PHYSICAL EVALUATION OF PROPOSED FLOODING OF BAHLA GRANDE, CAMERON COUNTY, TEXAS

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by

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INTRODUCTION

This report was prepared at the request of the Texas General Land Office in response to certain questions raised concerning the proposed opening of a cut between the Brownsville Ship Channel and Bahia Grande on the Rio Grande delta, Cameron County, Texas (fig. 1). Local interests have suggested that flooding Bahia Grande, according to provisions in State Senate Bill 28, would (1) return the environment to a salt water wetland similar to its condition before a series of human alterations blocked the flow of salt water into Bahia Grande, (2) increase biological productivity of the area, which in turn would increase commercial fisheries and improve the local economy, and (3) reduce the dust that blows onto nearby communities such as Laguna Vista. Despite these compelling reasons for flooding Bahia Grande, questions have been raised regarding: (1) the areal extent of inundation, (2) the effects of inundation on storm flooding of adjacent areas, and (3) the requirements needed to maintain a viable wetland habitat.

The following report was organized to address these questions. In addition, the report briefly describes the geological origin of Bahia Grande, summarizes the important historical events that altered the area, examines the characteristics of adjacent flooded areas (San Martin Lake), and discusses anticipated effects of the proposed flooding of Bahia Grande.

ORIGIN OF BAHIA GRANDE

Bahia Grande and other shallow water bodies between Brownsville and southern Laguna Madre originated as a result of construction of the Rio Grande delta. The ancestral Rio Grande was a large river that captured runoff from a vast area of the southwestern United States and northern Mexico. As a result of abundant rainfall and sediment supply about 7,000 years ago, the river built a large delta into the Gulf of Mexico and extended the coastal plain seaward (Fulton, 1976). The surface of the alluvial and delta plain is crossed by a series of narrow, elongate ridges separated by broad, shallow depressions that were created as the river periodically shifted courses (Lohse, 1958; LeBlanc and Hodgson, 1959; Brown and others, 1980). The elongate ridges are remnants of abandoned river channels locally known as resacas (fig. 1). Natural levees parallel to the channels form the higher elevations, whereas flood basins occupy the lower elevations between the major channels.

Global climatic changes after the last ice age dramatically reduced the rainfall in what is now the desert southwestern United States. As a result of reduced runoff and sediment yield from this drainage area, the Rio Grande became smaller and delivered less sediment to the Gulf of Mexico (Lohse, 1958). The Gulf shoreline near the Rio Grande began retreating and the delta plain

foundered as the coastal plain subsided.

Lohse (1958) described the three phases of delta growth and the most recent history of shifting delta lobes. The oldest lobe was constructed north of the present river course and included the abandoned channels flanking Bahia Grande. Because of its greater age, this lobe has undergone the greatest subsidence and therefore the greatest inundation. Slow subsidence of the delta plain continues today and is recorded as a relative rise in sea level at the Port Isabel tide gauge (Swanson and Thurlow, 1973).

As their names imply and as shown on all maps (Table 1), South Bay, Laguna Larga, Bahia Grande, and San Martin Lake were all semi-permanent water bodies occupying flood basins between former river courses (fig. 1). These low depressions, which are generally less than 2 ft deep when flooded, were frequently inundated by salt water as the seaward end of the delta subsided and approached sea level. Small creeks and wetlands connected adjacent depressions and permitted exchange of water regardless of whether flooding was directed landward from the Gulf or flowed seaward from upland areas. The water table in these depressions is shallow because the depressions are near sea level. The shallow water table causes the depressions to hold water when they are flooded either as a result of abundant rainfall or abnormally high tides.

Climatic rainfall cycles cause periodic flooding and exposure of the depressions on the Rio Grande delta, thus they have characteristics of both ephemeral lakes and permanent tidal flats. At present, the climate of the Rio Grande delta is semi-arid and evapo-transpiration commonly exceeds precipitation (Brown and others, 1980). This deficit in rainfall causes increased salinities in shallow water bodies that can result in hypersaline conditions. During prolonged severe droughts, these water bodies evaporate and the mud flats are exposed to the prevailing south and southeast winds. The wind erodes (deflates) the mud flats and transports the eroded sediment inland as dust. These eolian processes have slightly increased the depths of the depressions down to the water table, which is lowered by the drought conditions. Some of the dust is deposited in ridges that rim the northern edges of the depressions forming clay dunes (lomas) that attain heights of as much as 30 ft (Price, 1958; 1963). The large number and sizes of these clay dunes indicate that eolian processes and wind-blown dust have been common for centuries.

The tide gauge nearest to Bahia Grande is in Laguna Madre at Port Isabel (fig. 1). This gauge shows that the unrestricted astronomical tide range is low, averaging about 1.0 to 1.5 ft (Breuer, 1962). Tidal influence in more remote and restricted areas, such as Bahia Grande, would be even lower. Consequently, salt-water exchange between Laguna Madre and adjacent shallow depressions depends largely on prevailing meteorological conditions commonly referred to as wind tides. Predominant southeasterly (onshore) winds and low barometric pressure promote flooding of the depressions, whereas strong northerly winds and high barometric pressure after the passage of cold fronts in the winter depress water levels and promote draining of the depressions.

Apparently systematic measurement of seasonal salinities and water temperatures were not reported for the shallow water bodies on the Rio Grande delta plain southwest of Laguna Madre. Nevertheless, the observations of Breuer (1962) for lower Laguna Madre can be used to characterize typical conditions in nearby water bodies. During summer months, long days and high temperatures cause high rates of evaporation that increase salinities in water bodies that have limited capacity for circulation and mixing. At times, heavy rains flood Bahia Grande with fresh water that reduces the salinity to a few parts per thousand (ppt).

RECENT HISTORY OF BAHIA GRANDE

The approximately 6,800 acres that compose Bahia Grande (fig. 2) were essentially unaltered before it was bisected by the old abandoned railroad grade constructed between Port Isabel and Brownsville (date uncertain). Slightly higher elevations associated with this embankment separate northern and southern compartments of Bahia Grande, limit the frequency and duration of saltwater flooding in the northern compartment, and restrict water circulation in both compartments established by wind-driven currents.

The second major alteration to Bahia Grande was associated with the Brownsville Ship Channel, which was dredged between 1934 and 1936 (Alperin, 1977). Most of the dredged material was placed in leveed disposal areas on the north side of the channel (fig. 1). These spoil banks formed high elevations and blocked the open exchange of water among Bahia Grande, adjacent water bodies, and the Brownsville Ship Channel.

In 1953, State Highway 48 (FM 1792) was constructed between Port Isabel and Brownsville. Raised elevations along the road bed further restricted the exchange of water between the Ship Channel and Bahia Grande except through a single set of small culverts. Aerial photographs indicate that a narrow meandering channel about 30 ft wide allowed limited water exchange between Bahia Grande and the Brownsville Ship Channel. The narrow connector channel made a turn (dog-leg) to the northwest just south of State Highway 48 because the culverts were not located in line with the opening to the Ship Channel. Instead, the culverts were northwest of the low levee used to contain spoil dredged from the Ship Channel.

At present (Feb. 1991), a twin set of 30 inch culverts and a single 45 inch culvert are the only openings beneath State Highway 48. The westernmost 30 inch culvert currently is the only culvert that is open enough to accommodate a small stream of water, the other culverts are closed by deposited sediment and possibly by culvert offset or collapse. Both sets of culverts are damaged by separation and settling and may need to be replaced if permanent flooding of Bahia Grande is desired.

According to marine biologists and local fishermen, Bahia Grande was a productive wetland

that contained blue crabs as well as some finfish and shrimp as recently as the late 1960s. But it was also a stressed environment subjected to large salinity and temperature fluctuations that periodically caused catastrophic mortality and possibly anoxic conditions (Ernest Simmons, personal communication, 1991). Some marine life transported into the shallows of Bahia Grande by abnormally high tides was trapped in the higher pools and died as the water receded and evaporated. Similar fish kills also resulted from sudden drops in temperature associated with the passage of Arctic cold fronts (Breuer, 1962).

In 1967, Hurricane Beulah made landfall in northern Mexico and caused severe damage in the lower Rio Grande Valley (U.S. Army Corps of Engineers, 1968). As a result of this storm, some sections of State Highway 48, including the section crossing Bahia Grande, were severely damaged and completely reconstructed in 1968. In addition to flow restrictions imposed by the highway, deposition caused by (1) placement of additional dredged material on spoil banks, (2) slope wash from the spoil banks, and (3) wave action along the banks of the Ship Channel has filled in the narrow opening into Bahia Grande, further restricting water exchange with the Ship Channel.

Local shrimping interests reopened the narrow channel connecting Bahia Grande with the Brownsville Ship Channel in April 1983. This reopened channel was approximately 10 ft wide and 5 ft deep near the Ship Channel and depths decreased toward State Highway 48. The channel, which allowed the accumulation of 6 to 8 inches of water in Bahia Grande, was dammed and nearly closed after being open about two weeks, but water remained in the lake for several months (Billy McKennon and Tony Reisinger, personal communication, 1991).

Field observations in November, 1986 and in February, 1991 showed that standing water extended into the upper reaches of Bahia Grande near its intersection with Highway 100 (fig. 1). After heavy rains, this basin fills with fresh water that becomes brackish as salt contained in the underlying soil is dissolved. Sparse stands of high marsh vegetation outline the perimeter of the barren mud flats and delineate the edge of frequent flooding. The high marsh assemblage of plants also indicates a transition between salt-water and brackish-water conditions (White and others, 1986).

RECENT HISTORY OF SAN MARTIN LAKE

The history of San Martin Lake is substantially different from that of Bahia Grande, to which San Martin Lake was originally connected. Before human alterations, this wetland system consisted of a series of interconnected water bodies that were segmented by clay dunes. The southernmost and largest segment was isolated by construction of the Brownsville Ship Channel (fig. 1). San Martin Lake now encompasses three long, interconnected water bodies on the north

side of the Ship Channel near Port Brownsville. The three segments are progressively larger in a downstream direction. Initially this waterway was restricted by the spoil banks and construction of highway 48 except for a small gap in the spoil banks near Loma de las Yeguas that allowed limited tidal exchange with the Ship Channel. However, after construction of State Highway 48, the largest segment of San Martin Lake was connected to the Ship Channel by a canal that is now approximately 120 ft wide and about 10 to 12 ft deep at the State Highway 48 bridge. This relatively deep man-made canal (known as the outfall) permits adequate tidal exchange of salt water and migration of marine organisms into the largest segment of San Martin Lake. The lake has a depth of about 6 ft along its central axis where it connects with the canal to the Ship Channel; elsewhere, San Martin Lake is extremely shallow.

Recent aerial photographs and field observations show that modifications to the San Martin Lake waterway increased discharge into the wetland system and altered the floral assemblages. These modifications were concentrated at both the upstream and downstream ends of the system. At the upstream end, a series of channels was constructed to improve drainage and to accommodate industrial discharges. The Rancho Viejo Floodway (fig. 1) and drainage ditches were constructed to divert floodwaters into San Martin Lake from the nearby resaca and surrounding upland areas. The drainage ditches also carry municipal waste-water discharge from several Brownsville sewage treatment plants (Brownsville Navigation District, 1983). Another channel system was constructed at a petrochemical plant so that cooling water extracted from the Ship Channel and discharged into holding ponds could then flow into San Martin Lake along with waste water discharged from the plant (Brownsville Navigation District, 1983). The downstream discharge associated with the floodway and industrial channels was variable, but large enough that it developed a braided stream and small delta at the junctures between the three lake segments.

The outfall canal cut at the downstream end of the waterway provides an outlet for storm waters and serves as an inlet for tidal flow into the main body of San Martin Lake. The funnel shape and moderate depths of the lake help maintain good water quality by enhancing tidal flow, water circulation, and water mixing. A low levee and road bed at the eastern end of the lake prohibits normal flow into a small arm of the lake that also connected into Bahia Grande. Together the upstream and downstream drainage modifications increased water circulation in San Martin Lake, concentrated upland runoff and attendant fresh-water inflow, and increased productivity of the wetland system.

Mangrove bushes, high marsh vegetation, and other salt-tolerant species characterize the wetlands surrounding San Martin Lake (White and others, 1986). Significant expansion of these wetlands, especially near the head of San Martin Lake, began shortly after construction of the floodway and Ship Channel. It is likely that nutrients contained in the agricultural runoff, industrial salt-water discharge, and municipal waste-water discharge were largely responsible for the

observed expansion of wetlands vegetation.

PROPOSED FLOODING OF BAHIA GRANDE

Areal Extent of Inundation

The area of Bahia Grande subjected to potential flooding directly depends on water levels; therefore, neither the area of inundation nor the shoreline position (land/water interface) is constant. Abnormally high tides or high rainfall cause greater inundation, whereas unusually low tides or droughts reduce the flooded area. The lines drawn to delineate the perimeter of Bahia Grande (fig. 2) represent the maximum limits of expected inundation based on field evidence and aerial photographic interpretation of past limits of prolonged flooding. In general, flooding will be more extensive closer to the Ship Channel and will diminish landward so that areas north of the old railroad grade will be inundated less frequently and will provide only extremely shallow water depths. Despite being photorevised in 1980 (Table 1), the topographic map exhibits minor discrepancies with more recent aerial photographs and field observations. These local differences in shoreline position are attributed to erosion and deposition near the railroad grade and the emergence of high marshes in the upper reaches of Bahia Grande. These minor topographic differences would not significantly alter projections of the area of inundation (fig. 2).

Effect on Storm Flooding

Bahia Grande can be flooded either by abnormally high tides or local intense rainfall. Storm-surge elevations of salt-water flooding recorded for the two most recent large hurricanes that impacted the Bahia Grande area (Beulah and Allen) are 7 ft and 8 ft above sea level, respectively (U.S. Army Corps of Engineers, 1968; 1981). Isohytal maps for the same storms show rainfall near Bahia Grande of 16 and 5 inches, respectively. These moderate flood depths and amounts of rainfall coupled with the generally poor drainage and low elevations demonstrate that the entire area is naturally flood prone (Brown and others, 1974). Furthermore, the volume of water that would be stored in Bahia Grande (approximately 10,000 acre ft) represents only a small fraction of the total flood water that would cover the area during a severe flood. Therefore, deliberately inundating Bahia Grande would not significantly increase the flooding of adjacent areas. Water stored in Bahia Grande would create a minor backwater effect that could delay drainage if surrounding upland areas were also flooded. However, after inundation of Bahia Grande, flood potential of adjacent areas would be no different from conditions that existed before tidal flow into Bahia Grande was restricted.

Salinity and Temperature Fluctuations

Large seasonal variations in water salinity and temperature are expected in Bahia Grande because of the large surface area, shallow water depths, high evaporation rates, high summer temperatures, periodic stream flooding, and periodic cold spells. This means that salinities in Bahia Grande can be either higher than or lower than salinities in the Brownsville Ship Channel, which typically are between 27 and 33 ppt (Breuer, 1972). Minimum salinities in Bahia Grande could occur anytime as a result of river flooding or prolonged rain, whereas maximum salinities would occur in the summer as a result of high evaporation, low rainfall runoff, and occasionally low tides which would cause the outflow of ponded water rather than the inflow of normal seawater.

Between February and April, 1985, salinity in Bahia Grande ranged from 10 ppt to 25 ppt (Tony Reisinger, personal communication, 1991). Extreme water salinities and temperatures are typically brief but may occur rapidly, such as during heavy rains and winter freezes. These significant departures from normal sea water conditions (35 ppt) periodically affect all waterbodies in the area (Breuer, 1962), but their influence on marine life would be accentuated in Bahia Grande because of its broad expanse and shallow water depths.

Water Circulation and Water Quality

Circulation of salt water in Bahia Grande resulting from tidal exchange or wind stress is primarily limited by the extant single inlet-outlet formed by the culverts beneath State Highway 48. The primary controlling elevation is at the base of the culverts because the water in the Ship Channel and connecting channel must be higher than the base of the culverts or be under moderate wind stress for water to flow into Bahia Grande.

Secondary restrictions to flow are created by the spoil banks and old railroad grade (fig. 1). Both of these artificial boundaries limit fetch and restrict currents flowing between the southern and northern compartments. Flow into the large northern compartment is restricted by three small openings through the old railroad grade; one in the middle and two at the eastern edge of Bahia Grande. Although elevations of the railroad grade were lowered by Hurricanes Beulah and Allen, the former railroad bed still presents a formidable barrier to water circulation. Under extreme conditions, water quality in Bahia Grande could deteriorate as a result of stagnation or red tide.

Historically, fish kills in lower Laguna Madre have been caused by pollution, rapid fresh-water influx, abrupt lowering of water temperature, and red tide (Breuer, 1962). Of these factors, relatively deep salt-water flooding and prolonged cold spells are probably the most common conditions that would cause large fish kills in Bahia Grande. Industrial or agricultural pollution

from surface runoff does not appear to be chronic in Bahia Grande (Brownsville Navigation District, 1983), but could become a problem in the future depending on utilization of the surrounding area and further alterations to the surface drainage pattern. A significant surface spill of agricultural chemicals (pesticides) occurred in 1982. This pollution event underscores the potential for the introduction of toxic chemicals into the water and sediment of Bahia Grande.

Using Bahia Grande for industrial discharges and waste-water disposal has previously been proposed (Brownsville Navigation District, 1983). An elaborate system of ditches, levees, and control gates as well as a moveable gate across the San Martin Lake outfall was proposed to allow permanent flooding of Bahia Grande and the other nearby waterbodies (Brownsville Navigation District, 1983).

Eolian Processes

The numerous clay dunes surrounding Bahia Grande and other lakes on the Rio Grande delta plain are ample evidence that evaporation and deflation were important processes long before the Brownsville Ship Channel and State Highway 48 were constructed. Nevertheless, the recent restriction of water flowing into Bahia Grande has aggravated the situation and has caused wind-blown dust to form more frequently. It is clear that flooding Bahia Grande will greatly reduce the frequency and duration of dust storms near Laguna Vista by covering the largest and closest source of eolian material. Dust may still originate in Laguna Larga unless the water level in Bahia Grande is high enough to cause periodic overflow into Laguna Larga.

Storm Scour

The shallow water depths and limited fetch in Bahia Grande will prevent the generation of moderately large waves and strong currents except during hurricanes. Ample riprap is already in place to protect the northern banks of State Highway 48 from erosion caused by small waves and currents generated in Bahia Grande. Cobble size pieces of broken concrete strewn northward from the riprap along State Highway 48 are evidence of strong flood-oriented storm surge currents that flowed across the roadbed during recent hurricanes. Such strong storm-generated currents are capable of locally scouring the lake bottom as much as two ft. Therefore, if pipelines are buried at a shallow depth, they should be examined to determine if exposure would pose a problem. Gas pipelines buried at shallow depths in the Gulf of Mexico have been uncovered as a result of negative buoyancy that caused the pipeline to move upward through the thin overburden.

DISCUSSION

Compared to Bahia Grande, water circulation within San Martin Lake is enhanced by greater water depths, a much larger connection with the Brownsville Ship Channel, and surface flow into its upper reaches that promotes periodic flushing. In San Martin Lake, high biological productivity and low susceptibility to fish kills are attributed to the substantial tidal exchange of salt water, formerly large industrial discharges of salt water, and occasional channelized discharge of surface water and sewage treatment plant effluent containing fertilizers. The plan to flood Bahia Grande and other lakes (Brownsville Navigation District, 1983) envisioned the discharge of 160,000 gallons per day of salt water in order to maintain adequate flooding of the water bodies. Thus, it appears that some pumping and/or periodic maintenance dredging may be necessary to maintain sufficient water depths and to control salinity fluctuations in Bahia Grande so that a productive marine habitat can be preserved.

The volume and rate of water exchange between Bahia Grande and the Brownsville Ship Channel will directly depend on the size and orientation of the opening. A large, straight canal, like the one at San Martin Lake, would provide greater exchange than the narrow, dog-leg channel that previously existed. Under present conditions, the diameters of the culverts beneath State Highway 48 will control the volume and rate of flow into and out of Bahia Grande. Furthermore, improved water circulation and water quality would be achieved if there was at least one other inlet-outlet connecting Bahia Grande with Laguna Larga or Laguna Madre so that a large-scale circulation system could be established. Fresh-water runoff from surrounding upland areas will tend to keep salinities in Bahia Grande below those in the Brownsville Ship Channel except during dry periods when evaporation in Bahia Grande exceeds inflow of salt water from the Ship Channel.

Although biological productivity would increase if Bahia Grande was flooded with salt water, the productivity would not necessarily be comparable to other large inundated areas such as San Martin Lake and South Bay where circulation and opportunities for fish migration are substantially greater. At present, water quality in Bahia Grande may be periodically degraded by a single restricted inlet and high evaporation with limited rainfall to counter hypersalinities. Under those conditions, algae are the most adaptable organisms that inhabit flats that are alternately submerged and exposed.

RECOMMENDATIONS

1. Evaluate feasibility of constructing a larger connecting channel between Bahia Grande and the Brownsville Ship Channel. Emphasis should be placed on reducing the constriction created by the small, broken culverts that cross State Highway 48.

- 2. Consider the possible need to repair the culverts at State Highway 48 to minimize flow retardation. Also consider methods to minimize sediment deposition at the culverts. If substantial roadwork is anticipated, then the culverts or bridge should be located so that a straight channel can be dredged between Bahia Grande and the Ship Channel.
- 3. Consider excavating additional openings through the old railroad grade to promote greater water exchange and to improve water circulation between both compartments of Bahia Grande.
- 4. Evaluate the feasibility of establishing a large-scale water circulation system with an additional inlet/outlet possibly in the vicinity of Laguna Larga.
- 5. Investigate the potential risks of gas pipeline exposure associated with permanent flooding of Bahia Grande.
- 6. Monitor the seasonal limits of flooding, water quality, and biological productivity in both compartments of Bahia Grande for at least a year after the channel is opened.

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Table 1. List of materials used to investigate Bahia Grande, Cameron County, Texas.

Aerial Photographs

Date	Type	Source	Format
Feb. 10, 1983	Color IR	U.S. Geological Survey (NHAP)	9X9
Nov. 1979	Color IR	NASA	9X9 (transparency)
Aug. 23, 1974	B&W	Texas Highway Department	9X9
Jan./Feb., 1960	B&W	Tobin Surveys	photo mosaic
Dec. 6, 1954	B&W	U.S. Department of Agriculture	photo index
Dec. 11, 1939	B&W	U.S. Department of Agriculture	photo index

Topographic Maps

1847	U.S. Army Corps of Engineers	sketch
1854 (T-453)	U.S. Coast Survey (NOAA)	smooth sheet
1936	U.S. Geological Survey	7.5 minute quadrangle
1955	U.S. Geological Survey	7.5 minute quadrangle
1980 photorevised	U.S. Geological Survey	7.5 minute quadrangle



Figure 1. Map showing locations of Bahia Grande, the Brownsville Ship Channel, and other features on the Rio Grande delta between Brownsville and Port Isabel.

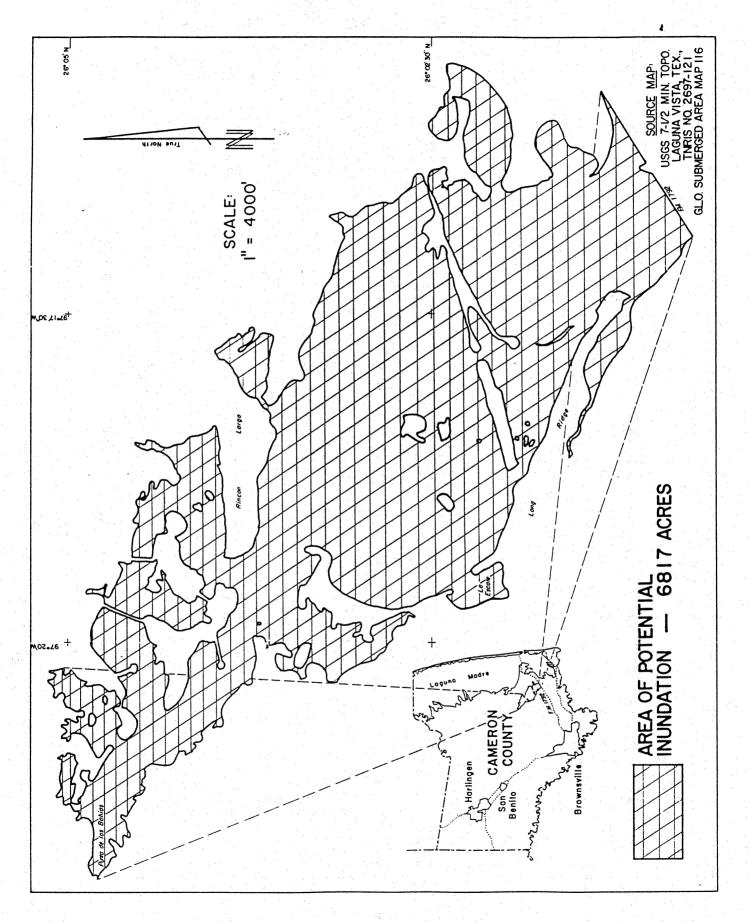


Figure 2. Projected limits of maximum flooding of Bahia Grande during normal conditions.