Analysis of Proposed Flooding of Bahia Grande, Cameron County, Texas

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Abstract

The objective of this report is to describe the numerical model simulations conducted using Advanced Circulation Model (ADCIRC) within the Surface Water Modeling System (SMS) user interface and the resulting trends associated with various channel configurations for the proposed flooding of the Bahia Grande basin in Cameron County, Texas. Included is a brief history of the Bahia Grande region and site descriptions, past and present, which provide insight into the motivation for flooding the Bahia Grande region. The proposal by the Fish and Wildlife Service for channel locations and dimensions is discussed and used as a guideline for this study. Model development is explained, including: a brief description of SMS and ADCIRC, data used in the study, the finite element network, model forcing parameters, and model calibration. Model results are presented for multiple channel configurations, including water surface elevations and vertically averaged velocities at several locations within the Bahia Grande region. Results are also provided to demonstrate the effect of diurnal winds on the water level elevations in the Bahia Grande and adjoining basins.

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Introduction

Currently, the Bahia Grande basin is a parched, barren wind-tidal flat. However, history shows that the region holds the potential to be a productive shallow water bay. As a consequence of several major construction projects, man has drastically altered the Bahia Grande environment, changing the frequently flooded shallow water bay into a broad, sand swept region that tends to be a public nuisance. The sand blowing from Bahia Grande is an aggravation for motorists traveling on Highway 100 or Highway 48 through a blinding sand storm and for public and private property owners in Laguna Vista and Bayview who are constantly experiencing property damage from sand blasting. It is a constant reminder of man's innate ability to drastically alter environments that have existed for thousands of years. Restoration of the Bahia Grande area to a productive shallow water bay is a goal of the U.S. Fish and Wildlife Service. An essential step to restoring Bahia Grande is establishing a connection between Bahia Grande and one of the nearby water bodies.

Existing Conditions

Site Description

Bahia Grande encompasses approximately 6,800 acres in Cameron County, Texas. The Fish and Wildlife Service, with help from The Conservation Fund and the Natural Resources Conservation Service, recently purchased Bahia Grande and surrounding lands. (Blankinship undated) The Bahia Grande basin spans from the Brownsville Ship Channel north to Highway 100. The southern edge of Bahia Grande is located approximately 4.5 miles inland along Highway 48 between Port Isabel and Brownsville. Two smaller basins, Laguna Larga and Little Laguna Madre, lie to the east of Bahia Grande. Each of these smaller basins is approximately 2,000 acres and are also included in restoration plans for Bahia Grande.

Historically, the area of Bahia Grande was connected with the Laguna Madre system by frequent inundation with salt water from wind-driven tides and storm surges. As shown on the following page in Figure 1, Bahia Grade was not directly connected to the Laguna Madre system through a specific inlet, but it was flooded mostly by wind-driven tides encroaching over the surrounding low lying areas.

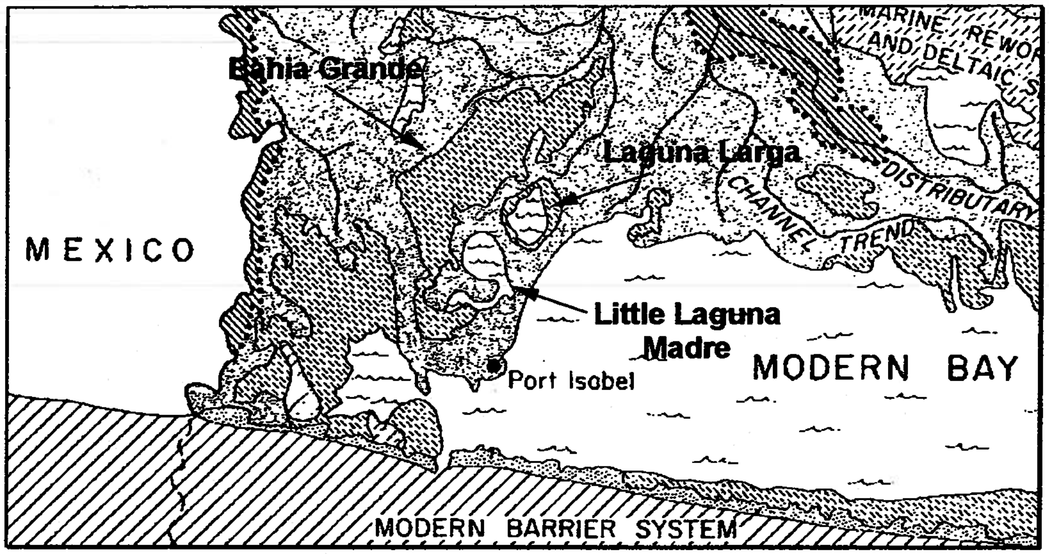


Figure 1: Illustration of historical Bahia Grande region. Note "Modern Bay" is Laguna Madre. (Brown 1980)

During the last century, several man-made structures altered the topography of the areas in and surrounding Bahia Grande, thus changing the frequency of basin flooding. First, a railroad that connected Brownsville and Port Isabel was constructed through the middle of Bahia Grande, essentially cutting the area into a northern and southern section. The railroad has since been abandoned, leaving the railroad grade and sand that has been accumulating on the old causeway for decades to act essentially as a dam. The only openings in the railroad causeway are a major breach located at the eastern edge of Bahia Grande and a recently cut, 30 yard breach, which was opened approximately one mile into the basin from the western edge during the summer of 2001. (Blankinship July 2001)

Another major development that affected Bahia Grande was the dredging of the Brownsville Ship Channel, which occurred between 1934 and 1936. When dredging the Ship Channel, a majority of the dredge material was deposited on its northern bank, drastically changing the natural topography of the land. Since Brownsville Ship Channel lies on the southern most edge of Bahia Grande, the raised elevations on the northern bank of the Ship Channel greatly decreased the frequency of salt-water inundation of Bahia Grande from surrounding water bodies and prohibited an open exchange of water between Bahia Grande and the Brownsville Ship Channel.

The construction of State Highway 48 in 1953 is the most recent structure to have a major impact on Bahia Grande. Running between Brownsville and Port Isabel approximately 0.5 miles to the north of the Brownsville Ship Channel, HWY 48 created another barrier for water exchange between the Brownsville Ship Channel and Bahia Grande. However, at the time of the construction and for over a decade after the highway was built, three culverts (two 30 inch and one 45 inch culvert) beneath the highway allowed an exchange of water between the ship channel and Bahia Grande through a tidal channel about 30 feet wide.

According to Robert A. Morton, who conducted a study of Bahia Grande for the Texas General Land Office in February 1991, only the western-most 30 inch culvert, of the three culverts under HWY 48, allowed for the passage of water. The other two culverts were blocked by sediment and were likely structurally damaged due to settling. As of June 2001, it was unclear if any of the three culverts would accommodate water flow. All three culverts were severely overgrown with brush and appeared to be at least partially blocked by sediment and other debris as shown in Figure 2 below. Differential settling was also apparent, and likely hampered or eliminated the possibility

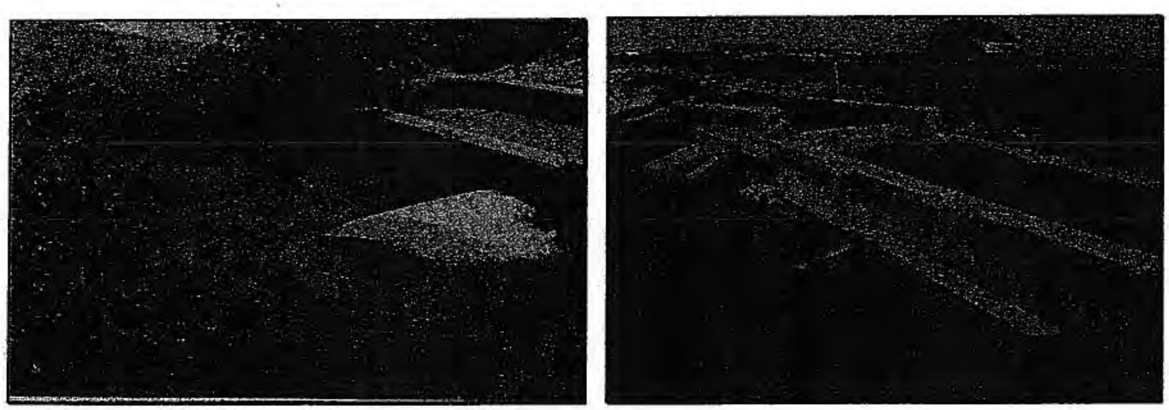


Figure 2: Culverts under Highway 48, photographed June 20, 2001, by the author.

of water exchange through the culverts under HWY 48. Above, Figure 2 exhibits the extent of differential settling in the vicinity of the culvert structures.

As Morton learned from marine biologists and local fishermen, Bahia Grande was a productive wetland as recent as the late 1960s, despite the numerous man-made obstacles. However, after receiving severe structural damage from Hurricane Beulah in1967, the section of HWY 48 that crosses Bahia Grande was completely rebuilt in 1968, once again prohibiting free water exchange between the Brownsville Ship Channel and Bahia Grande. At the same period, several other factors further stifled the flooding of Bahia Grande. The narrow tidal channel that connected Bahia Grande and the Brownsville Ship Channel was filled in due to a combination of additional dredge material being placed on the northern bank of the ship channel, "slope wash from the spoil banks," and wave action in Brownsville Ship Channel. (Morton 1991)

With the tidal channel between Bahia Grande and the Brownsville Ship Channel closed off and the culverts under HWY 48 blocked and damaged, Bahia Grande is presently only flooded under extreme weather conditions, either by runoff from heavy precipitation or from storm surges and rainfall that accompany tropical storms.

Environmental Conditions

Cameron County is a subtropical and sub humid region, usually experiencing an average of 26 inches of precipitation per year. Precipitation is mostly limited to rainfall, as snowfall in the region is rare. A majority of the rainfall in the area is concentrated in the fall and winter months with occasional rains in spring and summer months. Temperatures range from an average daily range of 50°F to 69°F in January to an average daily range of 75°F to 97°F in July.

Two prevailing wind patterns are evident in Cameron County. From March through November, steady south to southeasterly winds blow between 15 and 20 miles per hour during the day and die down to between 4 and 11 miles per hour during the early morning hours. In December through February, the region is exposed to short-lived strong northerly winds up to 26 miles per hour that accompany winter storm systems.

Along the Gulf of Mexico shoreline in Cameron County, the mean astronomical diurnal tide range is 1.4 feet, and the mean tide range along the Lower Laguna Madre shoreline is 1 foot. (White 1986) Due to the region's small astronomical tidal ranges, wind-driven tides usually play a significant role in the Laguna Madre bay-lagoon system.

Possible Future Site Conditions

With proper preparation and planning, the Bahia Grande area may be restored to a productive shallow water bay system, which will provide a multitude of benefits regionally and globally. Flooding Bahia Grande and nearby Laguna Larga and Little Laguna Madre basins will provide a nursery for marine life, offer a habitat for many bird species, and reduce public and private expenditures due to property damage caused by wind blown sand from the region. On a larger scale, if the flooding of Bahia Grande is successful, the project may potentially serve as a model for organizations interested in restoring wetland areas throughout the world.

To increase the opportunity for a successful restoration of Bahia Grande, Laguna Larga, and Little Laguna Madre basins, examples of existing productive wetland systems in the area were studied. Nearby San Martin Lake and South Bay are two shallow water bay systems in the vicinity of Bahia Grande that provide valuable insight into the possible future characteristics of Bahia Grande. Figure 3 illustrates the locations of San Martin Lake and South Bay with respect to Bahia Grande.

San Martin Lake and South Bay

As in Figure 3, South Bay is located immediately inland from the Gulf of Mexico and to the south of the Brownsville Ship Channel. A wide, shallow channel joins South Bay with the Ship

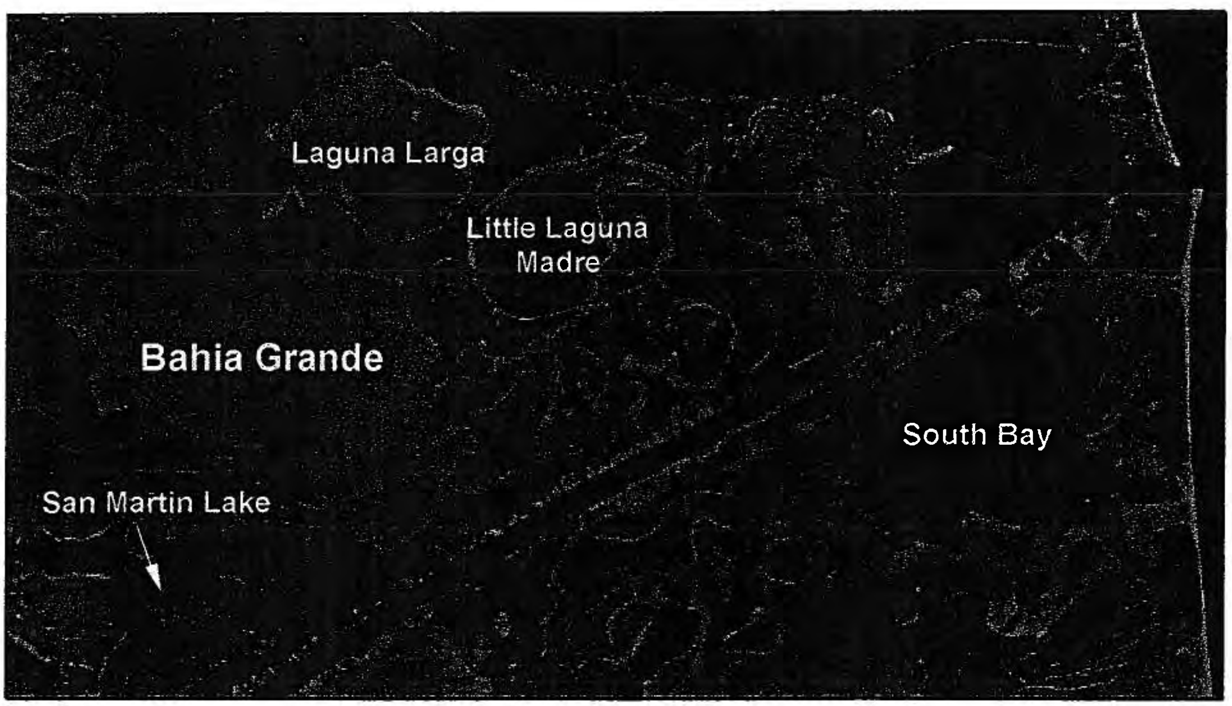


Figure 3: Bahia Grande region with lakes and basins of interest noted.

Channel which allows for large tidally driven exchanges of salt water and unobstructed migration opportunities for marine organisms. South Bay topography is similar to that of Bahia Grande, given that the depths in South Bay range from 0.5 to 3.0 feet with an average depth of less than 1 ft. Acting as a nursery and home for at least 26 species of mollusks, 8 species of crustaceans, and the "only sizable concentration of oysters south of Corpus Christi," South Bay is a productive ecosystem and a valuable resource for Southern Texas. (White 1986)

San Martin Lake is adjacent to the western edge of Bahia Grande. It is connected to the Brownsville Ship Channel through a canal that is approximately 120 feet wide and 10 to 12 feet deep at the HWY 48 bridge. San Martin Lake "has a depth of about 6 ft along its central axis where it connects to the Ship Channel; elsewhere, San Martin Lake is extremely shallow." (Morton 1991) San Martin Lake also has upstream and downstream drainage inflows, including drainage ditches that divert floodwaters and carry municipal waste-water discharge from several Brownsville sewage treatment plants to the lake. Also, a petrochemical plant's cooling water that is extracted from the Brownsville Ship Channel is discharged into holding ponds and then flows into San Martin Lake. (Morton 1991) Coupling tidal inflows and discharges into San Martin Lake from other sources creates adequate circulation in the lake to maintain a productive wetland system.

Possible Channel Types and Dimensions

To begin the restoration of Bahia Grande shallow water bay system, it will be necessary to establish a hydrologic connection between Bahia Grande and the Brownsville Ship Channel and/or San Martin Lake. The channel, or combination of channels, should allow for an estimated tidal inundation of between 4,000 and 5,000 acres in the Bahia Grande basin. (Broska 1999) However, it is not possible to design a channel that would exchange one hundred percent of the water in the basin with each tidal cycle. Such a channel would have unreasonable dimensions (3390 feet wide by 14 feet deep) as concluded by James Broska using a very simple approach – discharge (Q) equals velocity (V) times area (A). Complete water exchange during each tidal cycle also means frequent drying of the basin, leaving the area uninhabitable by many species of sea grass and marine life. Because plant and animal life thrive in waters that are well circulated, sensible water exchange and circulation are a concern in determining channel placement and dimensioning.

Biologists, hydrologists, engineers, and others familiar with the Bahia Grande region have suggested channel design options. Figure 11 in Appendix A illustrates the locations of the proposed channels presently being considered by the FWS. Summarized below is the plan of action for the restoration of the Bahia Grande wetland, written by project proponents from FWS, Stephen Labuda and David Blankinship.

The main plan includes constructing three channels, which are illustrated in Figure 11: Channel A, Channel B, and Channel C. Channel A will be the main channel and will provide an estimated 7,300 foot connection between Bahia Grande and San Martin Lake. Preliminary dimensions of the channel are a bottom width of 20 feet and a depth of 2 feet below mean sea level. A water control structure is being considered to regulate water flows and prevent potential pollution of Bahia Grande from oil or chemical spills. Channel B will be approximately 5,000 feet in length, and will connect the Bahia Grande and Laguna Larga basins. Channel C will be an estimated 6,100 feet long, and will connect Bahia Grande and Little Laguna Madre basins. Channels B and C also have preliminary dimensions of 20 feet bottom width and a depth of 2 feet below mean sea level.

Two additional channels are being considered. Channel D is an optional channel, estimated to be 1,200 feet long, and would connect Laguna Larga and Little Laguna Madre basins. Dimensions for Channel D are as stated above for Channels B and C. Channel E would connect Bahia Grande basin directly to the Brownsville Ship Channel through a 2,000 foot long channel. This channel option would provide the most efficient means of re-flooding Bahia Grande; however, Channel E would pass through lands of the Brownsville Navigation District (BND), which has not consented to the use of the land.

Objectives

This study was conducted at the request of the Fish and Wildlife Service (FWS) in conjunction with an ongoing project to re-flood Bahia Grande in Cameron County, Texas. Specifically examined are several of the possible channel configurations between San Martin Lake, Brownsville Ship Channel, and Bahia Grande, and the resulting hydrodynamics of the shallow water estuary systems that may be created if these channels are in place. With the use of the Surface-Water Modeling System (SMS), a two dimensional numerical model of Bahia Grande and surrounding water bodies out to and including the Gulf of Mexico was developed to analyze the Bahia Grande system. Results from models incorporating various channel dimensions and configurations were evaluated with the purpose of maximizing project value. The effects of wind and tide were also included in the analysis.

Model Development

Description of SMS and ADCIRC

Surface-Water Modeling System, or SMS, is a computer program used for creating, editing, and presenting finite element networks employed in hydraulic modeling. SMS is essentially a pre- and post-processor that gives the user the capability of running several hydrodynamic models from within the windows based SMS environment.

Of particular interest for this study, SMS supports the two-dimensional hydraulic model, Advanced Circulation Model (ADCIRC). ADCIRC was developed at the Waterways Experiment Station to simulate hydrodynamic circulation in coastal areas, along shelves, and within estuaries.

ADCIRC uses a finite element approach to solve "shallow-water equations in non-linear form, including nonlinear convective acceleration terms, finite amplitude terms, and bottom friction terms." (Lam 1998) ADCIRC allows the user to input desired steady state or dynamic boundary conditions and parameters to produce results that include vertically averaged vector velocities and water surface elevations at each node throughout the finite element network. For simulations in this report, ADCIRC version 31.06 was used.

Developing Finite Element Network

Data and Sources

Topographic and bathymetric data used to create the finite element grid for this study were obtained from several sources. Topographic data for Bahia Grande and the immediate surrounding area are from survey data collected by the Natural Resources Conservation Service (NRCS), with Richard Bettge as the lead engineer. The horizontal and vertical datums for this survey are based upon the NAD 83 Datum and NAVD 88, respectively.

Bathymetric data for the Gulf of Mexico immediately east of Brazos Santiago Pass between the southern tip of South Padre Island and Brazos Island were obtained using a GEODAS search of the NOS Hydrographic Surveys digital database. Six surveys (H06491, H06493, H06496, H10472, H10429, and H10436) were located and compiled resulting in over 85,000 survey points in the area of interest.

U. S. Nautical Chart 11302, Intracoastal Waterway: Stover Point to Brownsville was used to determine the approximate depth of the Brownsville Ship Channel and Laguna Madre. Data from "Physical Evaluation of Proposed Flooding of Bahia Grande, Cameron County, Texas" by Robert A. Morton were used to approximate depths in San Martin Lake and the San Martin Lake Channel.

The Mesh

The finite element network, or mesh, used to evaluate the hydrodynamic flow in Bahia Grande is composed of over 5,000 triangular elements and nearly 3,000 nodes. The finite element network used for Alternative IV is shown in Figure 12 and Figure 13 of Appendix A. The mesh covers several distinct regions: the Gulf of Mexico, Laguna Madre, the Brownsville Ship Channel, San Martin Lake, Bahia Grande, Laguna Larga, Little Laguna Madre and connecting channels.

For Bahia Grande and the Gulf of Mexico, electronic survey data were imported into SMS. These data became scatterpoints, or points that "are used by SMS to reference data information to scattered points across the map." (National Highway Institute, undated) Each of the scatterpoints is associated with an x- and y-coordinate and the elevation of the location. A mesh, composed of trianglar elements, is then developed within the specified boundaries. Each element has a node at the corners of each leg of the element. The nodes represent points in space, while the elements represent areas. When creating the mesh, SMS was set to linearly interpolate the x- and y-coordinates and the elevation of each node from the scatterpoints. The resultant mesh represents the topography and bathymetry within the mesh boundaries, in this case, Bahia Grande and a small area of the Gulf of Mexico. In the Bahia Grande area, topographic maps and aerial photographs were used to estimate elevations in areas where survey data were unavailable. The NRCS survey data represented as scatter points are shown overlaid an aerial photograph of the Bahia Grande basin in Figure 14 in Appendix A.

The Brownsville Ship Channel was modeled to have a depth of 42 feet in the middle of the channel. This depth of 42 feet extends for between 300 and 500 feet in both directions from the center of the channel, the distance depending on the width of the channel. From the edge of the deepest portion of the channel, the channel bottom linearly slopes up to a depth of 4 feet below MSL, except at the connection with the designed Channel E which varies upon channel dimensions and at the entrance to the San Martin Channel.

Laguna Madre has average depths of 3 to 4 feet. For modeling purposes, Laguna Madre is assumed to have a uniform depth of 4 feet. For further simplification, South Bay and the inter-coastal waterway are not modeled in this study and are assumed to have an insignificant impact on modeling results in the Bahia Grande area.

San Martin Lake is connected to the Brownsville Ship Channel through a canal that is approximately 120 feet wide and 10 to 12 feet deep. San Martin Lake is the deepest in the center where the canal joins with the lake. Outward from the center, the lake bottom tapers upwards into extremely shallow depths. The San Martin Lake Channel and San Martin Lake are represented in the model as describe above.

Boundary Conditions and Model Parameters

The Bahia Grande area is subject to diurnal tides with a tidal range along the southern Laguna Madre coastline averaging 1.1 foot. Tidal boundary conditions for the Bahia Grande model are simulated using sinusoidal tides with a period of approximately 25 hours and maximum amplitude of 0.1676 meters, 0.55 feet, at the eastern Gulf of Mexico boundary.

Because strong, constant southeasterly winds are an important force of the most significant tides in the Laguna Madre and Bahia Grande regions, wind is an important input parameter when modeling the hydrodynamics of Bahia Grande. Wind forces should be added to the model for a more complete analysis of the interactions of the nearby water bodies and the shallow waters within Bahia Grande, Laguna Larga, and Little Laguna Madre basins. Wind was not included in this first stage analysis so that the effect of tidal forcing could be fully determined.

The following are select parameters used within ADCIRC for modeling purposes: Tau_0 was 0.002, time step was 3 seconds, data was written every 22.5 minutes or 60 minutes for the longer runs of 28 days.

Model Calibration

Model accuracy was evaluated by comparing model results with actual velocity and water surface elevation data gathered for a study conducted by James Broska, a hydrologist with the FWS. By establishing a tide gage in the San Martin Lake Channel, Broska was able to determine the tidal efficiency, or the "ratio of the water-level amplitude measured at the site (the San Martin channel) to the oceanic tidal amplitude." (Broska 2000) After gathering data for two short time periods, Broska determined that the resulting tidal efficiency was over 90%. Velocity measurements were also gathered in the San Martin Channel using an Acoustic Doppler Current Meter (ADCM). Velocities were recorded over a period of 43 days, resulting in a "high of 1.22 fps and a low of -1.09 fps for incoming and outgoing tides, respectively." The average recorded velocity was 0.34 fps for incoming and –0.33 fps for outgoing tides. (Broska 2000)

The measurements during the field study were gathered by attaching the tide gage and the ADCM to pilings located immediately north of the HWY 48 San Martin channel bridge. A feature point was created in the project grid to represent the estimated location of the data collection. The project model was run for ten days using the actual tide data, recorded at the Port Isabel tidal station, as the boundary condition for water surface elevation in the Gulf of Mexico in an attempt to recreate the velocity data measured in the field by James Broska.

The field data provided by FWS show that the ratio of tidal amplitude and range at the feature point in San Martin Lake to the gulf boundary is approximately 0.9. The results of the model show a similar result with a ratio between 0.9 and 1.0. Velocities recorded by FWS exhibit a maximum and minimum of approximately 1.2 fps and –1.2 fps. The model outputs were very close to 1.2 fps and –1.2 fps when the measured water surface at Port Isabel was applied at the gulf boundary.

Analysis of Flow Conditions

Alternative Channel Conditions

Multiple conditions were modeled and evaluated to determine the channel configurations that would result in optimum flow conditions in Bahia Grande and adjoining Laguna Larga and Little Laguna Madre basins. Alternatives I and II are options with Channel A connecting to Bahia Grande from San Martin Lake. In Alternative I, each channel has a depth of 2 feet below mean sea level (MSL). Channels 1, 2, 3, and 4 have widths of 20, 50, 100, and 200 feet respectively. In Alternative II, Channels 5, 6, 7, and 8 have a depth of 4 feet below MSL and have widths of 20, 50, 100,and 200 feet respectively. Alternative III options consist of Channel E connecting Bahia Grande to the Brownsville Ship Channel. Each channel in Alternative III is 200 feet wide. Channels 9, 10, 11, and 12 have depths of 4, 6, 9, and 12 feet below MSL. Alternative IV is modeled with a combination of Channel A, B, C, and E – Channel A having a width of 50 feet and a depth of 4 feet below MSL, Channels B and C having a width of approximately 60 feet and a depth of 2 feet below MSL, and Channel E having a width of 200 feet and a depth of 9 feet below MSL.

Volume of flow into Bahia Grande during one tidal cycle (approximately 12.5 hours or one half of a tidal period) was calculated for each channel option using velocity and water surface elevation data from feature points in the center of Channel A and Channel E. The flow entering Bahia Grande during a tidal cycle is assumed to be equivilant to the flow leaving the basin in one tidal cycle. The locations of the feature points within the mesh are shown in Figures 4 and 5.

Using the velocity and the water surface elevation data from the feature points shown above, flow into the Bahia Grande basin using the following methodology:

- Terminology:
  - Volumetric Flow Rate (Q), ft^3/sec
  - Velocity (V), ft/s
  - Cross Sectional Area of Channel (A), ft^2
  - Depth of Channel below MSL (D), ft
  - Width of Channel (W), ft
  - Effective Cross Sectional Area of Channel (A_e), ft^2
  - Water Surface Elevation (WSE), ft
- Assume uniform velocity at all points within the channel cross section at the location of the feature point.

- At each time step (22.5 minutes):
  - Calculate A_e
    - $A_e = (D + WSE) \times W$
  - Calculate Q
    - $Q = V \times A_e$
  - Calculate Volume of Flow
    - Volume = Q x 22.5 minutes x 60 sec/min
- Calculate Total Flow Into Bahia Grande in one tidal cycle

Sum Volume of Flow over 12.5 hour period (flood portion of tide cycle)

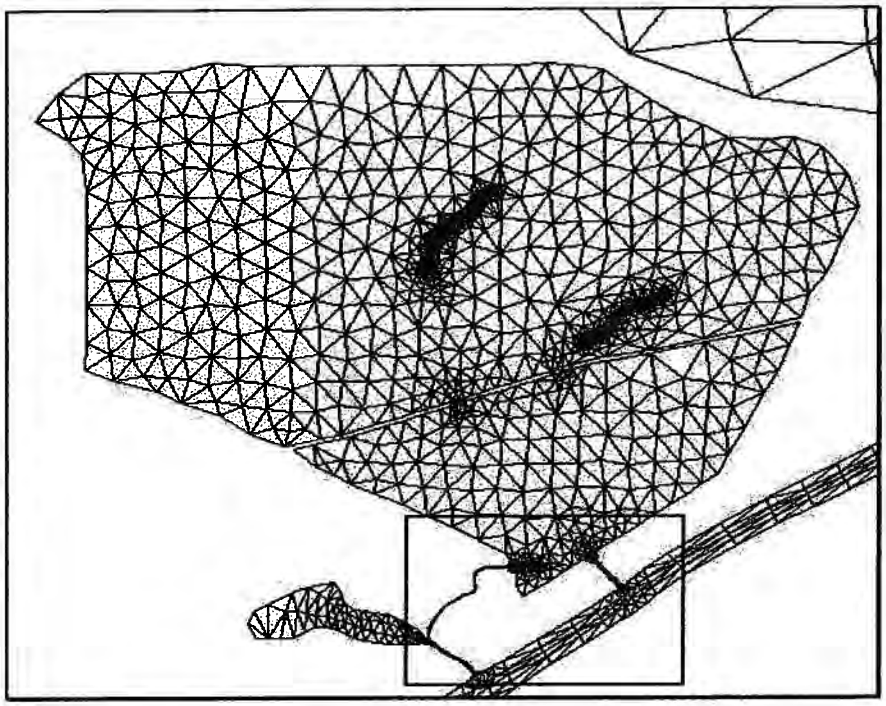


Figure 4: Bahia Grande with Channel A and Channel E feature points shown

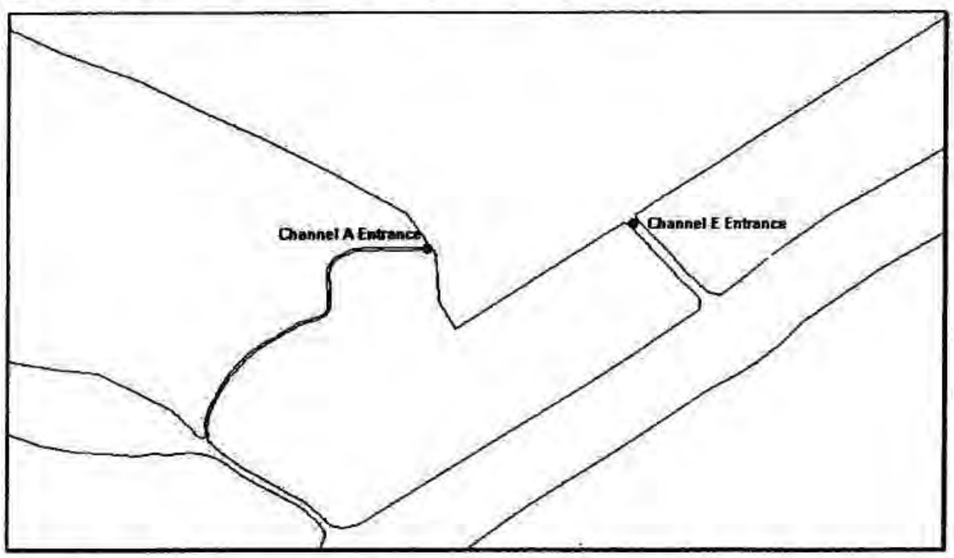
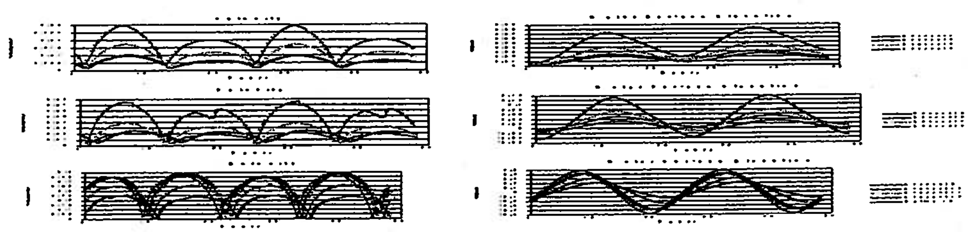


Figure 5: Location of Channel A and Channel E feature points

The calculated volume of water that will be exchanged in Bahia Grande with either San Martin Lake or the Brownsville Ship Channel are detailed in Tables 1 – 4 and Figures 6 – 8. Velocities and water surface elevations for the feature points used to calculate the water volume exchange are shown in Figures 16 - 23 in Appendix B. (Note that the absolute value of the velocities are shown.) Also, velocities and water surface elevations for several locations within Bahia Grande, Laguna Larga, and Little Laguna Madre basins, as indicated in Figure 24 in Appendix B, are given in Figures 25 – 29, also in Appendix B.

Alternative I

Table 1: Alternative I – Channel A with depth of 2 feet below MSL



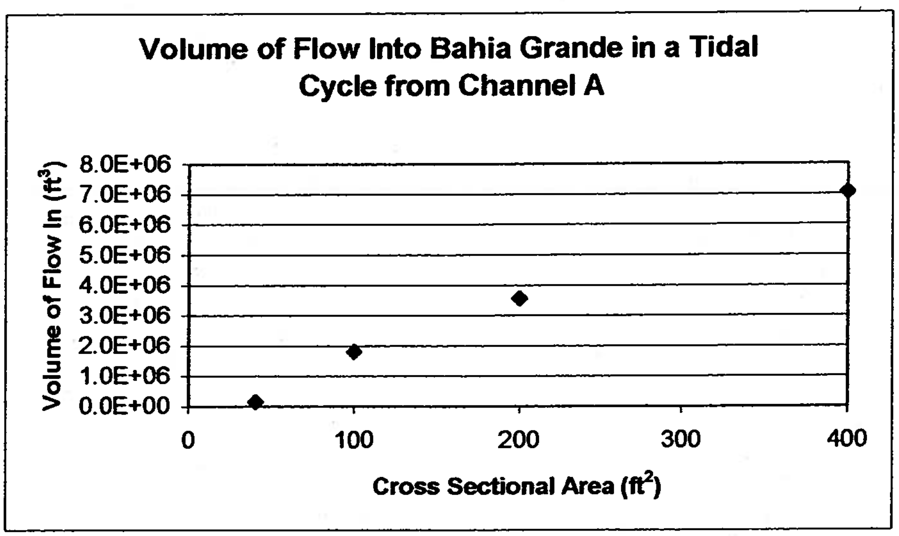


Figure 6: Alternative I – Volume of flow into Bahia Grande in one tidal cycle vs. cross sectional area.

Alternative II

Table 2: Alternative II – Channel A with depth of 4 feet below MSL

	Channel Width (ft)	Channel Depth (ft)	Channel Cross Sectional Area (ft^2)	Volumetric Flow In (ft^3/12.5 hours)
Channel 5	20	4	80	2,479,204
Channel 6	50	4	200	4,677,237
Channel 7	100	4	400	8,971,760
Channel 8	200	4	800	16,953,344

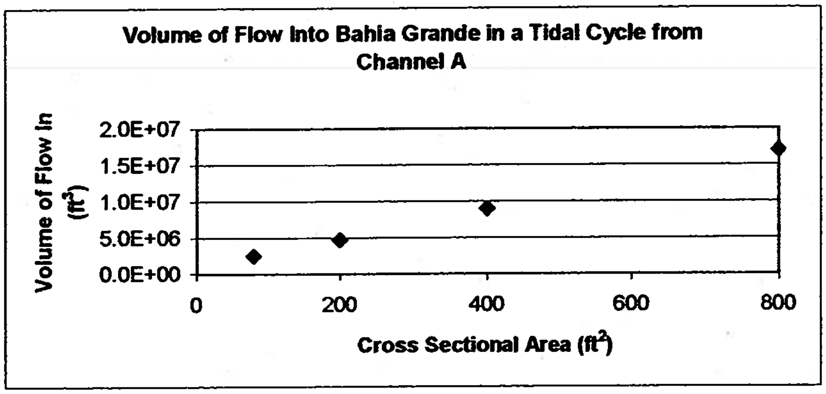


Figure 7: Alternative II – Volume of flow into Bahia Grande in one tidal cycle vs. cross sectional area.

Alternative III

Table 3: Alternative III – Channel E with width of 200 feet

	Channel Width (ft)	Channel Depth (ft)	Channel Cross Sectional Area (ft^2)	Volumetric Flow In (ft^3/12.5 hours)
Channel 9	200	4	800	38,397,248
Channel 10	200	6	1200	62,256,416
Channel 11	200	9	1800	89,956,877
Channel 12	200	12	2400	110,042,048

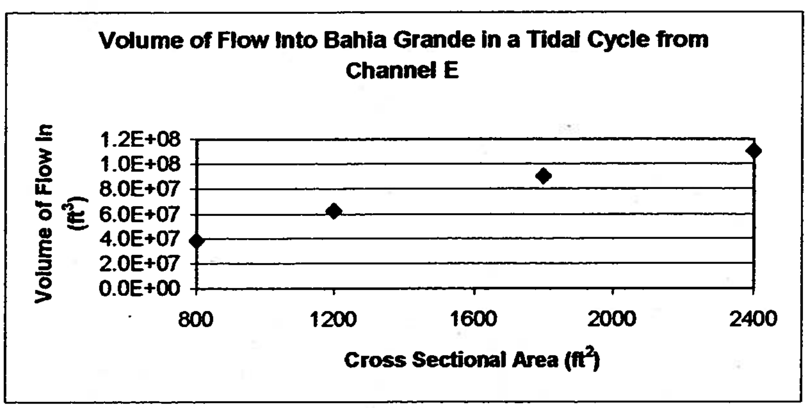


Figure 8: Alternative III – Volume of flow into Bahia Grande in one tidal cycle vs. cross sectional area

Alternative IV

Table 4: Alternative IV – Channel A with width of 50 feet and depth of 4 feet below MSL, Channel E with width of 200 feet and depth of 9 feet below MSL

	Channel Width (ft)	Channel Depth (ft)	Channel Cross Sectional Area (ft^2)	Volumetric Flow In (ft^3/12.5 hours)
Option 13				
Channel A	50	4	200	2,946,489
Channel E	200	9	1800	80,892,543
Total			2000	83,839,032

Alternatives Analysis

In the first three alternatives, the channel flow rates increased in a nearly linear fashion with respect to the cross sectional area of the channel. However, Channels 1 –8 produce a dramatically lower flow volume in per channel cross sectional area than Channels 9 – 12, as seen below in Figure 9. For example, Channel 8 and Channel 9 both have a cross sectional area of 800 ft^2. Channel 8

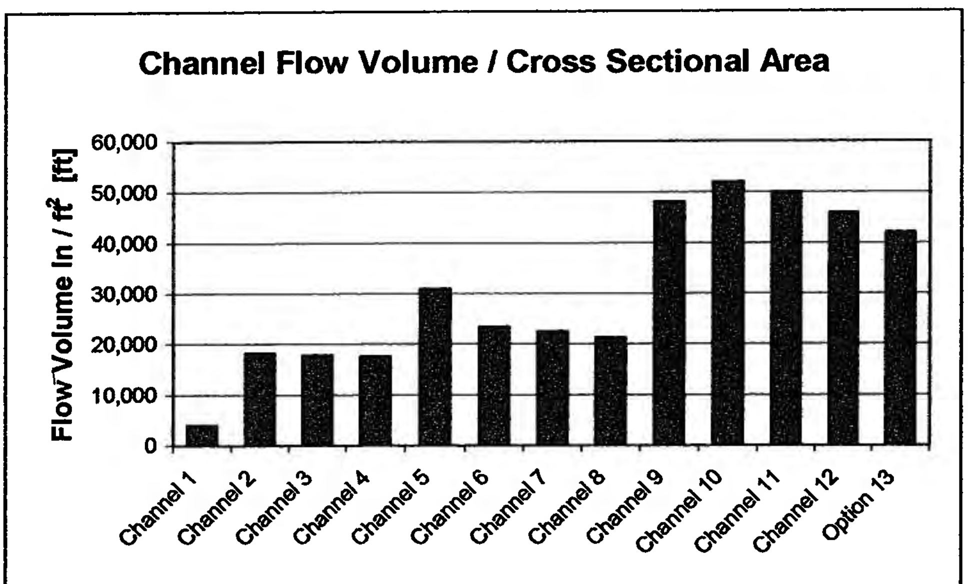


Figure 9: Channel flow volume per cross sectional area.

produces nearly 17 million cubic feet of flow into Bahia Grande, where Channel 9 produces a flow of over 38 million cubic feet.

The percentage of water exchanged in one tidal cycle is another measure used to evaluate the various channel options and is calculated by dividing the volume of flow into Bahia Grande by the estimated total volume of water in Bahia Grande. By processing bathymetric survey data that was collected by personnel of the USFWS-Branch of Water Resources in July 1999, through a Triangulated Irregular Network (TIN), which estimates elevations between known survey points, James Broska determined that the potential volume of water in Bahia Grande is over 700 million cubic feet. (Broska 2000) For calculations in this report to determine the percentage of water exchanged in one tidal cycle, 700 million cubic feet was assumed to be the total volume of water in Bahia Grande. As shown below in Figure 10, Channels 1 – 7 provide less than 2% water exchange. Channel 8 provides approximately 2.5% exchange, where Channels 9 – 12 provide between 6% and 16% exchange.

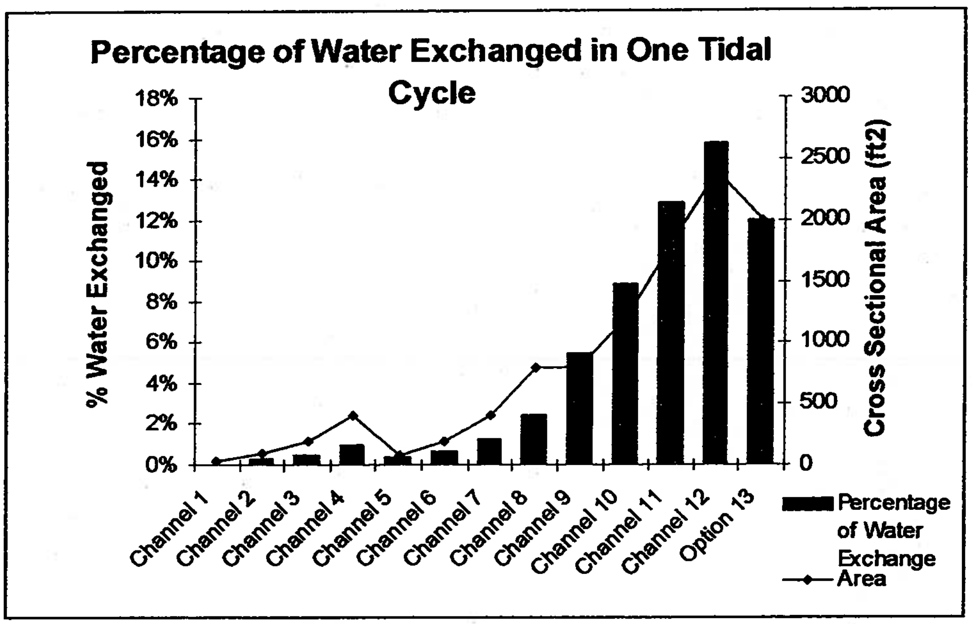


Figure 10: Percentage of water exchanged in one tidal cycle in Bahia Grande.

Wind Effects on Circulation

The previous analyses for the alternative channel geometries did not include the effect of wind. This section includes the wind and compares the wind with the no-wind condition. Moreover, the actual expected astronomical tides are included beginning at midnight March 26, 2002. The boundary condition for this time period is given in Figure 11and the resulting tidal condition in the

Brownsville ship channel at the entrance to Bahia Grande is given in Figure 12. Both of these results are for wind conditions of 0, 15 and 20 mph. In neither case is it clear that there is any effect of the increasing wind speeds.

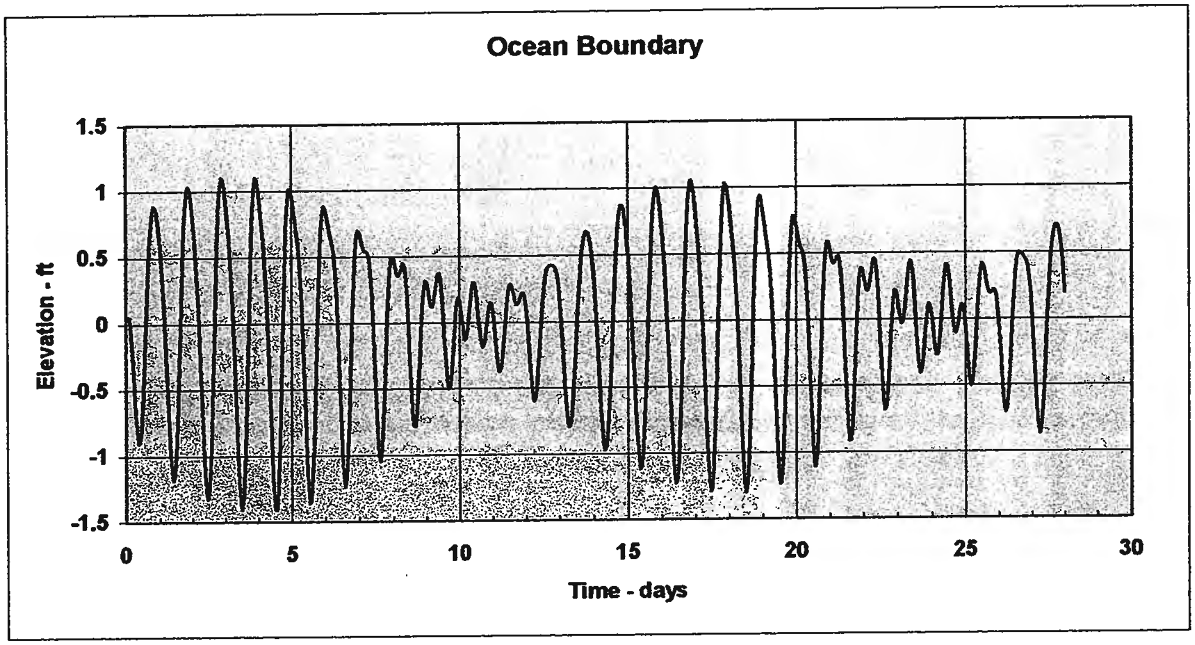


Figure 11 Ocean boundary tidal conditions (from March 23, 2002).

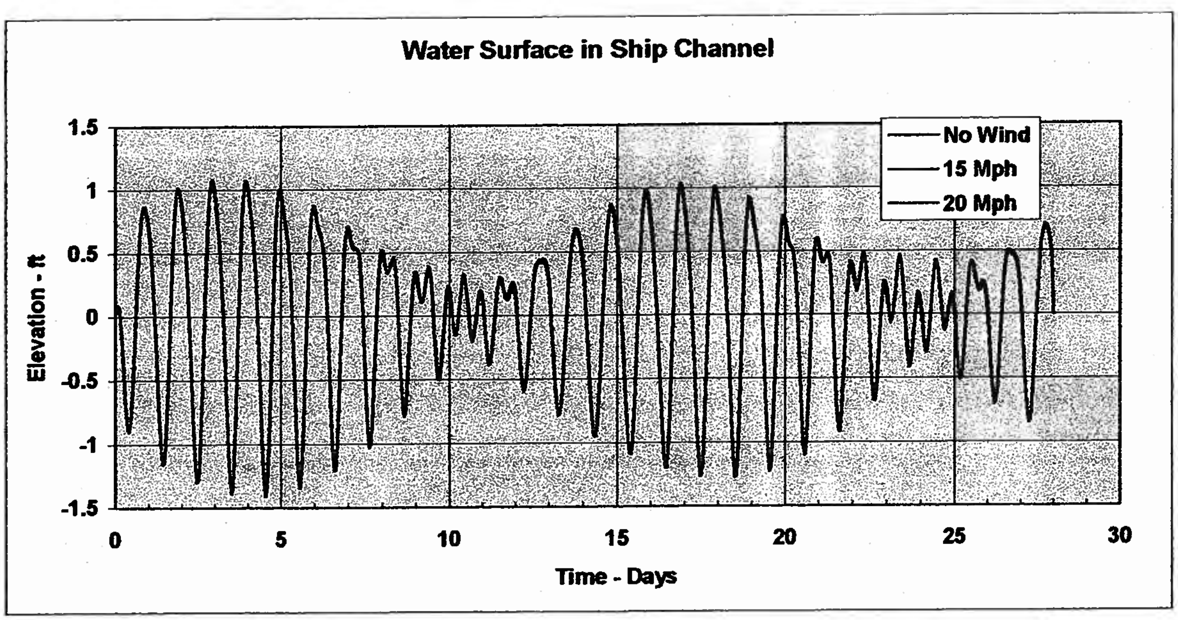


Figure 12 Water surface elevation in Brownsville ship channel for three wind conditions (0, 15 and 20 mph).

The wind conditions used in this simulation are diurnal. In other words the winds start at noon and continue until midnight. At that time the winds are assumed to lay until the next noon. The water surface elevation near the entrance to Bahia Grande over the 28-day period is given in Figure 13. Notice that the elevations are not significantly different for the no wind and the 15 mph case. However, there is a noticeable difference for the 20 mph case. This causes a significant lowering of the water level at the entrance to the Bahia Grande. The difference between the low water inside and the water level in the ship channel will cause a larger inflow of water and generate more mixing than for the no-wind and the 15 mph case.

The response for the three wind conditions at the northern end of Bahia Grande is shown in Figure 14. The range of the tidal effect does not change with increasing wind, but the high and low levels are elevated. The effect is an increase of up to 0.5 ft when the windspeed is 15 mph. The effect increases to nearly 0.7 ft for a windspeed of 20 mph during pre-spring tide conditions.

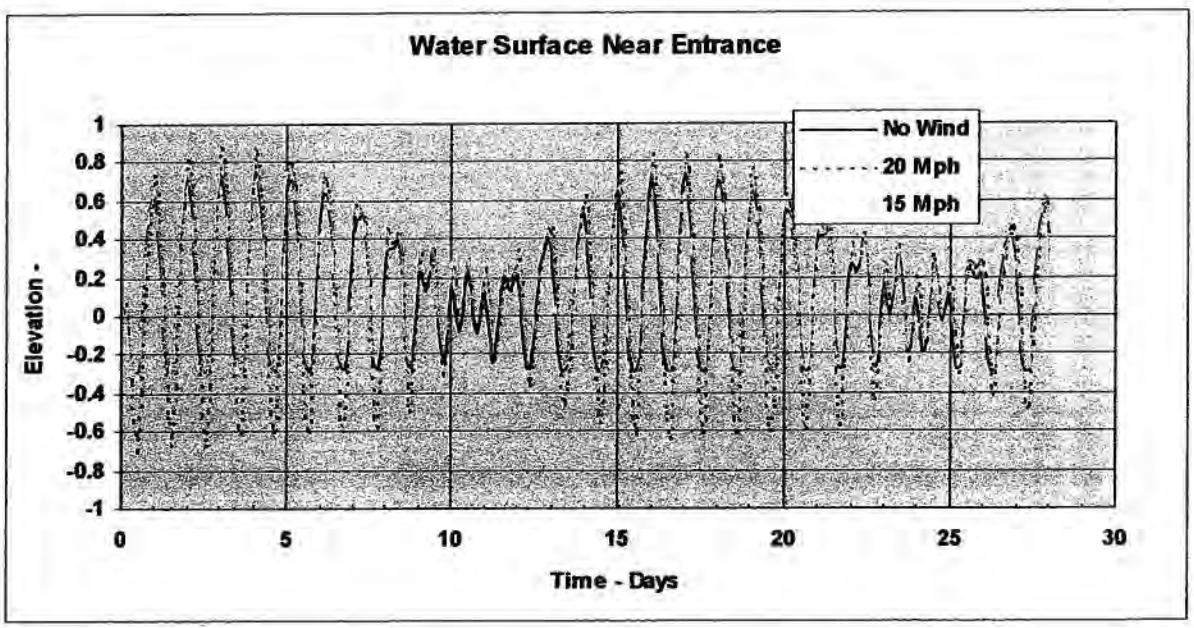


Figure 13 Water surface at the entrance in Bahia Grande.

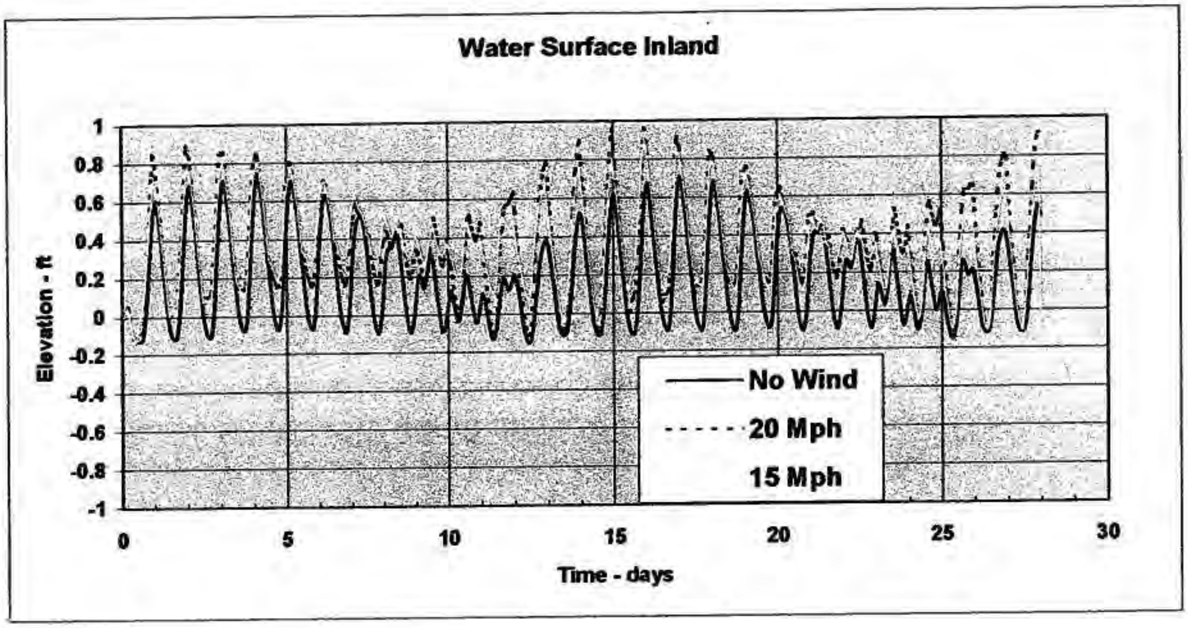


Figure 14 Water surface at the northern end of Bahia Grande.

A projected improvement in the Bahia Grande is to tie in the Laguna Larga via a new channel connection. The effect of wind in the Laguna Larga on water levels for the 28 day period is shown in Figure 15. Note that there is an apparent significant swing in the water surface. However, the scale is not the same as that given for the previous comparisons; the variation is only about .07 ft during a tide although the variation over a fortnight month is closer to 0.5 ft. In summary, there is a wind effect in Laguna Larga but it varies more over a month than a day.

In Little Laguna Madre, the wind effects are similar to those in Laguna Larga – significantly smaller than in Bahia Grande at the northern or southern end. This is shown in Figure 16. Again notice that the effect is more associated with the spring tides than with the diurnal wind and tide patterns.

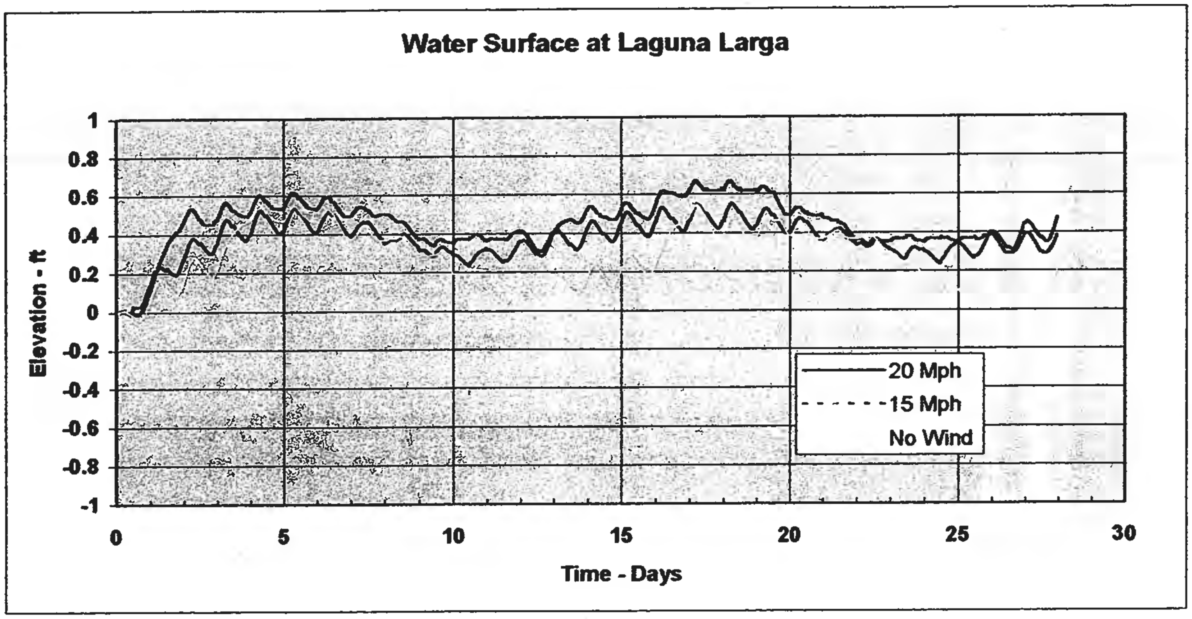


Figure 15 Water surface at the center of Laguna Larga.

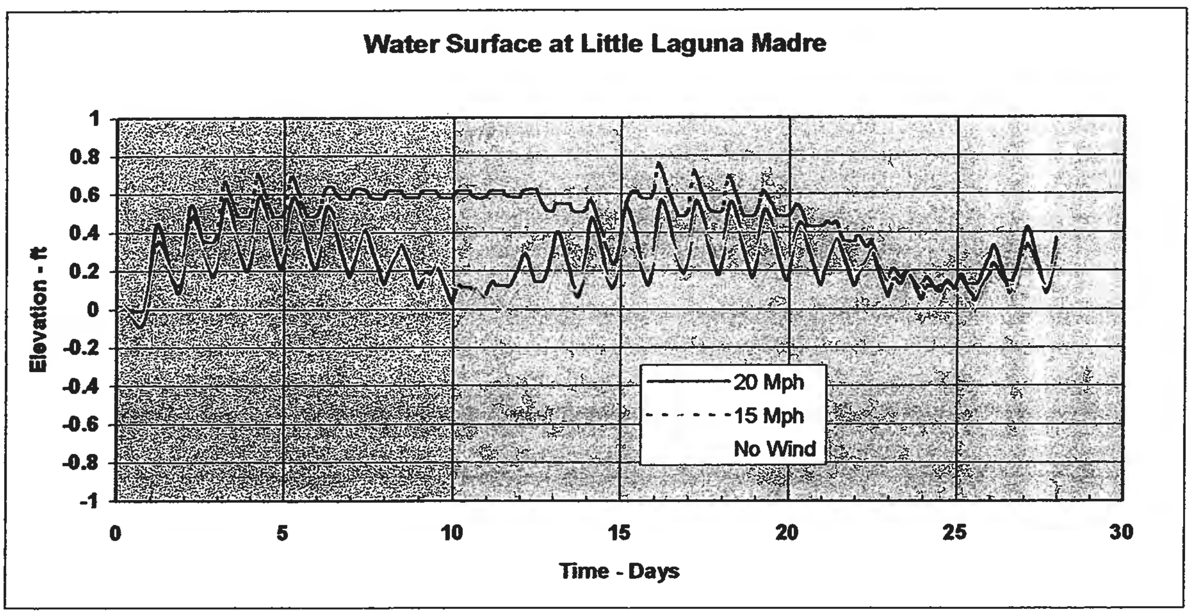


Figure 16 Water surface at the center of Little Laguna Madre.

In addition to the water surface elevations in the three basins, the water velocity was determined as it entered the basins from the Brownsville ship channel into Bahia Grande and as it flowed from Bahia Grande into Laguna Grande. The velocity for each is given in Figures 17 and 18, respectively. Note that positive flow in both cases indicates flow into Bahia Grande. It appears that the flows are affected more by wind than tide as they enter and depart from Laguna Grande. In neither case however is the effect of the 15 mph wind significant. The 20 mph wind is much more effective in increasing the flow into Bahia Grande from the ship channel and from Bahia Grande into Laguna Larga.

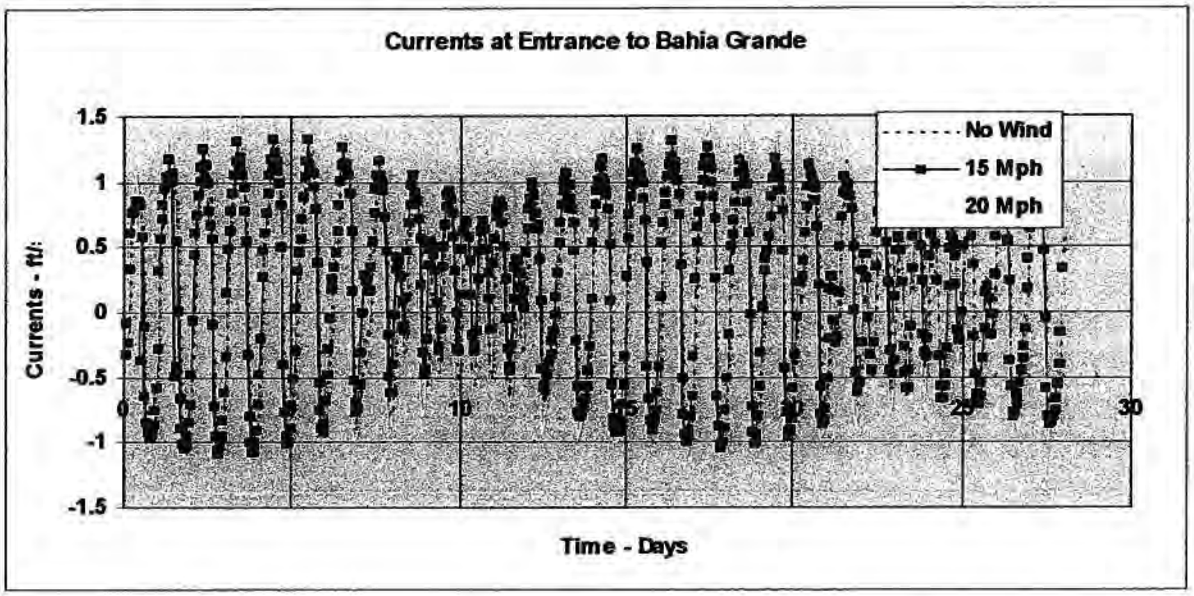


Figure 17 Currents entering Bahia Grande from Brownsville ship channel.

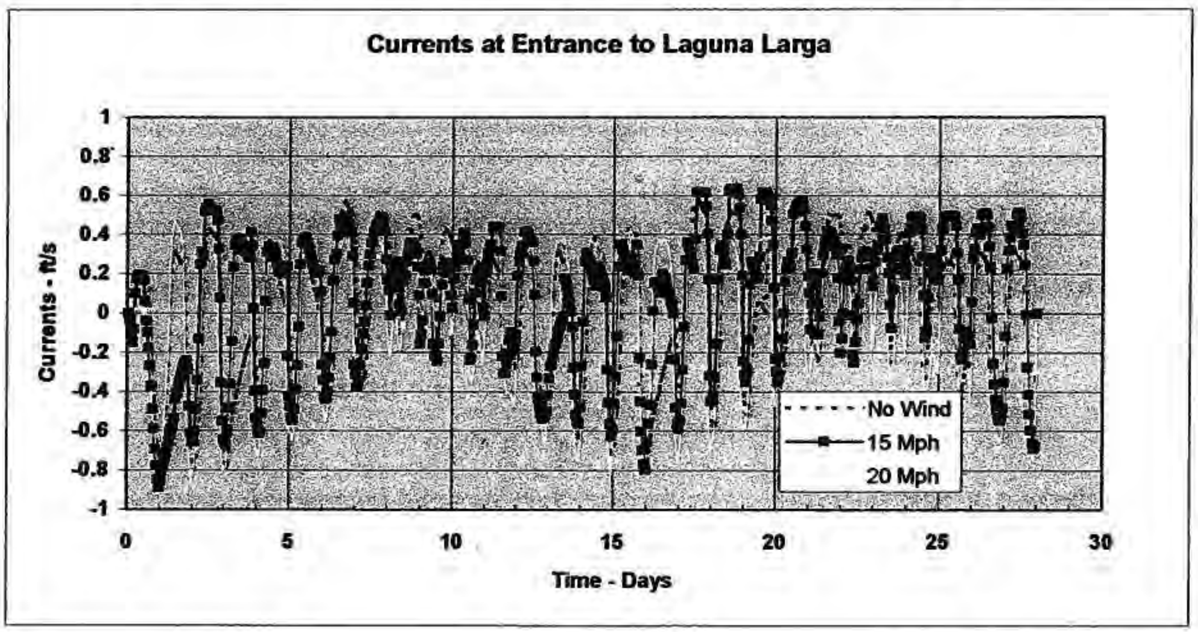


Figure 18 Currents entering Laguna Grande from Bahia Grande. (Note that flow into Bahia Grande is positive and flow into Laguna Grande is negative.)

Conclusions and Recommendations

The reflooding of Bahia Grande, Laguna Larga, and Little Laguna Madre basins will be a significant accomplishment for the FWS and other organizations involved. Impacts of the project will be felt locally and globally if the project is successful. The success of the project will be partially determined by channels that are established to connect the basins with the nearby water bodies.

After evaluating several channel options for the flooding project with the use of a numerical model of the region, it has been determined that constructing a channel connecting San Martin Lake to Bahia Grande may not be an effective means of moving water in and out of the basin. First, the proposed channel dimensions for Channel "A" (20 feet wide and 2 feet below MSL) produces an exchange of less than 0.1% of the total water volume of Bahia Grande basin in one tidal cycle, based on a total volume of 700 million cubic feet of water. Increasing the width and the depth of the channel to 200 feet wide and 4 feet below MSL produces an exchange of approximately 2.5% of the water in Bahia Grande in one tidal cycle. Not only does this channel produce a small water exchange percentage, by constructing this channel, an estimated 6 million cubic yards of soil will be displaced and must be redistributed throughout the refuge or transported to another location.

Because one of the objectives of flooding the Bahia Grande basin is to create an ecosystem in which plant and animal life will flourish, salinity in the basin should a consideration for channel design purposes. The large surface area of Bahia Grande will promote evaporation, which will be exacerbated by the strong winds customary in the region. A tidal exchange of 2.5% may not be able to regulate salinity in the basin, leading to a continuous increase in salinity due to evaporation.

The channels connecting Bahia Grande basin to Laguna Larga and Little Laguna Madre, channels "B" and "C", respond positively with channel widths of approximately 60 feet and a depth of 2 feet below MSL. (For this report, the FWS proposed channel that connects Laguna Larga and Little Laguna Madre, Channel "D", was not modeled due to time constraints.) However, a concern with constructing a channel with depths as shallow as 2 to 4 feet below MSL is that plant growth in the channel may drastically reduce the water flow. By constructing a deeper channel, plant growth will be restricted because of the limited amount of sunlight reaching the bottom of the channel.

Clearly a channel connecting the Brownsville Ship Channel and Bahia Grande basin, Channel "E", will produce the maximum exchange rate. By constructing Channel "E", tidal exchanges of up to 16% of the total volume of Bahia Grande are achievable. If Channel "E" is constructed, building Channel "A" will not significantly impact the water exchange in Bahia Grande. Thus, Channel "A" should not be built if Channel "E" is constructed; thereby minimizing impact on the delicate ecosystem surrounding Bahia Grande and drastically reducing project cost.

The effects of wind were modeled using wind speeds of 15 and 20 mph. The winds were structured to start at noon and continue until midnight at which time they layed until noon. The winds appear to cause a setup at the northern end of Bahia Grande at a speed of 15 and 20 mph. Moreover at the southern end of Bahia Grande there is a significant setdown of the water level. This will result in additional water entering from the ship channel. This will effect a greater circulation. Of course this means a greater circulation with the ship channel. If the channel does not exchange water readily with the Gulf of have any additional sources of exchange, the greater circulation will be with the same water.

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U. S. Nautical Chart 11302; Intracoastal Waterway: Stover Point to Port Brownsville; Including Brazos Santiago Pass, Texas. 28th Ed., August 28, 1999.

Proposed Channel Locations

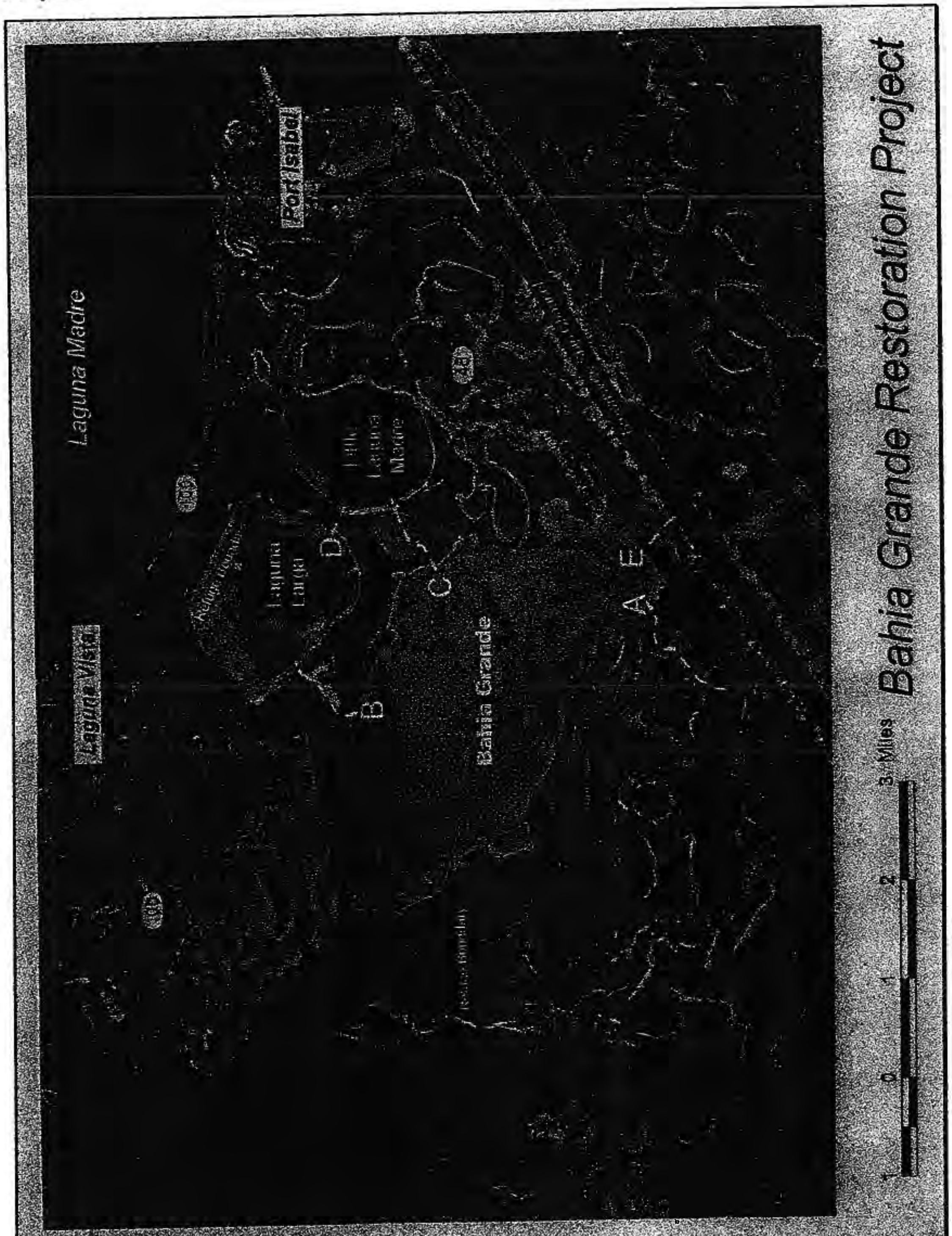

Figure 19: Aerial photograph of Bahia Grande and surrounding region with proposed channel locations and FWS Refuge Boundary labeled. Provided by David Blankinship, FWS.

Base Case (Alternative IV)

Grid

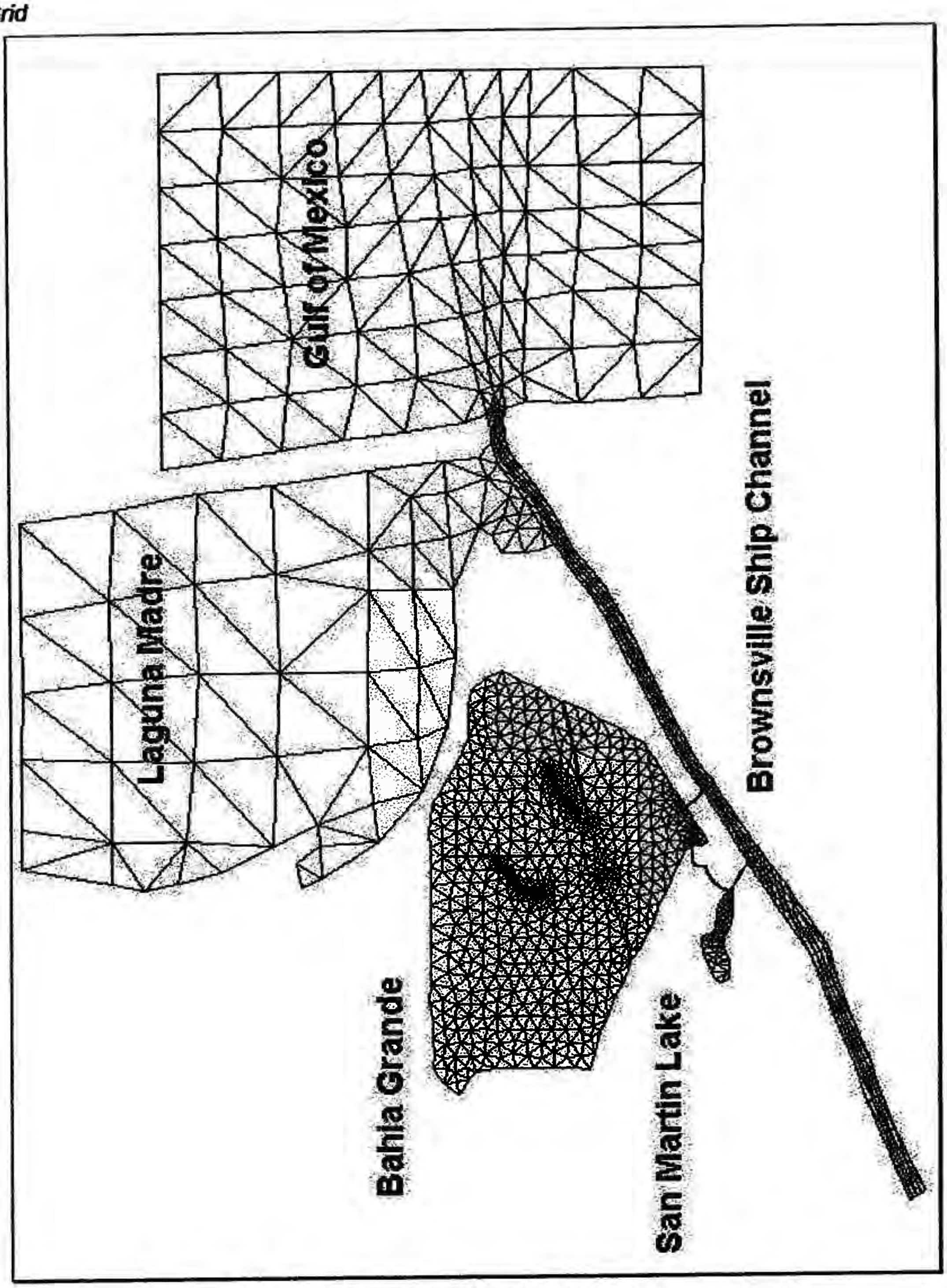

Figure 20: Project grid used within SMS for Alternative IV

Grid with Elevation Contours

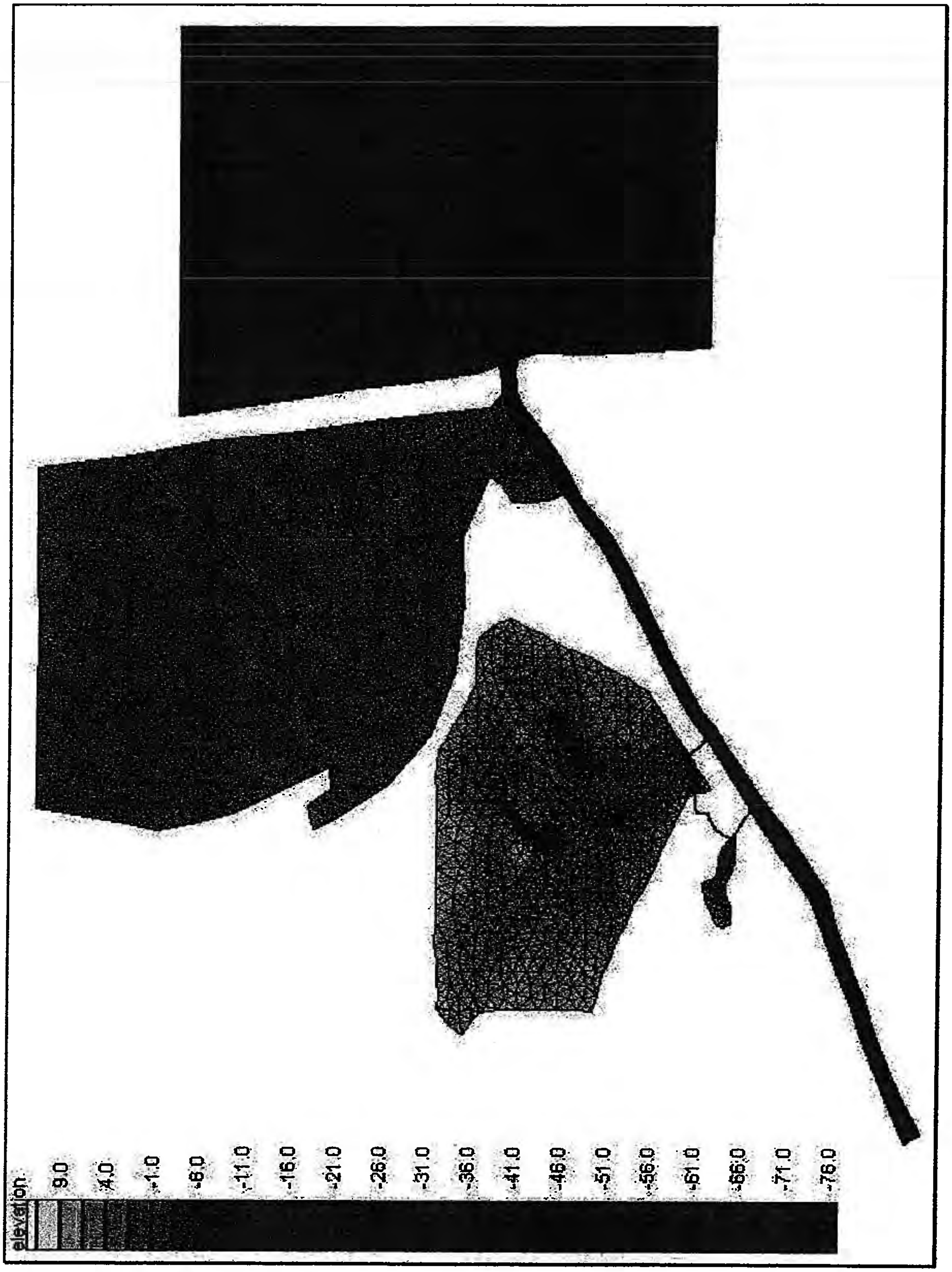

Figure 21: Project grid with elevation contours

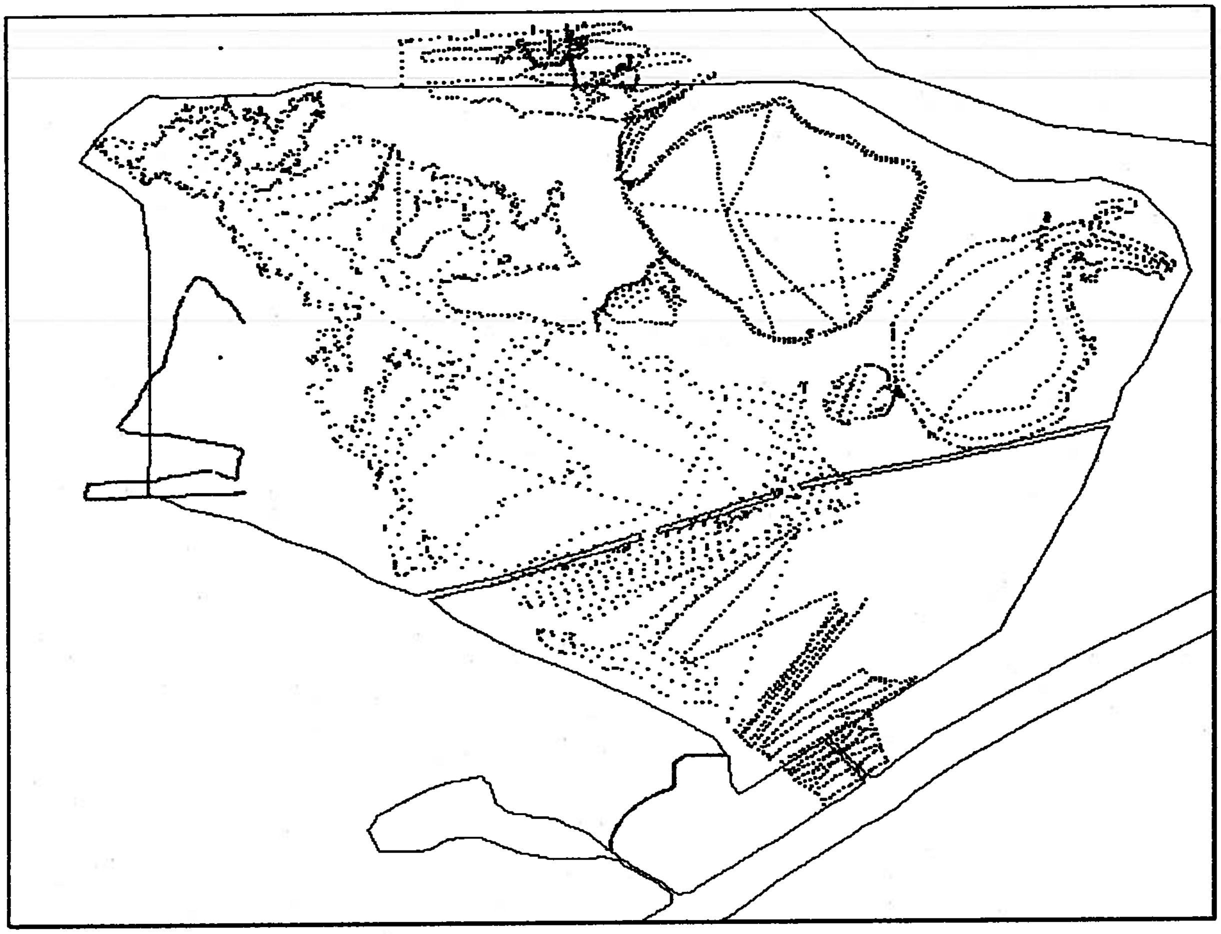

Figure 22: NRCS survey points shown on Bahia Grande portion of mesh boundary from project model.

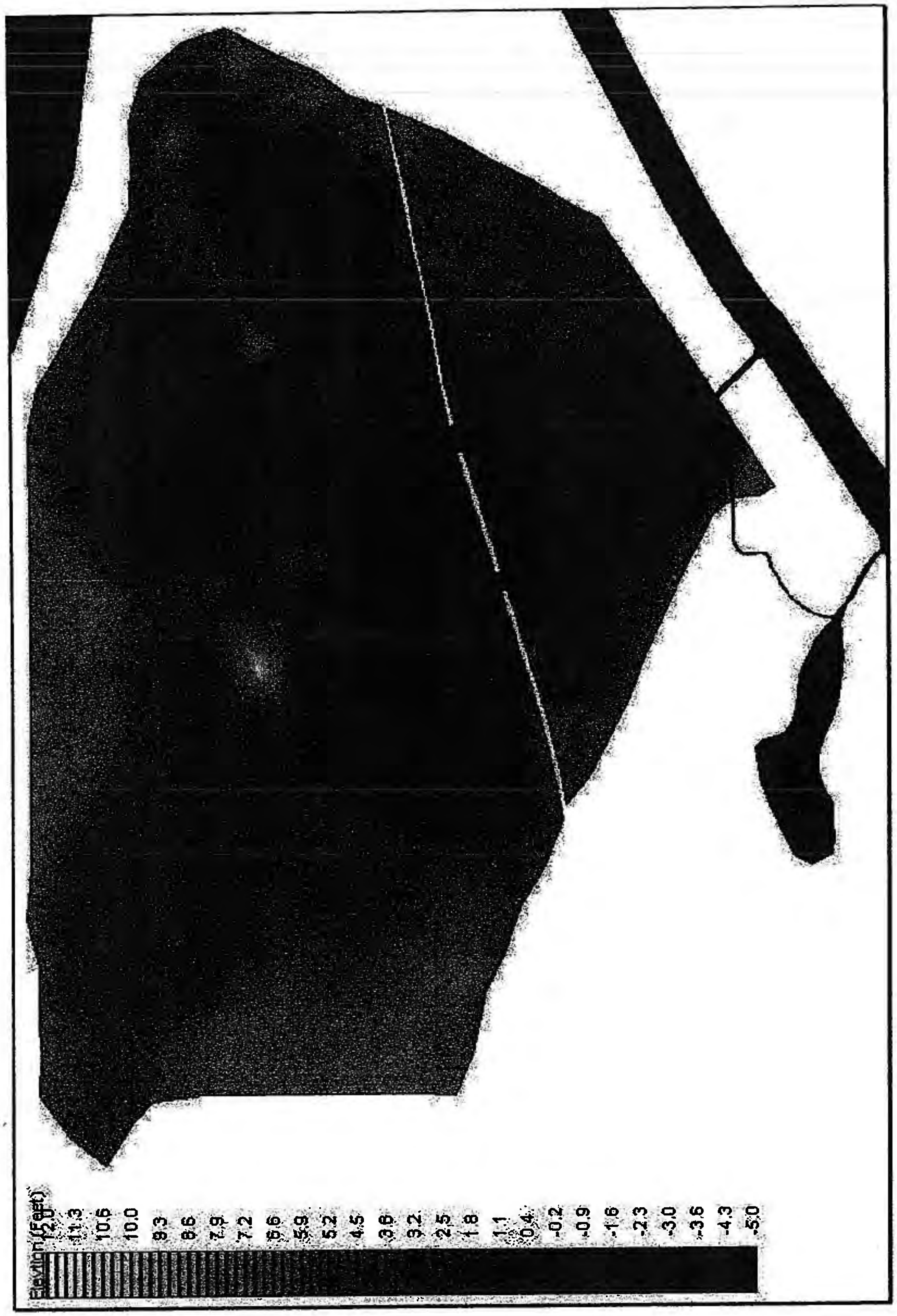

Figure 23: Elevation contours within the Bahia Grande basin region

Appendix B: ADCIRC Results

Alternative I – Water Surface Elevation and Velocity at Channel A Entrance

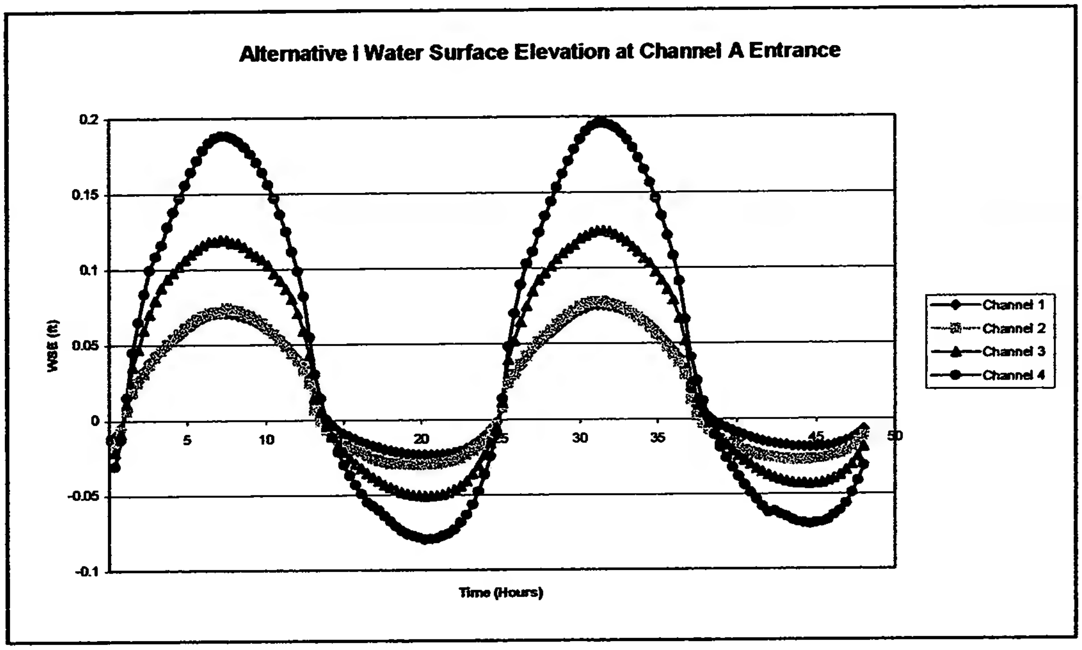

Figure 24: Alternative I – Water Surface Elevation at Channel A Entrance

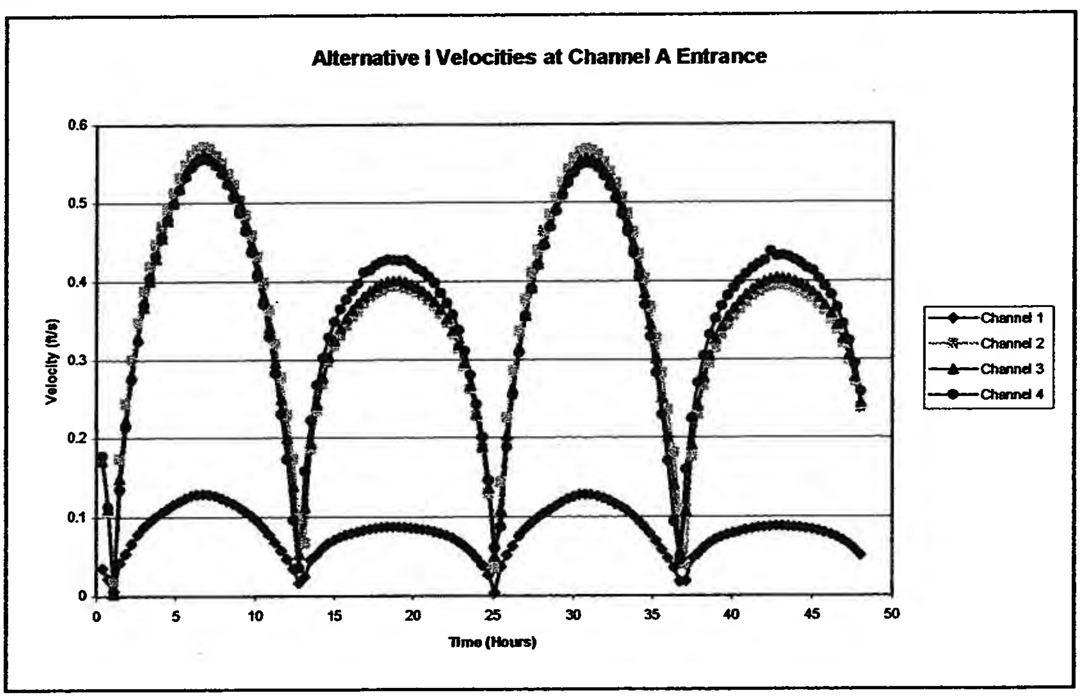

Figure 25: Alternative I – Velocity at Channel A Entrance

Alternative II – Water Surface Elevation and Velocity at Channel A Entrance

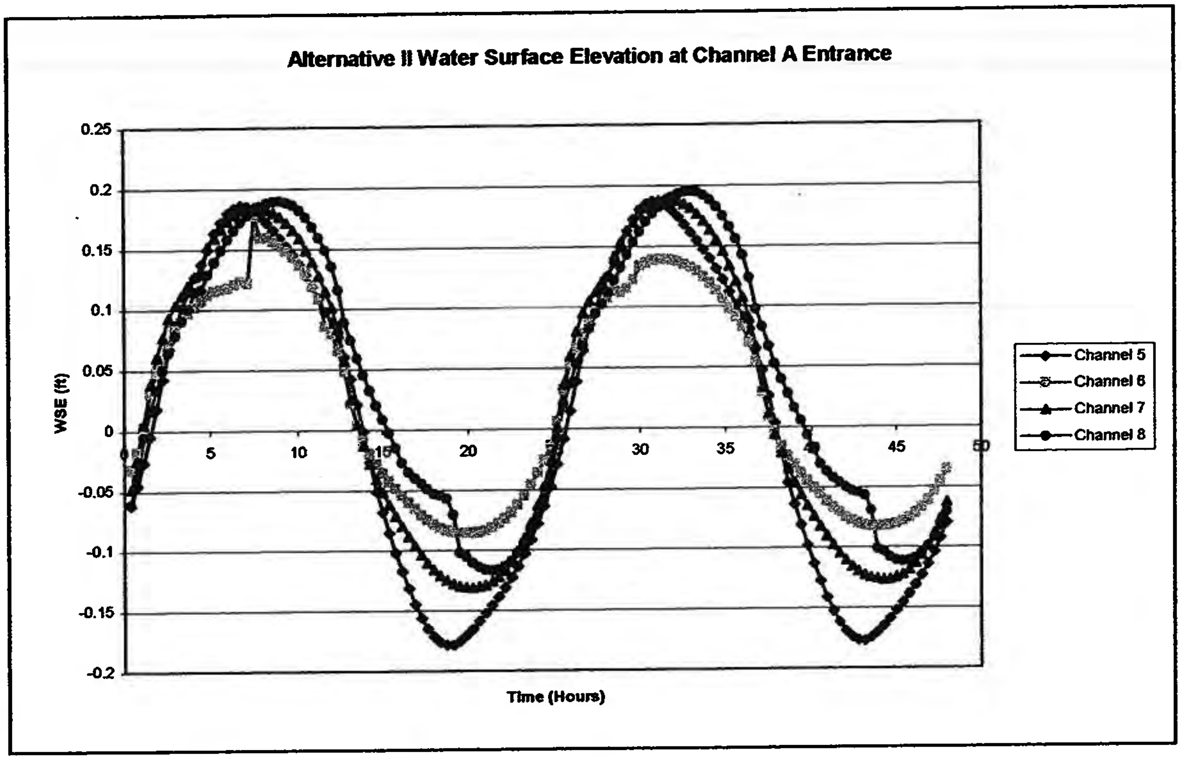

Figure 26: Alternative II – Water Surface Elevation at Channel A Entrance

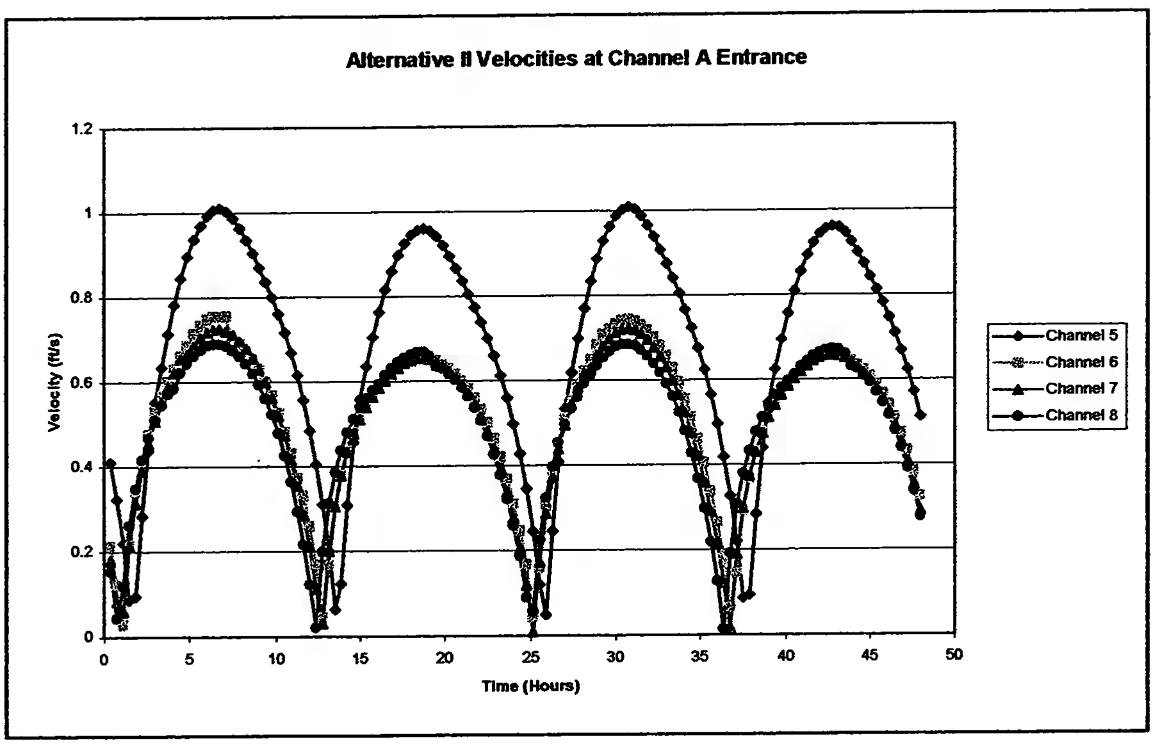

Figure 27: Alternative II – Velocity at Channel A Entrance

Alternative III – Water Surface Elevation and Velocity at Channel E Entrance

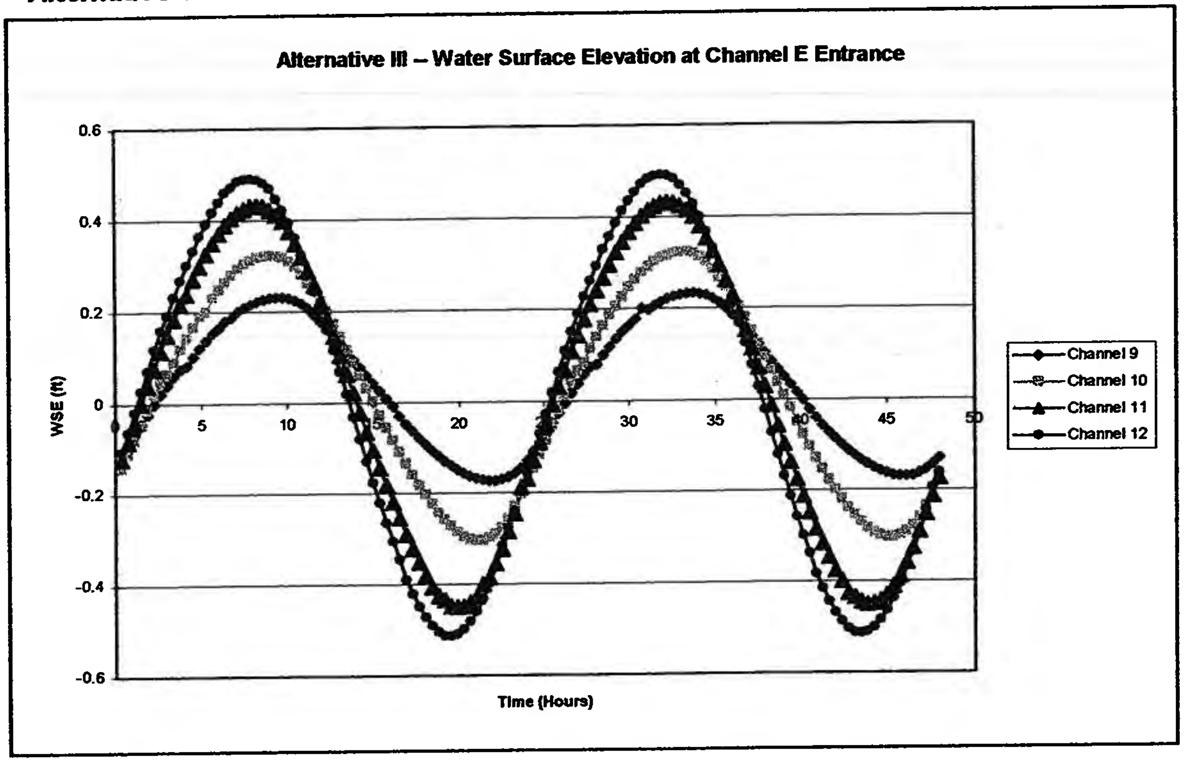

Figure 28: Alternative III – Water Surface Elevation at Channel E Entrance

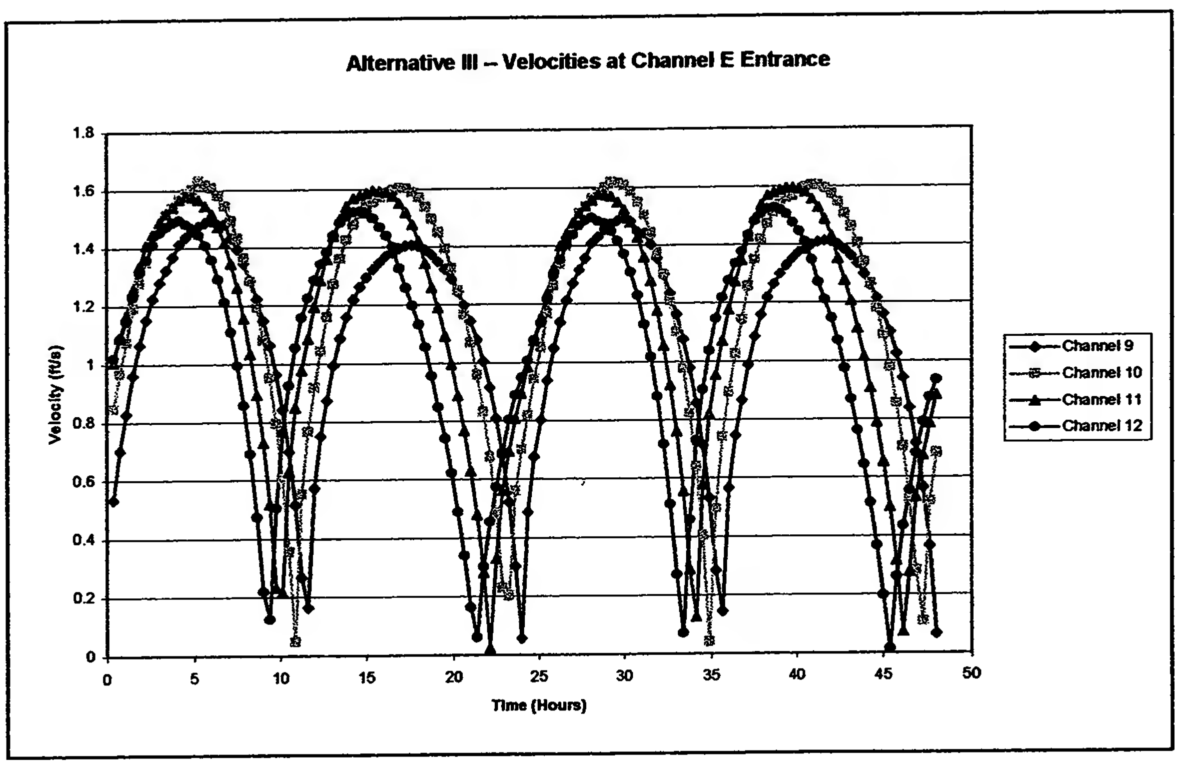

Figure 29: Alternative III – Velocity at Channel E Entrance

Alternative IV – Water Surface Elevation and Velocity at Channel A and E Entrances

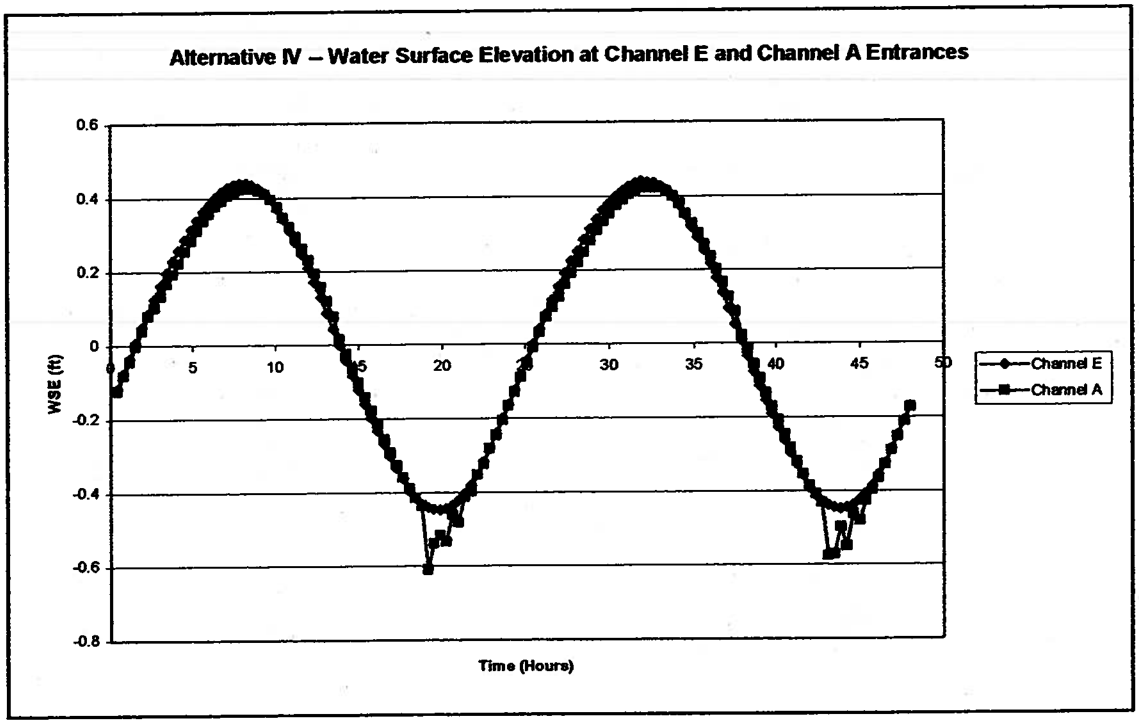

Figure 30: Alternative IV – Water surface elevation at Channel A and Channel E Entrances

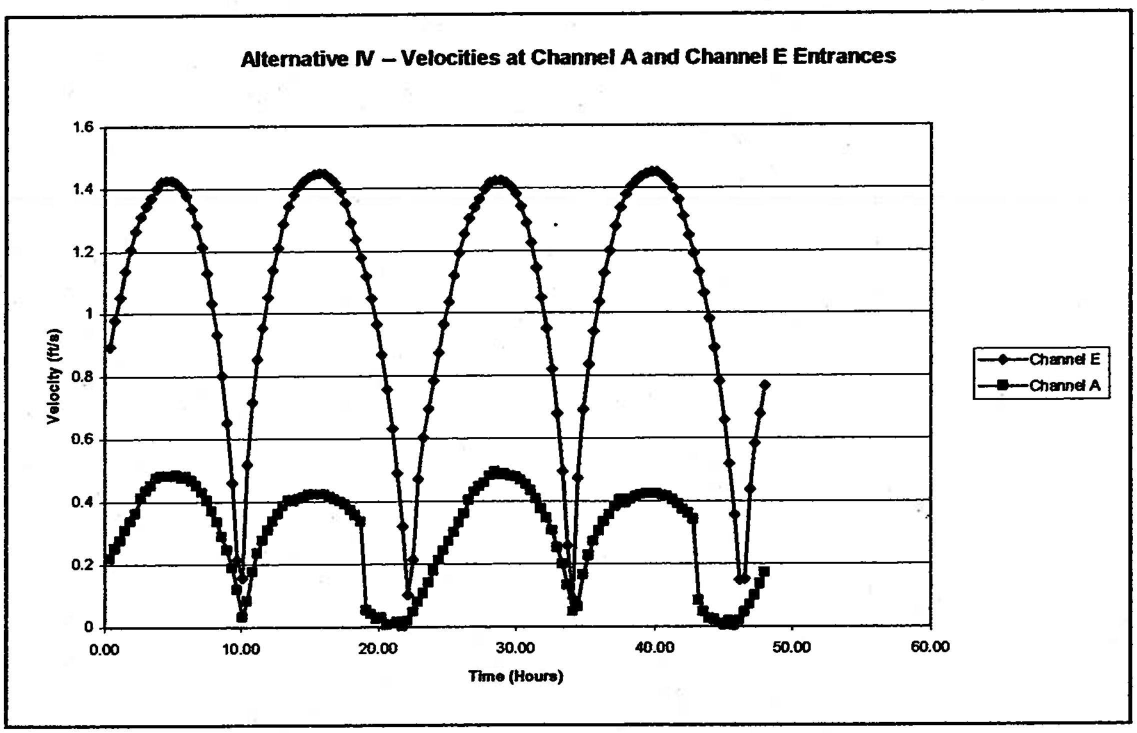

Figure 31: Alternative IV – Velocities at Channel A and Channel E Entrances

Locations of Feature Points Used to Evaluate WSEs and Velocities within Bahia Grande, Laguna Larga, and Little Laguna Madre Basins

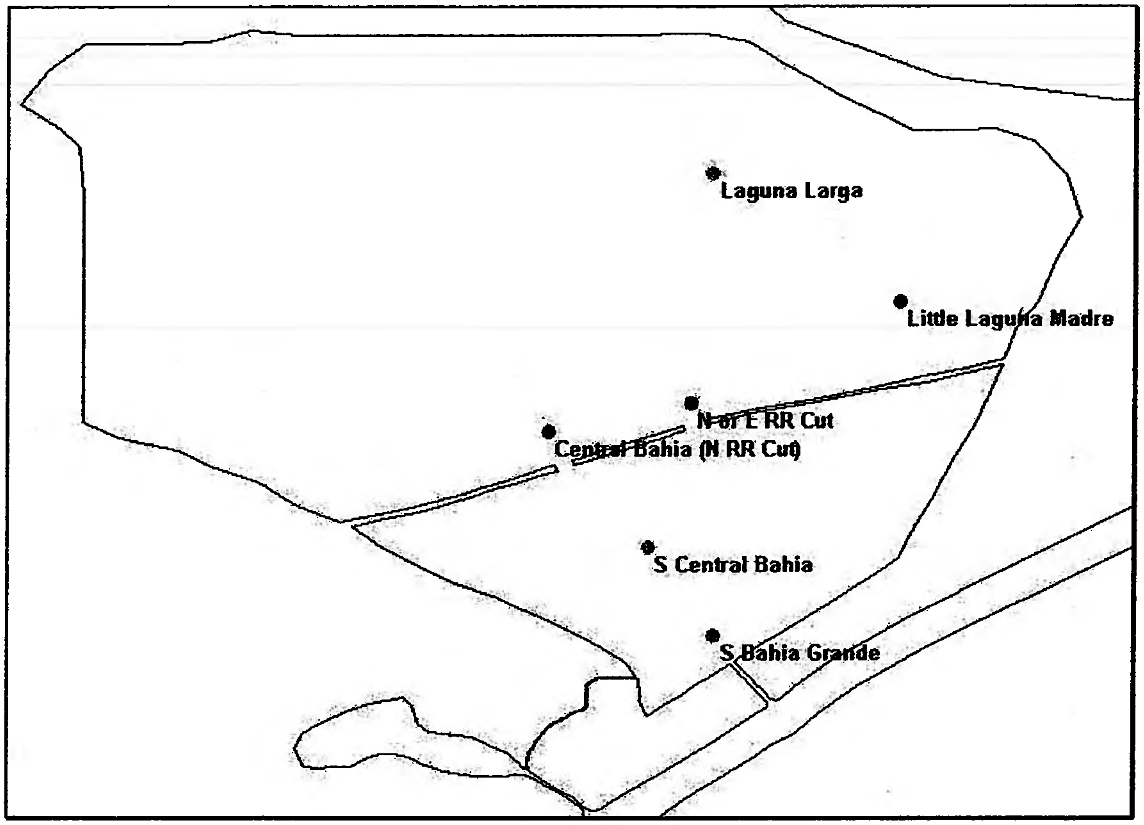

Figure 32: Feature Points within Bahia Grande, Laguna Larga, and Little Laguna Madre basins used to evaluate water surface elevation and velocity.

Feature Point: South Bahia Grande – WSE and Velocity

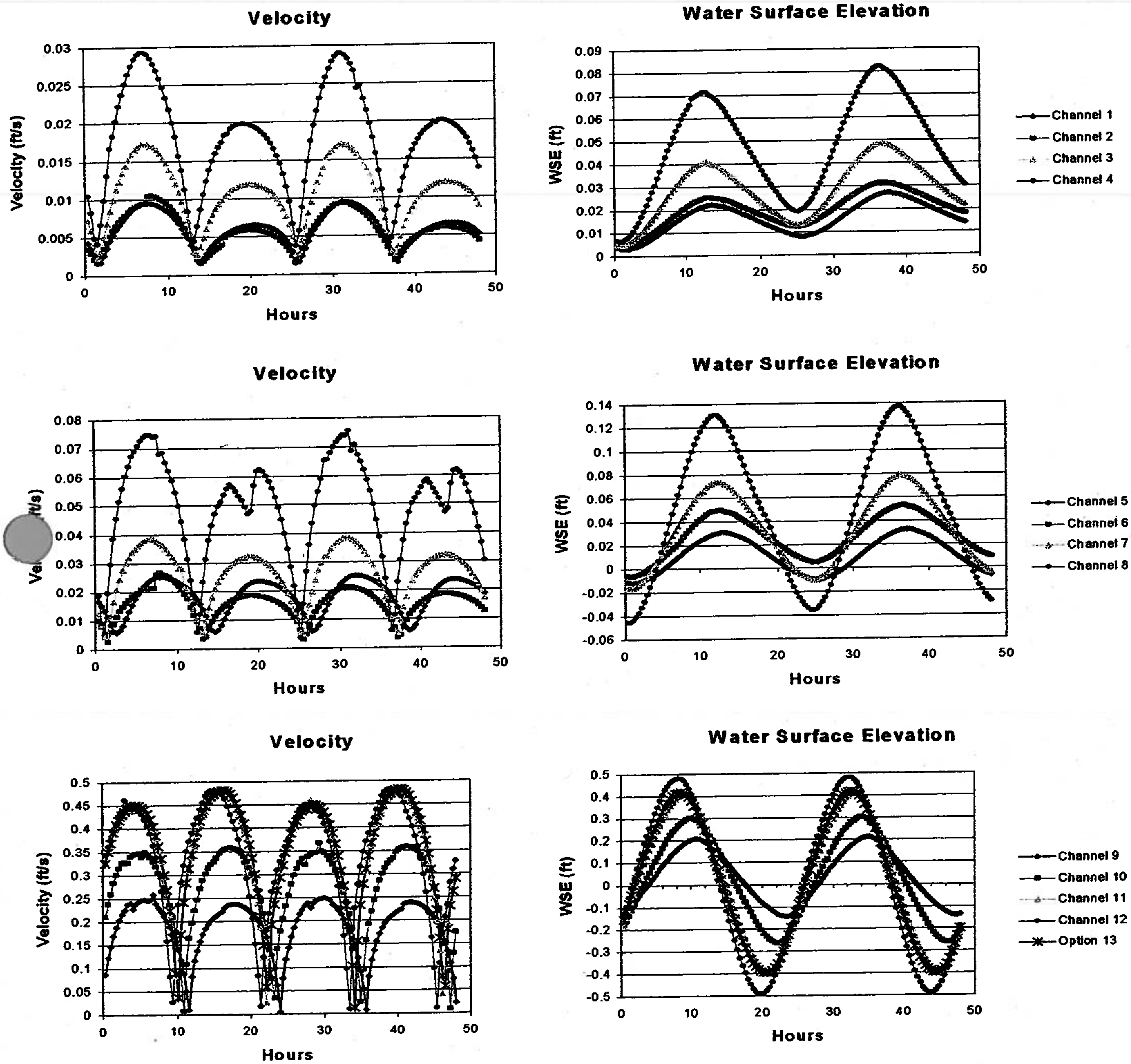

Figure 33: Velocity and Water Surface Elevation at South Bahia Grande feature point.

Feature Point: South Central Bahia Grande – WSE and Velocity

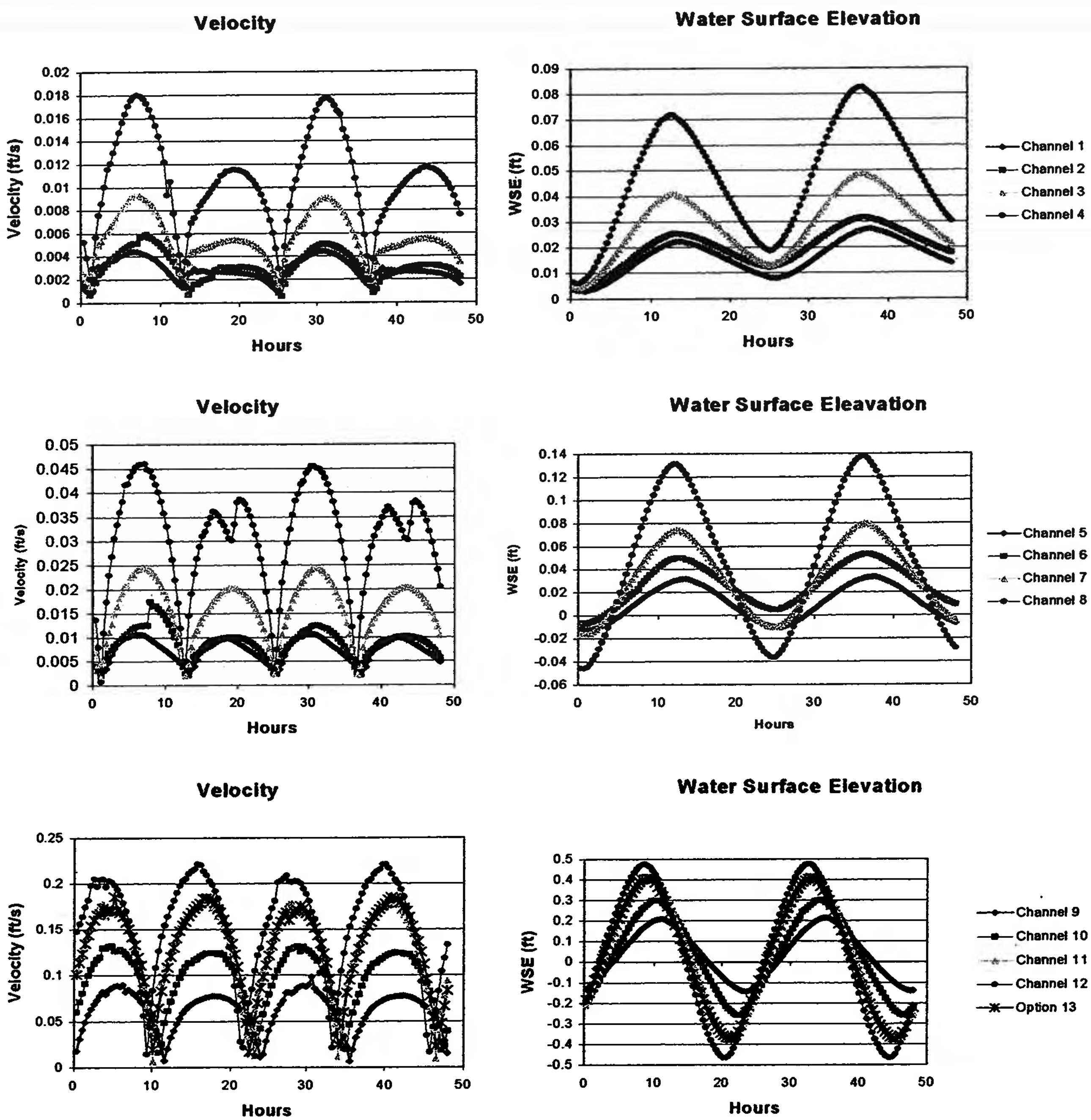

Figure 34: Velocity and Water Surface Elevation at South Central Bahia Grande feature point.

Feature Point: Central Bahia Grande (North of Railroad Cut) – WSE and Velocity

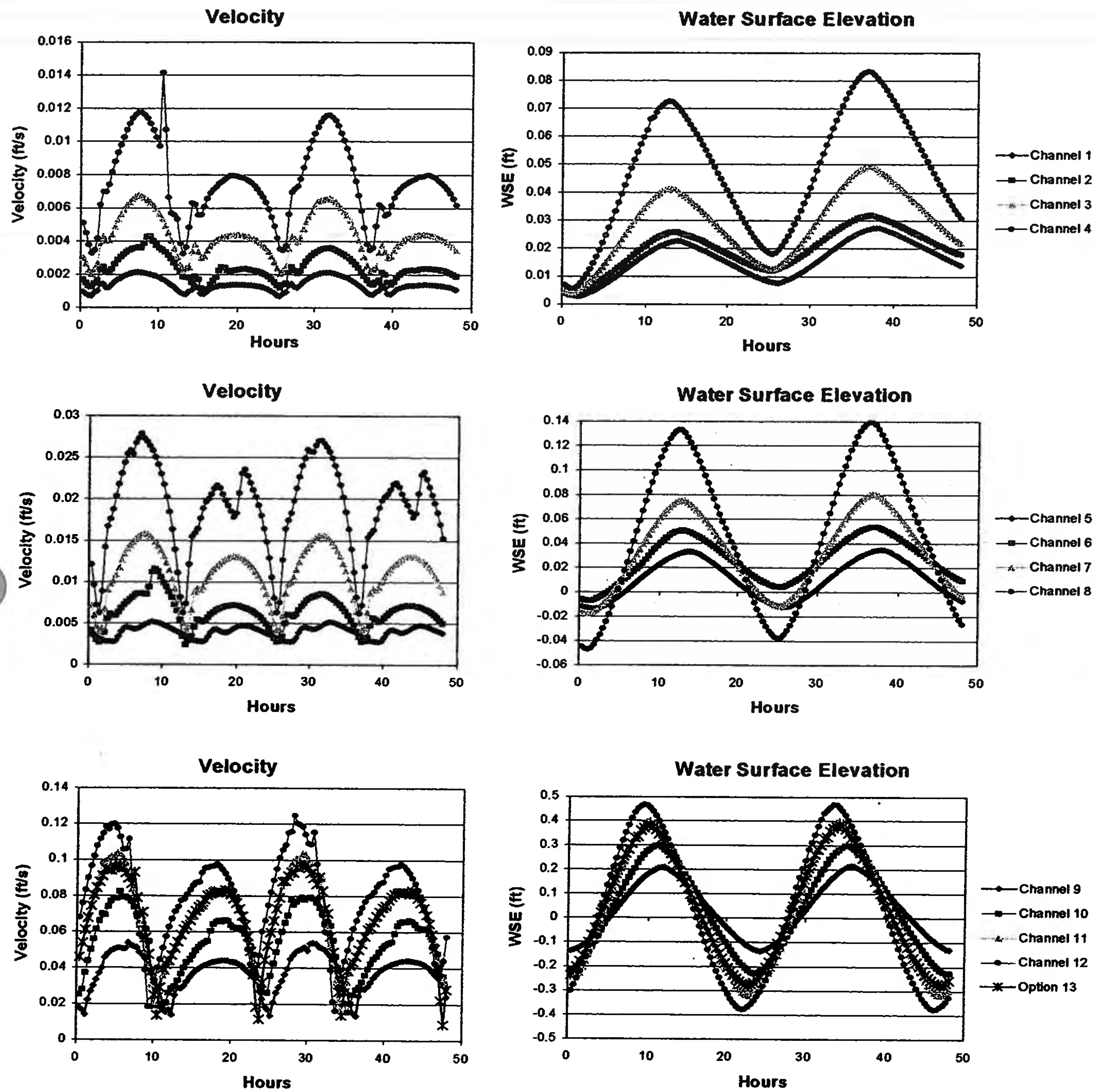

Figure 35: Velocity and Water Surface Elevation for Central Bahia Grande feature point.

Feature Point: North of East Railroad Cut – WSE and Velocity

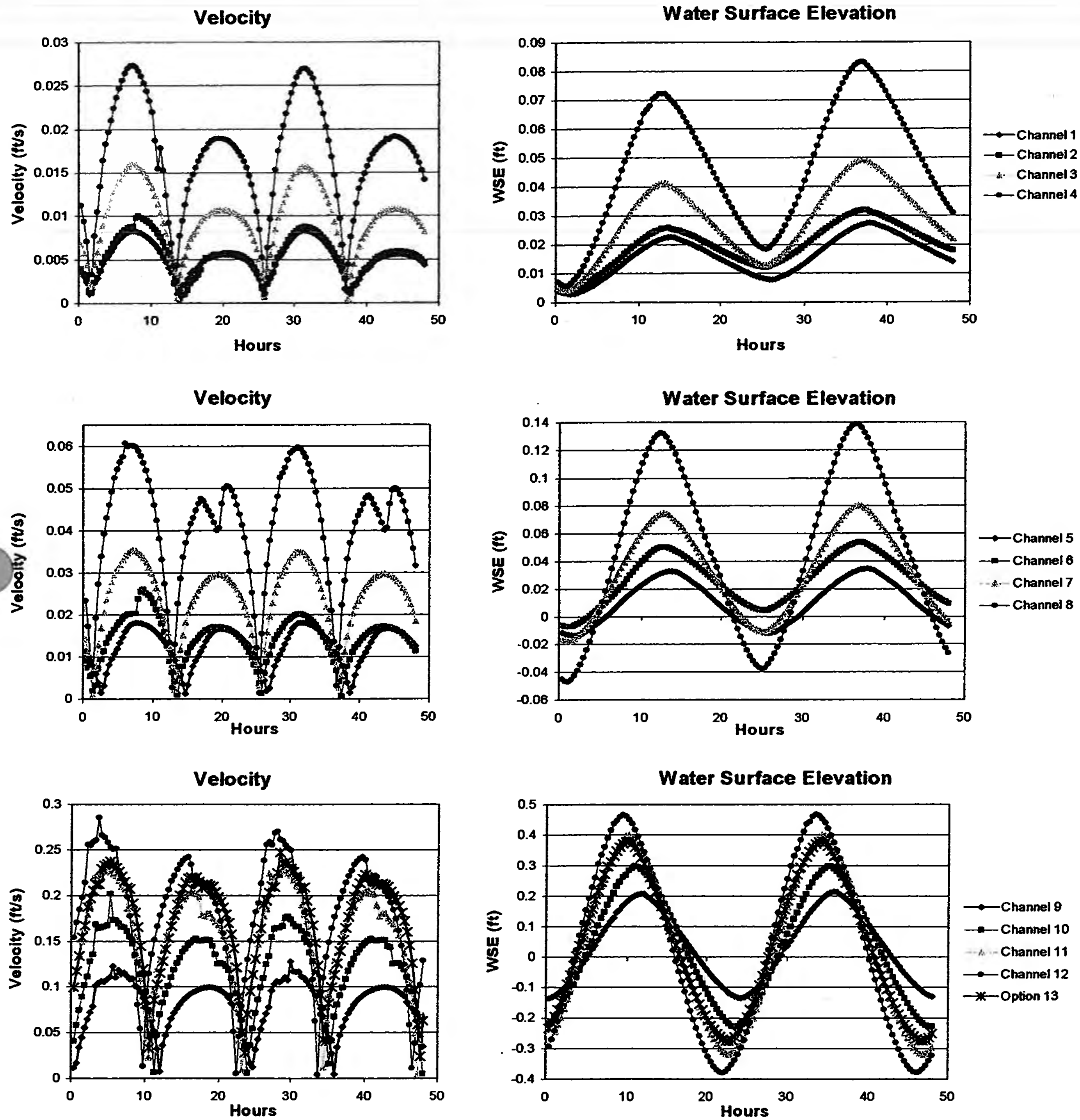

Figure 36: Velocity and Water Surface Elevation for North of East Railroad Cut feature point.

Feature Points: Laguna Larga & Little Laguna Madre – WSE and Velocity

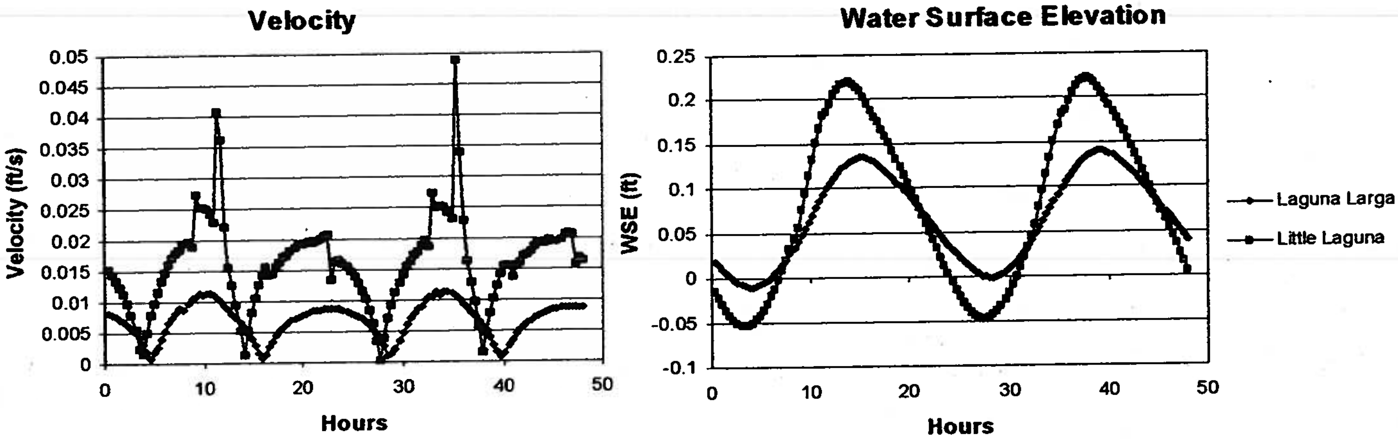

Figure 37: Velocity and Water Surface Elevation for Laguna Larga & Little Laguna Madre feature points.

Meeting Minutes from February 27, 2002

Discussed proposed plan for re-flooding Bahia Grande, Laguna Larga, and Little Laguna Madre. In summary, the FWS and other interested parties would like to re-flood the aforementioned basins for ecological and economic reasons. Parties discussed the strong desire to establish a channel directly from the Brownsville Ship Channel under HWY 48 to the Bahia Grande Basin. However, the land between the Brownsville Ship Channel and HWY 48 is owned by the Brownsville Navigation District and they have not consented to the use of the land for this purpose. An alternate plan is to build a shallow channel connecting the San Martin Lake with the Bahia Grande Basin on land owned by the FWS. Dimensions of the channel have been proposed as 20 feet wide and 2 feet below mean sea level (MSL). Along with building the connection between San Martin Lake and Bahia Grande, the FWS also have proposed constructing an additional two channels. One channel would connect the Bahia Grande and the Laguna Larga basins, while the second channel would connect the Bahia Grande and the Little Laguna Madre basins. The proposed dimensions for these channels are the same as the main channel above. These proposed channel locations are documented in Figure 5.

The FWS desire to minimize negative impact of construction equipment and soil removed from the channels on the wildlife refuge lands. Potential spoil areas have been suggested by the FWS and can be seen in Figure 5. It was suggested, however, that the spoils be placed along the banks of the channels so the soil would not have to be hauled to various locations around the refuge. The FWS representatives were not averse to building small islands along the channel banks with the spoils.

The FWS and area engineers are not certain of the stability of the soil in and around the basins. They feel that special precautions will need to be taken (such as mud mats under the equipment) to prevent heavy digging equipment from getting stuck in the area of the basins.

The FWS felt the need to place a water control structure at the entrance to Bahia Grande in a channel from San Martin Lake due to the possibility of pollution from oil or chemical spills.

The FWS want to move forward with this project as rapidly as possible. As soon and the funding and the plans are in place, they hope to being constructing the project. They are looking to being the project in 6 to 18 months.

Meeting Attendees and Contact Information

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