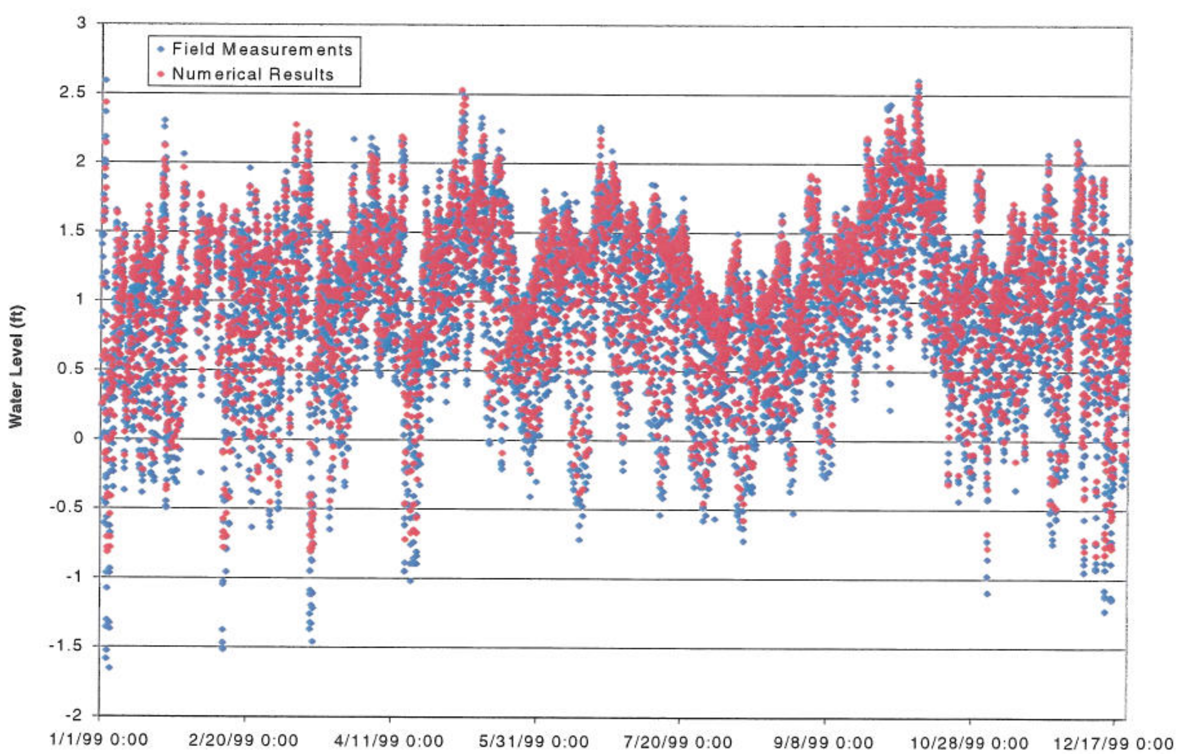

Figure 16: 1999 existing water level results for Calcasieu River at Cameron (Gauge 08017118)

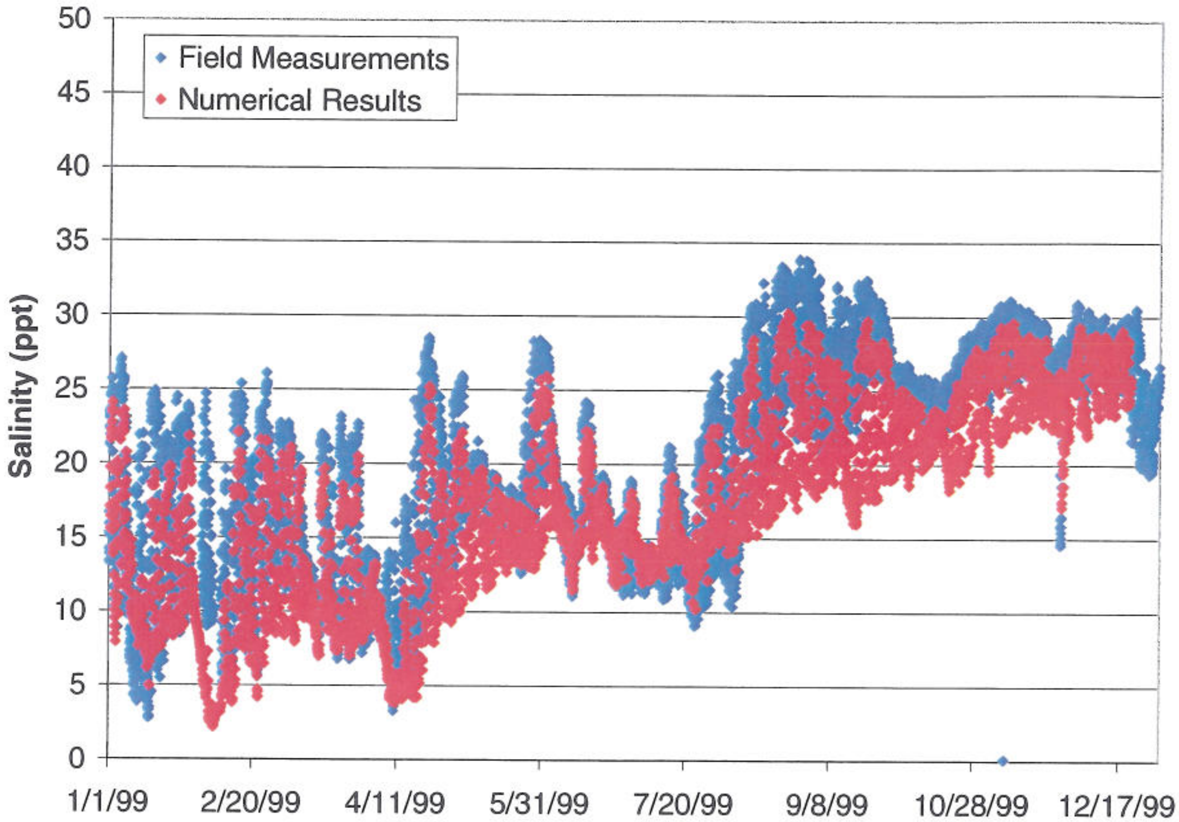

Figure 17: 1999 existing salinity results for Calcasieu River at Cameron (Gauge 08017118)

Table (1) Summary of error analysis

Station	Salinity Data			Water Level Data		
	Corr. Coeff. %	RMS Error ppt	RMS Error %	Corr. Coeff. %	RMS Error ft	RMS Error %
Station 09-2r	80.95%	3.41	14.09	89.23%	0.29	6.57
Station 095	88.64%	3.27	12.39	89.71%	0.32	5.65
Station 118	81.42%	4.86	14.37	90.40%	0.32	5.59
Station 17-1R	80.85%	4.61	17.47	88.07%	0.51	10.88
Johnson Bayou	85.15%	1.94	14.19	88.94%	0.37	8.92
Lower Sabine	82.06%	4.93	16.88	79.55%	0.60	9.51
Upper Sabine	81.22%	2.20	13.93	89.46%	0.49	8.33

The results of the H3D model can be presented in an animated fashion to better understand the dynamics of flow and salinity variation with time. The movies can present these patterns either for the entire Calcasieu-Sabine Basin as a plan view of a certain layer, or as a vertical slice along a specific location. Figure (18) shows a plan view of the salinity contour map at the water surface for the Calcasieu-Sabine estuary. Similarly, Figure (19) shows a salinity longitudinal profile of salinity along the Sabine ship channel.

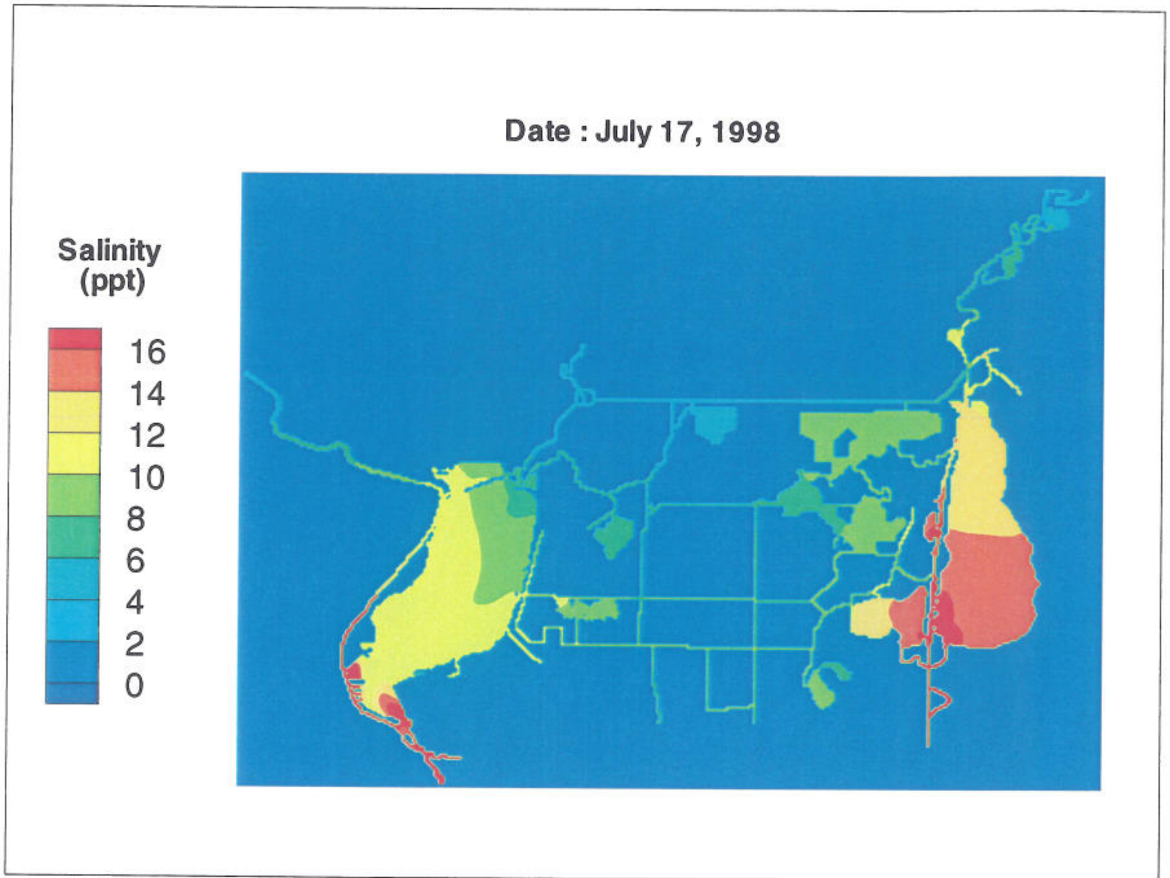

Figure 18: Typical model output showing a salinity map at the water surface for the Calcasieu-Sabine Basin

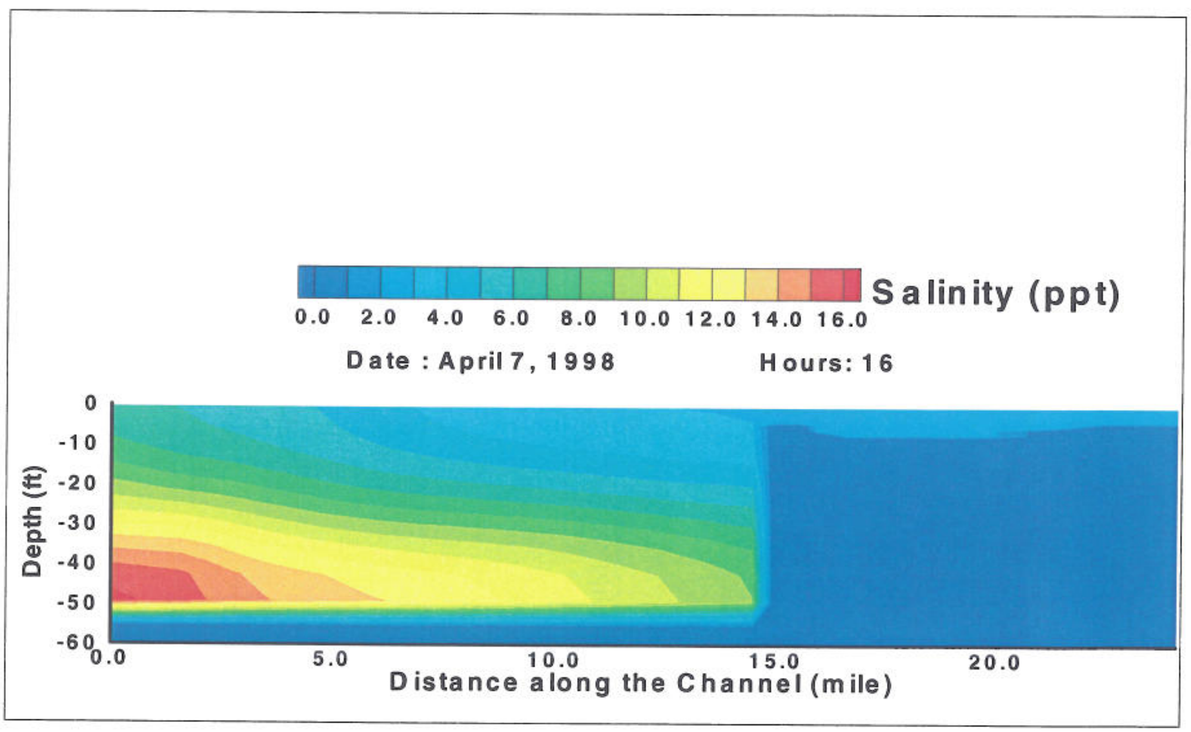

Figure 19: Typical model output showing longitudinal profile of salinity along the Sabine Ship Channel and Sabine Lake

BROWN LAKE MODEL SETUP

The large-scale model was used to provide boundary conditions for a high-resolution model for the project area. The high-resolution model for Brown Lake had a 25 × 25 meter uniform Cartesian grid in the horizontal direction, and 26 variable thickness layers in the vertical direction. The layout of the project area model is shown in Figure (20). Detailed bathymetry information for the project area was obtained from field surveys as shown in Figure (21) performed by C.H. Fenstermaker & Associates. The field survey consisted of retrieving strategic existing marsh elevations, elevations within the existing Alkali Ditch and Kelso Bayou, elevations around and adjacent to the Crab Gully structure beneath Hwy. 27, and elevation shots within Brown Lake itself. Information was also obtained from surveys performed by NRCS, which gave existing elevations between Hwy 27 and the Calcasieu Ship Channel around the Crab Gully box culvert structure. Brown lake, as shown in Figure (20), is connected to the GIWW through Alkali ditch, and to the Calcasieu ship channel through Kelso Bayou and Crab Gully Culverts. Added to the existing topography were the newly constructed impoundment cells within the Brown Lake area. The basin-wide model provided salinity, velocity components, and water level information at these three locations.

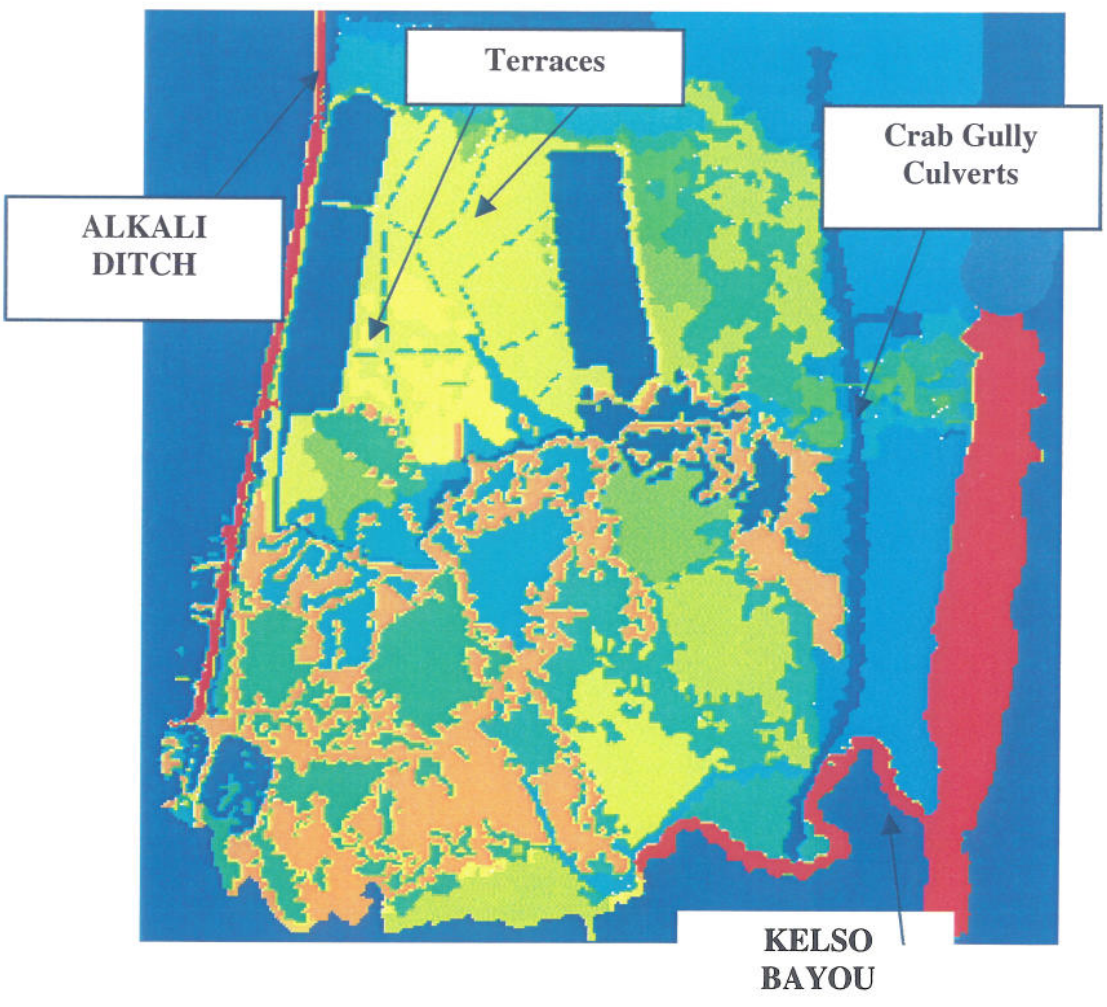

Figure 20: Layout of the project-area numerical model

Figure 21: Original Survey Data

PROPOSED RESTORATION PROJECT

The proposed restoration project (Figure 22) consists of a levee system (Figure 23) with three hydraulic structures. Structure 8 and 8-a (Figure 24) on the west side of the levee system consists of three 0.914-meter (36 inches) circular culverts that allow only water inflow to the system. A flap gate is installed on the inside end of the barrels to prevent water outflow. Structure 14 on the south side of the levee, as shown in Figure (25), consists of two 2.136-meter (7 ft) wide bays of variable crest weirs. Structure 15 on the south side of the levee system, as shown in Figures (26) and (27), consists of five 3.66-meters (12 ft) wide bays. Each bay has a 1.22-meter (48 inches) circular culvert. The inside end of each bay is divided into two variable crest corrugated Aluminum weirs with a 0.15 m (6 inches) vertical slot in between. The vertical slots are permanently open. Structures 14 and 15 allow for both inflow and outflow of water depending on the operation schedule. It is also proposed to construct a system of terraces. These terraces are intended to create a sediment build up over the years and eventually allow for vegetation growth.

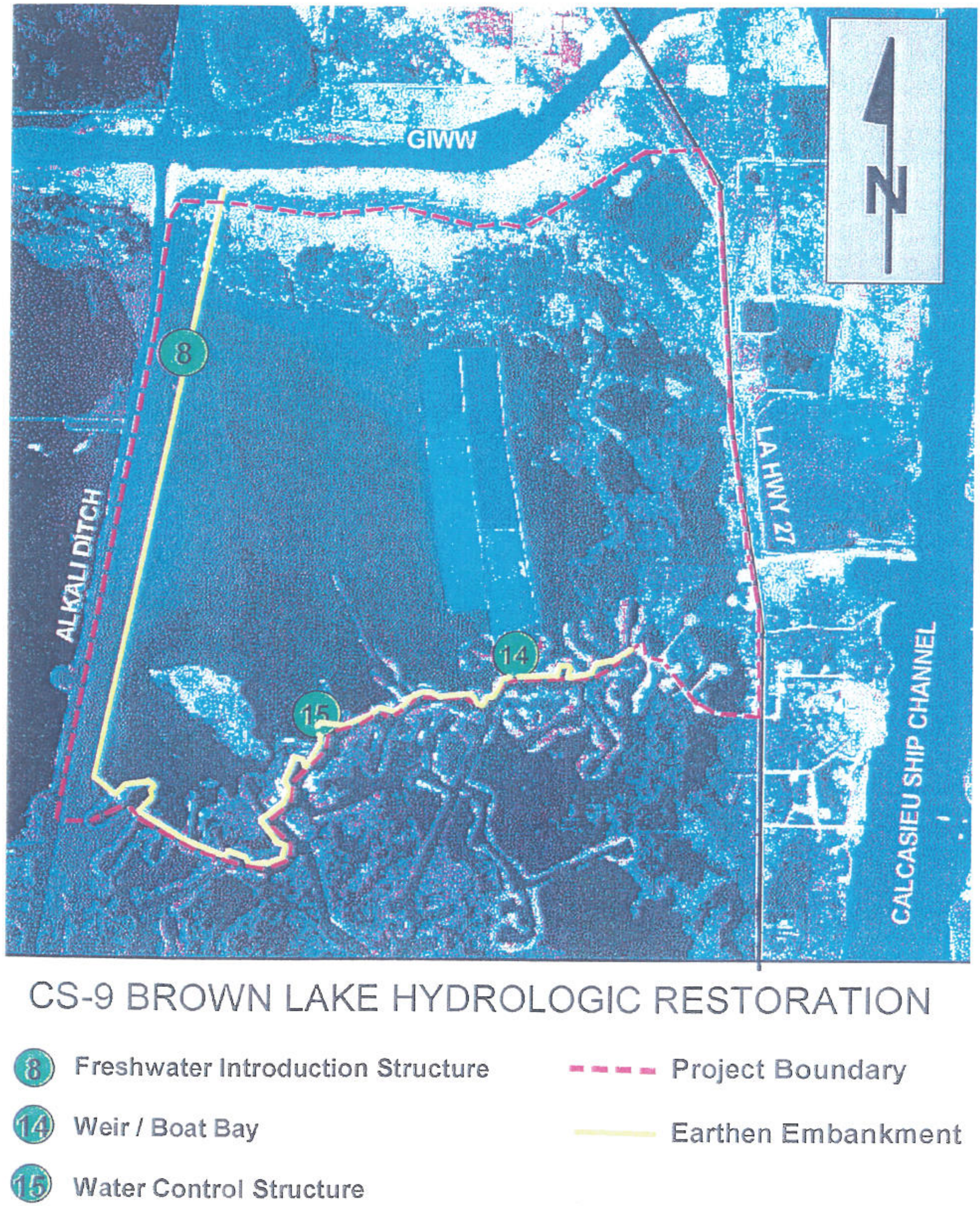

Figure 22: Proposed Restoration Project

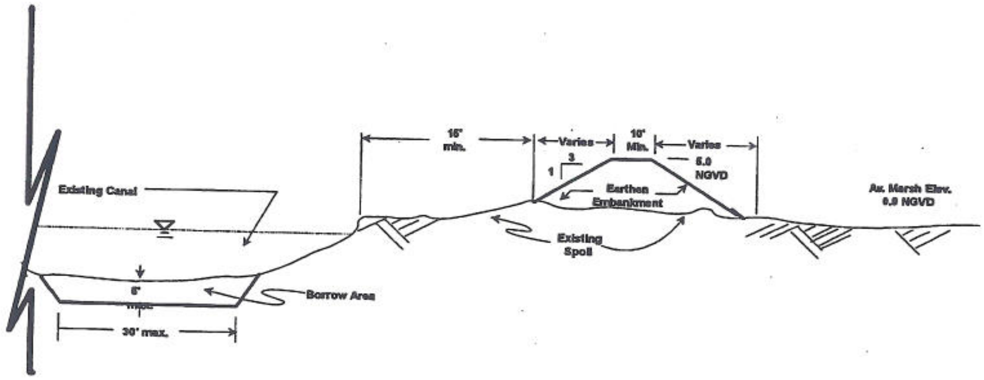

Figure 23: Proposed levee system

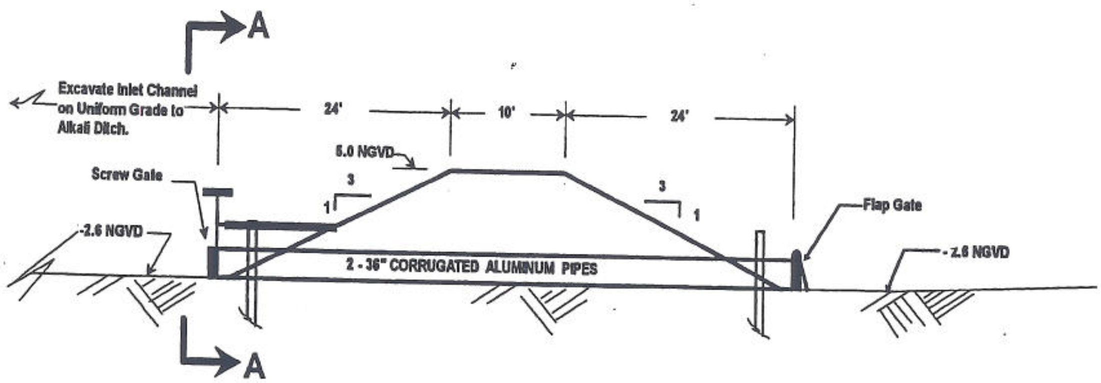

Figure 24: Structures 8 & 8A

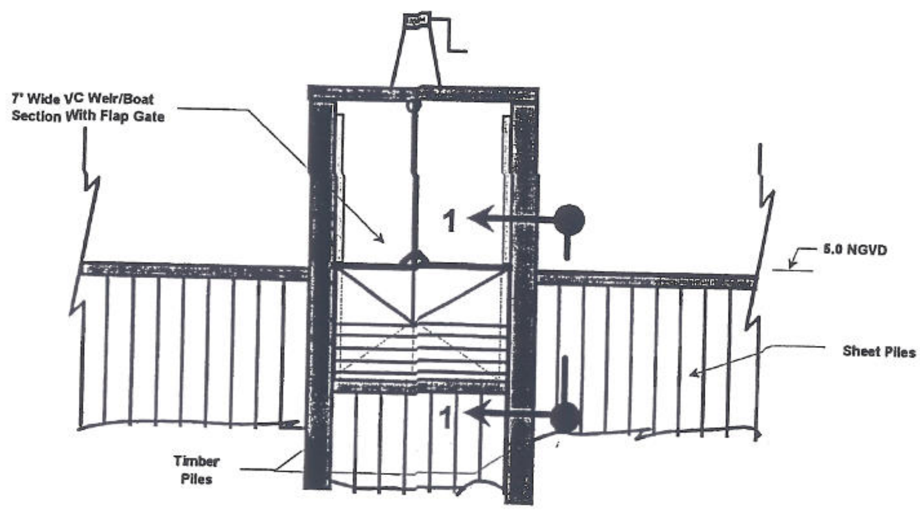

Figure 25: Structure 14

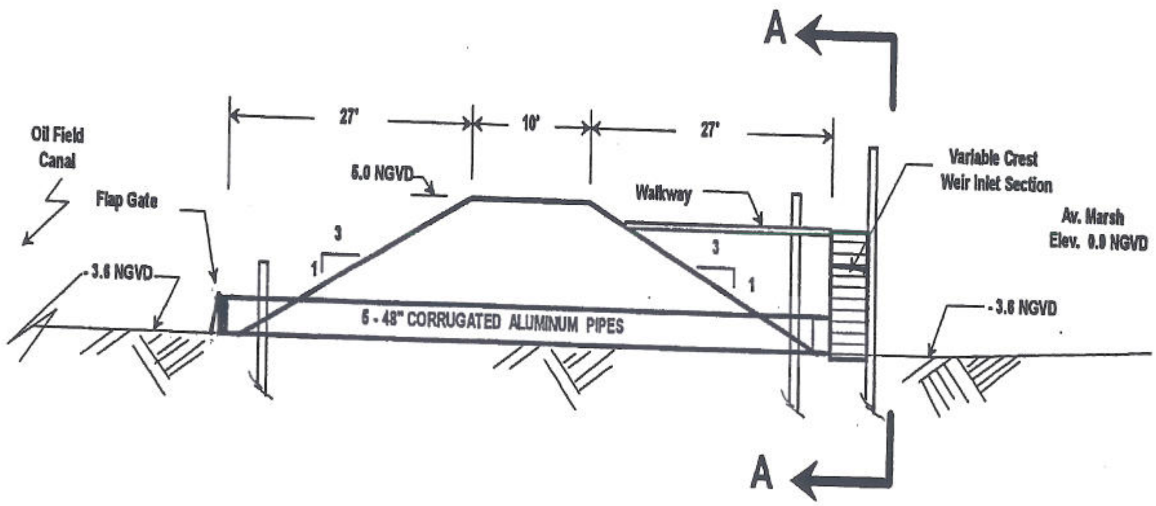

Figure 26: Structure 15

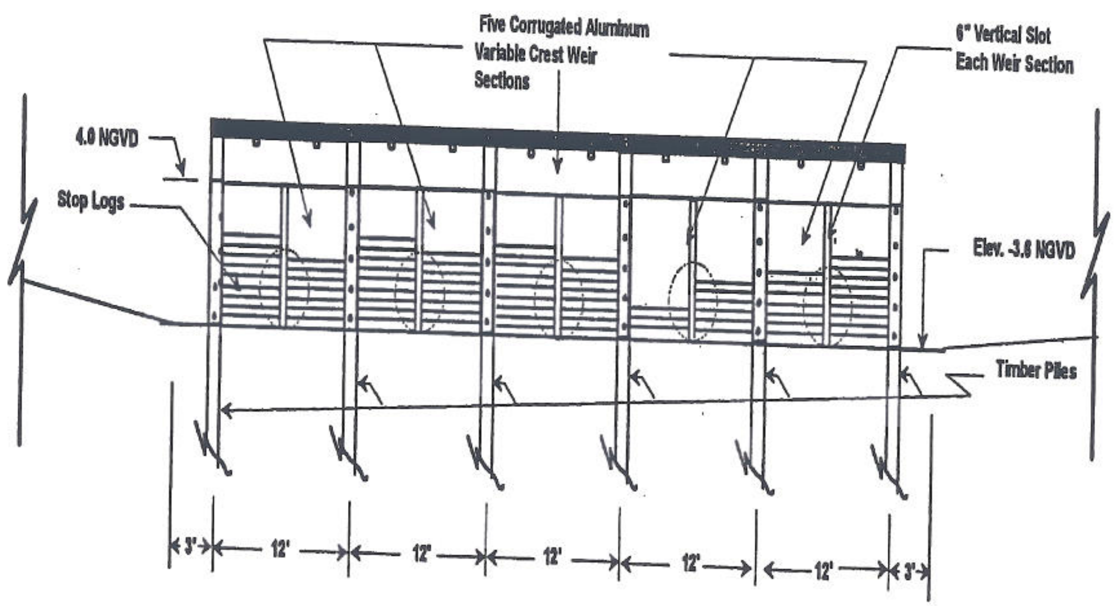

Figure 27: Structure 15 (Elevation View)

There are three modes of operations for the aforementioned structures: normal, drawdown, and emergency. These modes of operations are briefly described below:

Normal Operations

December-April
Structure 8- Screw Gate Open
Structure 14- Stop logs @ -1.1 NGVD, Flap Gate Open
Structure 15- 3 Pipes Stop Logs @ -0.1 NGVD, Flap Gates Open, 2 Pipes Stop Logs @ -3.6 NGVD, Flap Gates Open

May-August
Structure 8-Screw Gate Closed
Structure 14- Stop Logs @ -1.1 NGVD, Flap Gates Open

Structure 15- 3 Pipes Stop Logs @ -0.1 NGVD, Flap Gates Open, 2 Pipes Stop Logs @ -3.6 NGVD, Flap Gates Open

September-October
Structure 8- Screw Gates Closed
Structure 14- Stop Logs @ -0.1 NGVD, Flap Gate Operating
Structure 15- 3 Pipes Stop Logs @ -0.1 NGVD, Flap Gates Operating, 1 Pipe Stop Logs @ -3.6 NGVD, Flap Gate Operating, 1 Pipe Stop Logs @ -3.6 NGVD, Flap Gate Open

November
Structure 8- Screw Gate Closed
Structure 14- Stop Logs @ -1.1 NGVD, Flap Gate Operating
Structure 15- 3 Pipes Stop Logs @ -0.1 NGVD, Flap Gates Operating, 2 Pipes Stop Logs @ -3.6 NGVD, Flap Gates Open

Drawdown Phase

December-January
Structure 8- Screw Gate Open
Structure 14- Stop logs @ -1.1 NGVD, Flap Gate Open
Structure 15- 3 Pipes Stop Logs @ -0.1 NGVD, Flap Gates Open, 2 Pipes Stop Logs @ -3.6 NGVD, Flap Gates Open

February-June
Structure 8-Screw Gate Closed
Structure 14- Stop Logs @ -1.1 NGVD, Flap Gates Operating
Structure 15- 3 Pipes Stop Logs @ -0.1 NGVD, Flap Gates Operating, 2 Pipes Stop Logs @ -3.6 NGVD, Flap Gates Operating

July-August
Structure 8- Screw Gates Closed
Structure 14- Stop Logs @ -0.1 NGVD, Flap Gate Operating
Structure 15- 3 Pipes Stop Logs @ -0.1 NGVD, Flap Gates Operating, 2 Pipe Stop Logs @ -3.6 NGVD, Flap Gates Open

September-October
Structure 8- Screw Gate Closed
Structure 14- Stop Logs @ -1.1 NGVD, Flap Gate Operating
Structure 15- 3 Pipes Stop Logs @ -0.1 NGVD, Flap Gates Operating, 1 Pipes Stop Logs @ -3.6 NGVD, Flap Gate Operating, 1 Pipe Stop Logs @ -3.6 NGVD, Flap Gate Open

November
Structure 8- Screw Gate Closed
Structure 14- Stop Logs @ -1.1 NGVD, Flap Gate Operating
Structure 15- 3 Pipes Stop Logs @ -0.1 NGVD, Flap Gates Operating, 2 Pipe Stop Logs @ -3.6 NGVD, Flap Gates Open

Emergency Phase

When water salinities >15 ppt (100 feet inside the management unit at structure 15), the structures will operate as follows:

Structure 8

When salinities in the Alkali Ditch are 5 ppt less than or equal to the salinities in the project area, the screw gate may be opened

Structure 14

Variable crest weir will remain at -1.1 NGVD and the flap gate operating

Structure 15

Stop logs in the variable crest weirs on 3 barrels will remain at 0.1 NGVD, and the flap gates operating. Stop logs in the variable crest weir on one of the barrels will be set at -3.6 NGVD, and the flap gate operating. Stop logs in the variable crest weir will set at 1.9 NGVD on the remaining barrel and the flap gate open

MODEL VALIDATION

The model was used to reproduce the existing conditions of the water level and salinity patterns within and around the project area. The model's boundaries were nested to the previously mentioned basin wide model. These boundary inputs are shown in Figure (28). Four stations within the project area were used to validate the model. Figure (29) shows the locations of these stations. The model results were compared to field observations of water level and salinity in the year of 1998 as shown in Figures (30) through (37). The comparison between the field measurements and calculations showed good agreement. The same level of agreement between field measurements and calculations was observed for the year of 1999 as shown in Figures (38) through (45). It should be noted that all model parameters from the basin-wide numerical model were used for the high-resolution project-area model without any adjustments.

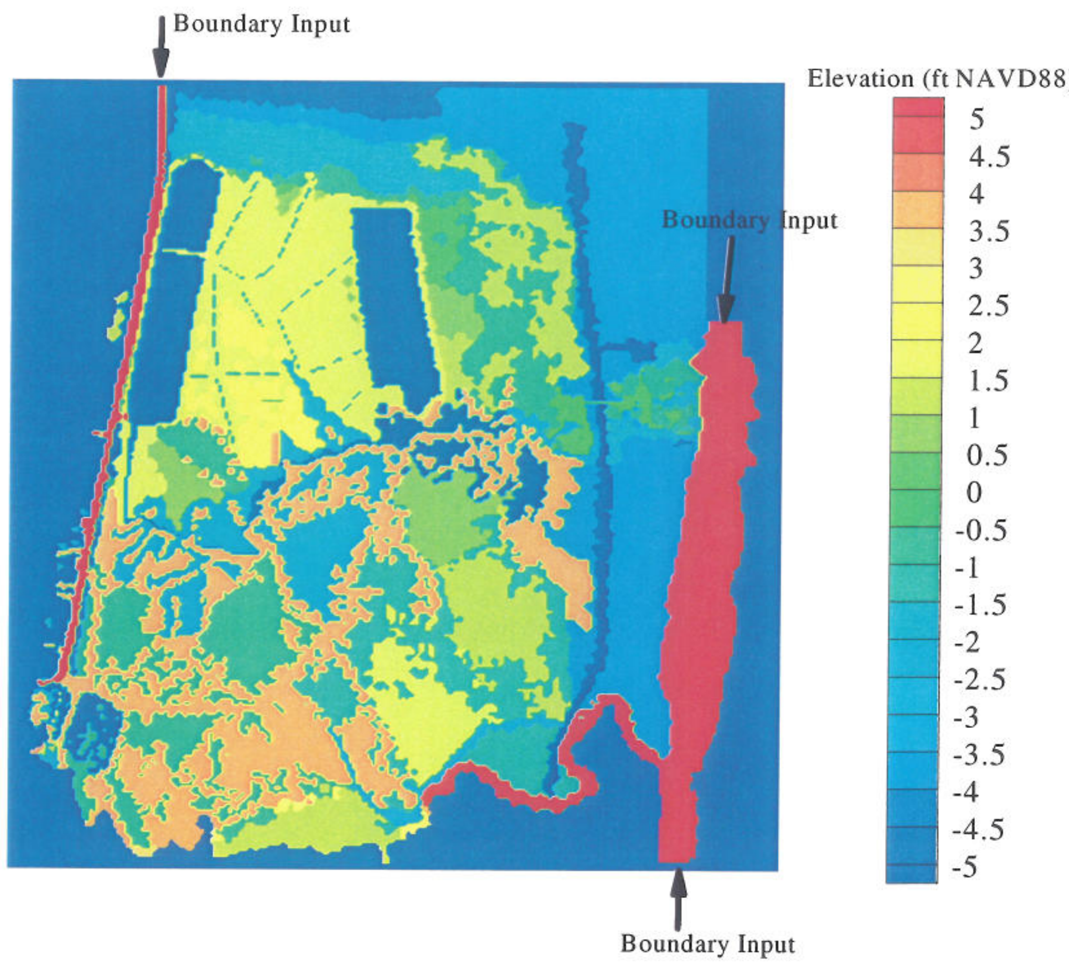

Figure 28: Boundary inputs

Figure 29: Gauging stations used for calibration

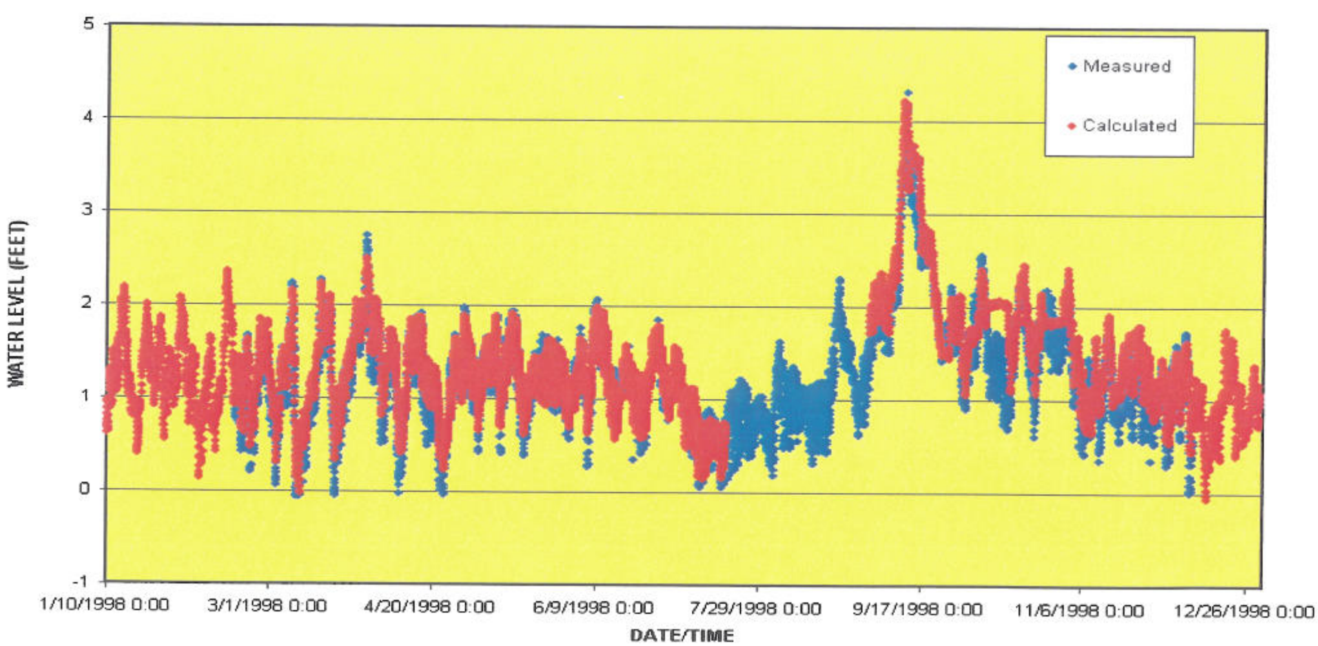

Figure 30: 1998 Without Project (Water Level), CS09-02

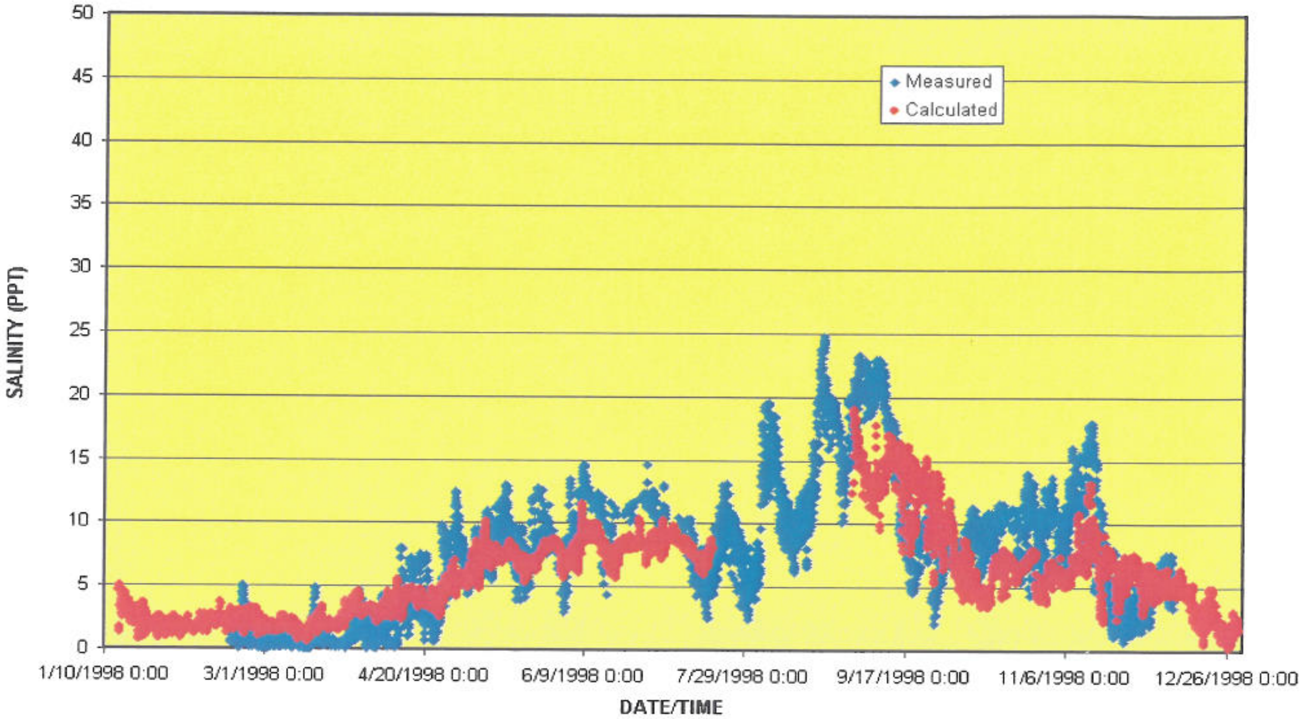

Figure 31: 1998 Without Project (Salinity), CS09-02

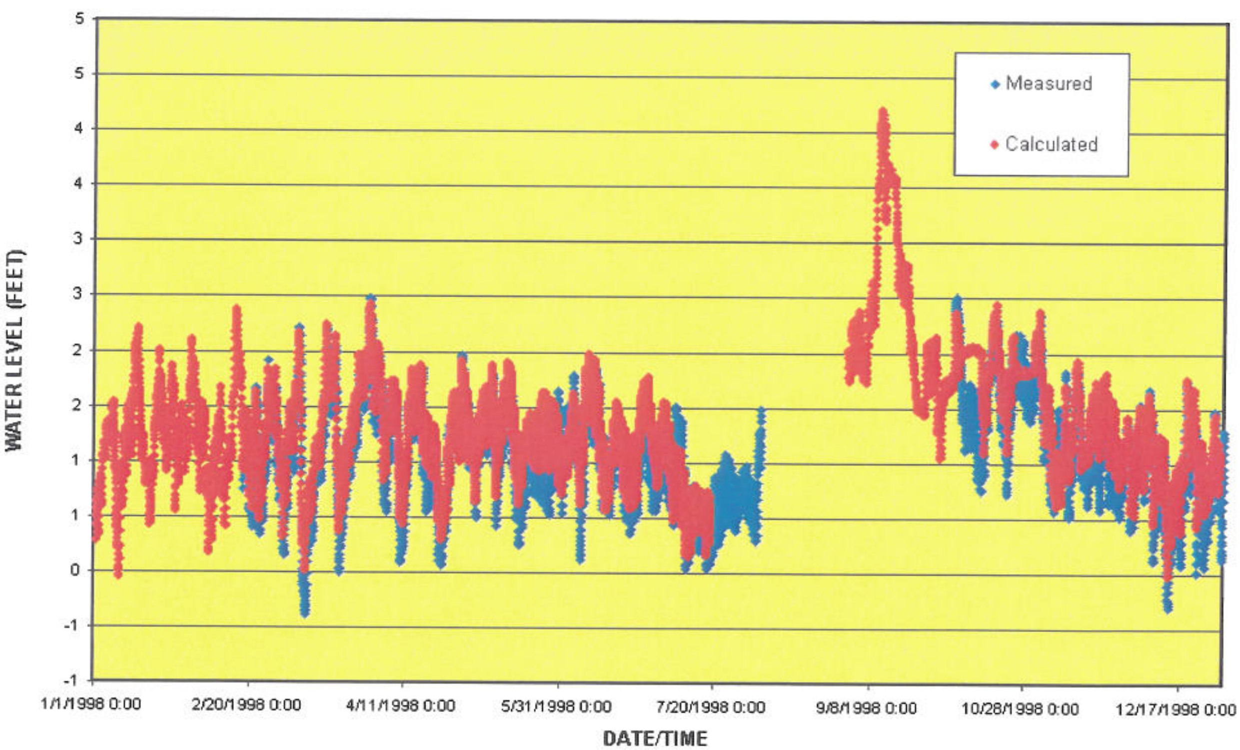

Figure 32: 1998 Without Project (Water Level), CS09-04

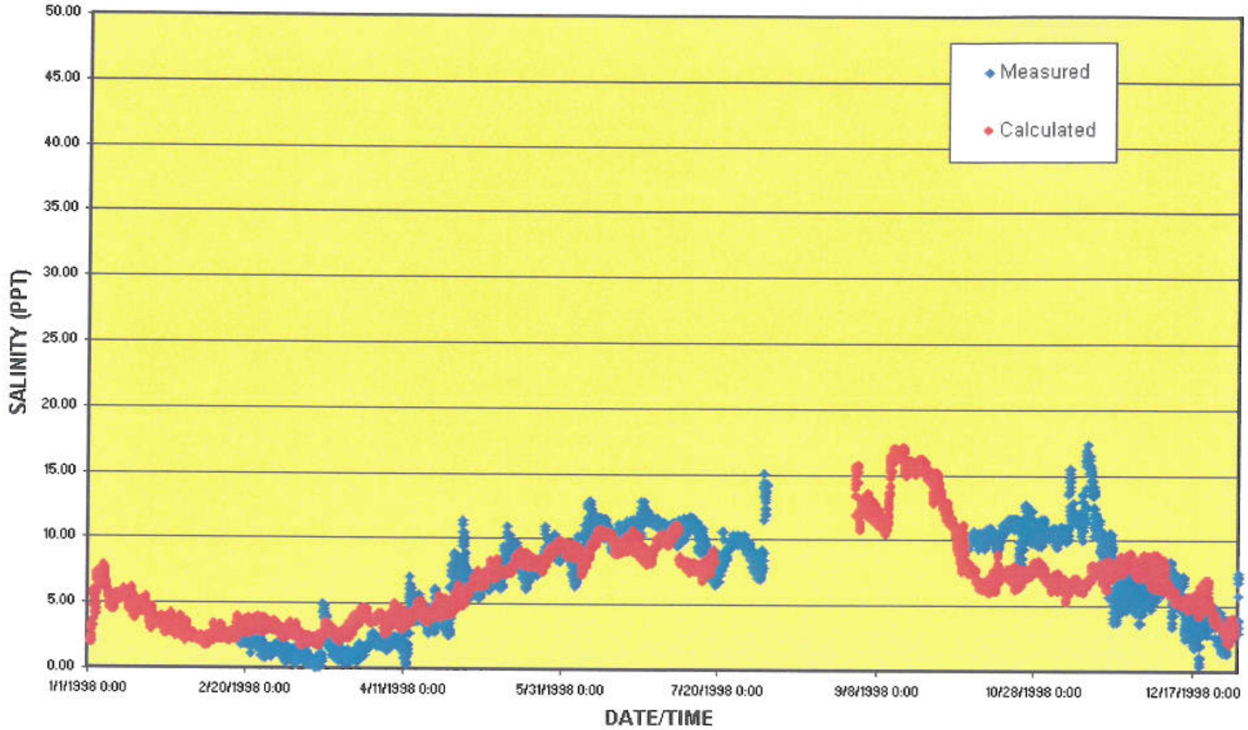

Figure 33: 1998 Without Project (Salinity), CS09-04

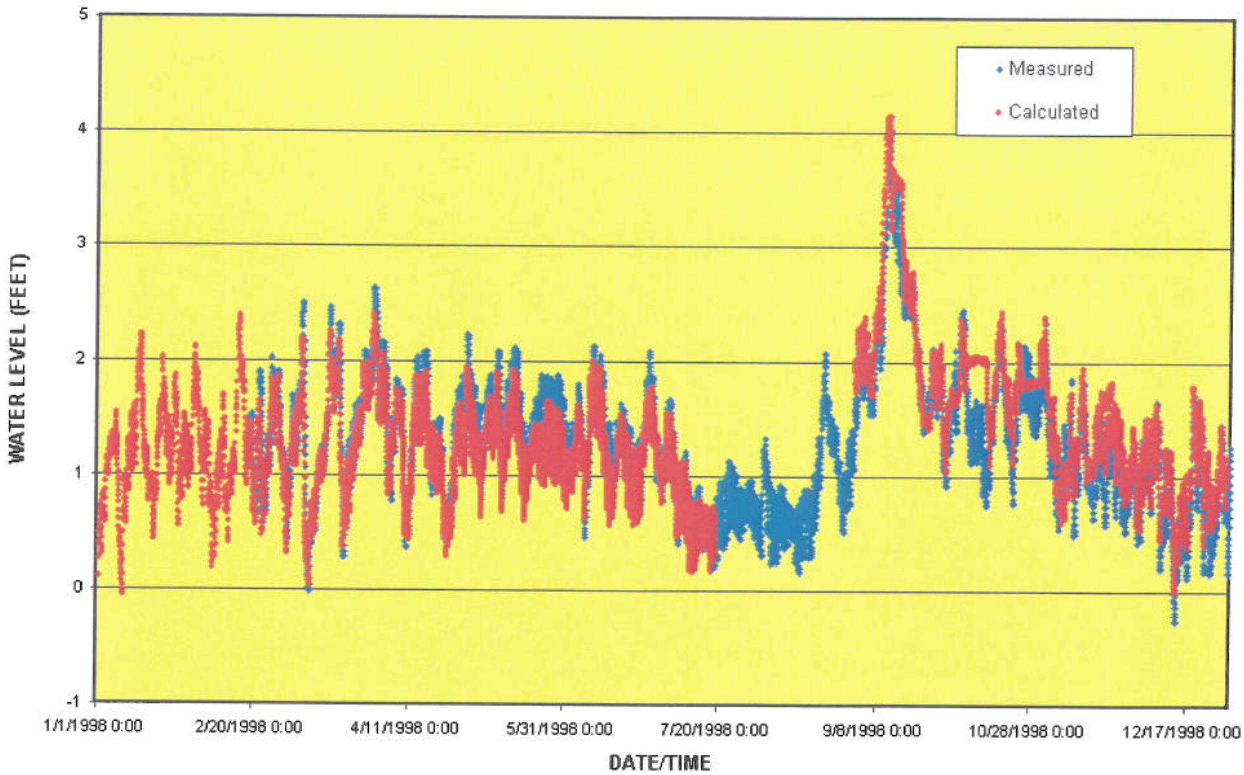

Figure 34: 1998 Without Project (Water Level), CS09-18

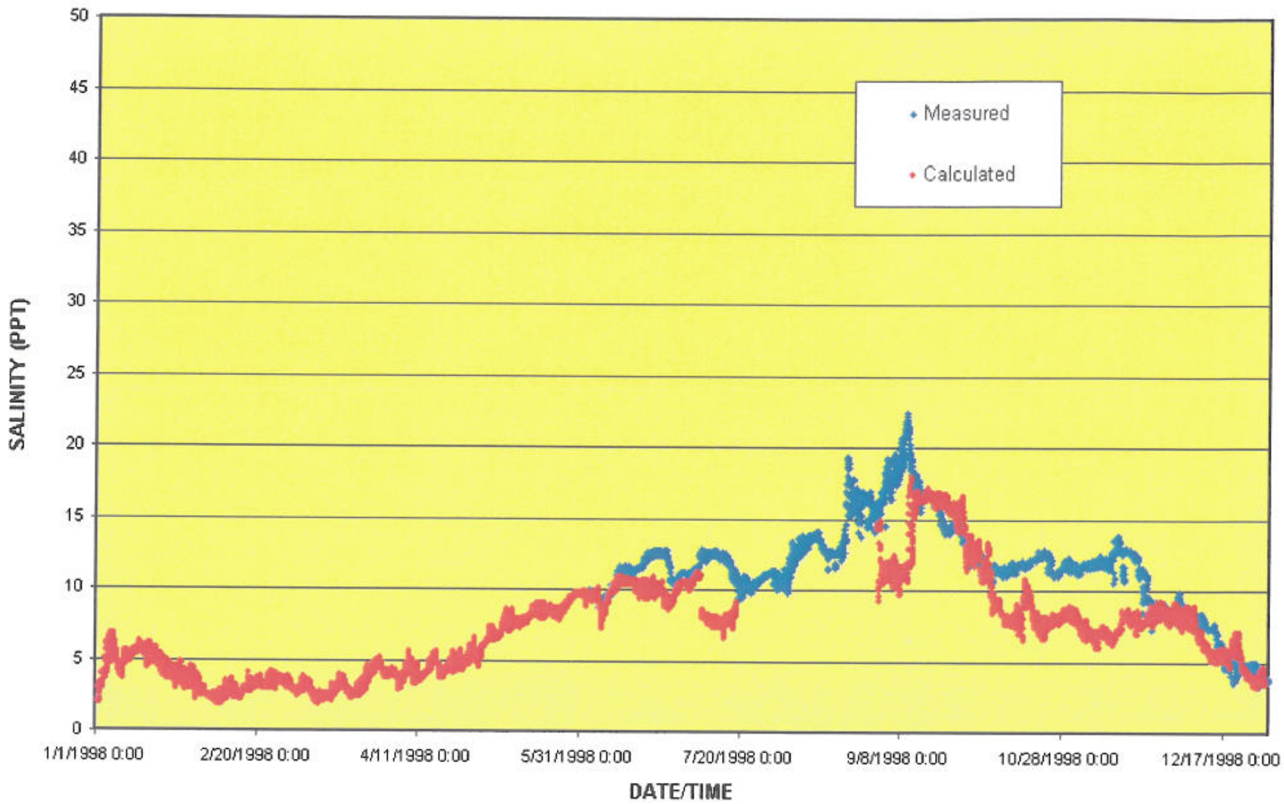

Figure 35: 1998 Without Project (Salinity), CS09-18

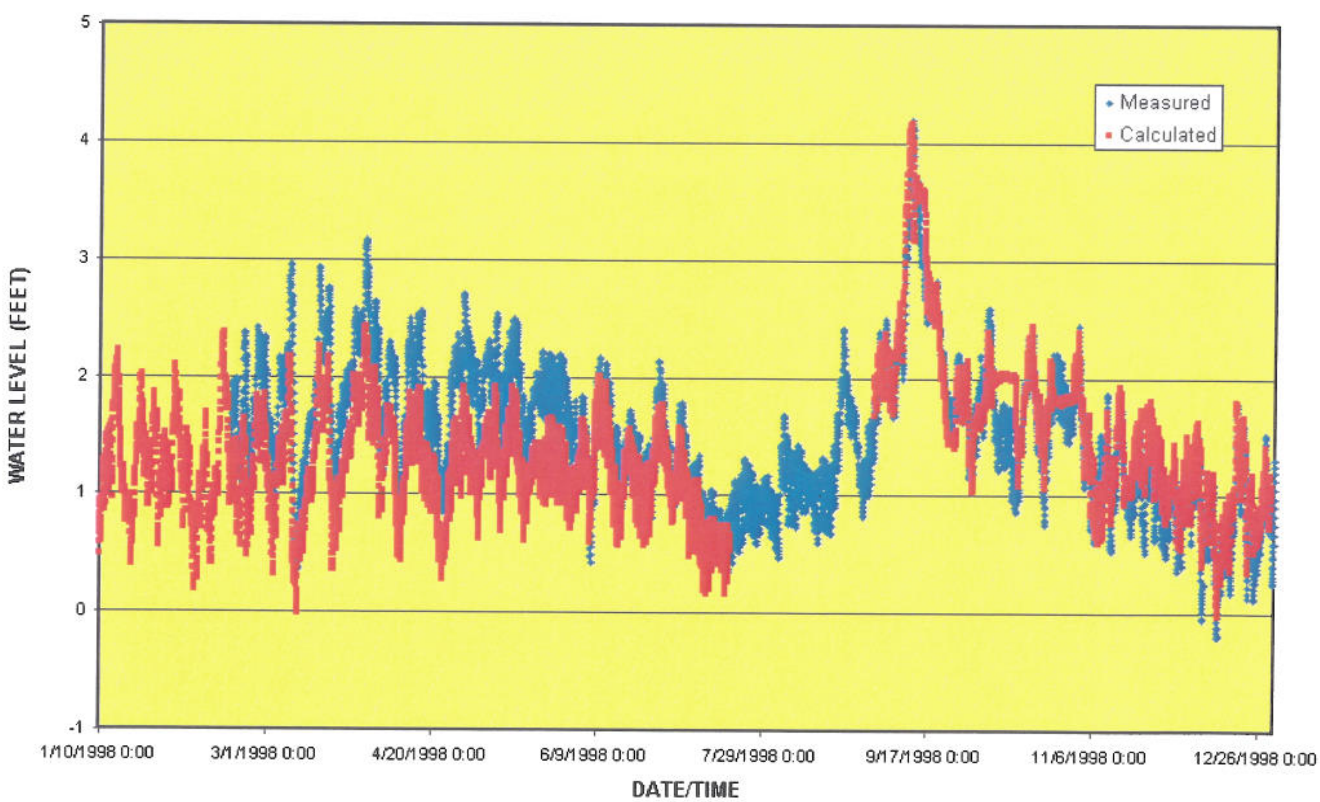

Figure 36: 1998 Without Project (Water Level), CS09-21

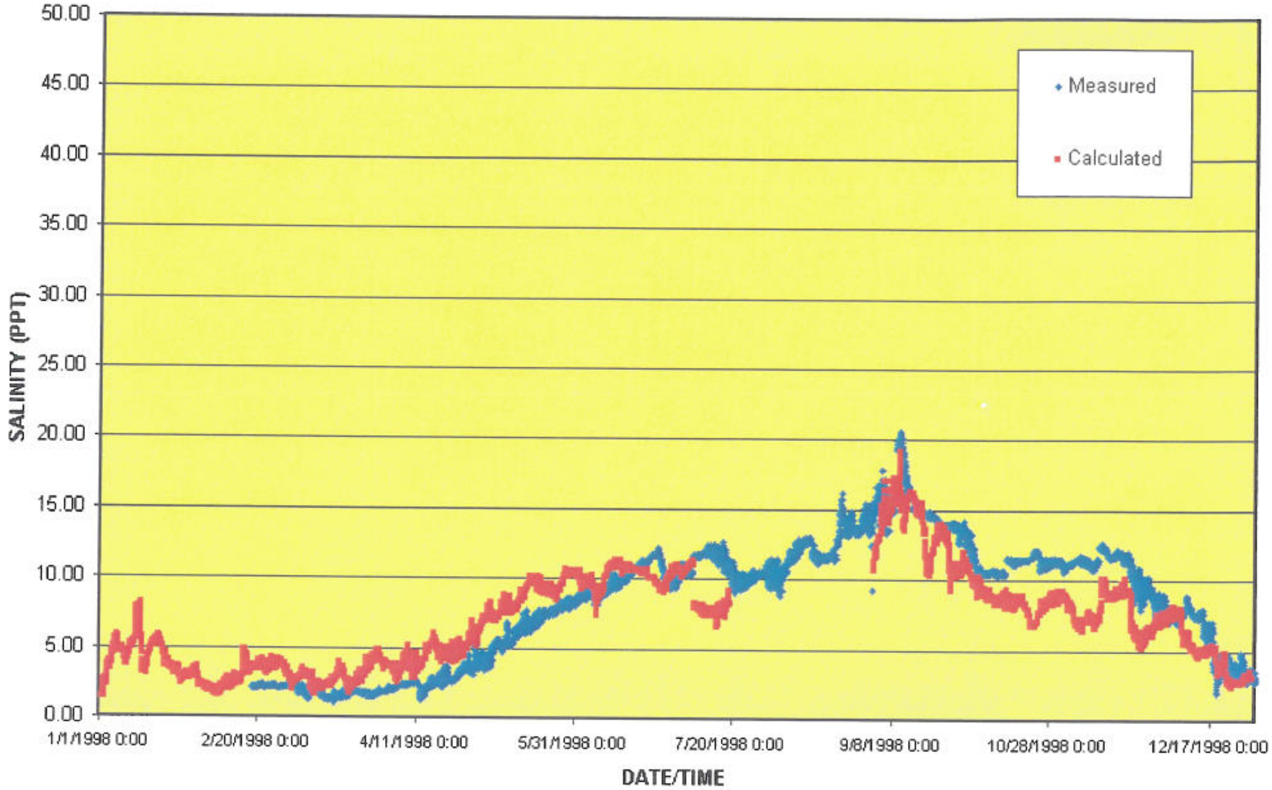

Figure 37: 1998 Without Project (Salinity), CS09-21

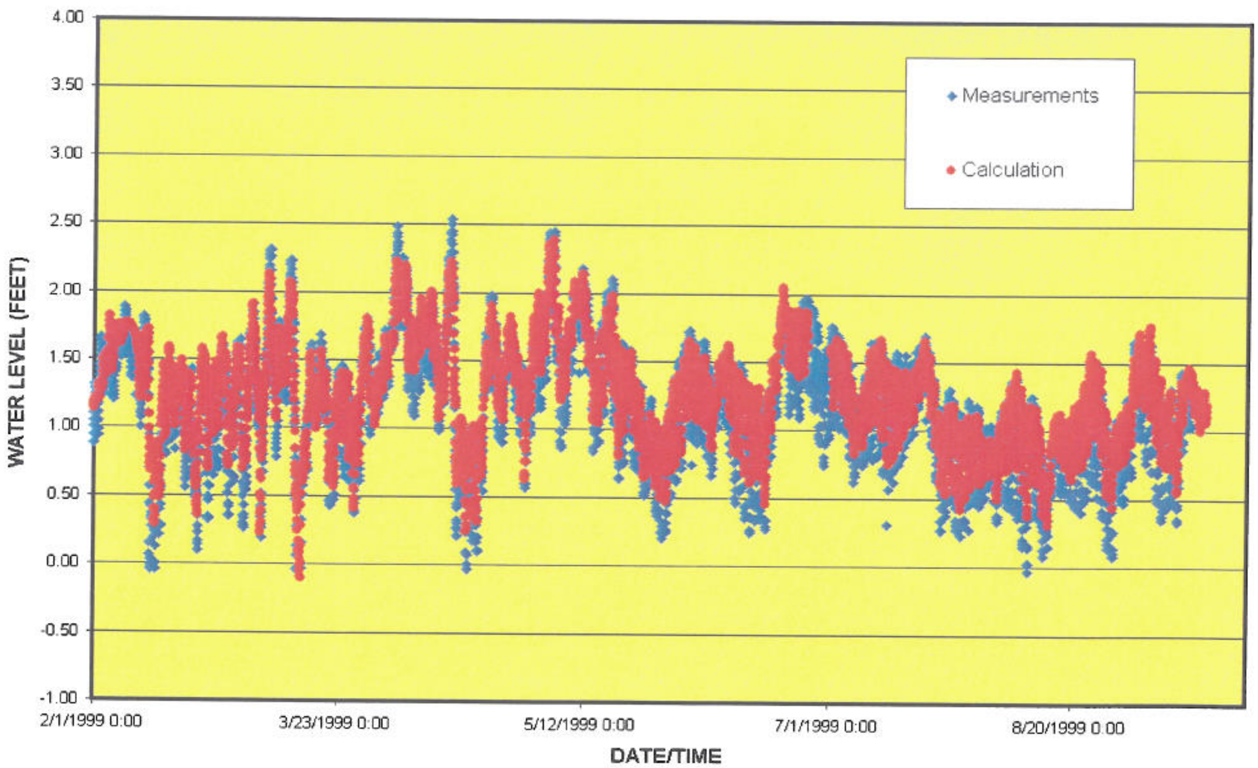

Figure 38: 1999 Without Project (Water Level), CS09-02

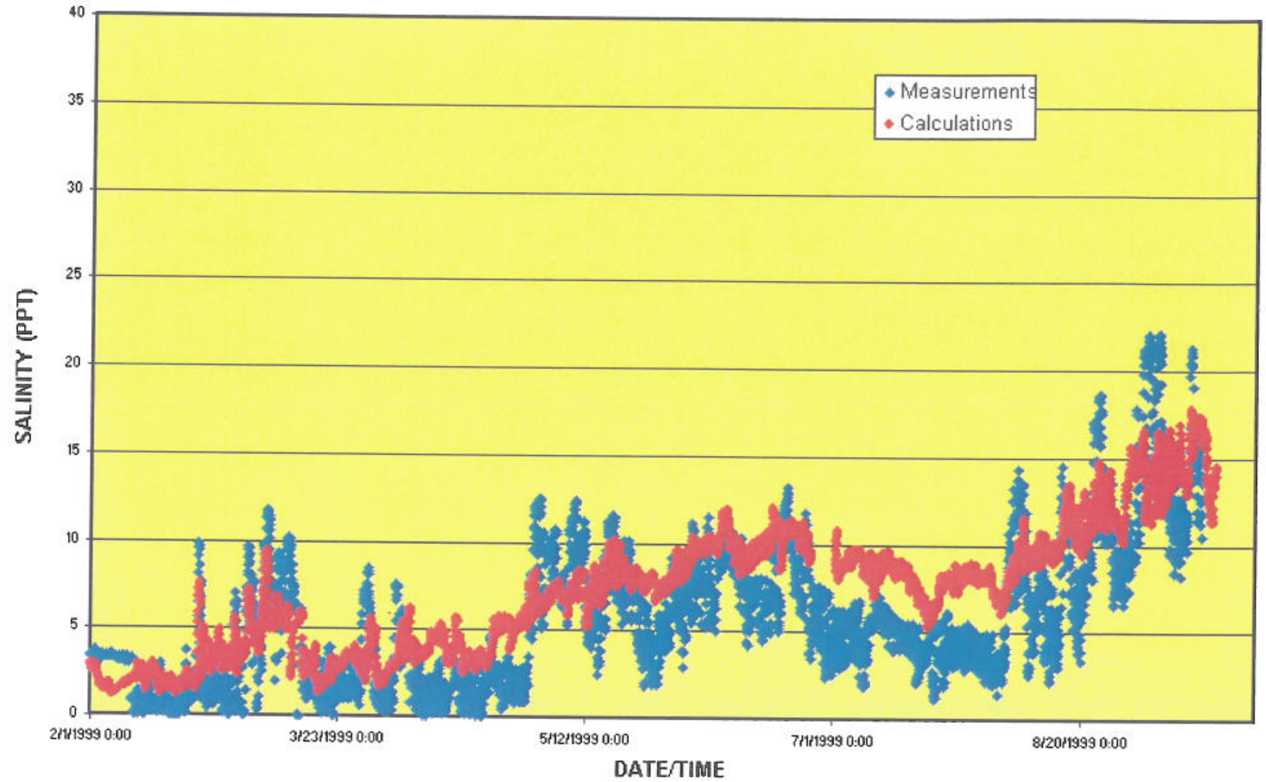

Figure 39: 1999 Without Project (Salinity), CS09-02

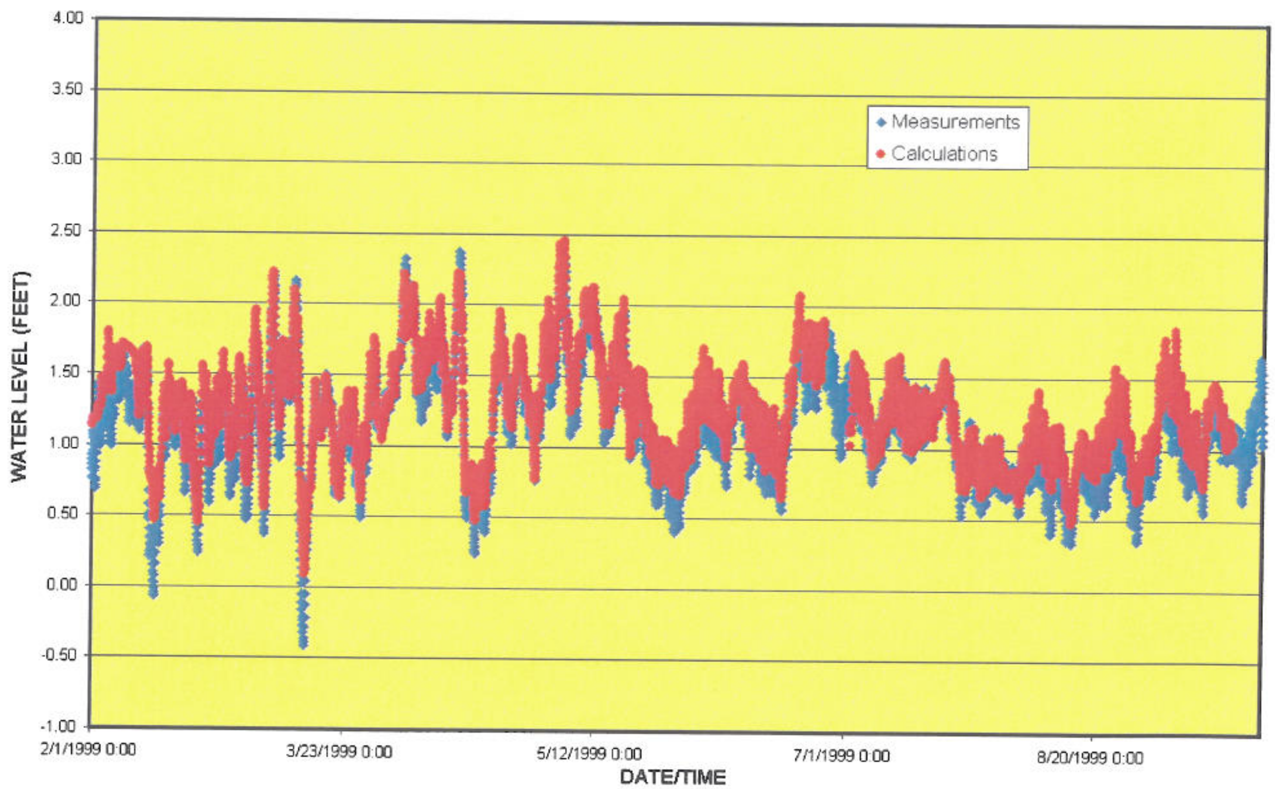

Figure 40: 1999 Without Project (Water Level), CS09-04

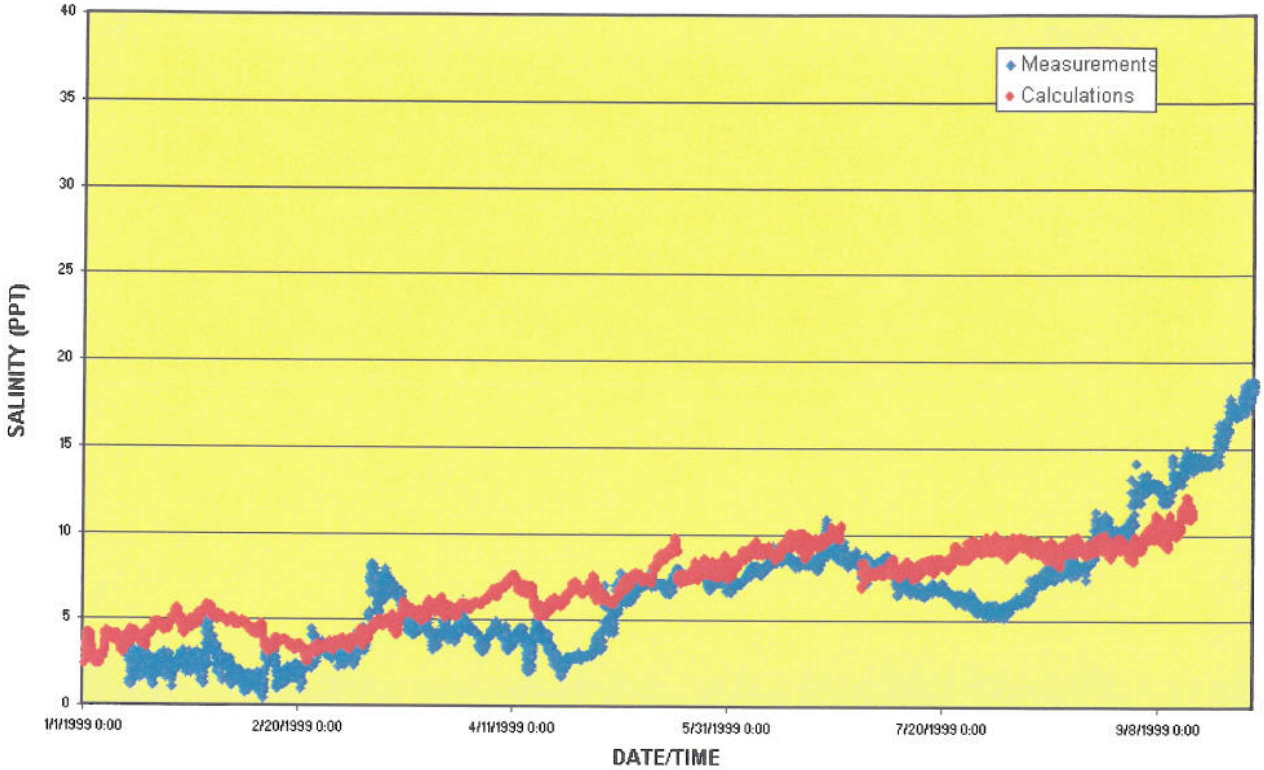

Figure 41: 1999 Without Project (Salinity), CS09-04

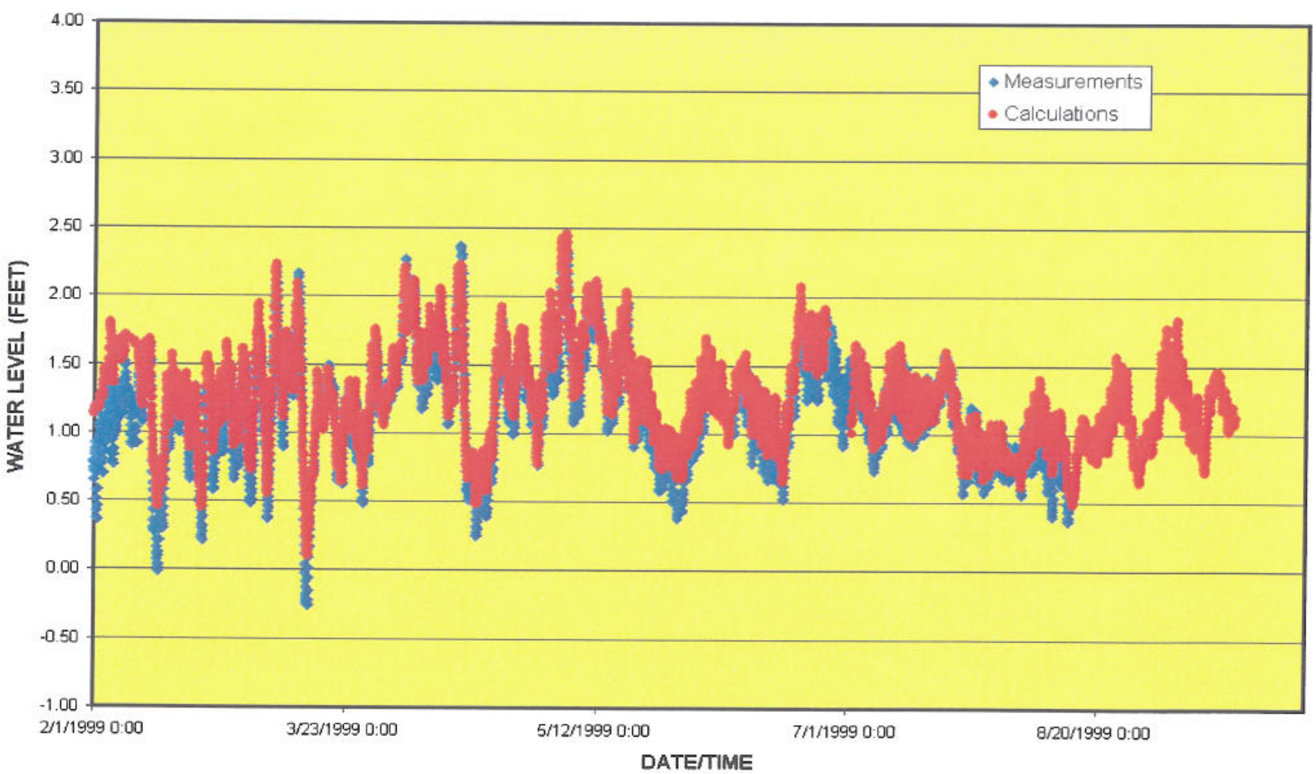

Figure 42: 1999 Without Project (Water Level), CS09-18

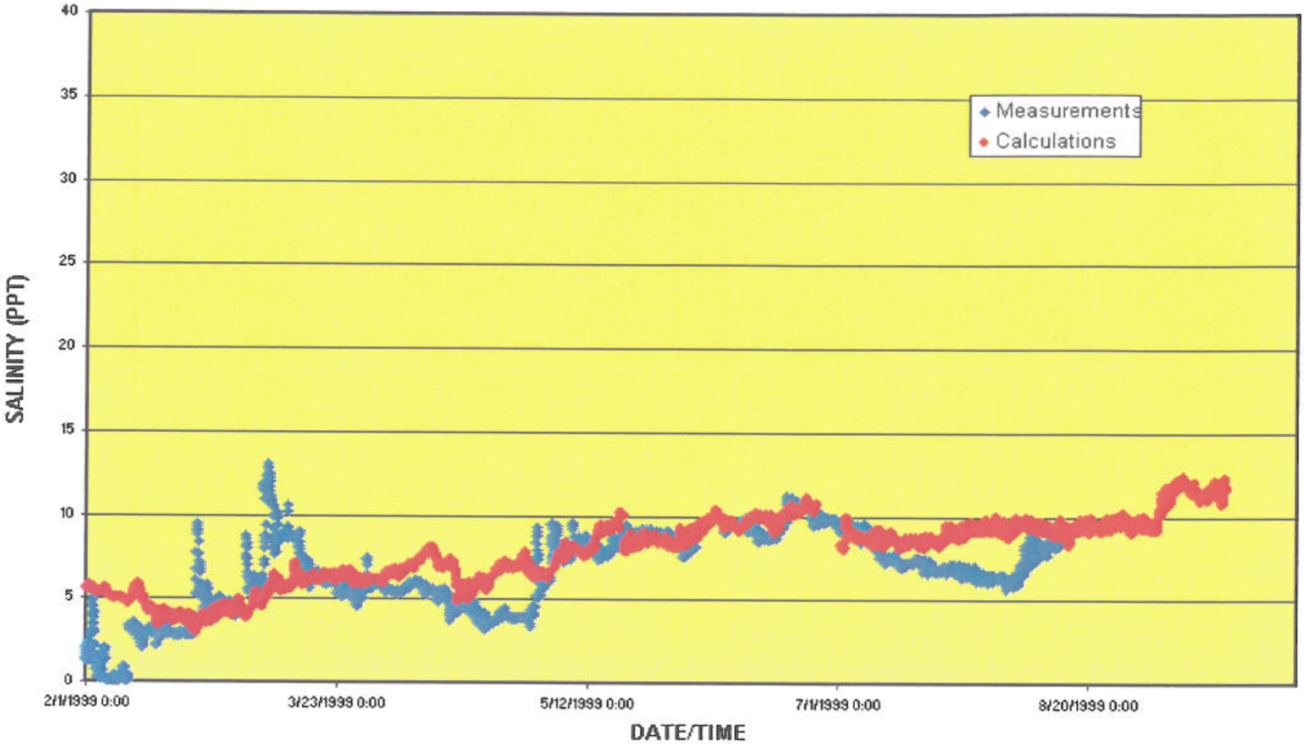

Figure 43: 1999 Without Project (Salinity), CS09-18

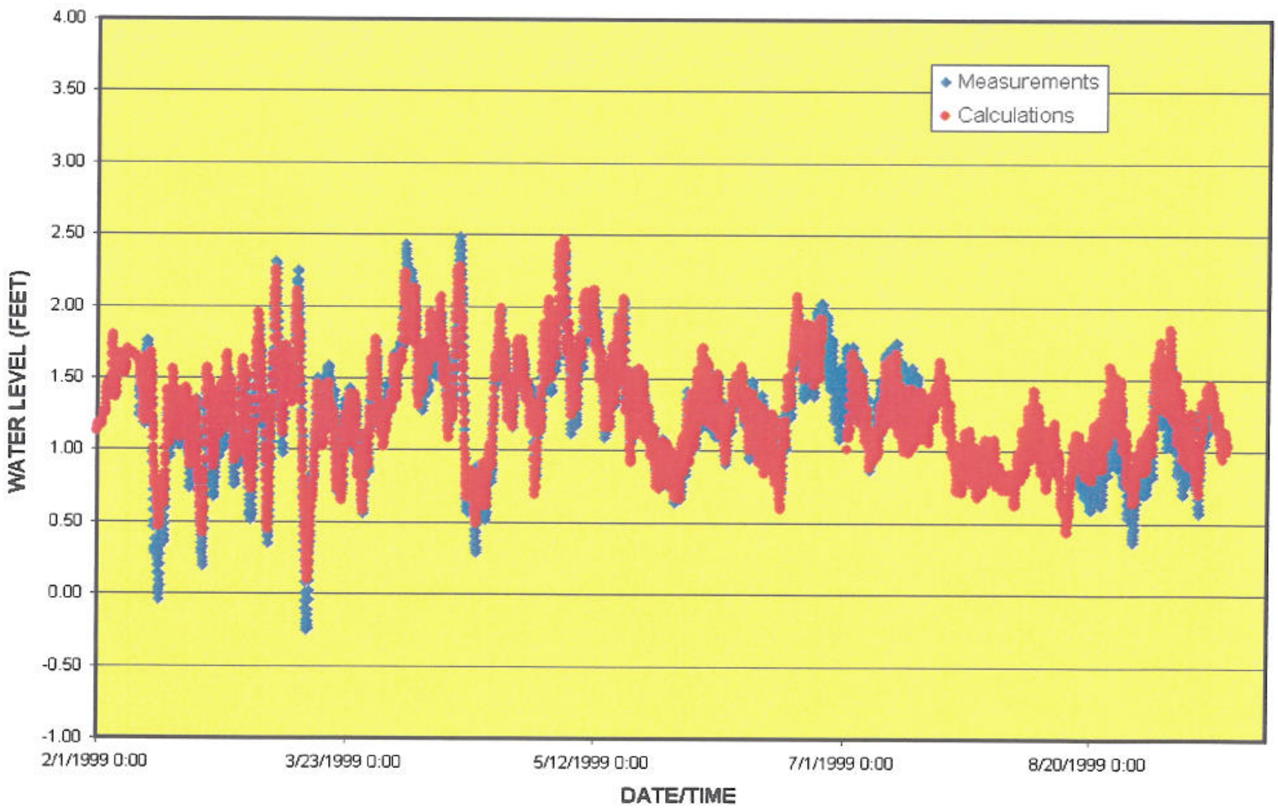

Figure 44: 1999 Without Project (Water Level), CS09-21

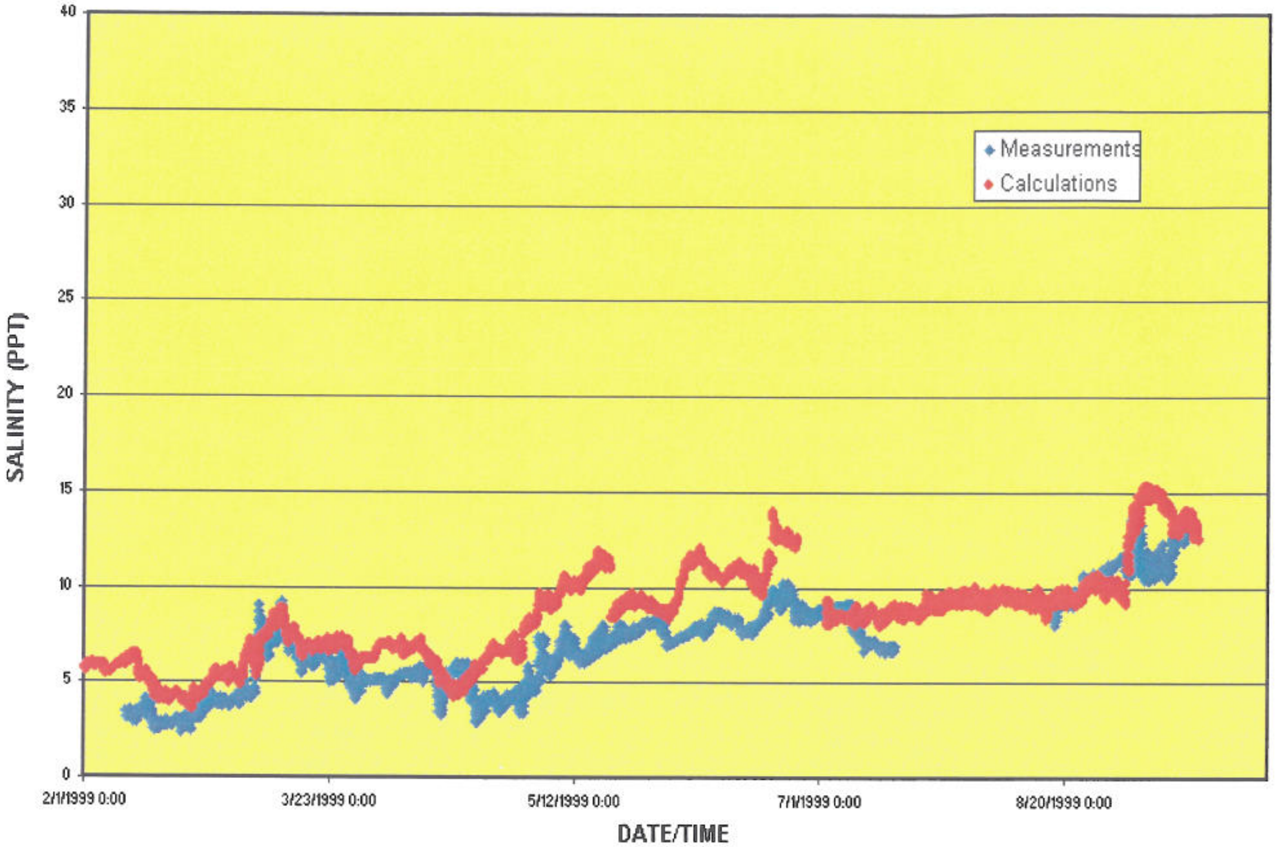

Figure 45: 1999 Without Project (Salinity), CS09-21

ASSESSMENT OF THE RESTORATION PROJECT

The restoration project is intended to reduce the tidal fluctuations, flooding durations, and the salinity level within the project area. The hydraulic structures are operated under three modes: normal, drawdown, and emergency to primarily achieve these goals. The operational modes were previously described. More details about the operation modes can be found in the NRCS plan/environmental assessment report (1997).

Comparisons of the calculated time series of water level for the year of 1998, with and without the project, are shown in Figures (46) through (61) for normal and drawdown operations, respectively.

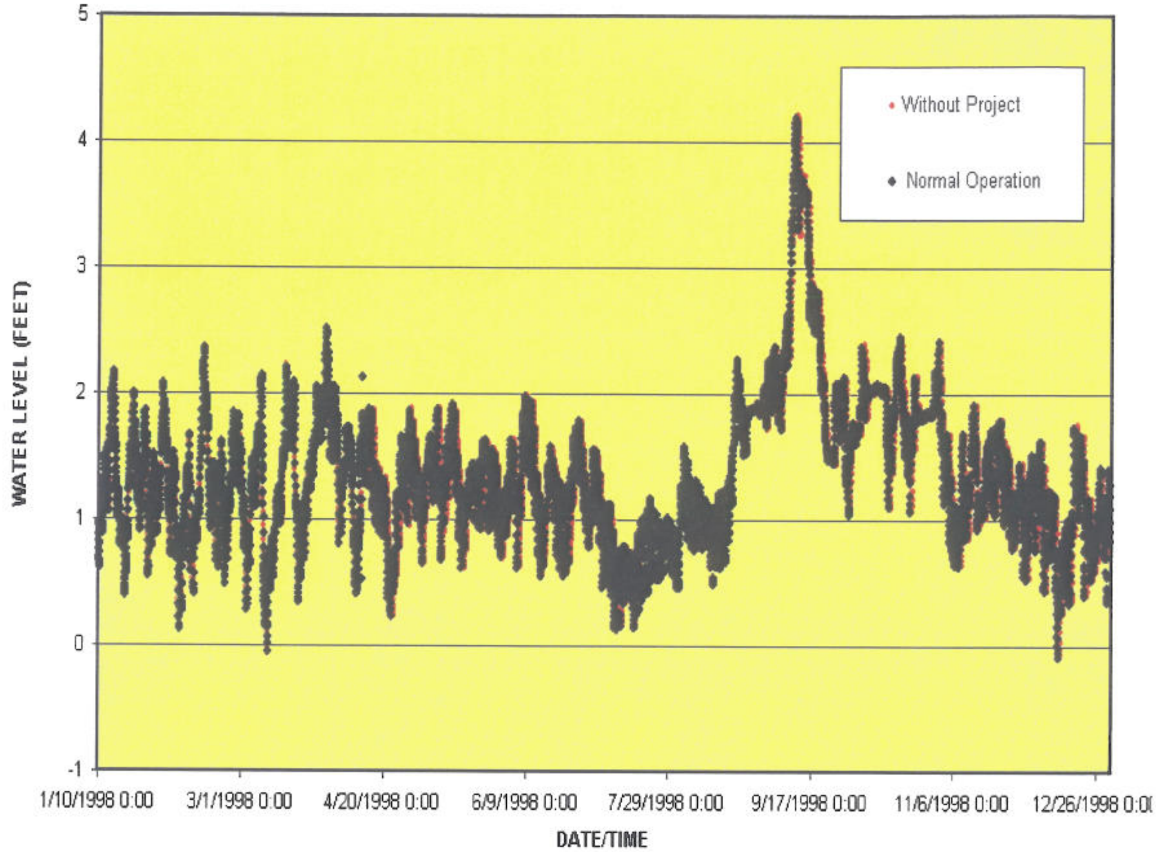

Figure 46: 1998 Normal Operation (Water Level), CS09-02

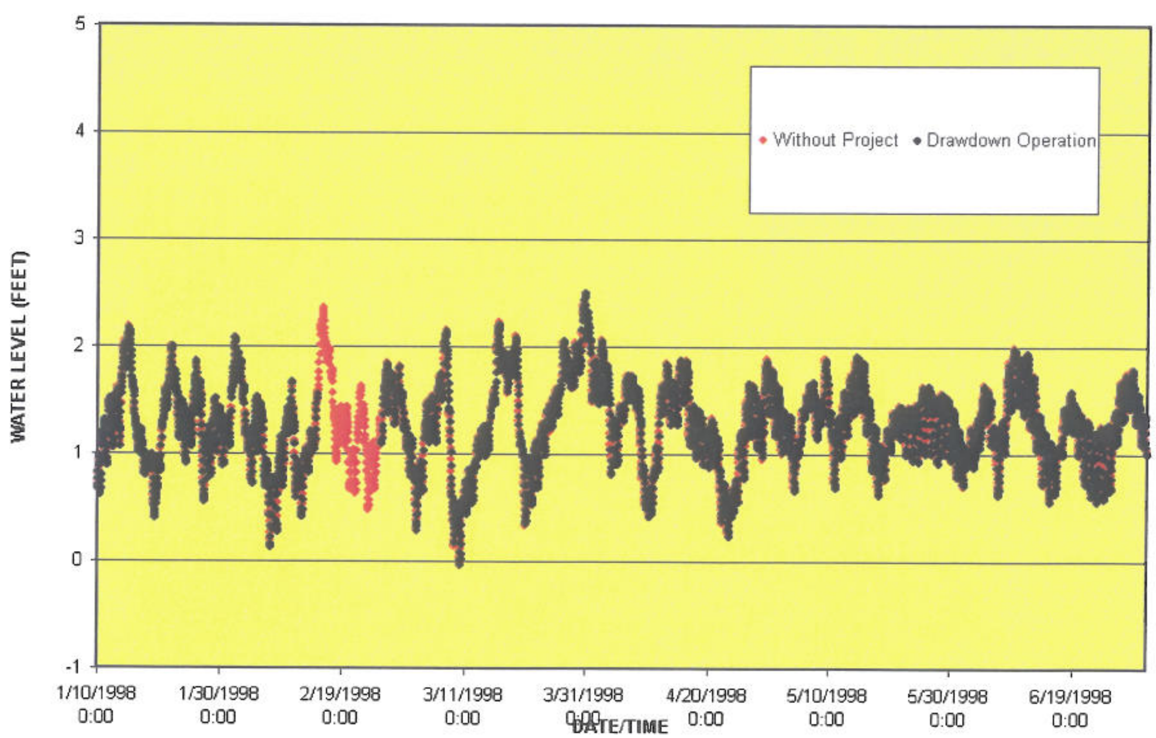

Figure 47: 1998 Drawdown Operation (Water Level), CS09-02

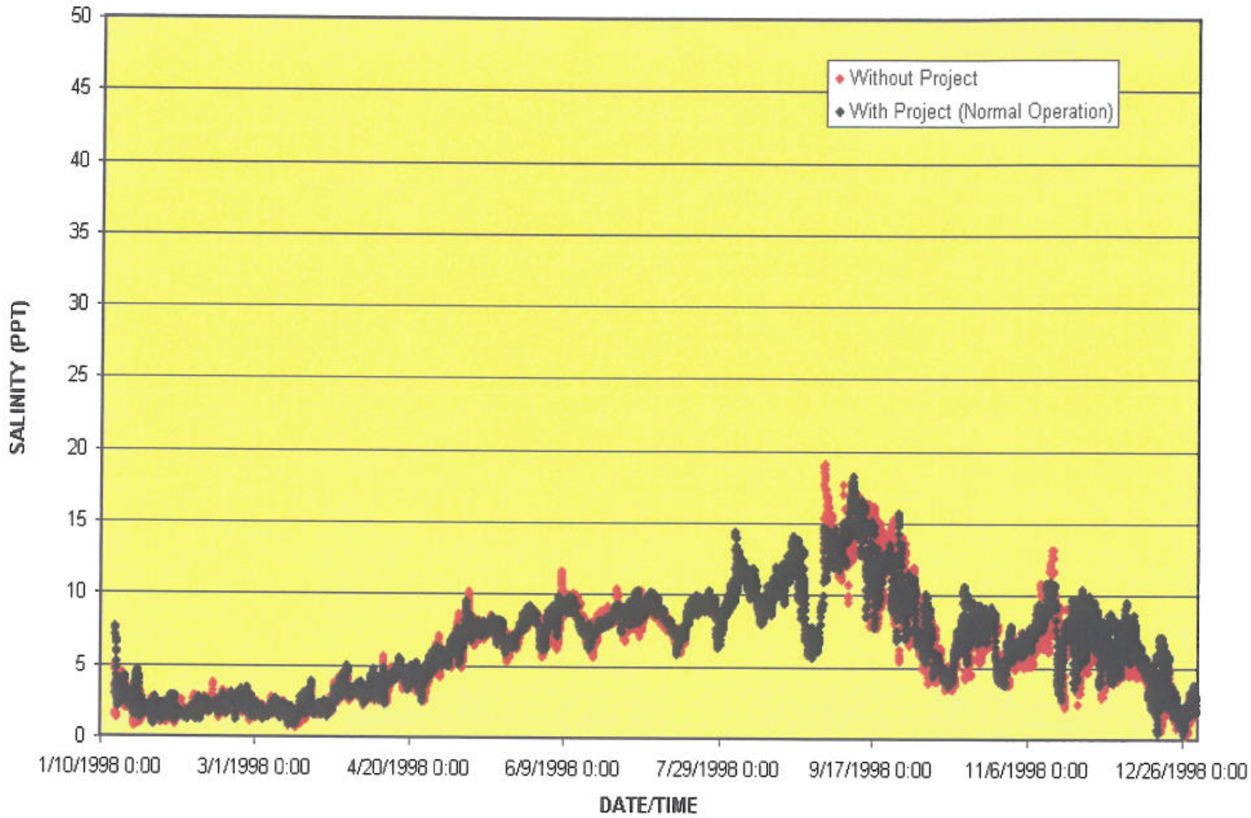

Figure 48: 1998 Normal Operation (Salinity), CS09-02

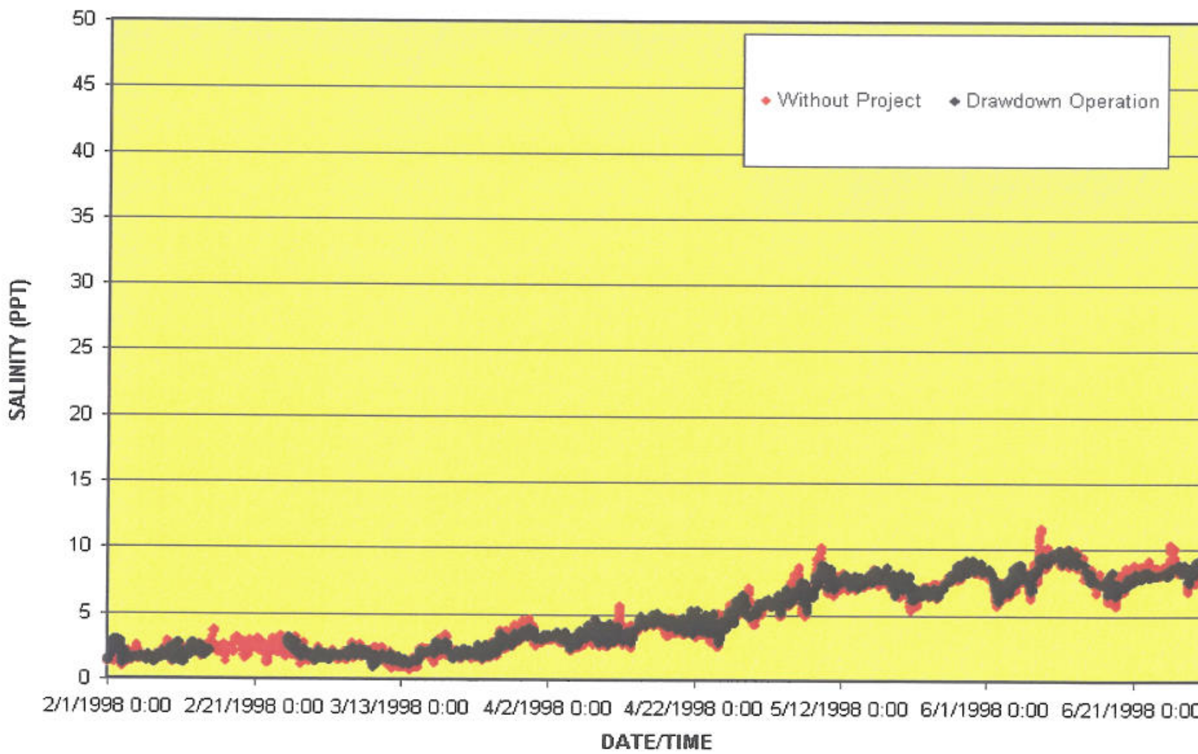

Figure 49: 1998 Drawdown Operation (Salinity), CS09-02

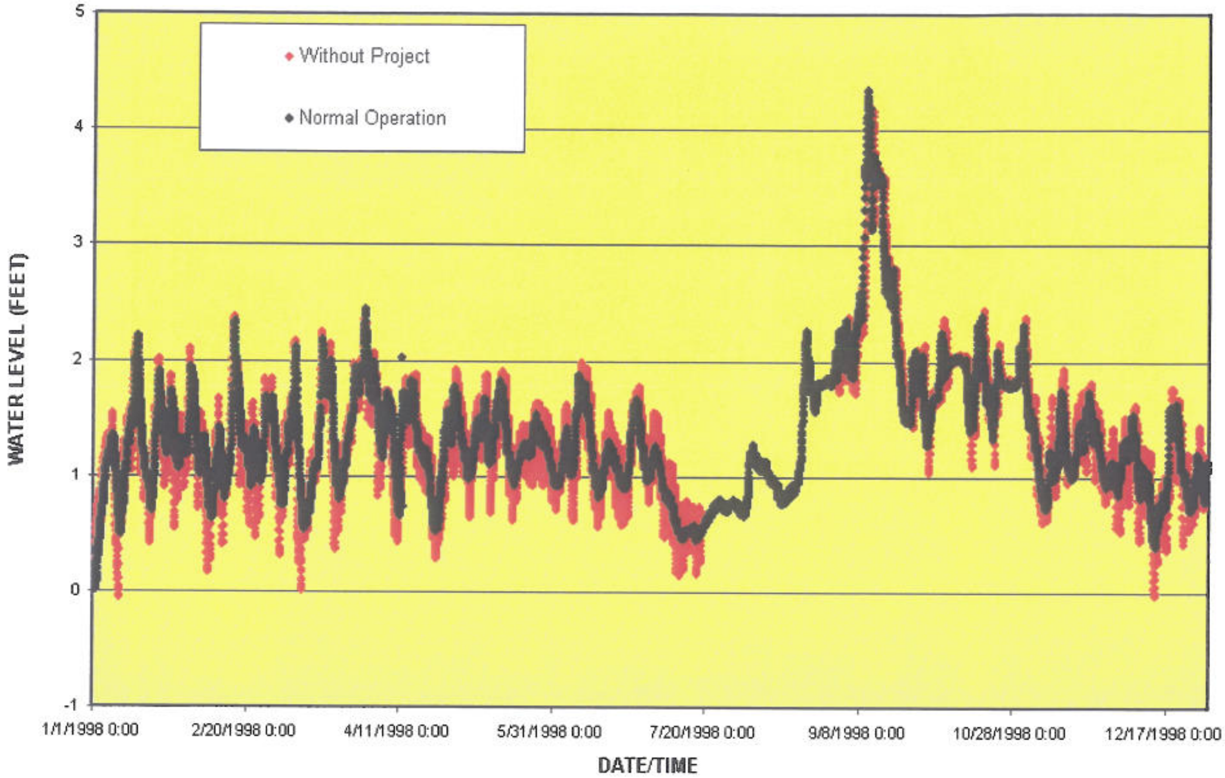

Figure 50: 1998 Normal Operation (Water Level), CS09-04

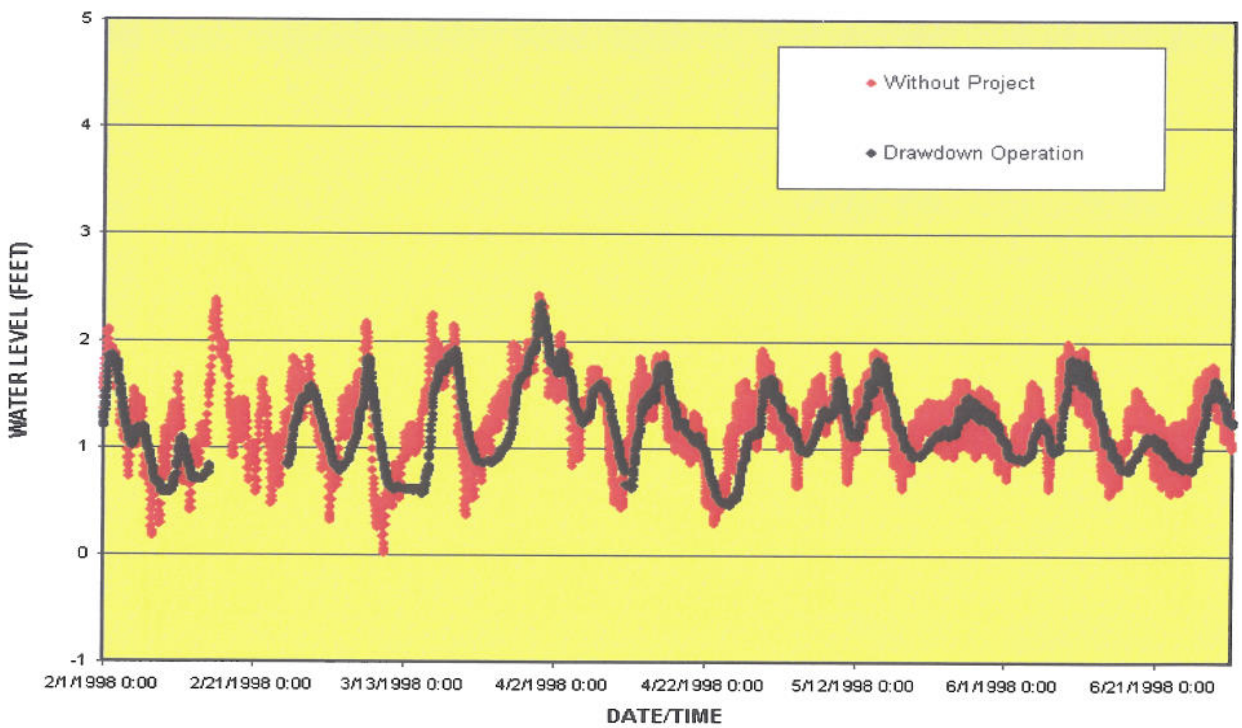

Figure 51: 1998 Drawdown Operation (Water Level), CS09-04

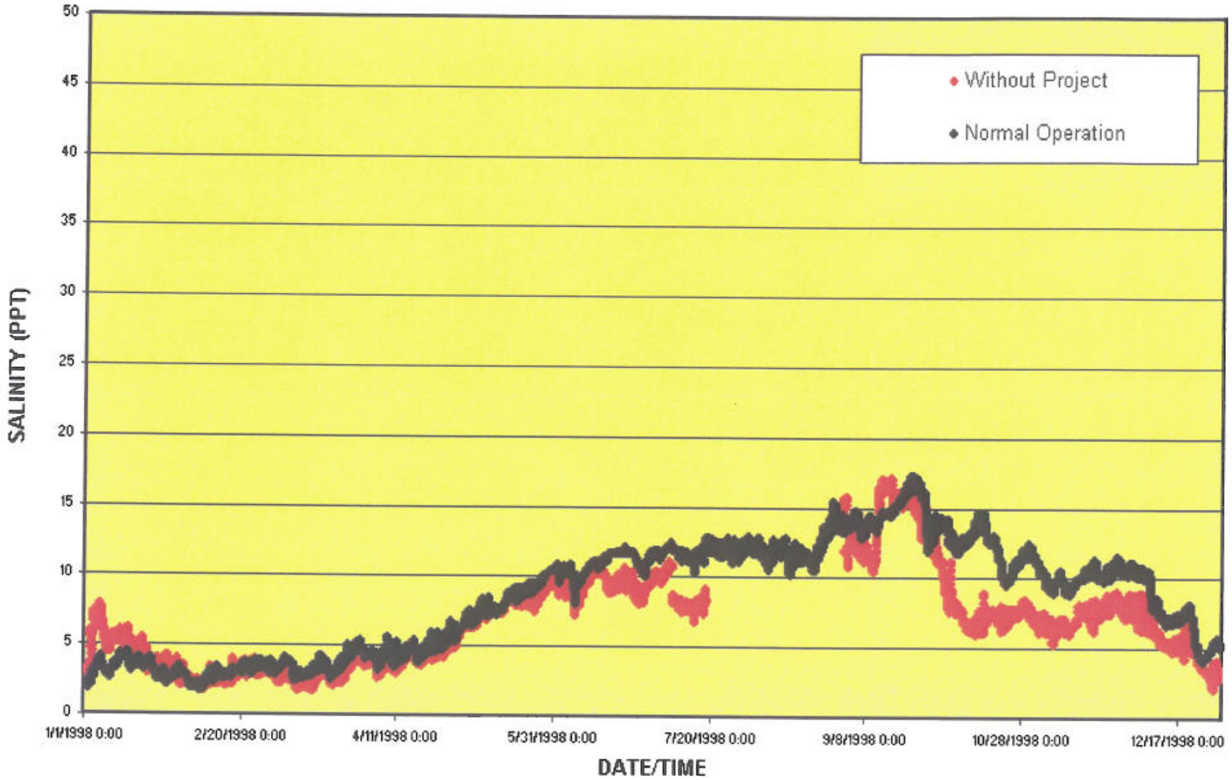

Figure 52: 1998 Normal Operation (Salinity), CS09-04

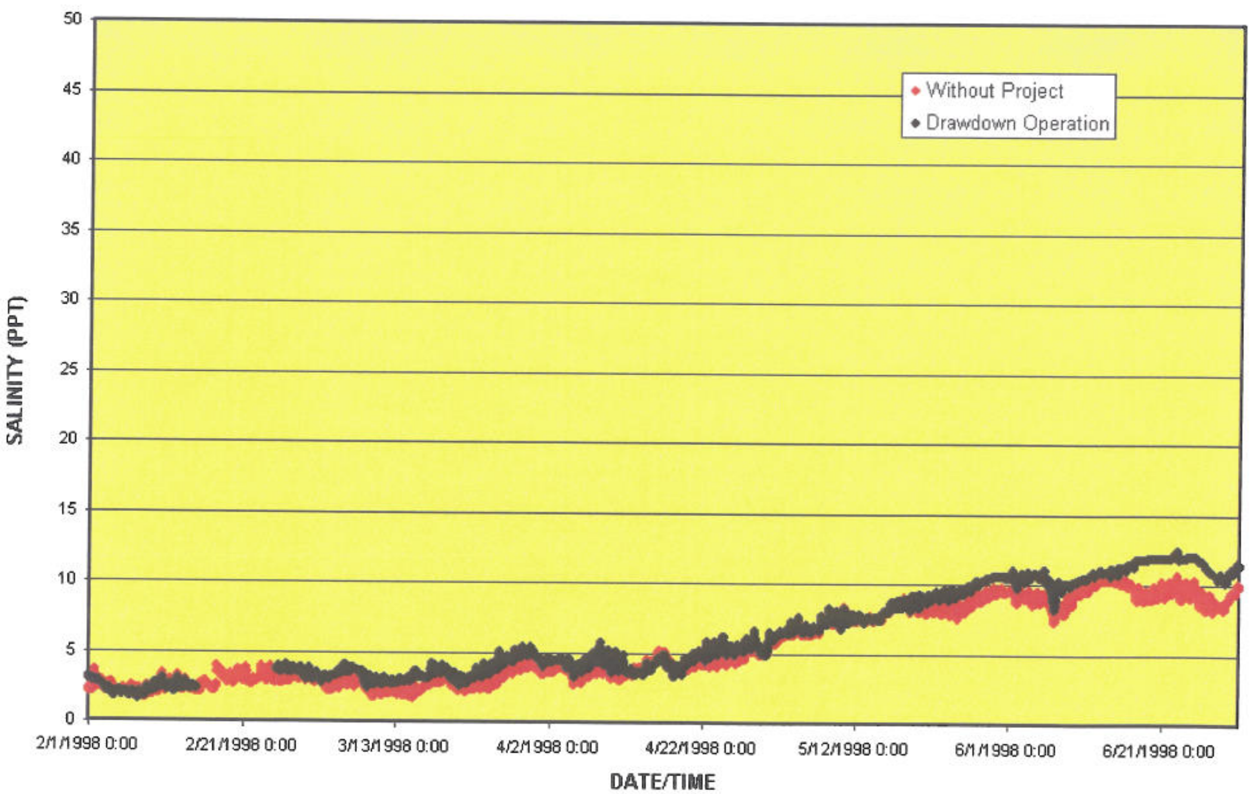

Figure 53: 1998 Drawdown Operation (Salinity), CS09-04

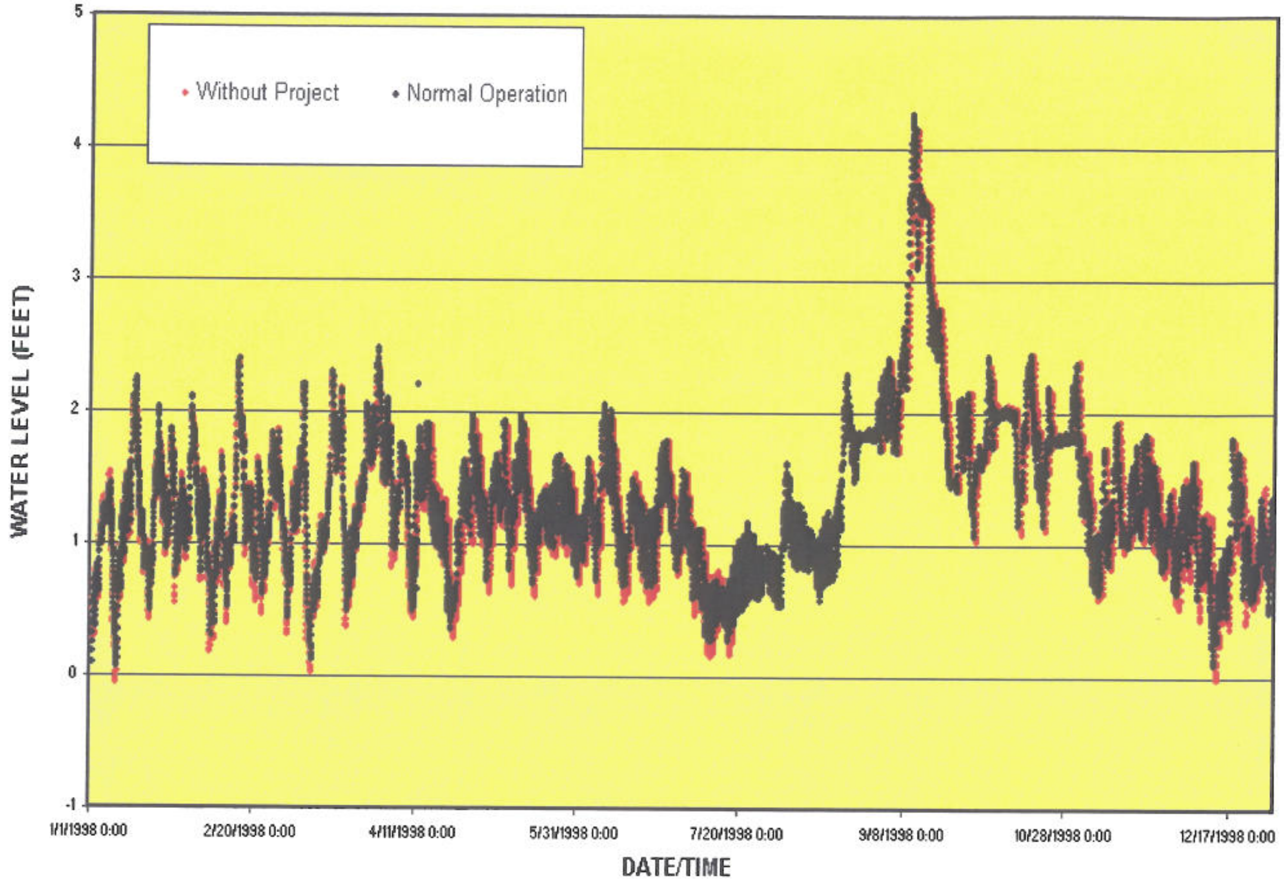

Figure 54: 1998 Normal Operation (Water Level), CS09-18

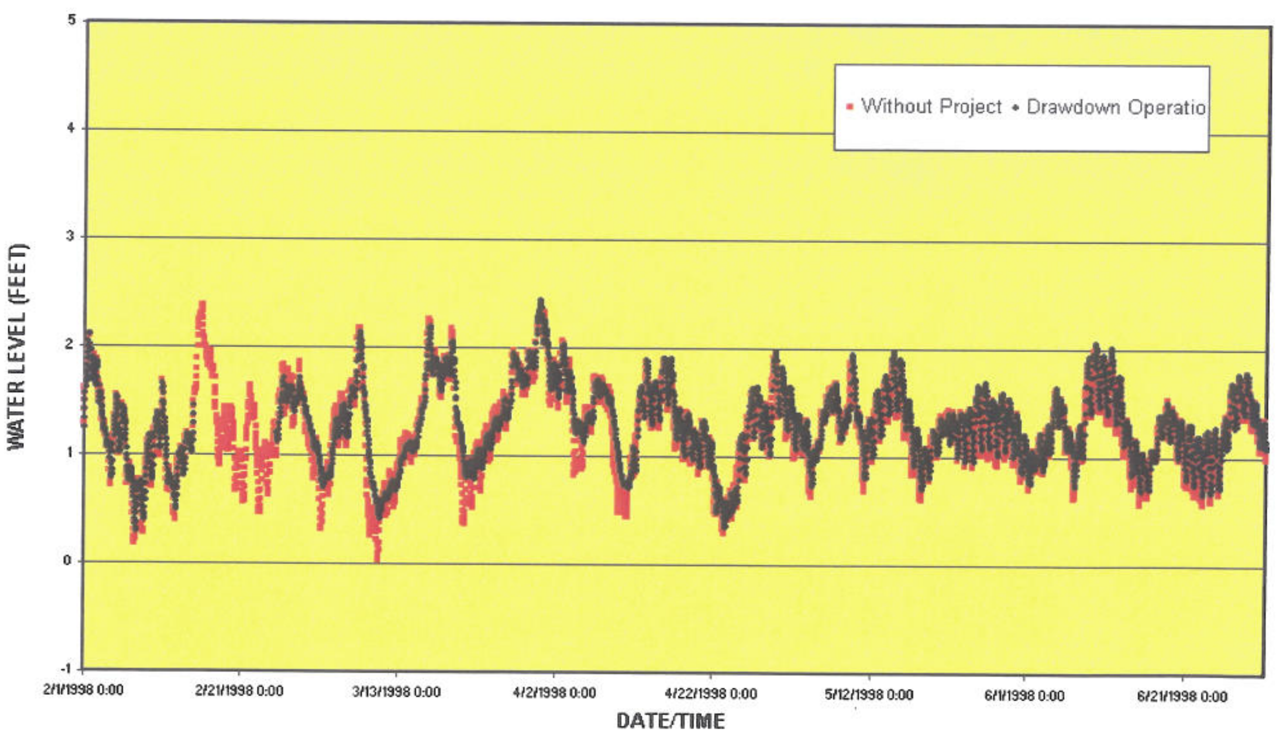

Figure 55: 1998 Drawdown Operation (Water Level), CS09-18

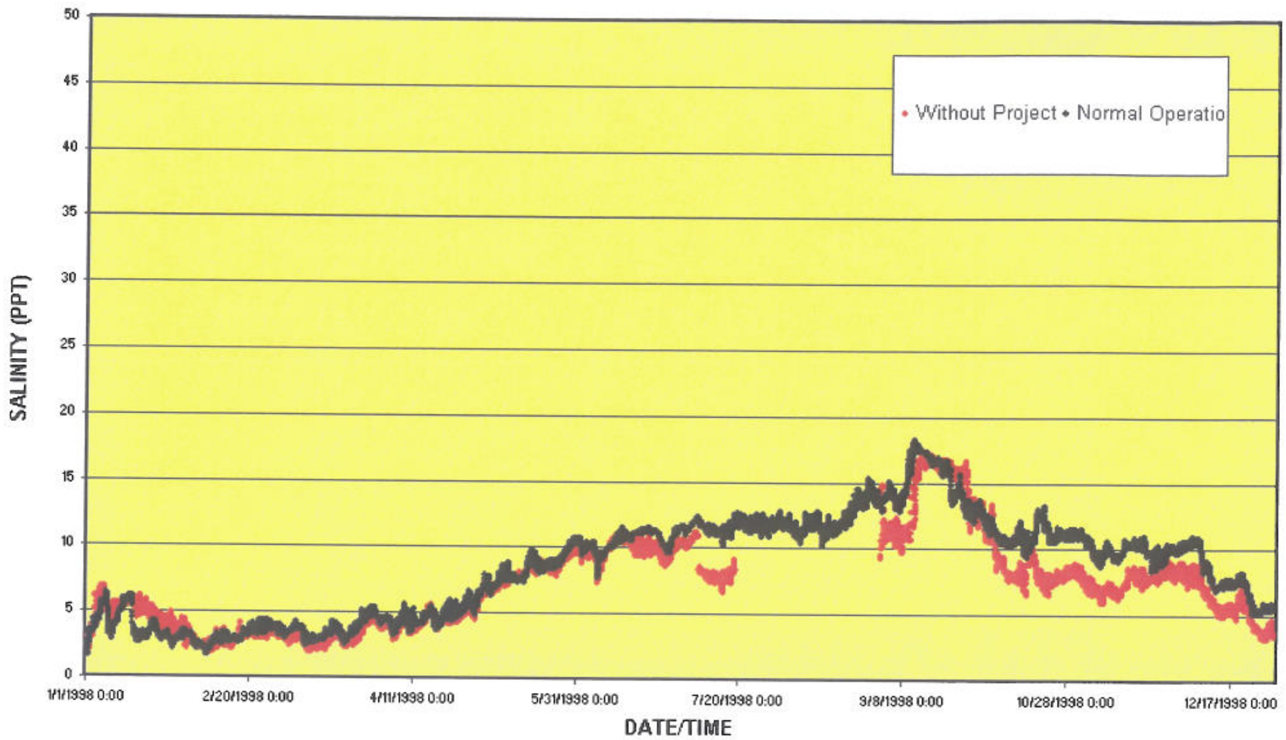

Figure 56: 1998 Normal Operation (Salinity), CS09-18

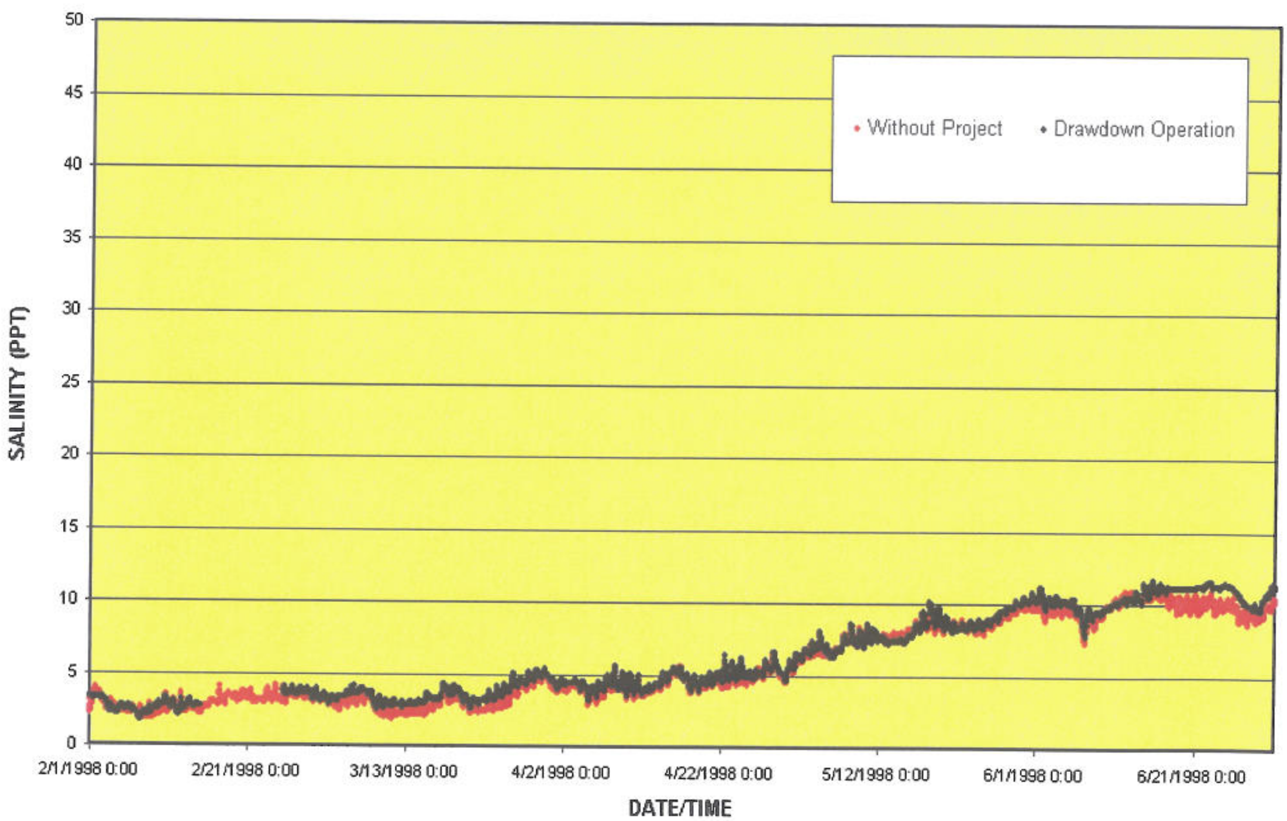

Figure 57: 1998 Drawdown Operation (Salinity), CS09-18

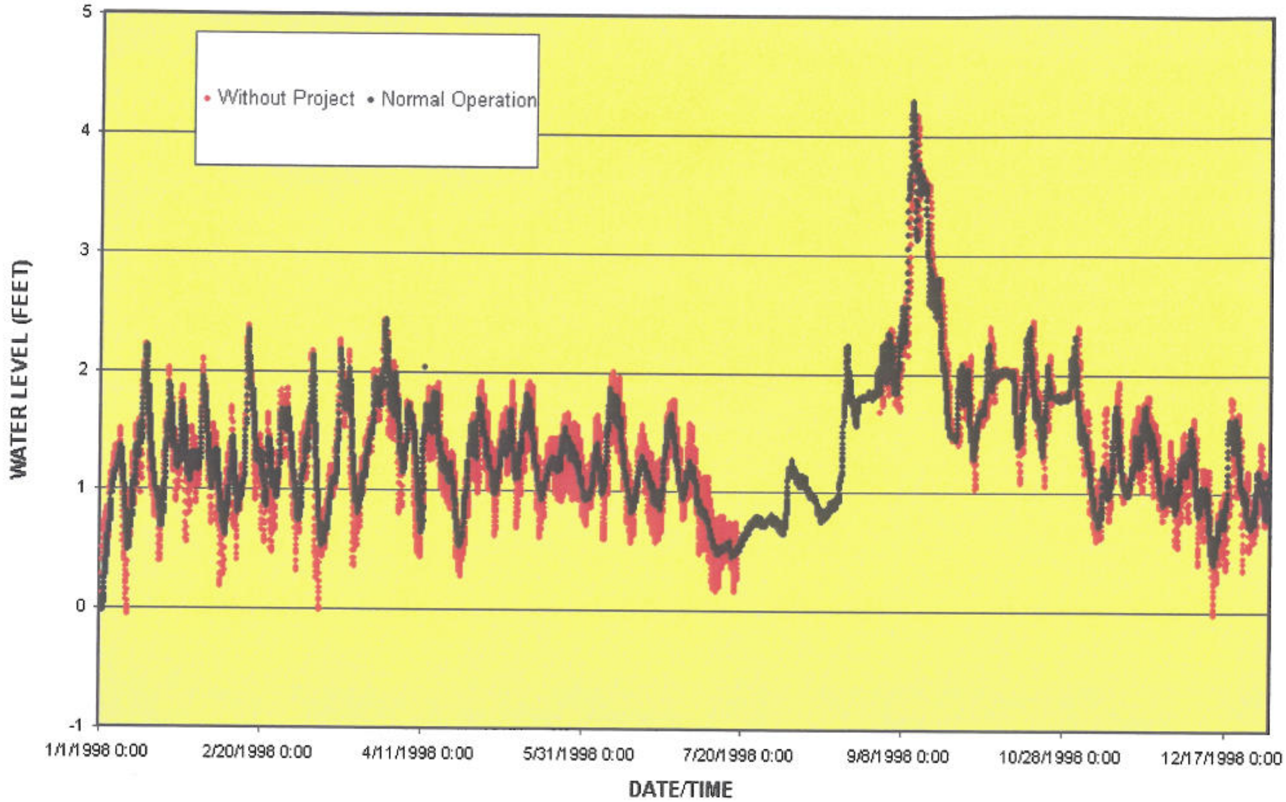

Figure 58: 1998 Normal Operation (Water Level), CS09-21

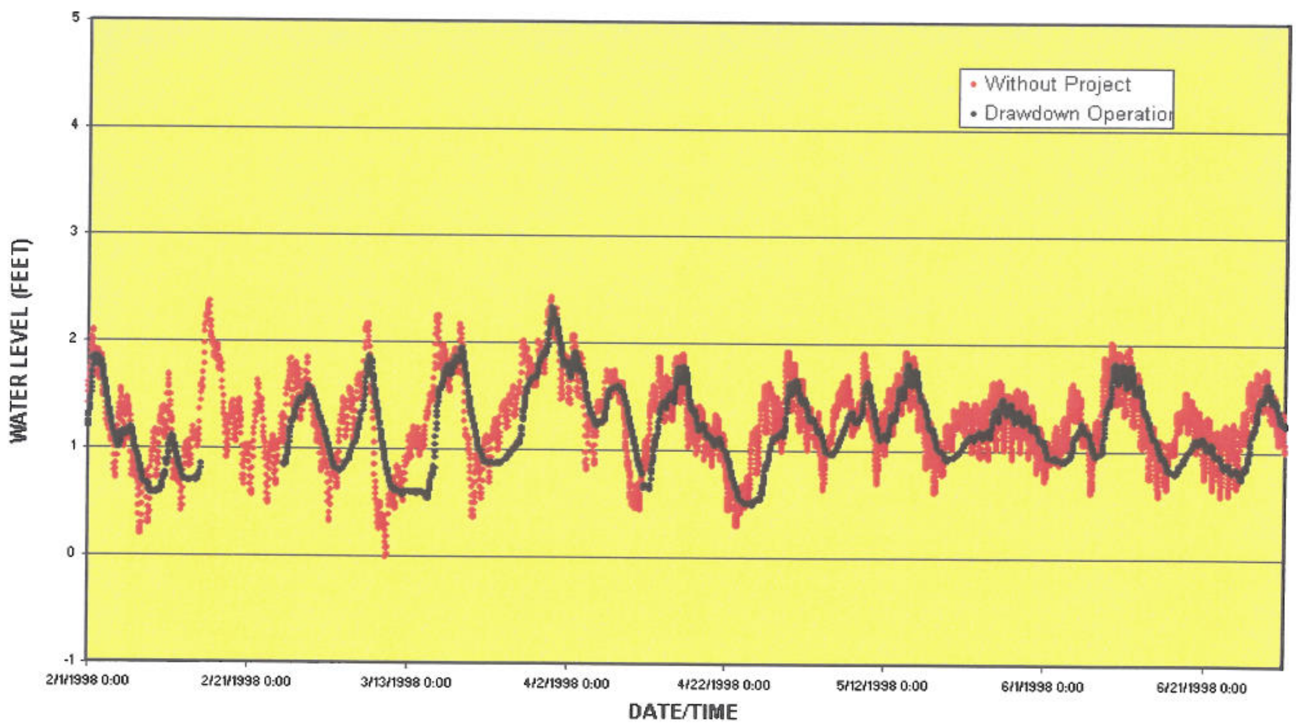

Figure 59: 1998 Drawdown Operation (Water Level), CS09-21

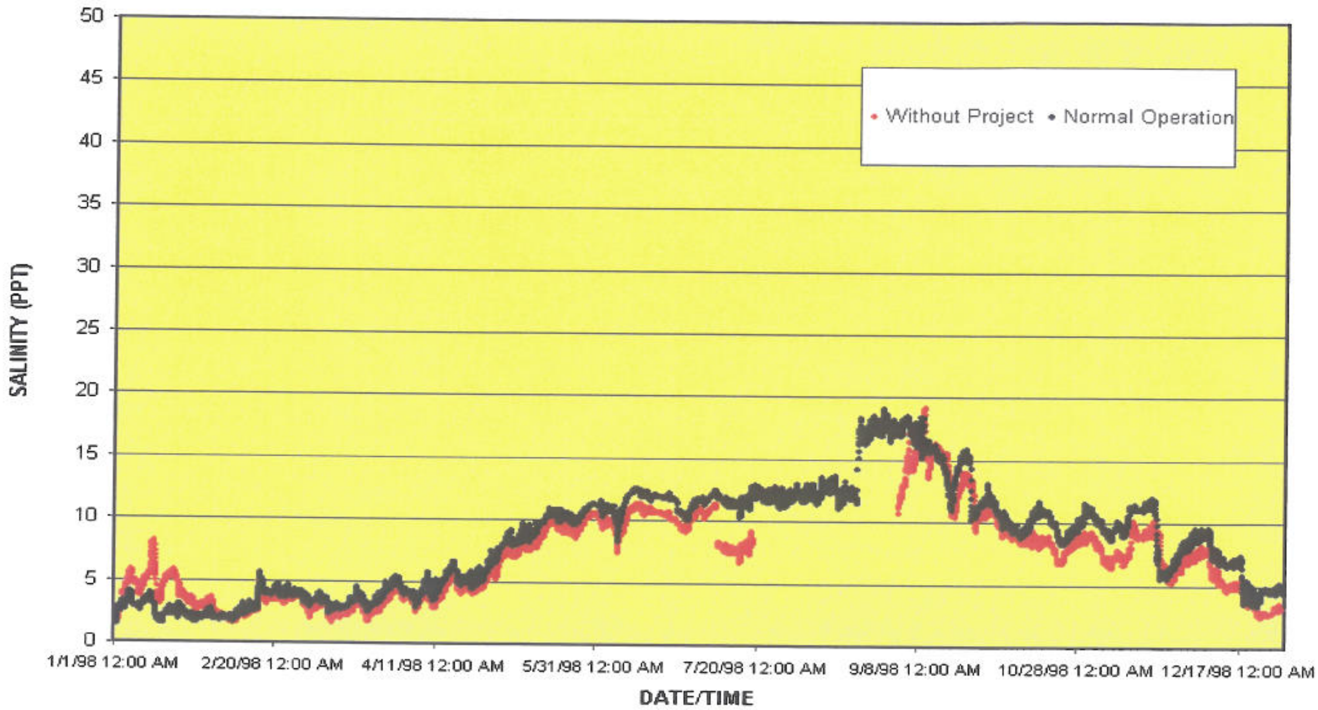

Figure 60: 1998 Normal Operation (Salinity), CS09-21

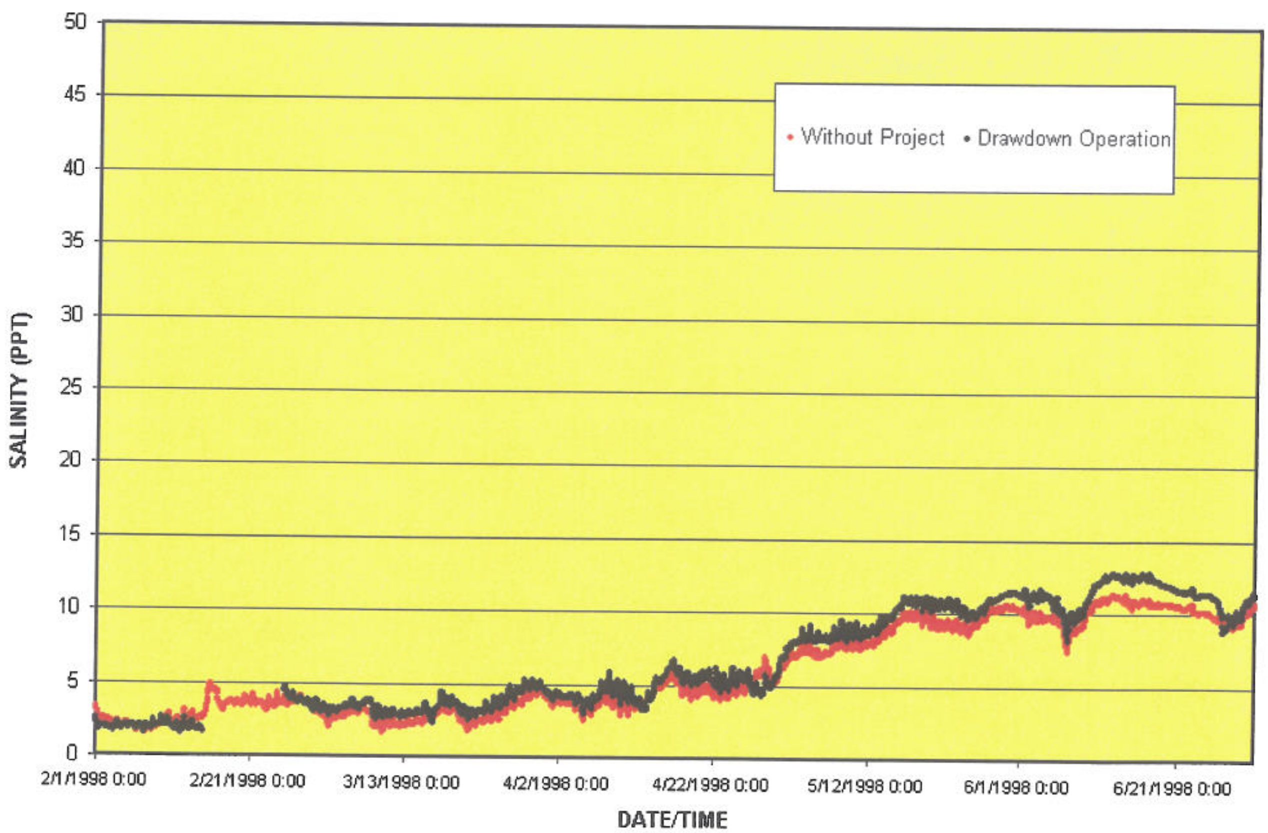

Figure 61: 1998 Drawdown Operation (Salinity), CS09-21

It was also observed that the Crab Gully culverts below Hwy. 27 were allowing high salinity water into the project area and was disturbing the drawdown operation. Therefore, it was deemed necessary to control the flow through the culvert openings by installing flap gates.

To access the impacts of the closing of the Crab Gully structure, simulations were ran for the years of 1998 and 1999 during both the normal and drawdown operations. Figures (62) through (93) compare existing conditions and Crab Gully closed for water and salinity levels for the normal and operational schemes previously outlined above.

The existing hydrodynamic model (H3D) was modified to include flap gates installed on each opening of the Crab Gully box culvert structure located along Louisiana State Highway 27. The flap gates were modeled such that they only allow flow from the Brown Lake project area to the Calcasieu ship channel, while preventing flow in the reverse direction, i.e. no flow is allowed from the ship channel to Brown Lake via the culvert openings.

To assess the impact of installing these flap gates on the drainage of Brown Lake, and to evaluate the head differential on the Crab Gully culvert structure, a 100-year, 24-hour storm event was modeled using the above mentioned hydrodynamic modeling software. The spatial extent of the storm was limited to inside the project area, around which a proposed embankment will be constructed. This is a conservative assumption that would maximize the head differential on the gated structure. The shaded area shown in Figure 94 represents the spatial extent of the 100-year storm (intensity of 1.1 inches/hr with a duration of 24 hours).

Two model simulations were performed, one during an flow tide and another during a ebb tide (outgoing) condition. Two factors were used to assess the impact of installing the flap gates at Crab Gully. The first being the time duration needed to drain a 100-year storm event out of the project area, and the second is the projected maximum head differential on the gates and the road-base during the storm.

Figure (95) shows the results for the 100-year storm during a flow tide. As expected, the water level was higher inside the project area than outside the project area for a total of 44 hours (i.e. longer than the scenario where the rainstorm occurred during an ebb tide). The maximum head differential that occurred during the rainstorm under this tide condition was 0.71 feet (8.5 inches).

Similarly, Figure (96) shows the results for the 100-year rainstorm during an ebb tide. The water level was higher inside the project area than outside the project area for a total of 36 hours. The maximum differential head on the gates during the storm was 0.16 feet (1.92 inches).

From the model results presented above and illustrated in the attached figures, it is concluded that installing flap gates at the existing Crab Gully box culvert structure will result in a maximum head differential of 0.71 feet for a 100-year storm (with intensity of 1.1 inches/hr with a duration of 24 hours). It is also concluded that the water level within the interior of Brown Lake will recede to the same level as the outside water level within a maximum of 44 hours. These estimates were conservative as they were calculated under two adverse conditions, namely, the storm was assumed to occur only within the interior of the project area, and that it will occur during a flow-tide conditions.

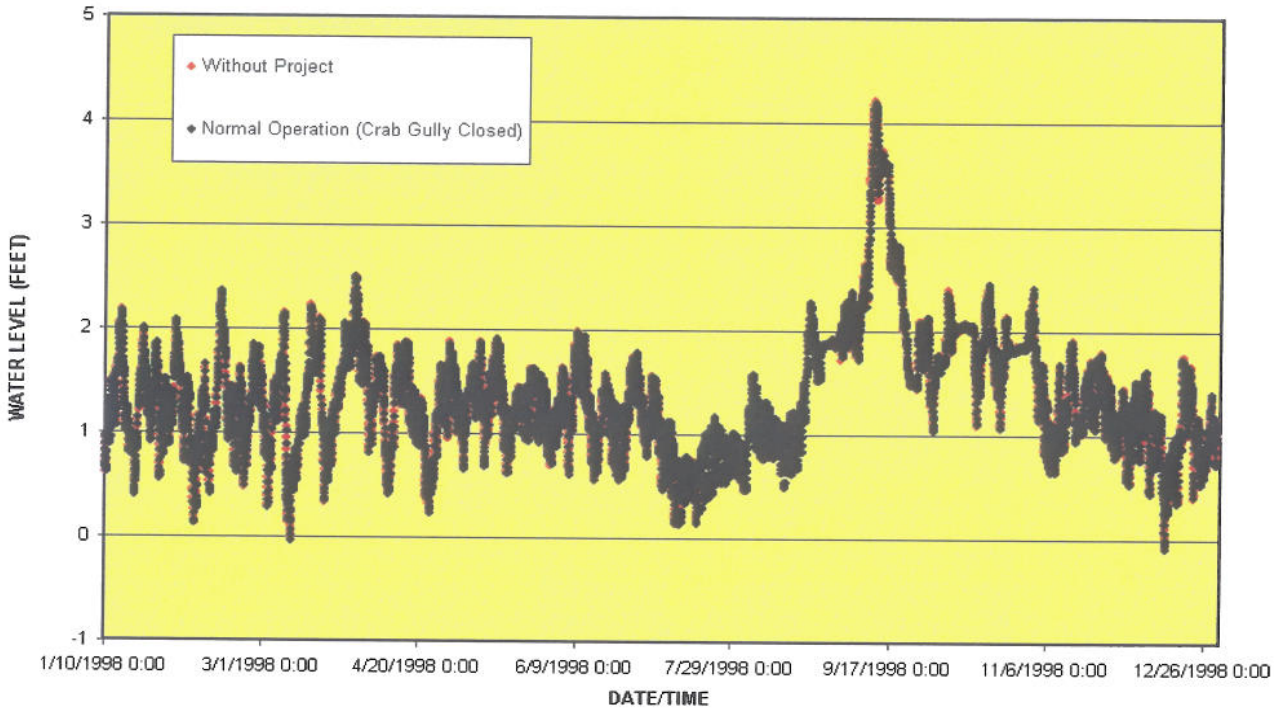

Figure 62: Gauge CS04-02, 1998 Normal Operation with Crab Gully closed (Water Level)

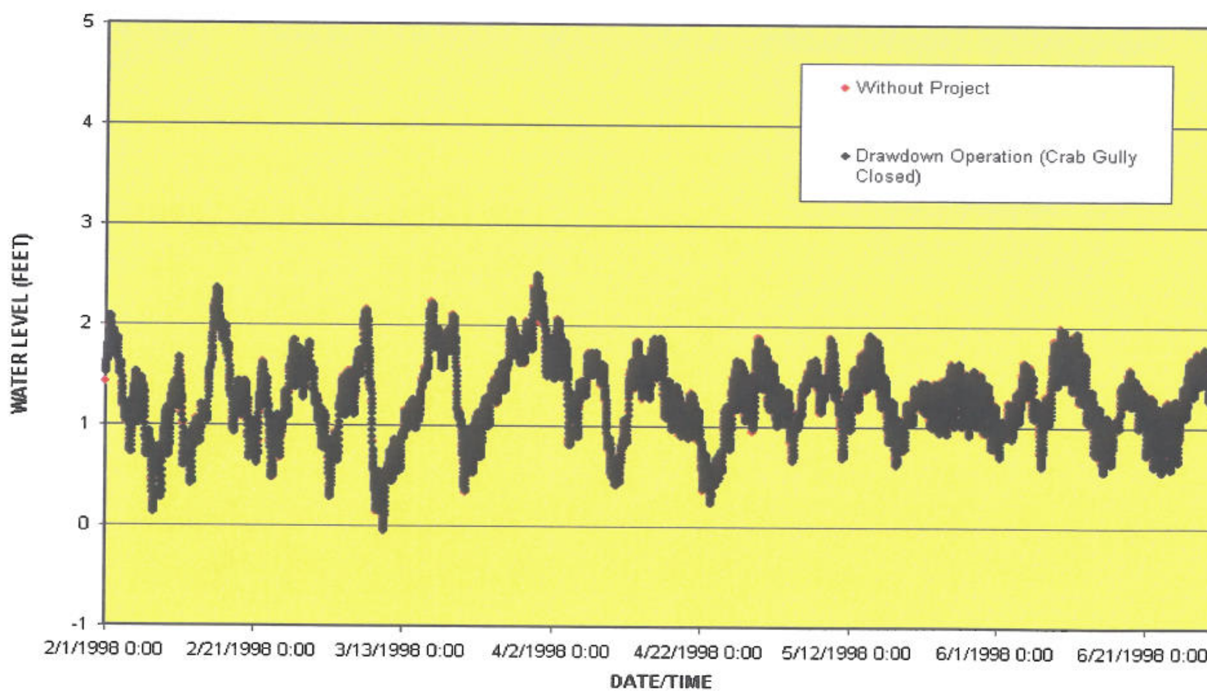

Figure 63: Gauge CS04-02, 1998 Drawdown Operation with Crab Gully closed (Water Level)

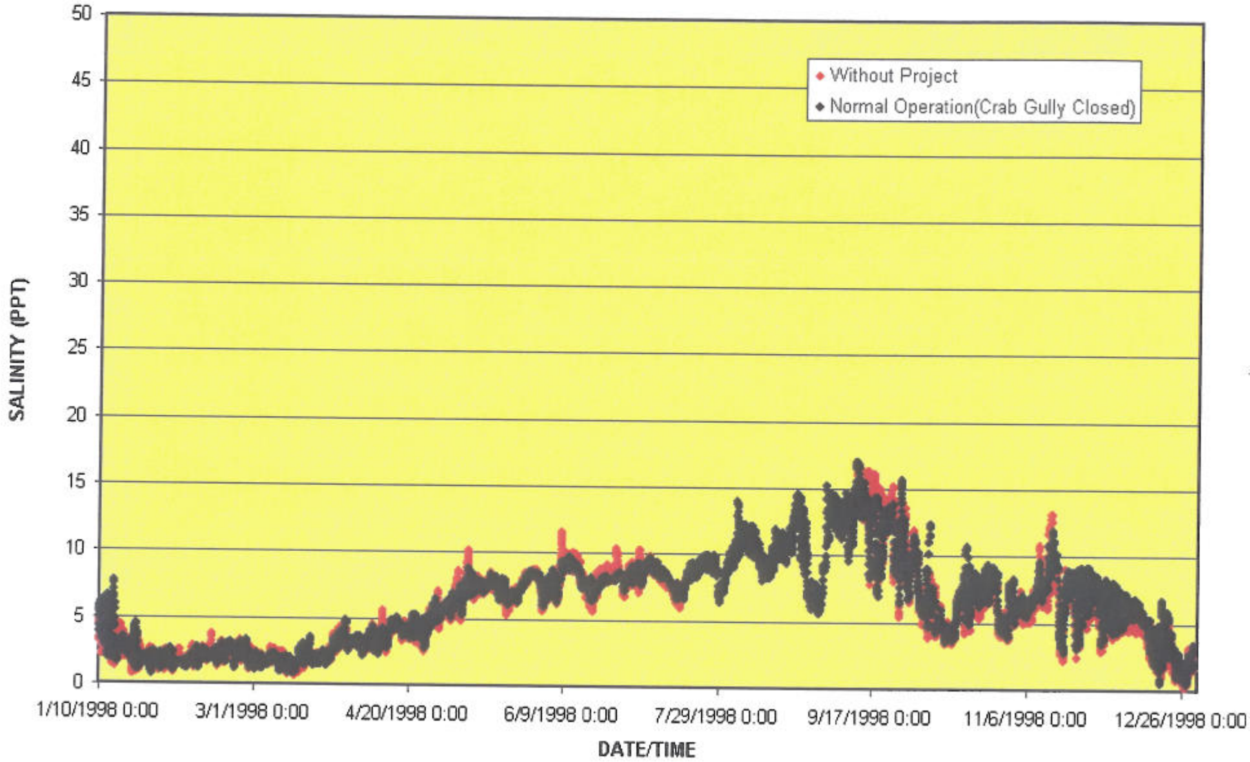

Figure 64: Gauge CS04-02, 1998 Normal Operation with Crab Gully closed (Salinity)

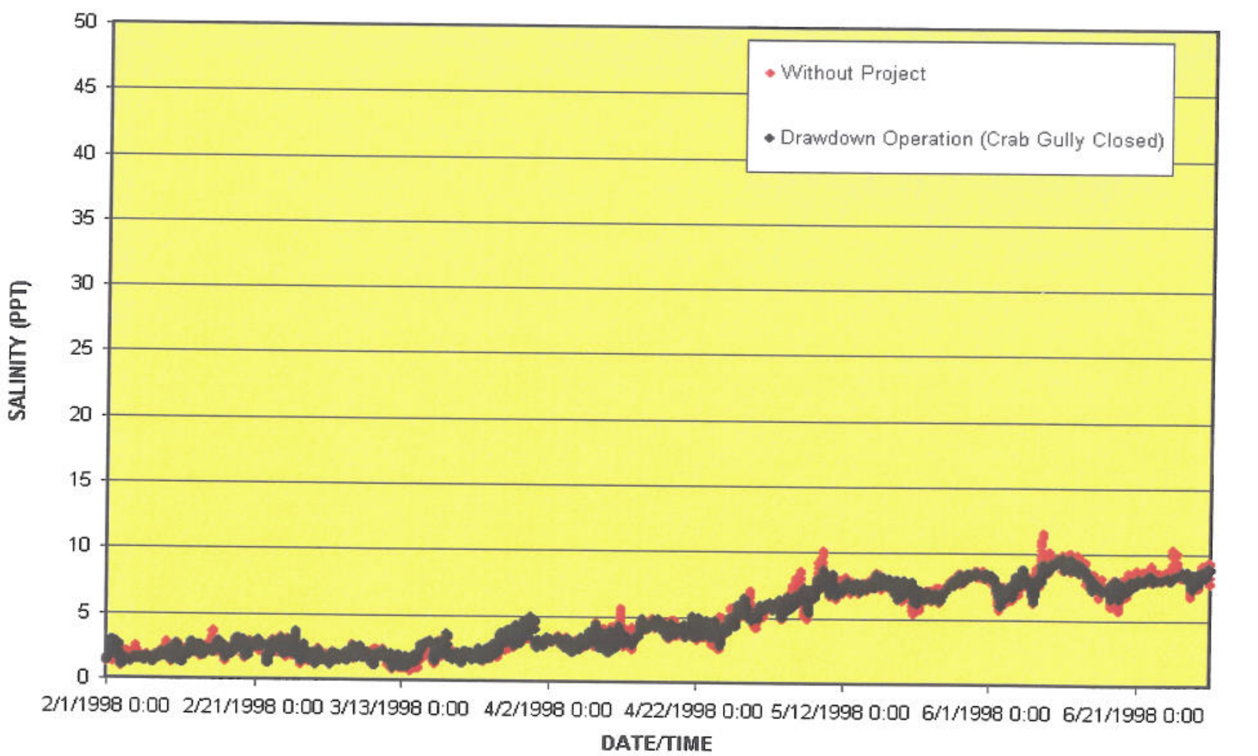

Figure 65: Gauge CS04-02, 1998 Drawdown Operation with Crab Gully closed (Salinity)

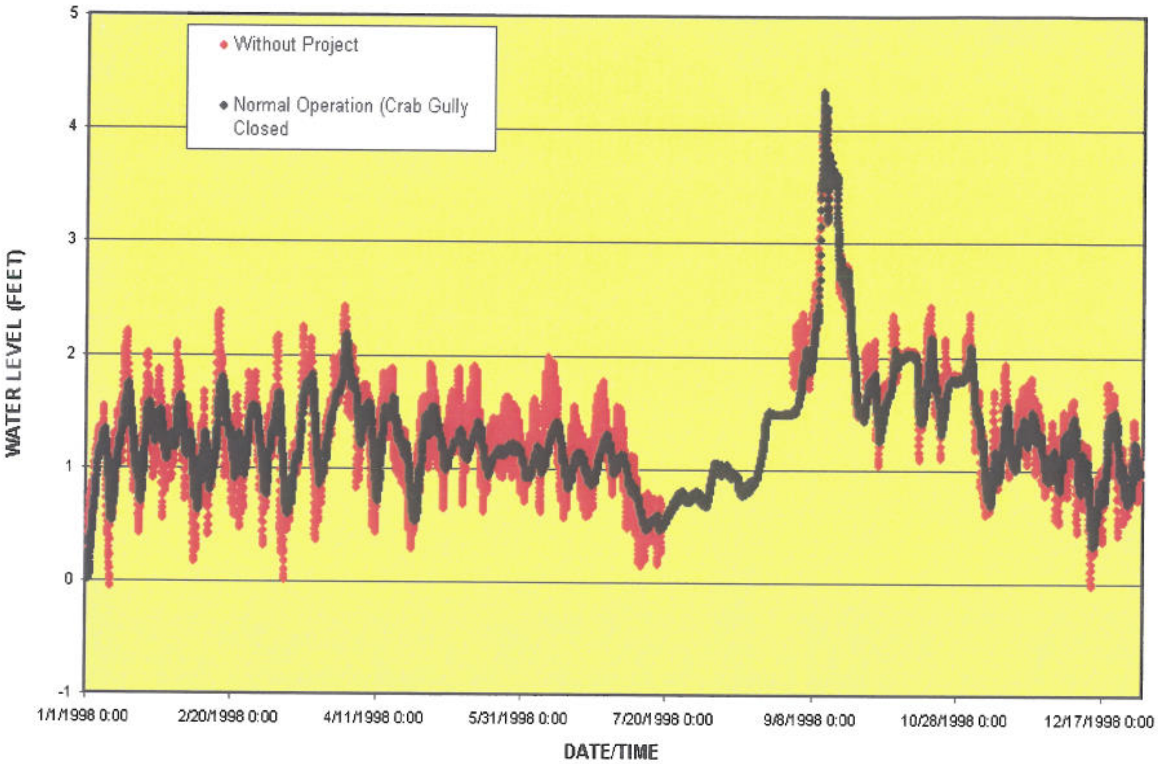

Figure 66: Gauge CS04-04, 1998 Normal Operation with Crab Gully closed (Water Level)

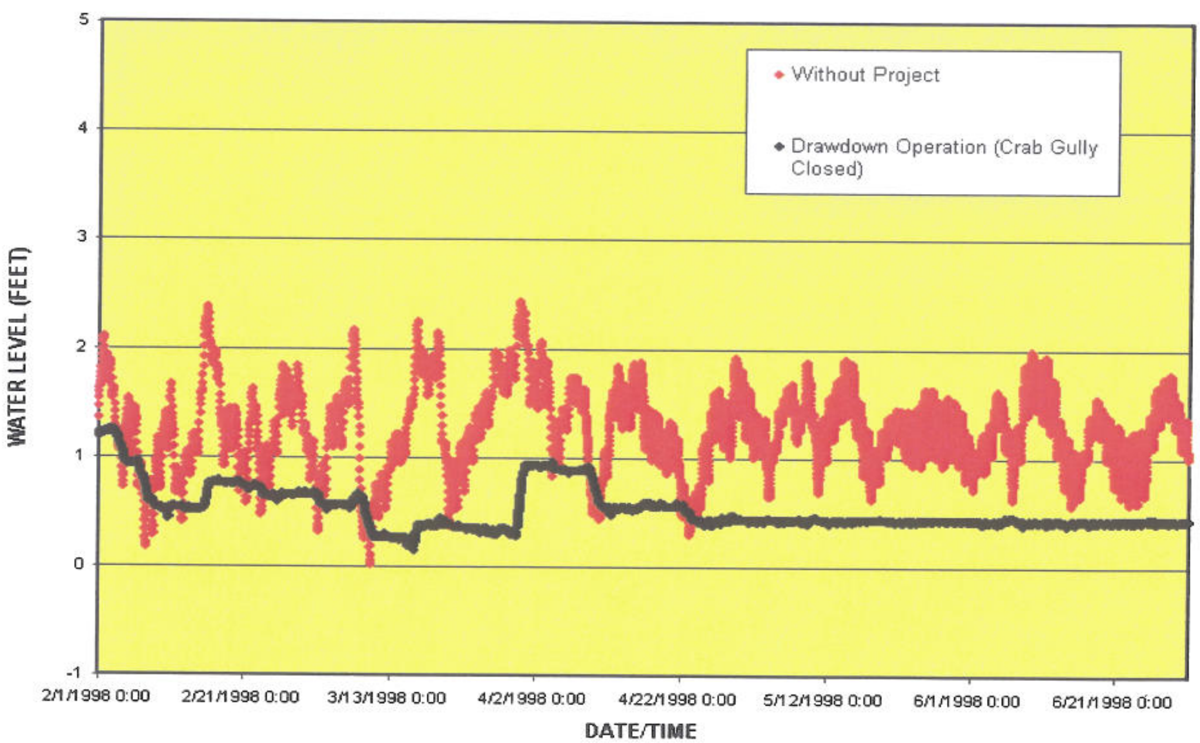

Figure 67: Gauge CS04-04, 1998 Drawdown Operation with Crab Gully closed (Water Level)

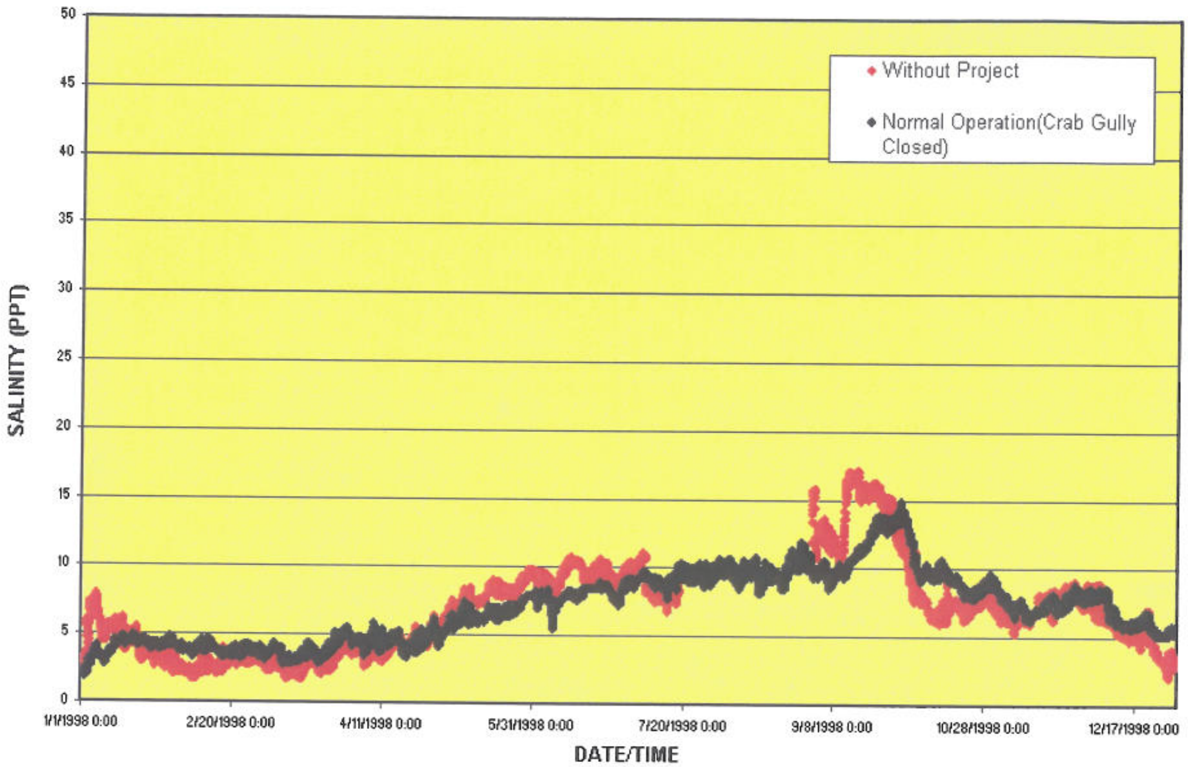

Figure 68: Gauge CS04-04, 1998 Normal Operation with Crab Gully closed (Salinity)

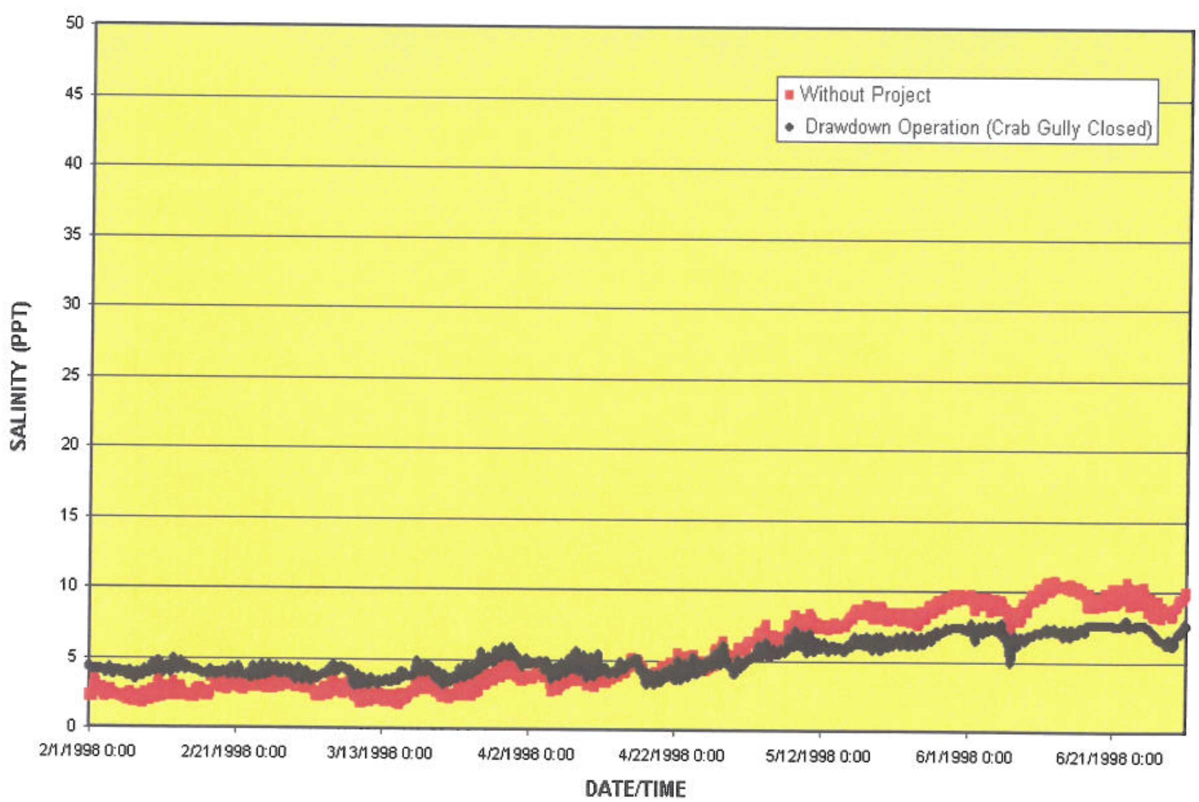

Figure 69: Gauge CS04-04, 1998 Drawdown Operation with Crab Gully closed (Salinity)

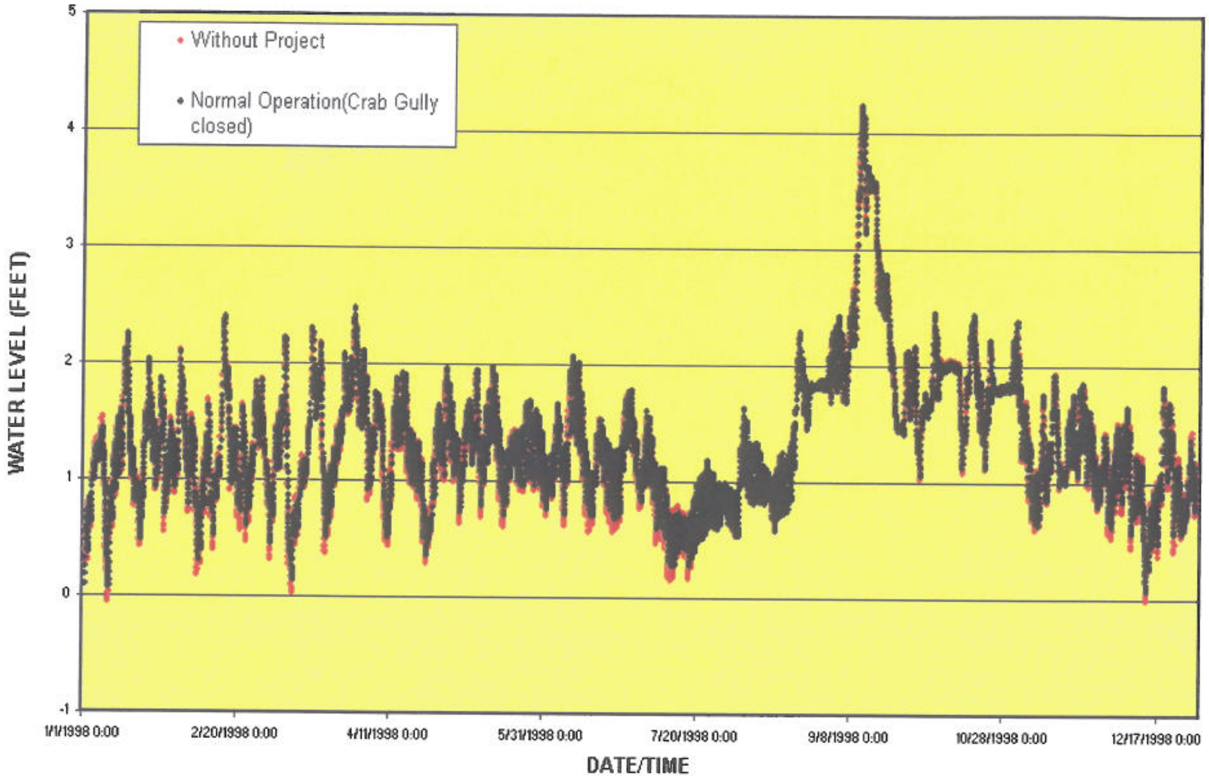

Figure 70: Gauge CS04-18, 1998 Normal Operation with Crab Gully closed (Water Level)

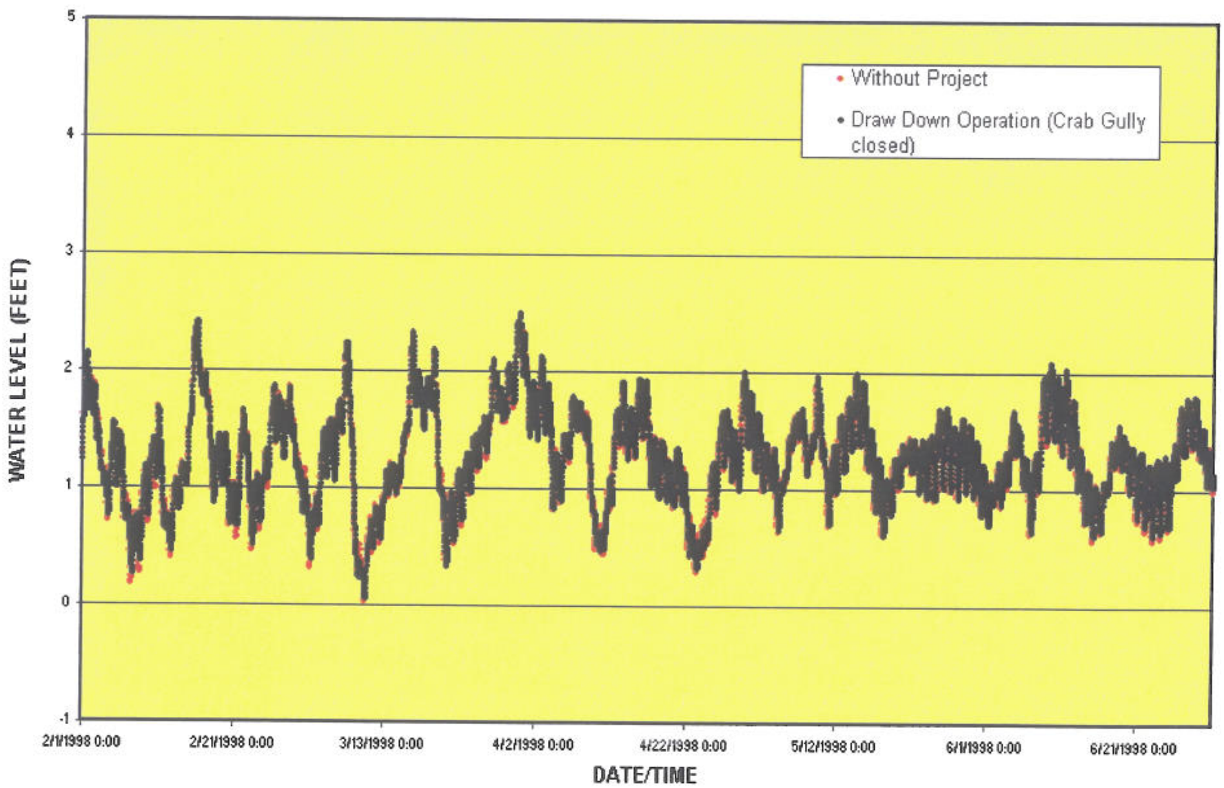

Figure 71: Gauge CS04-18, 1998 Drawdown Operation with Crab Gully closed (Water Level)

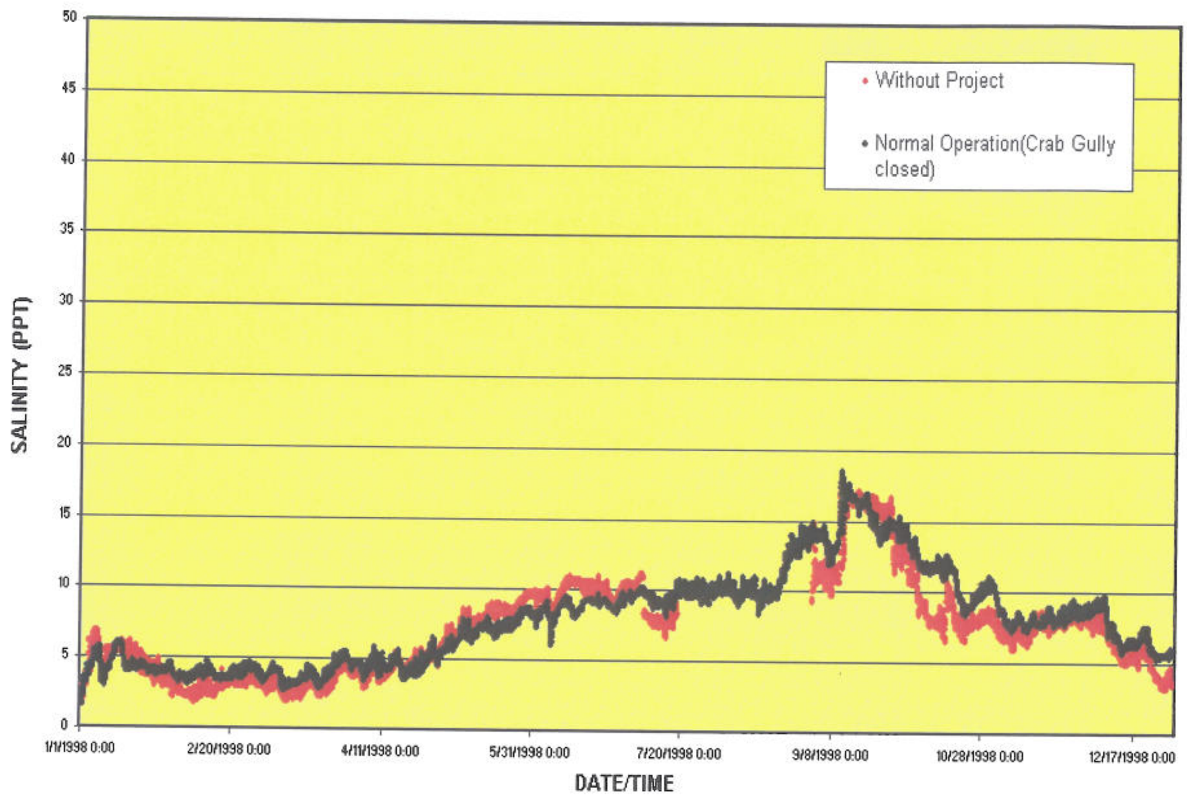

Figure 72: Gauge CS04-18, 1998 Normal Operation with Crab Gully closed (Salinity)

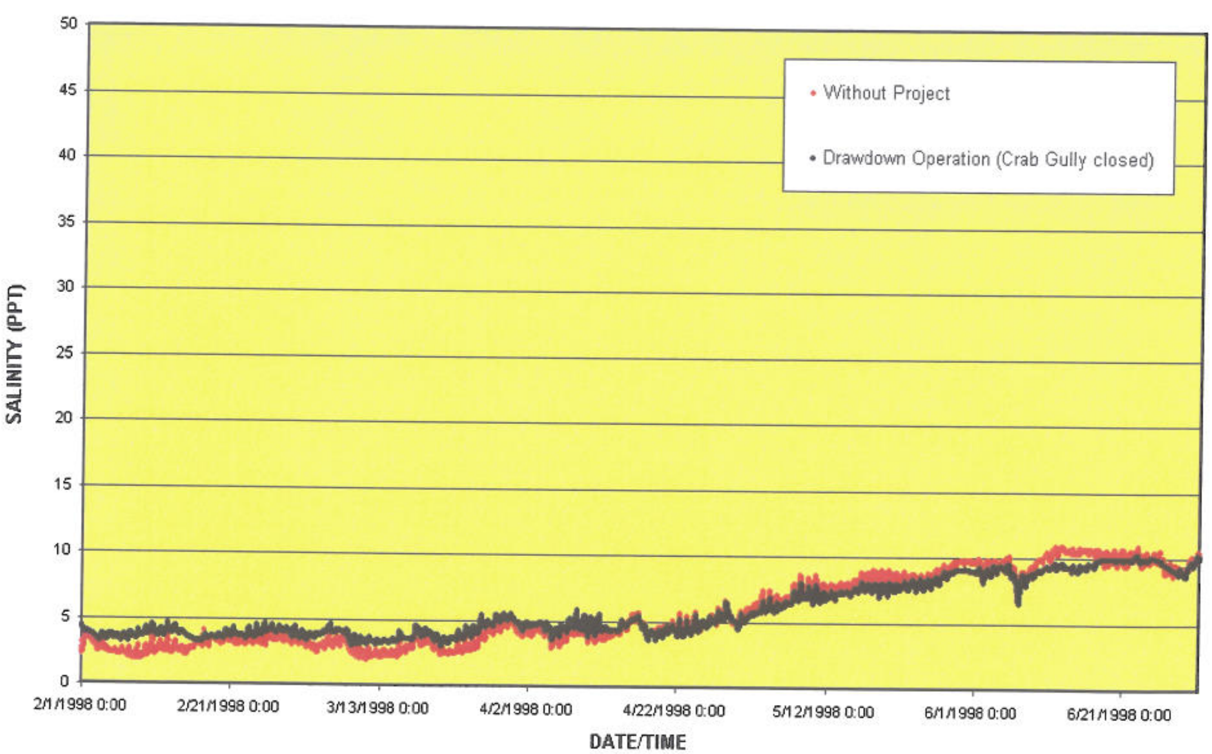

Figure 73: Gauge CS04-18, 1998 Drawdown Operation with Crab Gully closed (Salinity)

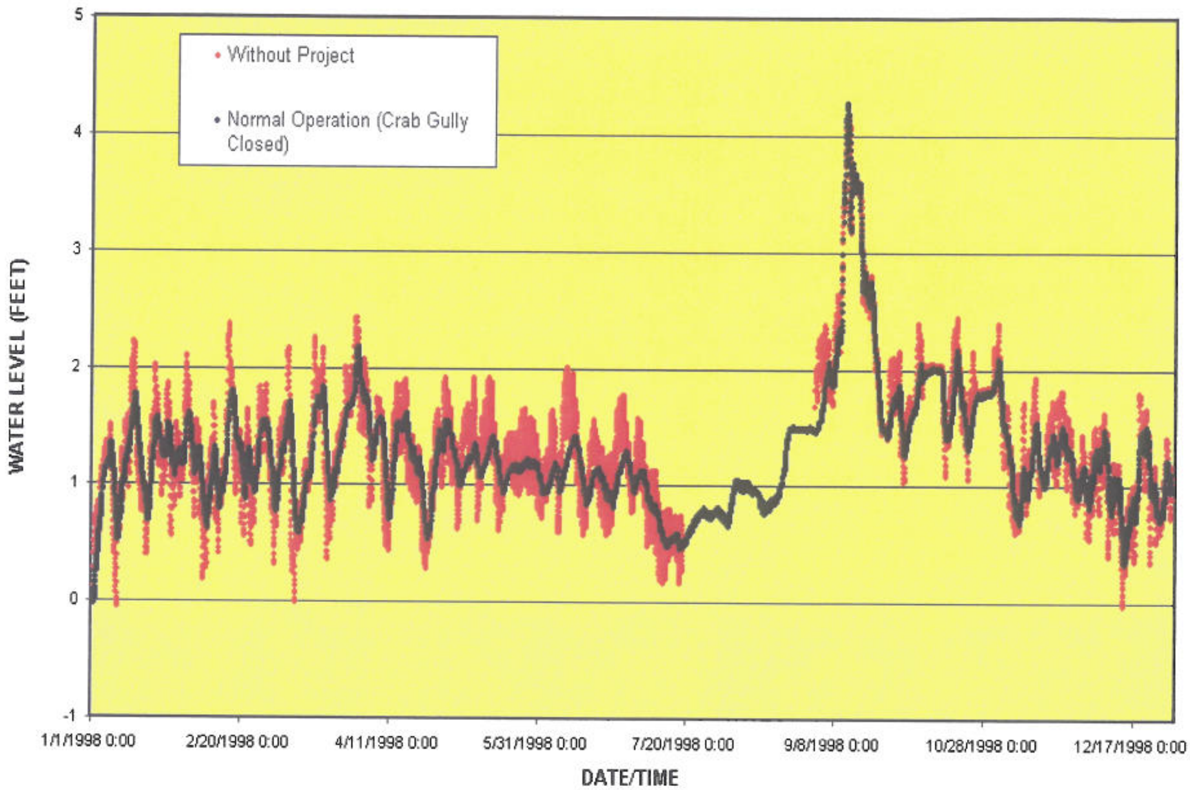

Figure 74: Gauge CS04-21, 1998 Normal Operation with Crab Gully closed (Water Level)

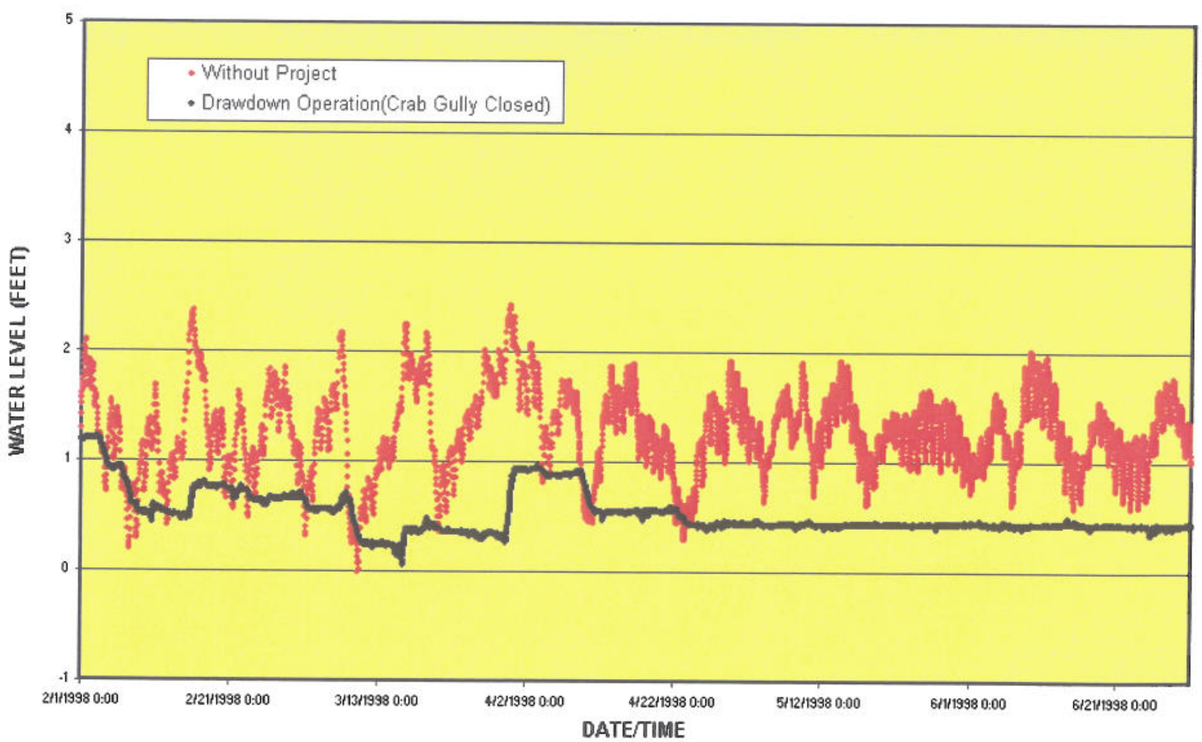

Figure 75: Gauge CS04-21, 1998 Drawdown Operation with Crab Gully closed (Water Level)

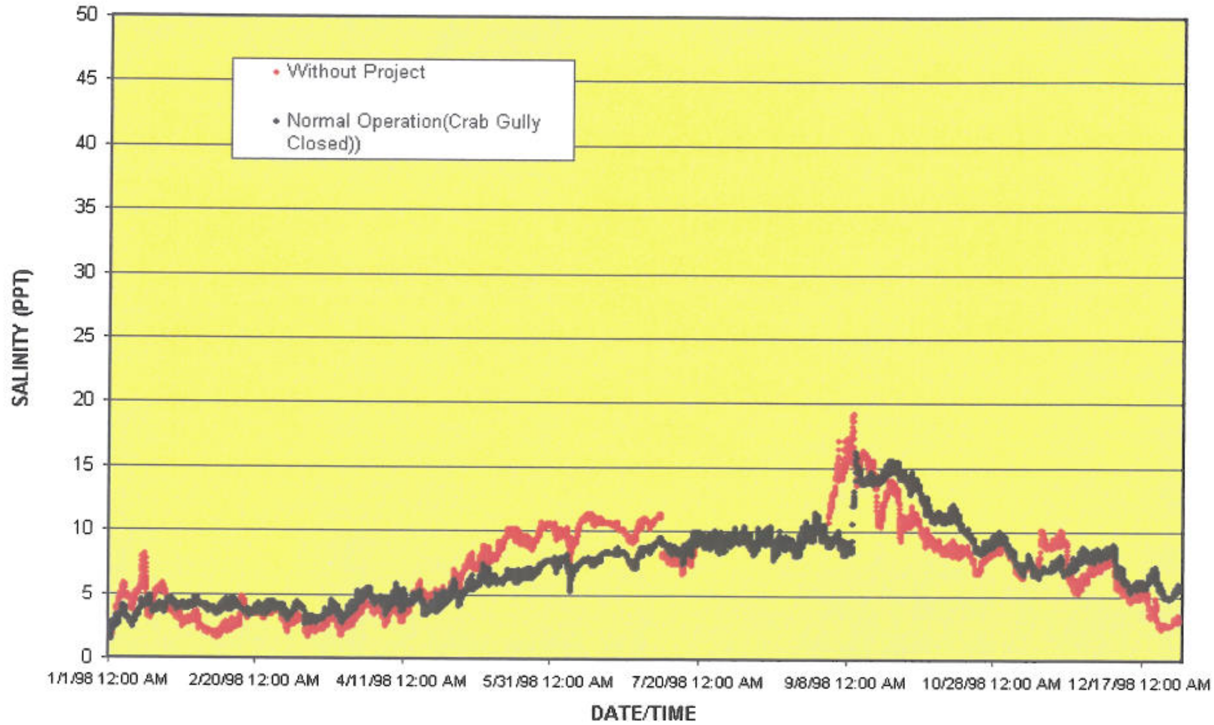

Figure 76: Gauge CS04-21, 1998 Normal Operation with Crab Gully closed (Salinity)

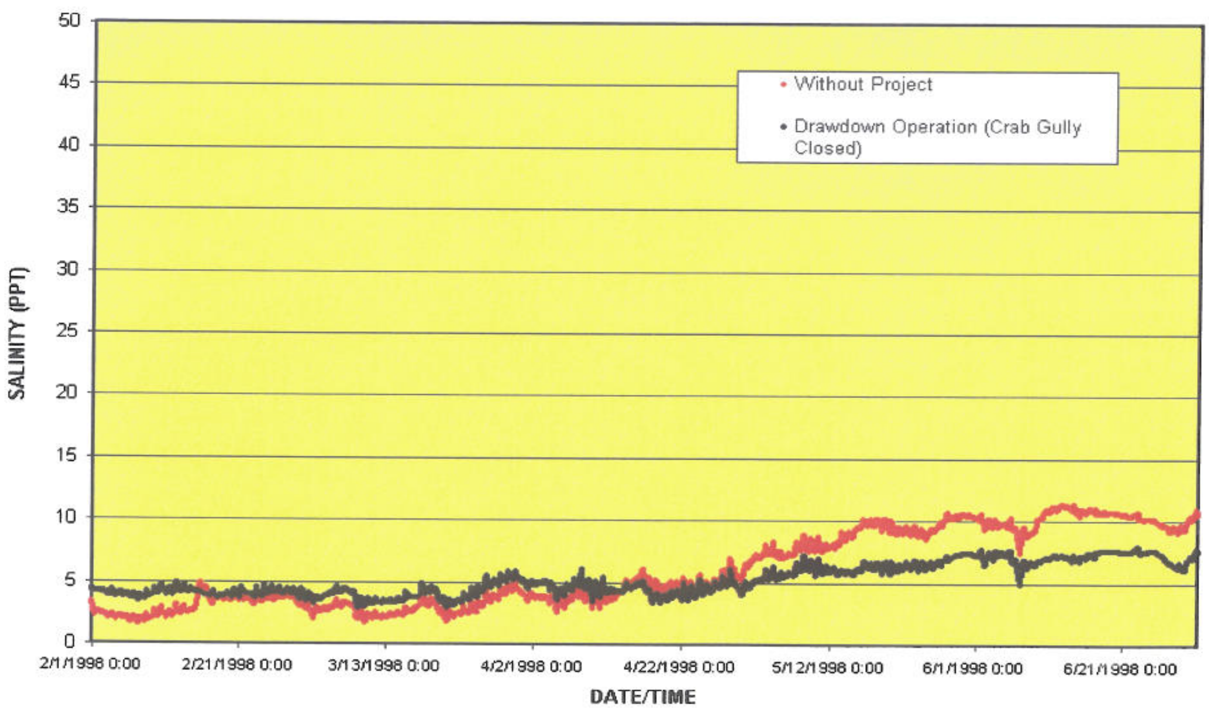

Figure 77: Gauge CS04-21, 1998 Drawdown Operation with Crab Gully closed (Salinity)

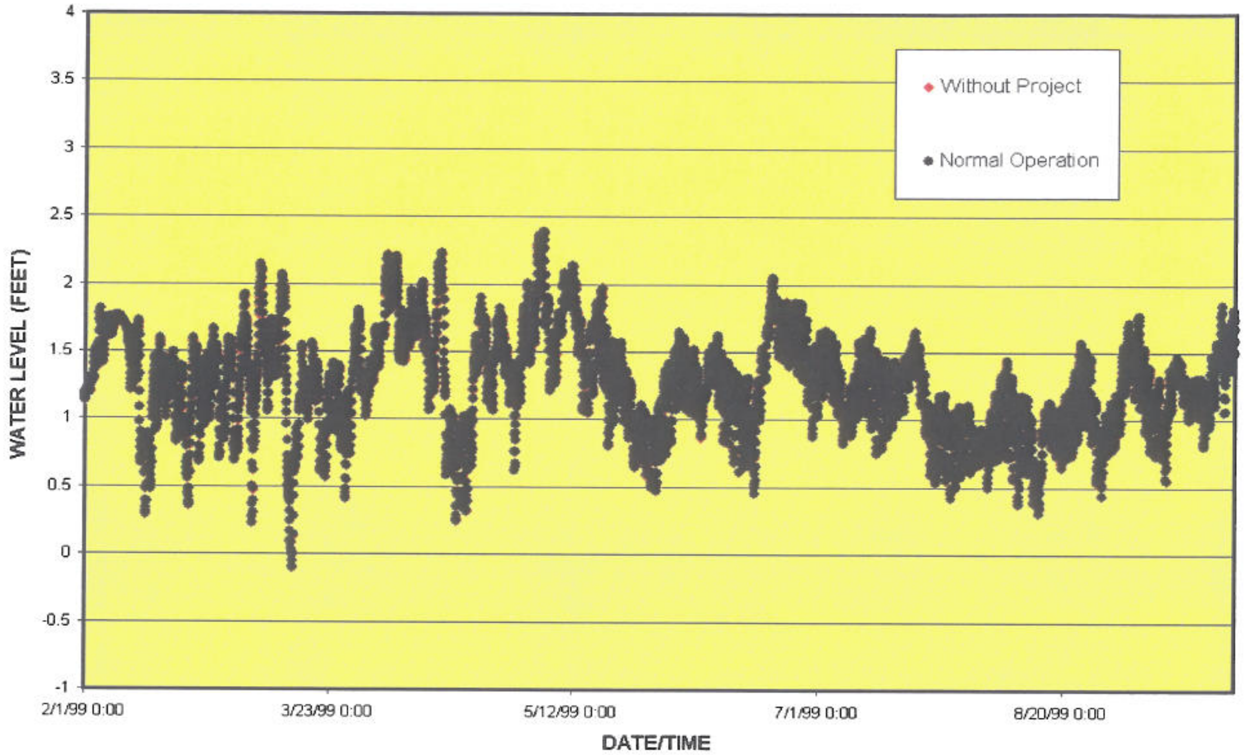

Figure 78: 1999 Normal Operation with Crab Gulley closed (Water Level), CS09-02

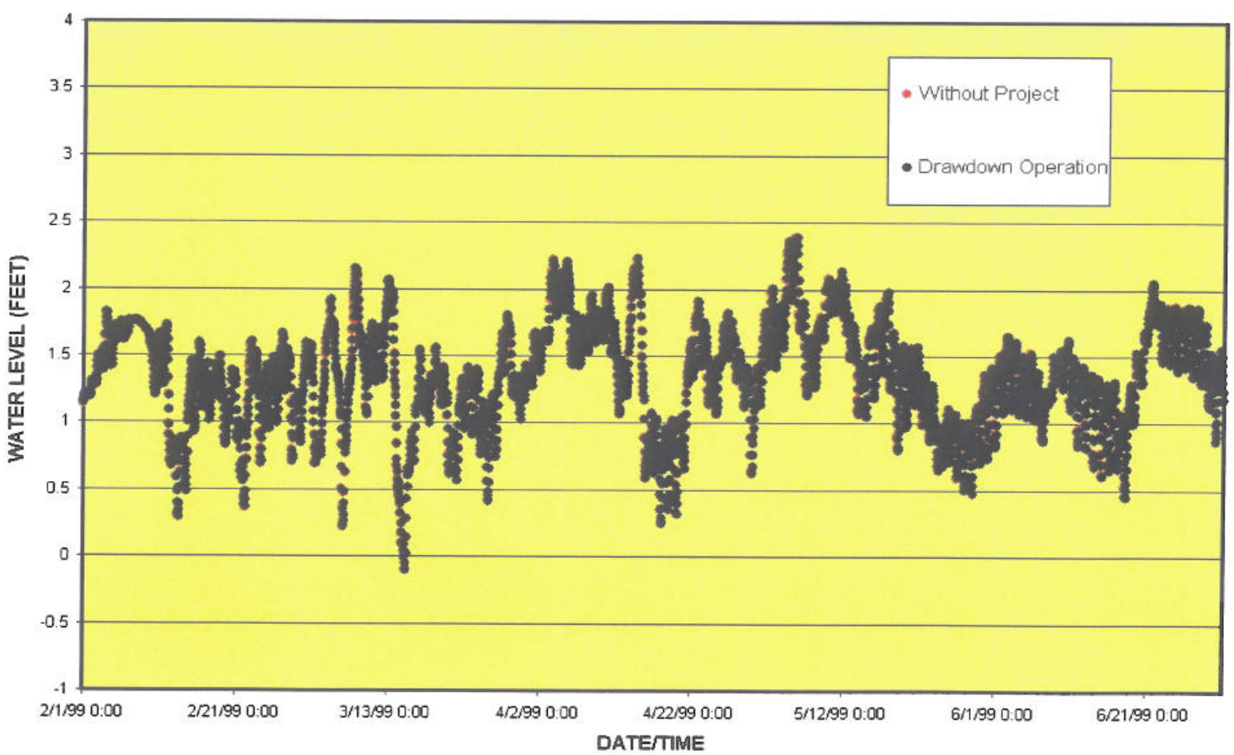

Figure 79: 1999 Drawdown Operation with Crab Gully closed (Water Level), CS09-02

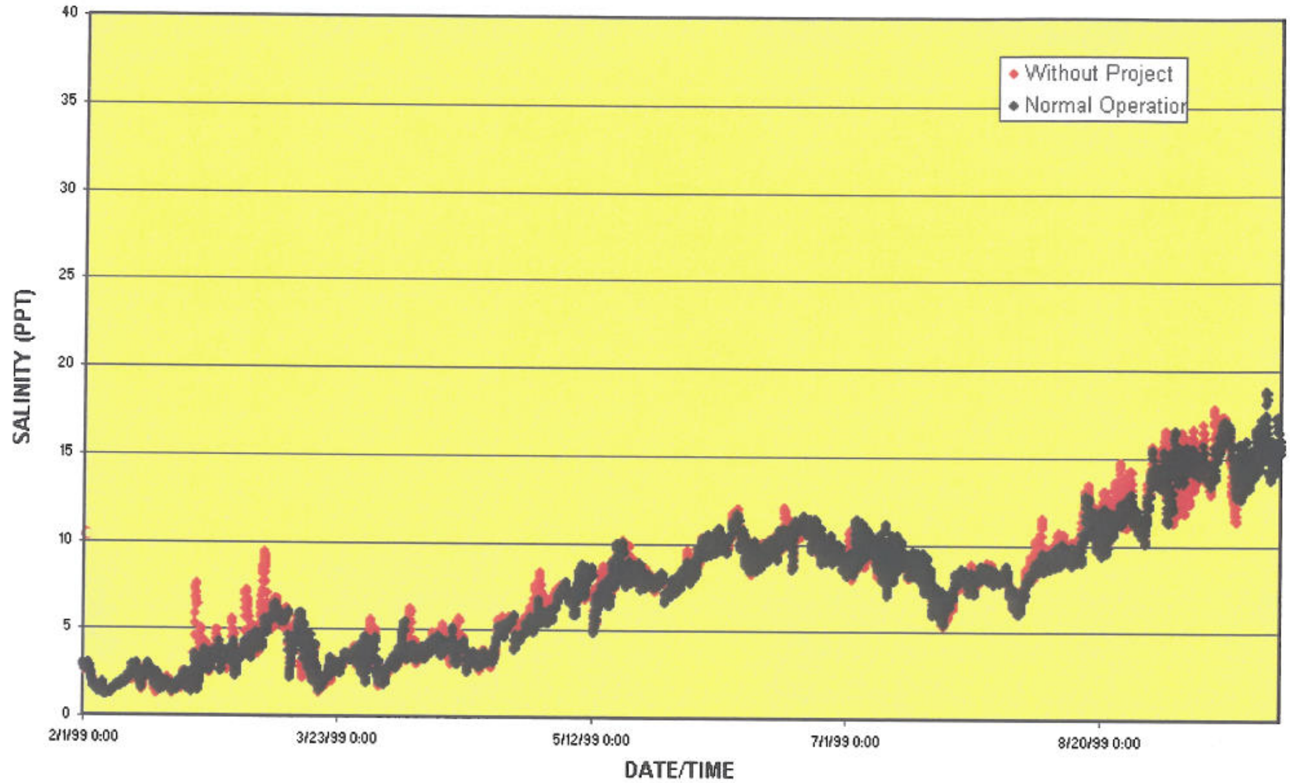

Figure 80: 1999 Normal Operation with Crab Gully closed (Salinity), CS09-02

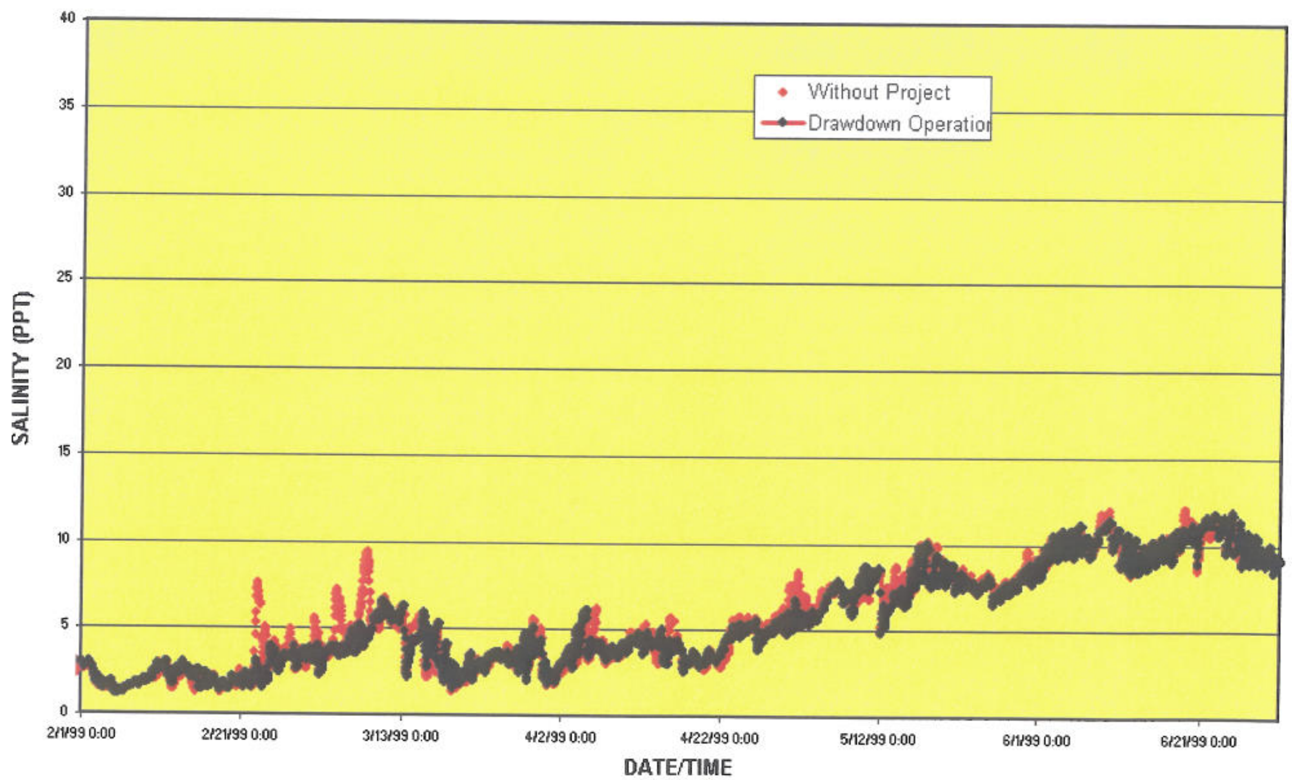

Figure 81 1999 Drawdown Operation with Crab Gully closed (Salinity), CS09-02

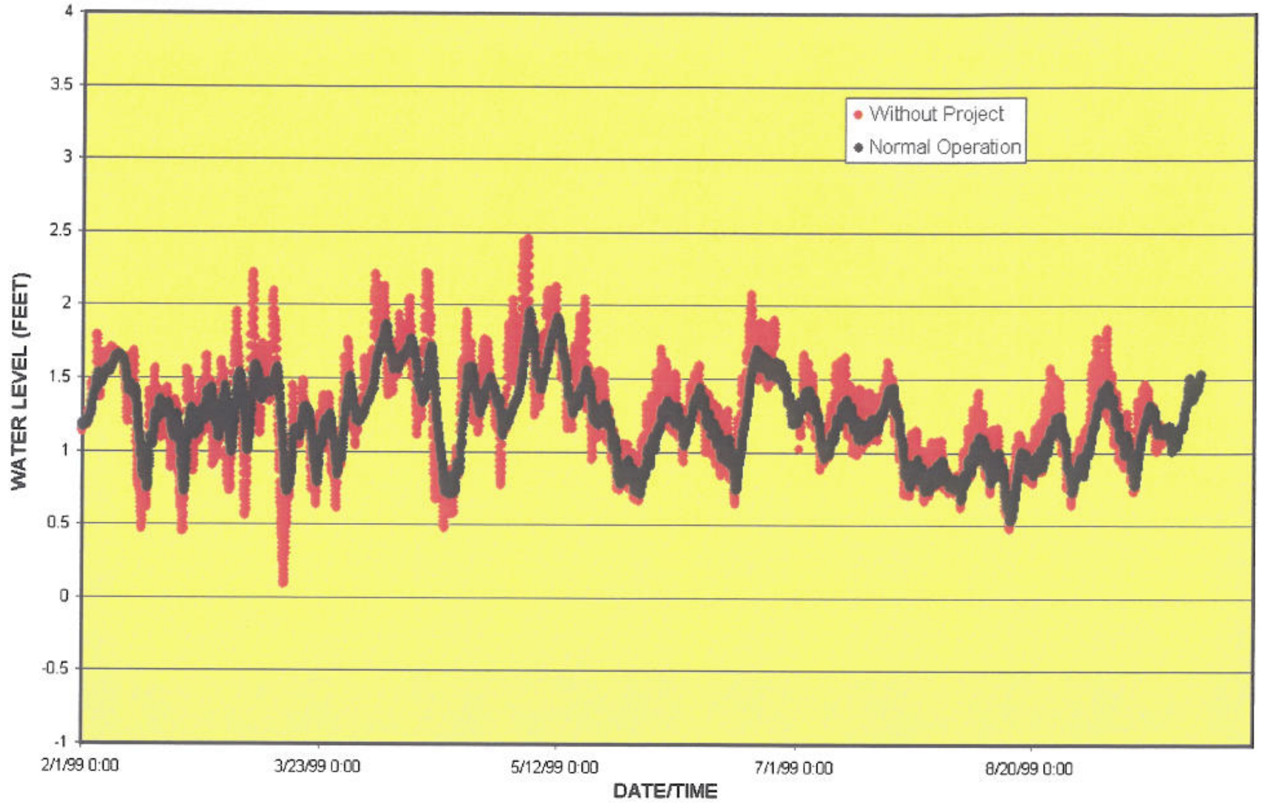

Figure 82: 1999 Normal Operation with Crab Gully closed (Water Level), CS09-04

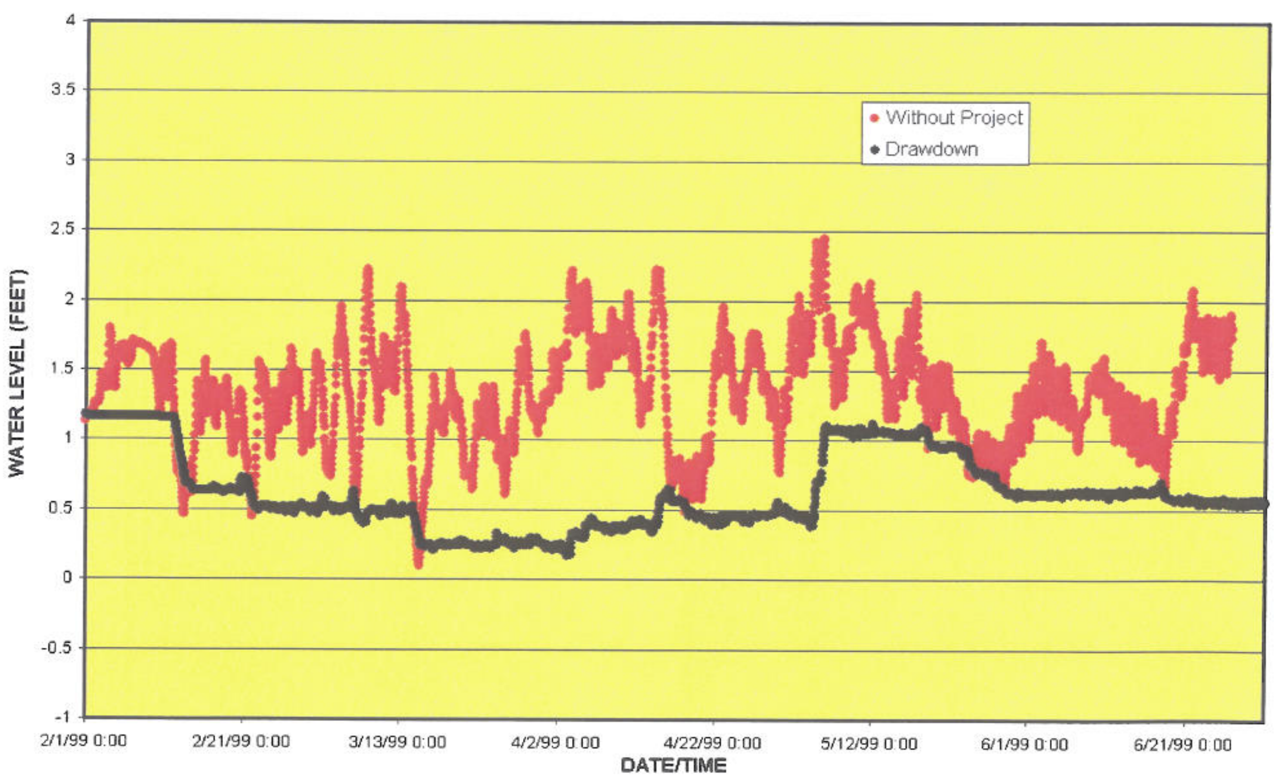

Figure 83: 1999 Drawdown Operation with Crab Gully closed (Water Level), CS09-04

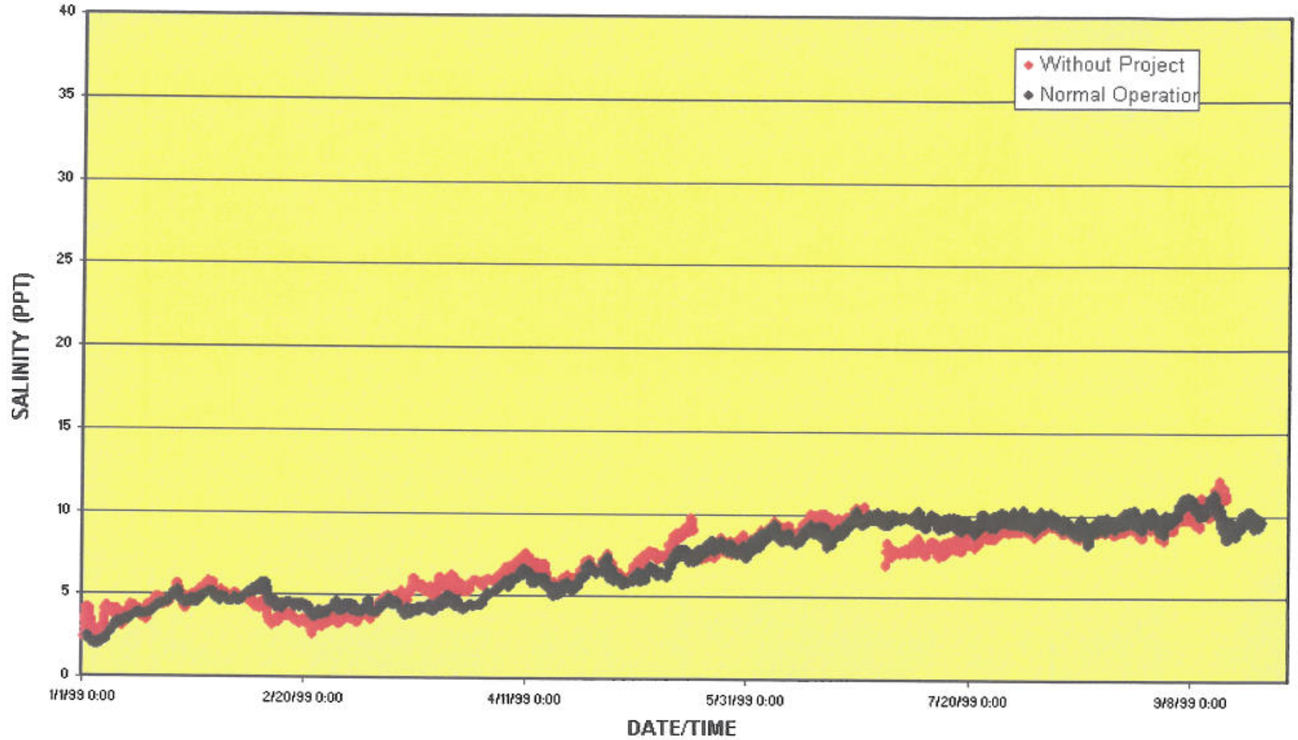

Figure 84: 1999 Normal Operation with Crab Gully closed (Salinity), CS09-04

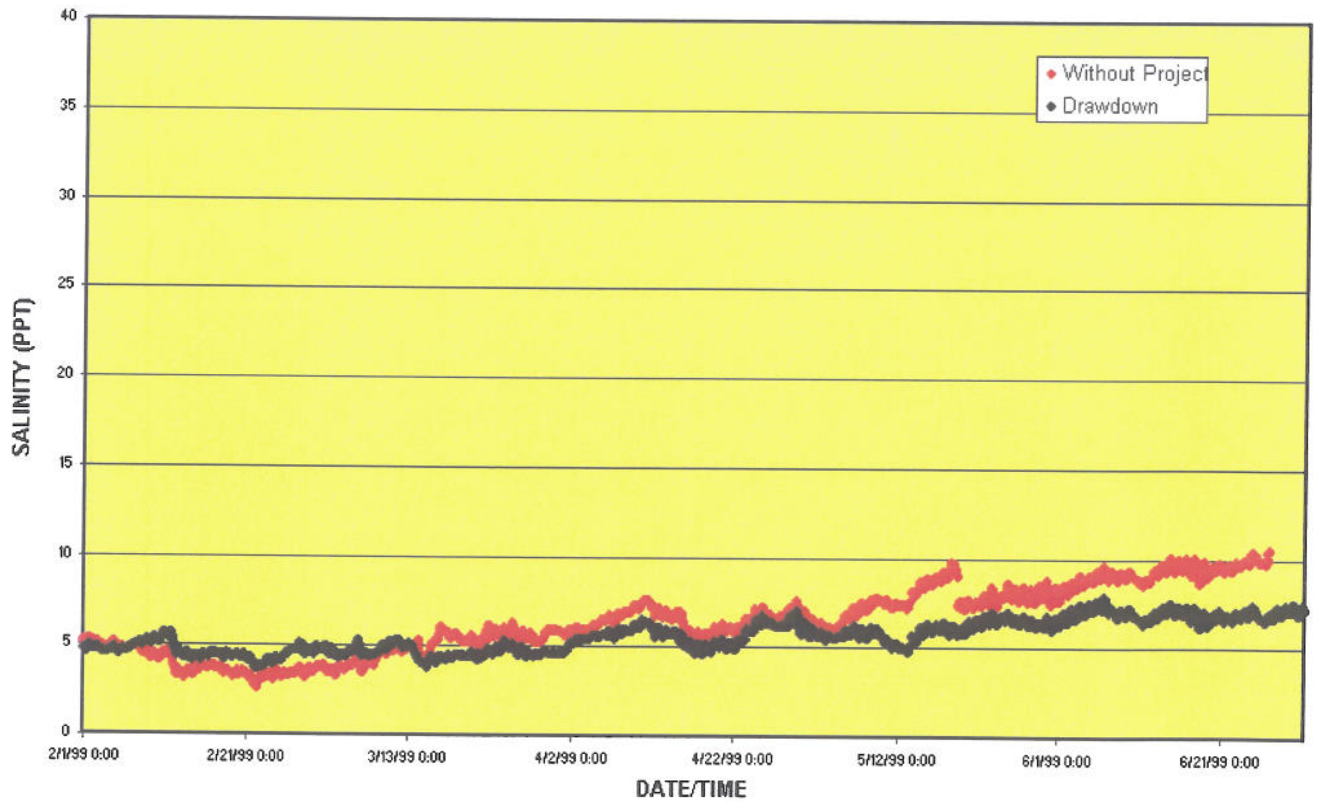

Figure 85: 1999 Drawdown Operation with Crab Gully closed (Salinity), CS09-04

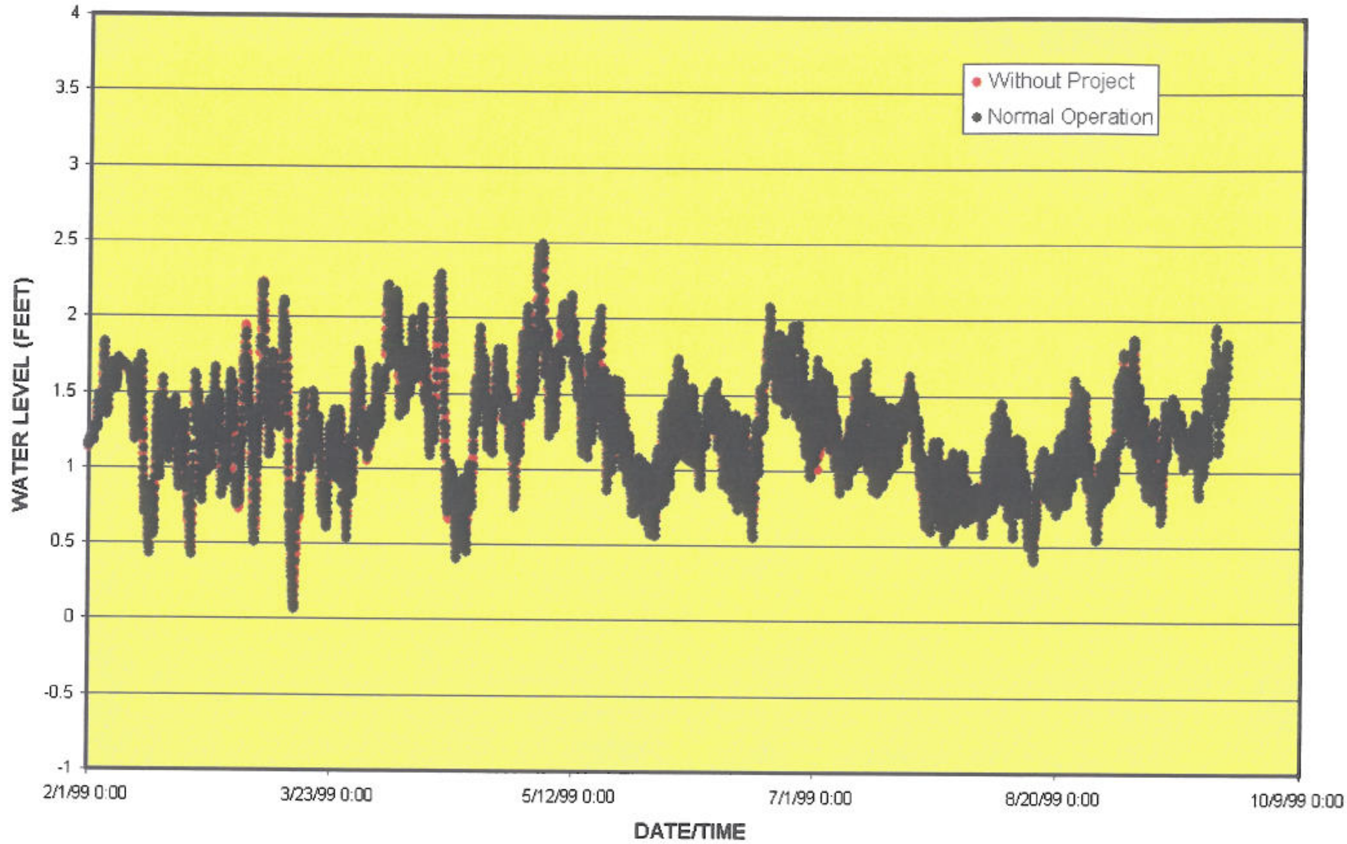

Figure 86: 1999 Normal Operation with Crab Gully closed (Water Level) , CS09-18

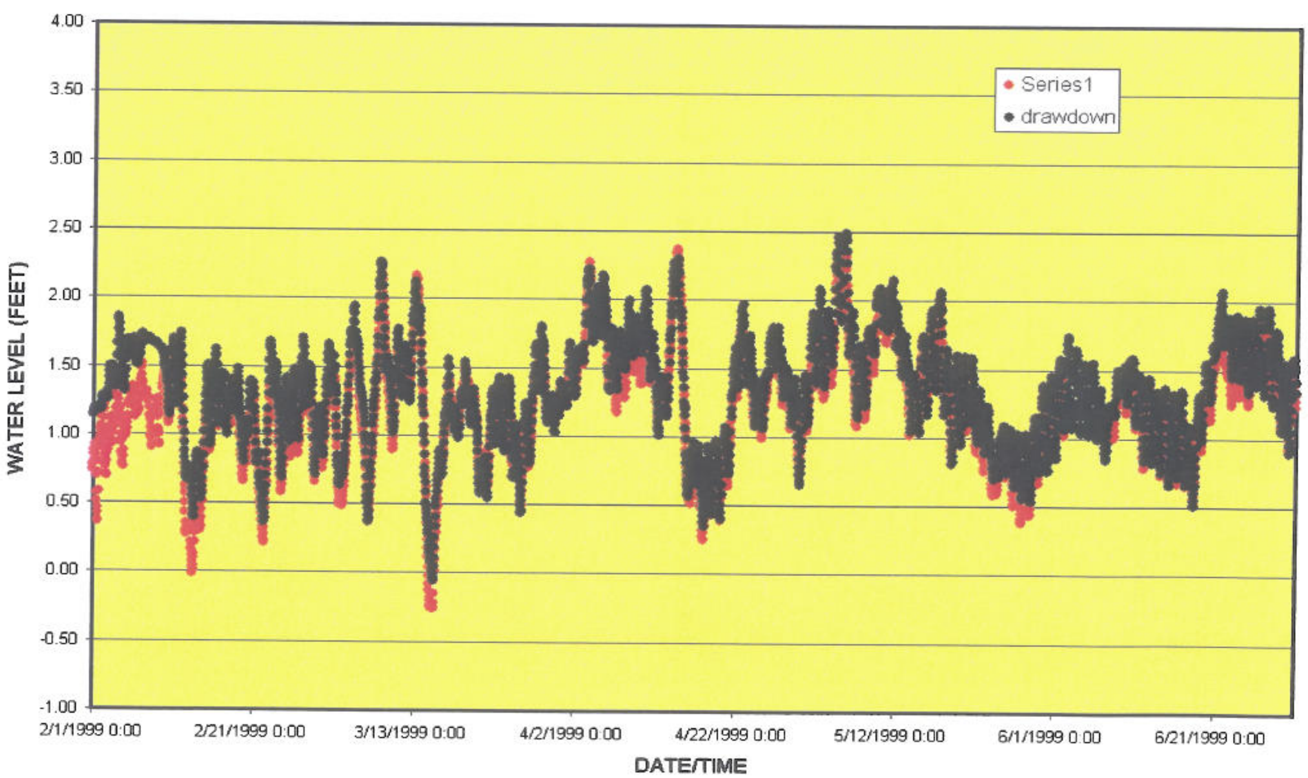

Figure 87: 1999 Drawdown Operation with Crab Gully closed (Water Level), CS09-18

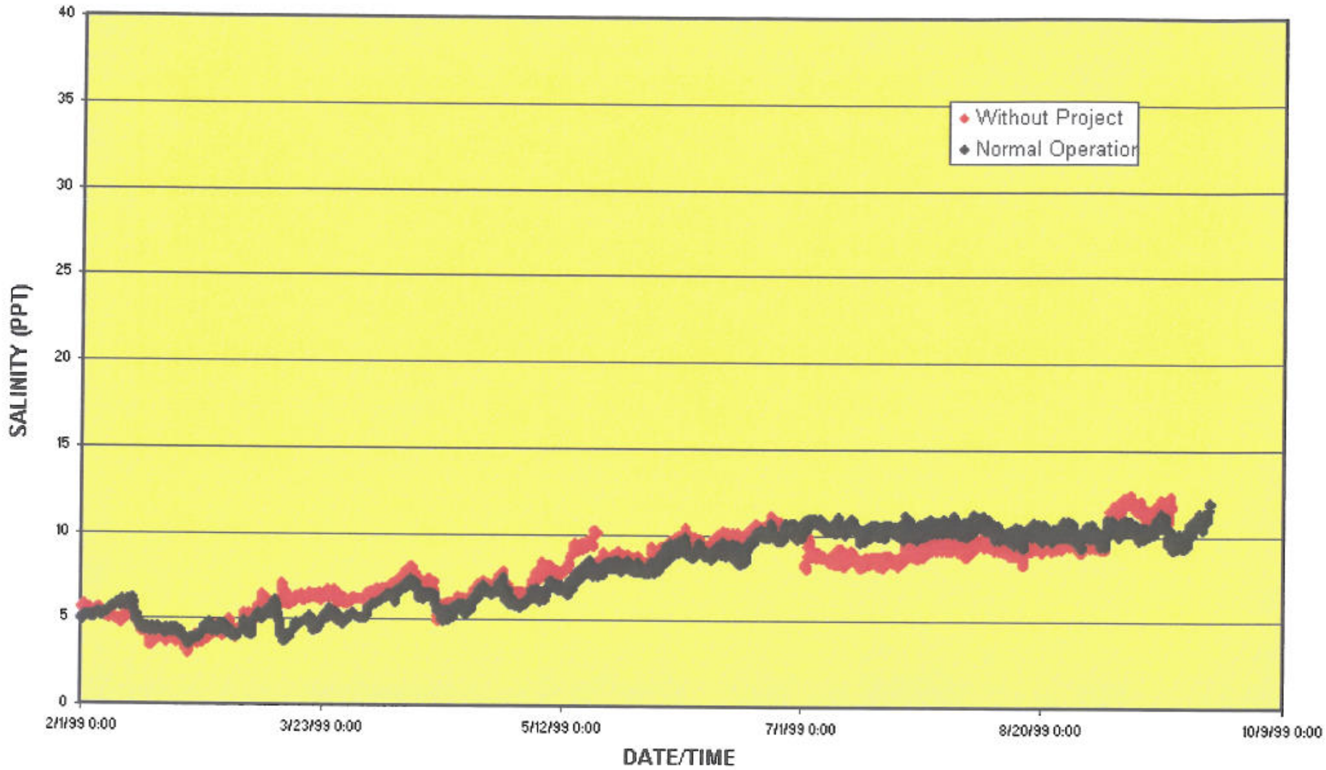

Figure 88: 1999 Normal Operation with Crab Gully closed (Salinity), CS09-18

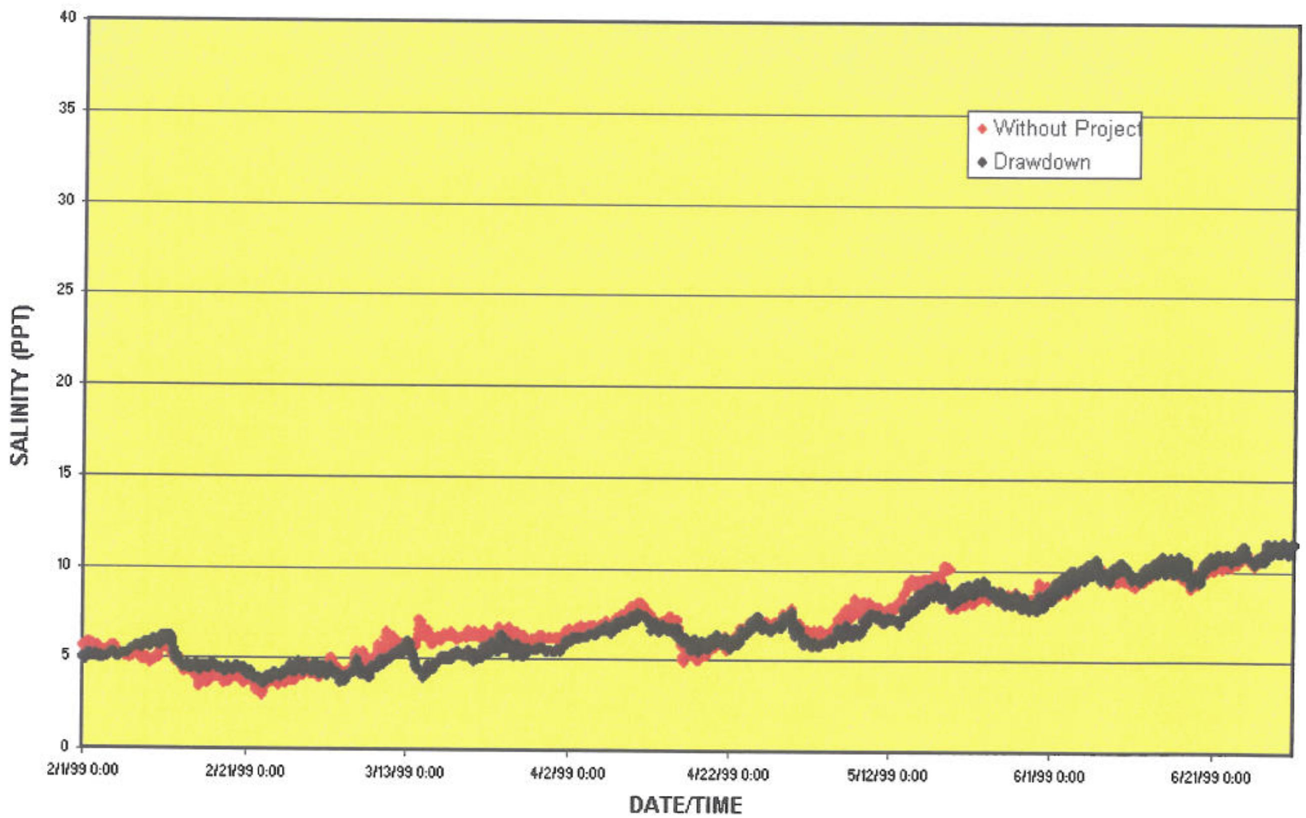

Figure 89: 1999 Drawdown Operation with Crab Gully closed (Salinity), CS09-18

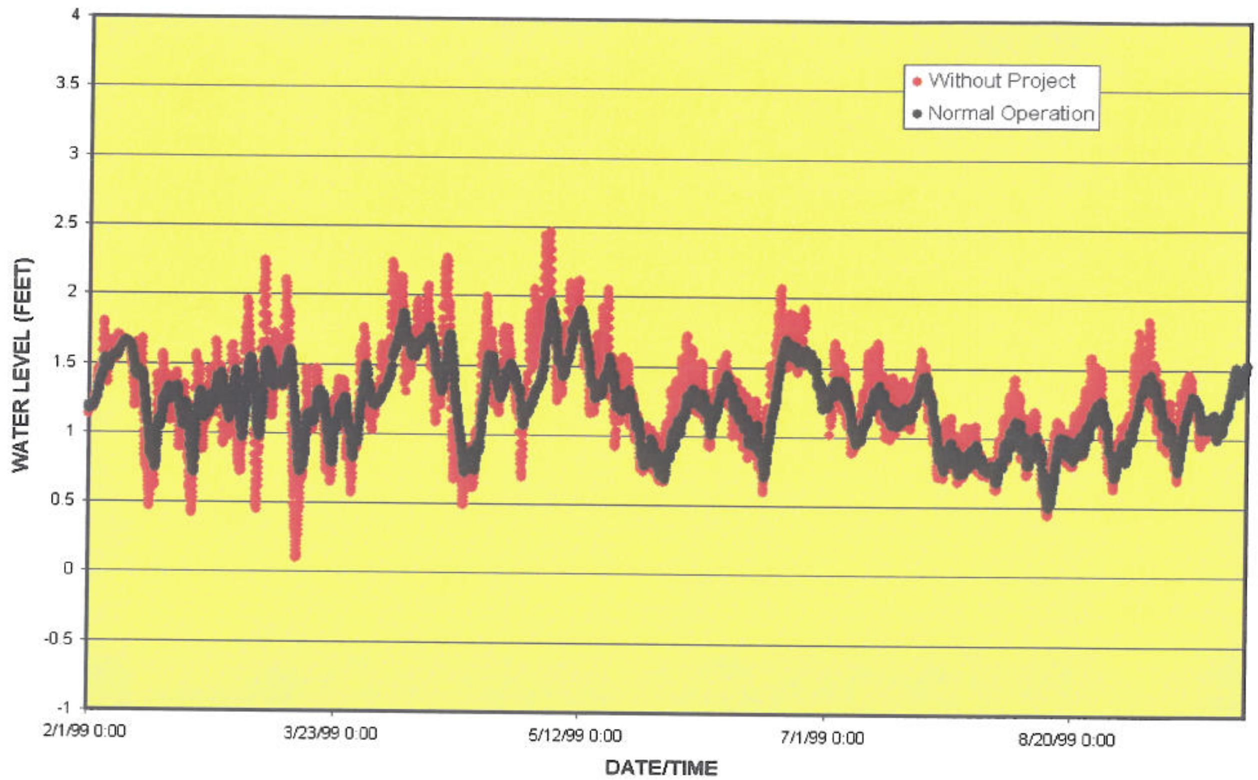

Figure 90: 1999 Normal Operation with Crab Gully closed (Water Level), CS09-21

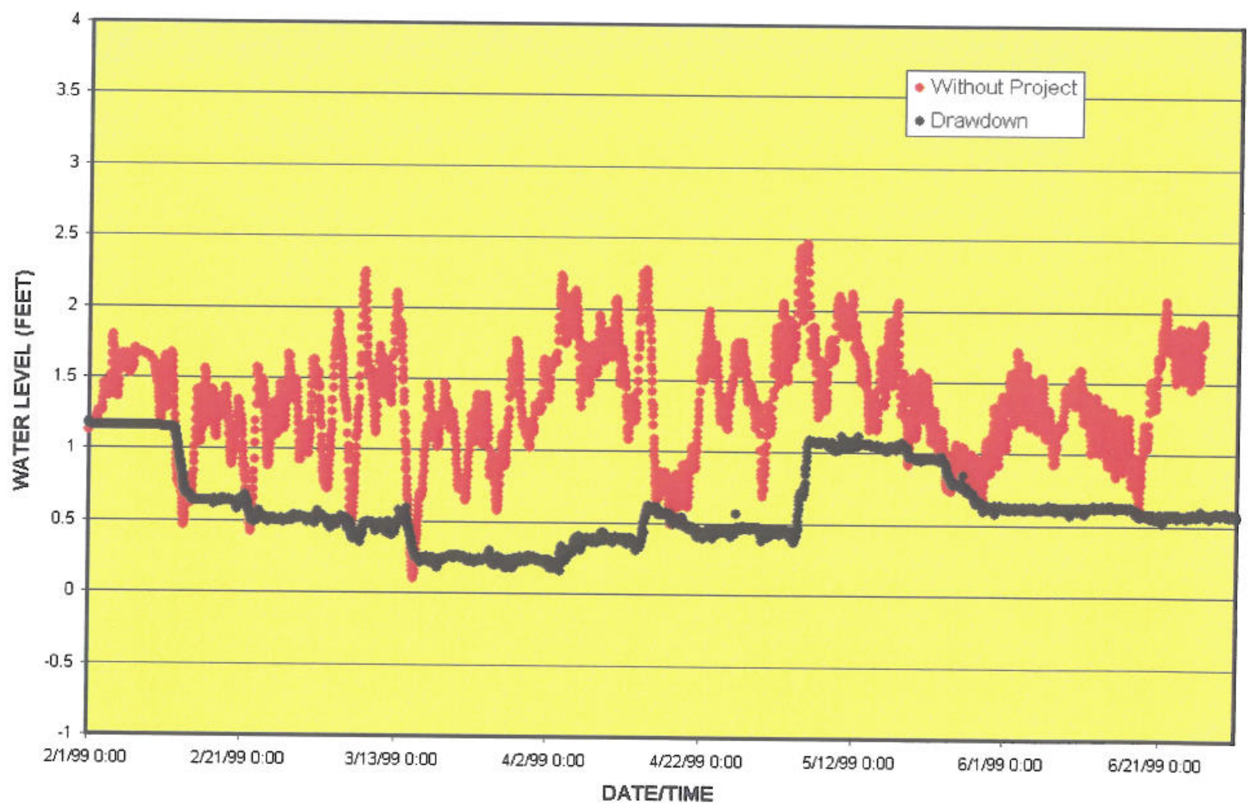

Figure 91: 1999 Drawdown Operation with Crab Gully closed (Water Level) , CS09-21

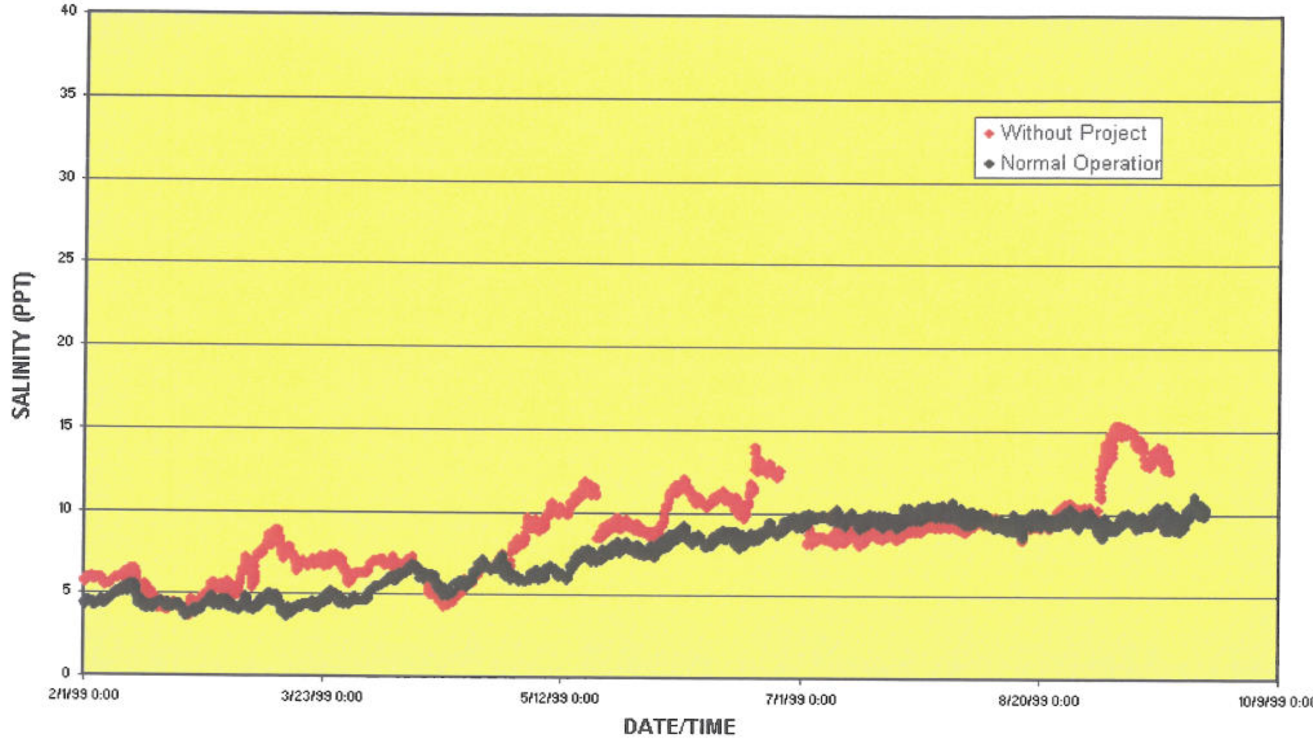

Figure 92: 1999 Normal Operation with Crab Gully closed (Salinity), CS09-21

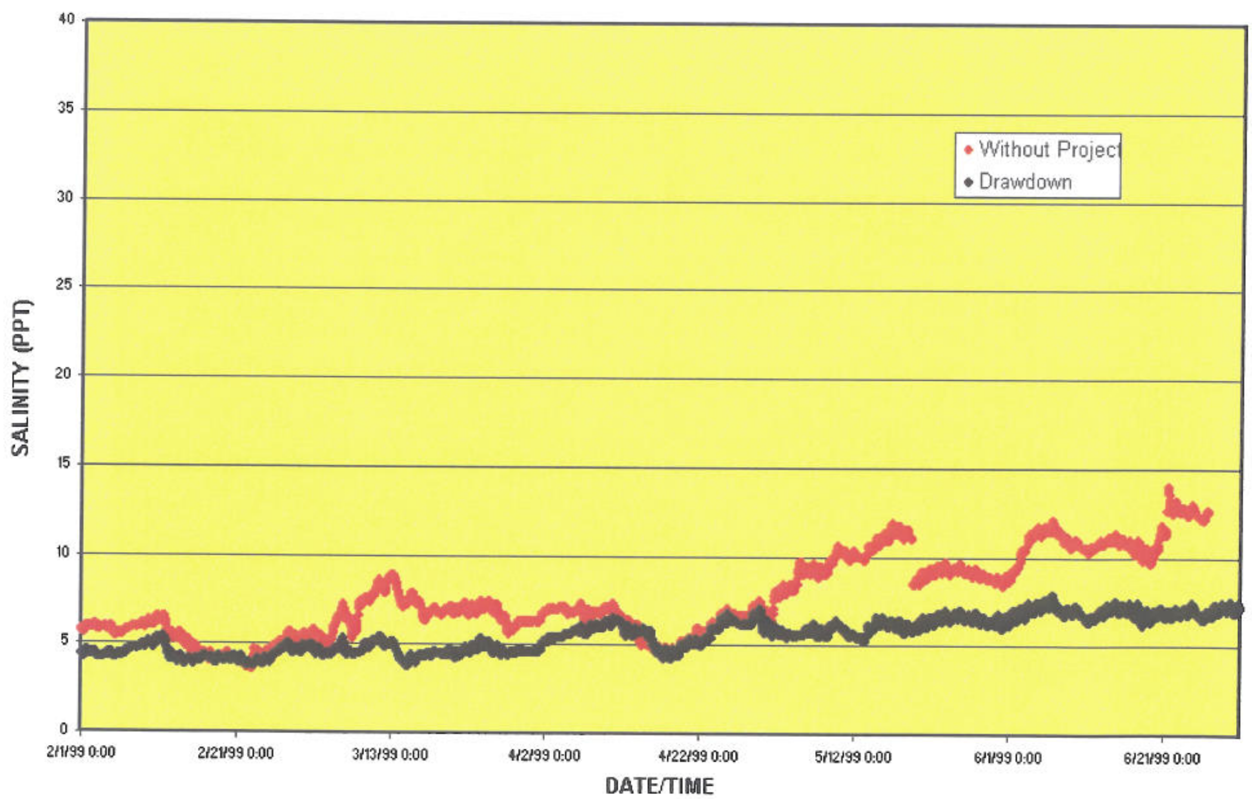

Figure 93: 1999 Drawdown Operation with Crab Gully closed (Salinity), CS09-21

Figure 94: Assumed spatial extent of the 100-year storm event

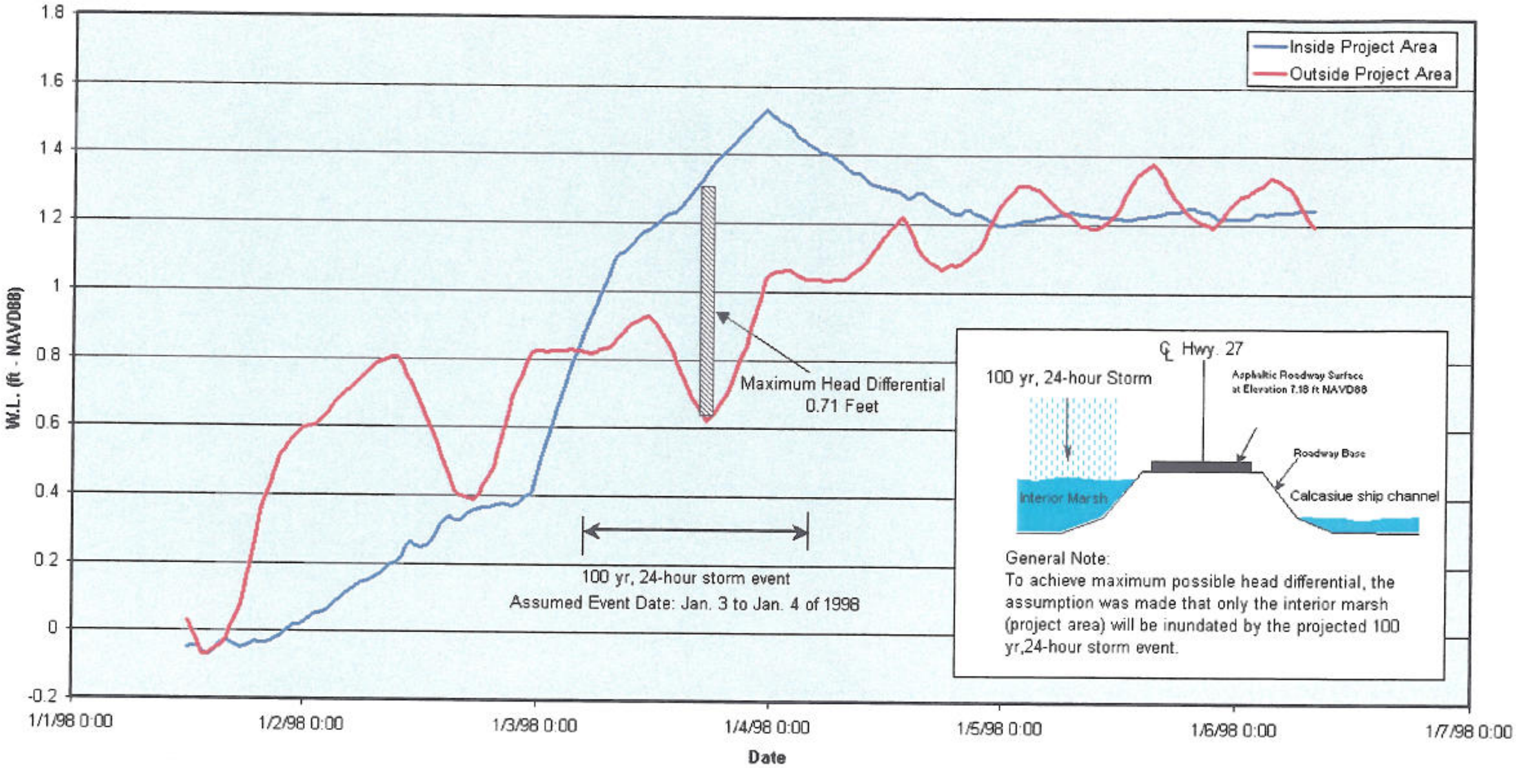

Figure 95: Maximum head differential during flow tide

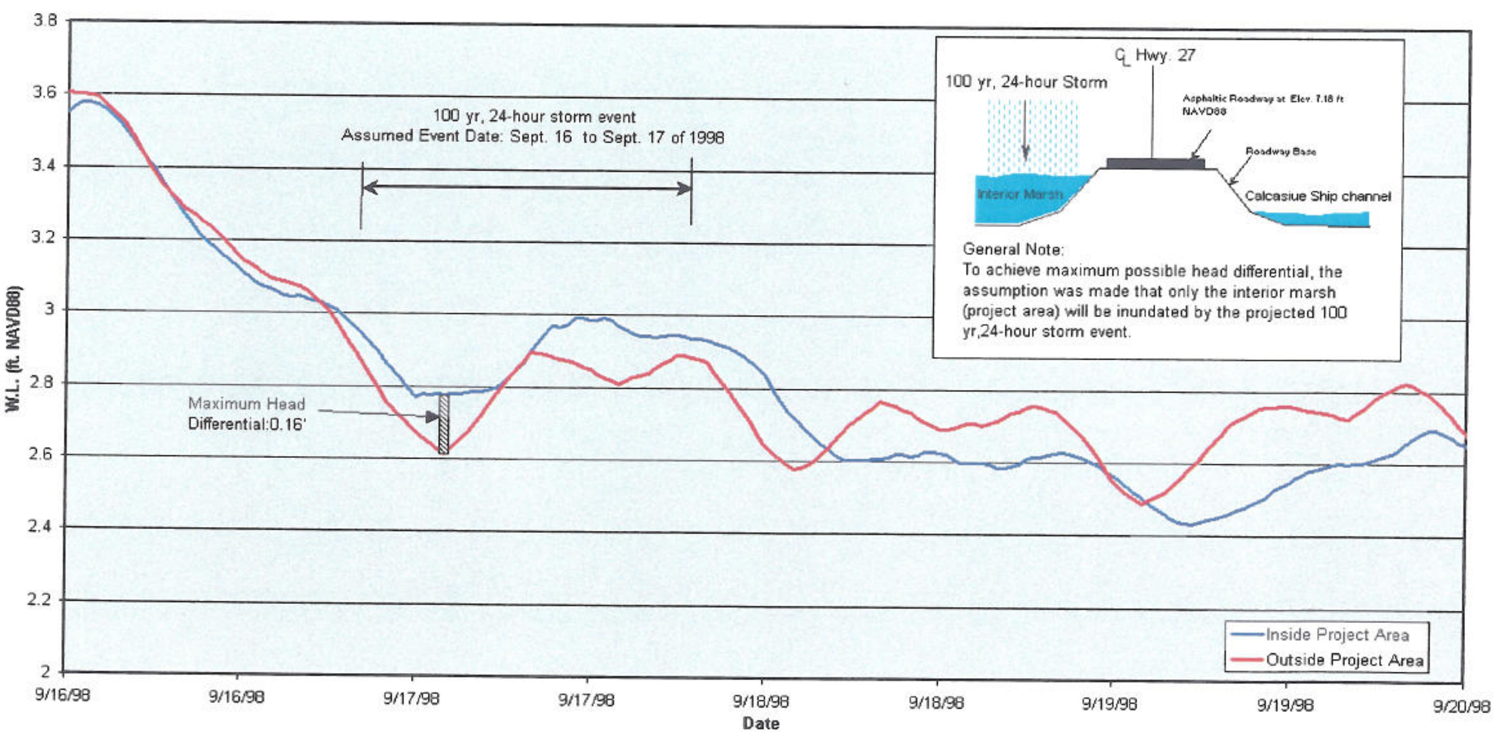

Figure 96: Maximum head differential during ebb tide

CLOSING REMARKS

This paper is intended to present a numerical model used to evaluate the feasibility of a wetland restoration project. The project consists of a levee system with three water-control structures, and a system of terraces. The model results showed the need of controlling the water exchange between the ship channel and the project area through the Crab Gully culvert openings. The model showed that the project is effective in reducing the high-frequency tidal fluctuations within the project area. The project was also proved to be effective in draining Brown Lake during the drawdown phase, which is beneficial to the vegetation re-growth within the project area.

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