GUANICA SUGAR MILL
PRELIMINARY DIAGNOSIS
COASTAL ENGINEERING STUDIES

Prepared for:

PUERTO ENSENADA DEVELOPMENT CORPORATION (PEDC)

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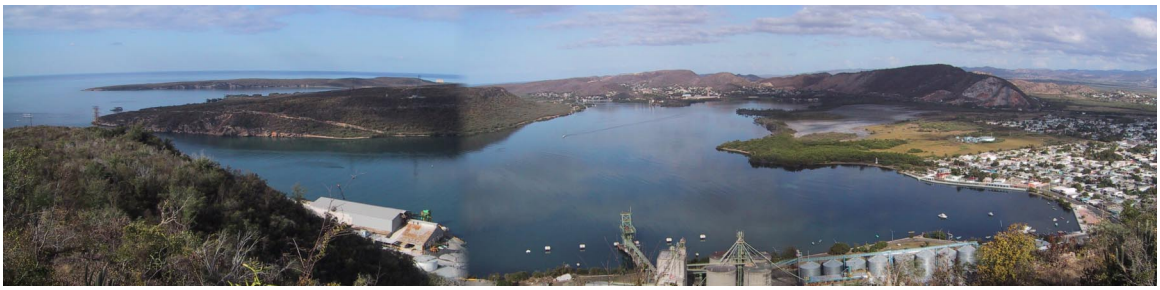
1.0 Phase 1: Coastal Engineering - Preliminary Diagnosis Executive Summary

This report summarizes the initial “Preliminary Diagnosis” Phase related to the coastal engineering aspects of the Guanica Sugar Mill project.



This phase involved preliminary data collection and a concentrated effort by senior coastal engineers, working directly with Felipe Nazario & Associates and CSA, to provide the client with a ‘professional judgment’ on the primary causes of the water quality problem and the likelihood of success in improving the existing situation. The intent of this work was to identify the scale of the required clean up effort so that the client can make an informed decision about whether or not to proceed with development.

Two principals from Baird & Associates (Dr. Rob Nairn and Mr. Kevin MacIntosh) as well as one additional coastal engineer / surveyor participated in the field portion of the preliminary diagnosis stage. The field work focused on key areas of the bay including near the Sugar Mill site and near the mouth of the Rio Loco. Sufficient information was collected to provide a "professional judgment" on the primary cause(s) of the water clarity / quality problem and the likelihood of success in improving the existing situation.

The beach at the Las Pardas site was also assessed in terms of its viability as a recreational site (swimming, snorkelling, windsurfing etc.) and its stability and runup / flooding potential during severe storm and hurricane events. This preliminary assessment provided adequate information for consideration of issues relating to hotel construction and maintenance (flooding, shoreline damage) and to identify whether or not further study is required.

The key observations and conclusions made during the preliminary diagnosis phase may be summarized as follows:

- It is the opinion of Baird & Associates that the primary cause of the impaired water clarity in Guanica Bay in the vicinity of the Sugar Mill Site is a combination of sediment discharged from the Rio Loco and the re-suspension of fine bottom sediments by waves and currents (the original source of the latter also being the river).

- The direct impact of the river discharge is most noticeable (results in brown water throughout the bay) and probably occurs approximately 5 to 15 times per year on average. The re-suspension of bottom sediments (resulting in murky green to brown water) probably occurs on most days during the year.

- The visual impact of both the river discharge (brown water) and the re-suspended sediment (murky green) do not meet the generally accepted standards for a proposed Caribbean development including both land based (condos, hotel etc.) and marine based (ie: Marina facilities).

Aerial photos of Guanica Bay

Suspended Sediment from Rio Loco:	Background Levels Near Rio Loco Delta

- Substantial sedimentation has occurred throughout Guanica Bay in the vicinity of the Sugar Mill Site over the past 30 years. As an example, as much as 2 m of sediment has accumulated in the old navigation channel to the Sugar Mill over this period. This observation influences the recommendations to improve the water clarity on the bay.

- It is our opinion that significant improvements to water clarity are practical and feasible. For the river discharge the solution could take the form of a wetland/wetpond located at the mouth and/or just offshore of the mouth of the river. To address sediment re-suspension it is necessary to eliminate or significantly reduce waves and currents in critical areas through the use of breakwaters or capping. The feasibility for improvements is aided by the

availability of land to create a sediment trap near the mouth of the Rio Loco and by the relatively localized nature of the sediment with highest potential for re-suspension.

- The additional studies proposed for PhaseII of the Sugar Mill project, relating to water circulation and quality in Guanica Bay and of the Rio Loco watershed, are essential for several reasons including:
    - To design a successful solution to the water quality / clarity issues in Guanica Bay
    - To determine the optimum designs relative to performance and cost
    - To provide scientific information / data in support of the EIS

1.1 Preliminary Diagnosis Objectives

The four primary objectives of this coastal / river engineering "preliminary diagnosis" study are provided below:

- 'professional judgment' on the primary causes of the water quality problem and the likelihood of success in improving the existing situation.

- Identification of the most likely successful strategies to solve the existing problems

- Scale of the required clean up effort will be identified.

- Preliminary consideration of the Las Pardas site as a recreational beach and hotel site from a coastal engineering perspective.

The following sections summarize the results of the preliminary diagnosis as well as outline required studies and schedules for continuation of the project.

1.2 Primary Causes of Water Quality / Clarity Issues

The work and analyses undertaken during the preliminary diagnosis stage suggest that the primary causes of the water clarity problem in Guanica Bay, in the vicinity of the Sugar Mill site, relates to suspended sediment contained in the flow from the Rio Loco and in re-suspended bottom materials due to wave and current action.

Water quality related to sewage and other sources may also be an issue which must be addressed, however, a detailed study of the water quality issue was beyond the scope of this investigation and there is presently inadequate information to provide comment on the magnitude of the water quality problem. Based on observations made during the preliminary reconnaissance, it is our opinion that the water quality issues, although very

important, are not as significant in terms of the development potential for this property and can be addressed through proper treatment. Water quality will be studied in more detail in Phase II of the proposed Sugar Mill site studies including numerical modeling of pollutant dispersion.

As shown in the attached pair of photos, the water clarity conditions do vary significantly from time to time. However, there appears to be an almost constant turbid section in the bay near the mouth of the Rio Loco which eventually affects water clarity at the Sugar Mill site and also has a visual impact on the overall area.

Guanica Bay near Sugar Mill Site
November 2000 March 2001

Photos of Water Clarity at Sugar Mill Site
March 2001

2 Site Investigations

2.1 Site Surveys and Reconnaissance

During the week of 26 Feb to 2 March 01, Baird engineers completed a preliminary site investigation including the following tasks:

- Reconnaissance of landside site conditions at the Sugar Mill Property;
- Define control points for kinematics DGPS survey (which can be used for any future surveys);

- Determine coordinates of visible control points to register the air photos for use in GIS;

- Hydrographic survey (to assess sedimentation rates in the bay and to provide input for future modeling of the bay);

- Completed 14 shallow sediment cores of the seabed in the bay (defines material that may be resuspended, provides information on sedimentation processes and provides preliminary information on foundation conditions for any structures on the bay);

- Collected approximately 40 sediment samples associated with cores and other locations (i.e. river bed/bank, flood plain delta and beaches) – a selected number will be tested to determine grain size gradations and water content/bulk density for future resuspension analysis;

- Deployment of a tide gage to measure tidal conditions 15-minute intervals on a continuous basis;

- Deployment of drogues to complete a preliminary assessment of current patterns on the bay;

- Reconnaissance of the river channel between the mouth and the highway bridge including the intermittent flood plain delta (to review river cross-section, banks conditions, flow conditions and discharge);

- Reconnaissance of the river channel further upstream to assess eroding bank conditions, sediment load, river cross-sections and flow conditions;

- Preliminary assessment of the Las Pardas beach including a near shore and beach profile, sediment samples, review of the beach plan form, dune formations and the salinas.

2.2 Analyses

Some preliminary calculations and assessments have been completed to support this initial diagnosis of the site conditions. These include:

- Review of wind and wave conditions in the bay itself;

- Evaluation of re-suspension potential (based on estimate of critical shear stress) and range of possible shear stresses generated by waves and currents;

- Assessment of watershed and river conditions with respect to possible range of discharge and sediment load;

- Assessment of the geomorphology of the river mouth delta features;

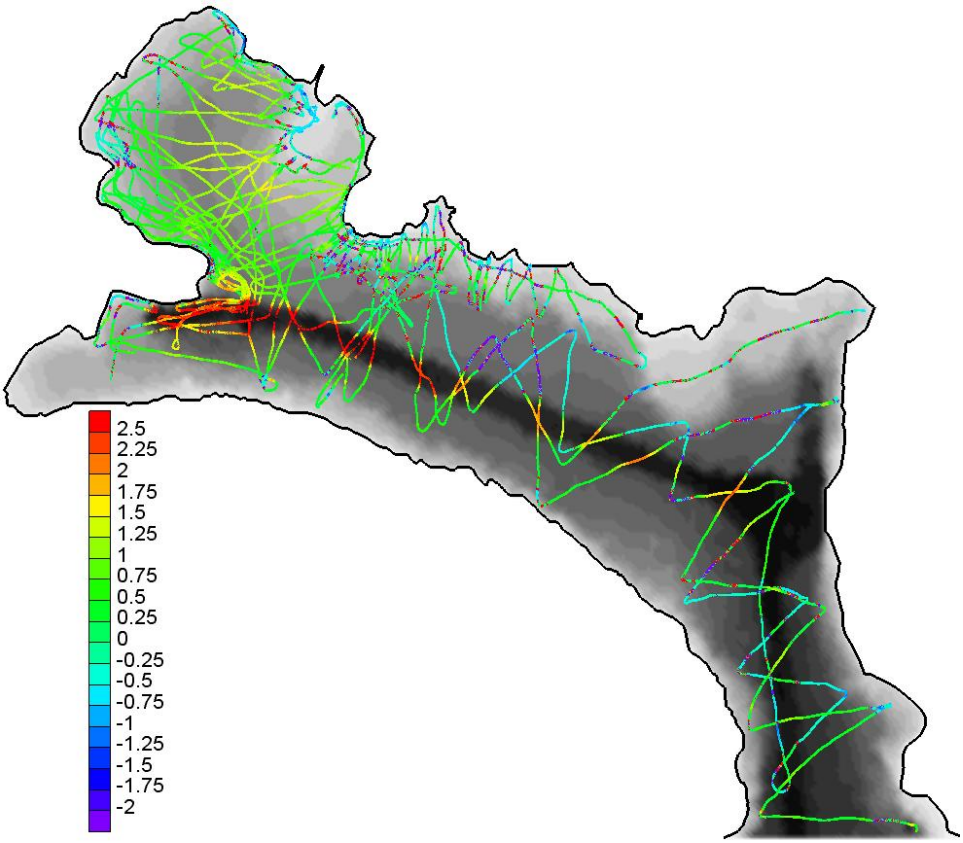
- Preliminary numerical model test of possible storm erosion and overtopping at Las Pardas beach.

2.3 Bathymetry / Survey Results

A hydrographic survey was undertaken as part of the preliminary diagnosis phase of this project.

A hydrographic survey was performed in Guanica Bay on February 28 to March 02, 2001. Real-Time Kinematic GPS equipment was used to establish/verify control monuments at the site and to provide horizontal location for the hydrographic survey. A Knudsen echosounder was used to record the water depths within the bay.

The data collected was compared to a 1970 bathymetric survey by writing a program to compare each 2001 survey point with the appropriate 1970 grid point (i.e., in the same location) and determine a difference in elevation between the two points. The "difference" file is shown in color superimposed on the 1970 surface in the Figure below:



The main observation from this analysis is that there has been substantial accretion of fine sediments throughout the western end of the bay near the Sugar Mill site. It is important to note that the comparison has limitations in that we are not certain of the accuracy of the 1970 survey, however, there does appear to be an obvious trend suggesting substantial accretion. This observation has a significant influence on recommended solutions as noted later in this document.

3 Overview of Site Conditions

This preliminary investigation of the site conditions was focused on assessing the influence of suspended sediment on water quality in the bay. Clearly, it is a key objective of the project (and necessary success factor for marina development) to achieve optimal water clarity.

It is noted that these findings are preliminary and based on limited information. Recommendations to further refine the understanding of the issues and possible solutions are presented in Section 6.

3.1 Evaluation of Sources

The sources of suspended sediment within the bay were identified as follows:

- Sediment load from the Rio Loco;
- Resuspension of sediments from the seabed in the bay;
- Possible point source inputs related to outfalls from the municipalities of Ensenada and Guanica and from the fertilizer plant in Guanica .

Clearly, the two most influential sources are sediment load from the Rio Loco and re-suspension of sediments within the bay. It is unlikely that the point sources contribute significantly to the degradation of water quality from a visual perspective (it is yet undetermined how these point sources may influence contaminant and bacterial conditions in the bay).

Water that eventually flows out of the mouth of the Rio Loco originates from run off of precipitation that falls over a large watershed and from complexities associated with several reservoirs and diversions. CSA have recently completed a report documenting these conditions upstream of Lake Guanica as part of an assessment of water supply for the region (an unrelated project to the Sugar Mill development).

Between Lake Guanica and the bay the river meanders through agricultural lands. The two primary sources of sediment to the river are run off from agricultural and open land, and riverbed and bank erosion. With respect to the latter, at a location in the vicinity of the first bridge north of the highway crossing, the riverbed had recently been dredged leaving large exposures of easily erodible banks. There was also evidence of bank erosion downstream of the bridge at the highway. A preliminary review of the sediment sample from river bank and flood plain delta suggests the sediment is a clayey sand (probably equal fractions of clay, silt and sand), this will be confirmed once the sieve analysis are completed.

Rio Loco Dredging

Vegetation in Upstream area of Rio Loco

Throughout the river (with the exception of the area that was recently dredged), the channel was densely overgrown with aquatic vegetation (and mangroves at the downstream end). During low flow conditions, this vegetation is beneficial in terms of minimizing background suspended sediment loads. Most sediment loading will occur during one of the two rainy seasons and in response to precipitation associated with large rainfall events.

During the dry seasons, any sediment load that reaches the bay discharges through the main channel and is mostly deposited in the main delta. During flood conditions the river must spill into the flood plain delta (the area of barren land between the river and the municipality of Guanica) and some of its sediment load will be deposited here with the remainder making its way into the bay through both the main channel and various locations along the fringe of the flood plain delta. During these high flow conditions clay and silt spread throughout the bay, however, sand will mostly be deposited on the submerged and flood plain deltas. It is possible that these high flow conditions occur 5 to 15 times per year on average.

There is evidence that river channel may once have been aligned further to the east. The evidence consists of the form of the shoreline indicating the old position of the river mouth and survey findings pointing towards the existence of an old delta. At this time it is unknown why the mouth of the river channel may have changed position, however, there are several possibilities:

- With ongoing deposition during flood stages on the river in the flood plain delta the elevation of this area has increased, forcing the river channel alignment towards the west;

- The old hydrographic chart indicates that dredge spoil (possibly from the original dredging of the navigation channel to the Sugar Mills) was deposited along the north shore in the vicinity of the old river mouth. It is possible that this activity may have contributed to, or been fully responsible for forcing the river mouth alignment towards the west.

- The old river alignment may have been block by debris during a high flow condition causing the creation of a new channel alignment which now parallels the road along the lower portion of the river.

The reason for the shift in the position of the river mouth will be an important question to answer in the next phase of the investigation. This information will be important, if not essential, for the evaluation of the viability of measures to intercept sediment load before it reaches the bay (such as a wetland or wet pond as discussed in Section 4).

3.2 Resuspension of Sediments in the Bay

As noted previously there are three main deposition zones for sediment discharged by the Rio Loco:

- The flood plain delta;

- The existing and possibly historic submerged deltas; and

- Deeper surrounding areas consisting of muddy sediments.

The flood plain delta is generally protected from re-suspension. A significant fraction of the sand transported down the river will be deposited in this area during high flow conditions. The remaining sand sized sediment discharged by the river is deposited on the submerged delta (in both current and possible historic locations). In addition some of the silt and clay carried by the river are deposited on the submerged delta (as confirmed by the sediment cores). The water depths on the delta range from 0.3 to 0.6 m (1 to 2 ft). The adjacent areas are deeper (between 1 and 3 m) and make up the third main depositional area defined by the preliminary seabed sampling. Most of the clay and some of the silt discharged by the river are deposited in these areas.

A preliminary review of the re-suspension potential of the sediments in the bay has been completed. There are two factors to consider in this assessment. First, the critical shear stress (shear stress is the force on the seabed created by waves and currents) that is the shear stress that initiates mobilization of the sediment. The critical shear stress is a

function of the condition of the bed sediments including grain size gradation, water content bulk density, consolidation and other factors. The driving forces (shear stress) for re-suspension result from the motion of the water related to the action of wind, tidal and density driven currents and waves. The shear generated by waves is also a function of water depth with higher shear stresses in shallower water. Our preliminary assessment indicates that clay and silt from the submerged delta are re-suspended very frequently (generally whenever wave heights exceed 10 to 20 cm in the delta area), perhaps 200-300 days or more each year. The softer finer clay and silt sediments in the deeper depositional areas are re-suspended much less frequently.

Once sediment is re-suspended from the delta it is distributed through the inner part of the bay (including the proposed marina location) through processes of diffusion and advection (or transport by currents). Preliminary observations of the current patterns and suspended sediment distribution in the bay suggest that the currents that are responsible for spreading the sediment are complex and three dimensional in nature.

Sediment Sample Photo

4 Most Likely Succesful Strategies

Some initial concepts have been considered to address the two primary sources of suspended sediment on the bay (the Rio Loco and re-suspension of sediments). With respect to the Rio Loco, the range of possible solutions fall into two groups:

- Controlling the source of the sediment load through best management practices in the agricultural land (such as the use of filter strips) and through bank stabilization measures;

- Intercepting the sediment at the mouth or at some other location along the river, (through a wetland or wetpond) and./ or possibly a wetland within the bay.

Our preliminary assessment suggests that some combination of these two approaches would produce a viable solution to prevent most of the sediment loading to the bay from the Rio Loco. Both solutions would result in a significant net improvement to the ecosystem of the bay.

To address the problem of re-suspension, particularly in the vicinity of the delta, an initial assessment of the following solutions has been completed;

- Construction of breakwaters around the perimeter of the delta to protect this area from wave action. It is possible this measure may also promote the creation of wetland on the delta that would further reduce the possibility of re-suspension.

- Capping of the delta with clean sand to prevent re-suspension of the underlying muddy sediments. This approach has the added benefit of creating a reflective surface for sunlight which will enhance the appearance of the bay. Additional investigations are required to assess the likely success of this approach.

- Dredging of the delta to remove the sediment down to a depth that reduces or eliminates the potential for re-suspension

Of these three concepts the breakwater/wetland alternative is most likely to provide a viable solution to the resuspension problem. It is important to note that these concepts do not address the potential resuspension of sediments in the deeper sections of the bay. However, at this time the resuspension of these sediments is not believed to be the primary source of suspended sediment.

5 Scale of Required Remedial Measures

A series of concepts have been considered as noted in the previous section. Conceptual cost estimates have been prepared for each concept. We have also provided an opinion on the likelihood of success for each concept. It is noted that these concepts are supported by the limited information that has been gathered and has relied on our experience at other locations. We are confident that the concepts identified are practical and feasible, however cost estimates must be considered approximate pending further data collection and analysis.

- Concept A: Dealing with Suspended Sediment from Rio Loco

  - Controlling the source of the sediment load through best management practices in the agricultural land (such as the use of filter cloth) and through bank stabilization measures;

  Cost: $200k to $1M depending on the scale of efforts.

  Approach: A lower level effort, including simply providing BMP (Best Management Practices Guidelines for Upstream activities) is recommended as an initial step. A monitoring program on suspended sediment loads in the Rio Loco is also required to document the impact of implementing BMP's. This concept alone will impact background levels of suspended sediment which is important to the overall project. It will <u>not</u> address large suspended sediment loads which occur during heavy rainfall events.

  - Intercepting the sediment at the mouth or at some other location along the river, (through a wetland or wetpond) and./ or possibly a wetland within the bay.

  Cost: $500k to $3.2M depending on the scale of efforts.

  Approach: This site provides an extraordinary opportunity to reroute the Rio Loco toward the east as well as intercept a large portion of the suspended sediment load through the creation of a wet pond/ wetland. The existing mud flats near the mouth of the Rio Loco could be utilized for this purpose. A phased implementation may be recommended depending on the results of Phase II studies including detailed numerical modeling of the Rio Loco and the impact of river rerouting on the suspended sediment distribution throughout Guanica Bay. The lower cost alternatives are likely to have a limited impact on background levels of suspended sediment only, whereas the upper costs (ie:$2M to $3.2M) have a high probability of generating significant improvements in the water clarity related to inflows from the Rio Loco.

- Concept B: Dealing with Resuspension of Bottom Materials in Guanica Bay

  - Construction of breakwaters around the perimeter of the delta to protect this area

from wave action. It is possible this measure may also promote the creation of a wetland on the delta that would further reduce the possibility of re-suspension.

Cost: $500k to $1.5M depending on the scale of efforts.

Approach: This task requires the proposed Phase II modeling in order to define the required extent of protection for the delta from both wind generated and boat wake generated waves. Similar concepts have been implemented successfully on other projects and this concept has the added benefit of potentially creating an expanded wetland at the mouth of the Rio Loco to further minimize background levels of suspended sediment.

- Capping of the delta and other areas surrounding any proposed marina or related water developments on the Sugar Mill site with clean sand to prevent re-suspension of the underlying muddy sediments. This approach has the added benefit of creating a reflective surface for sunlight which will enhance the appearance of the bay. Additional investigations are required to assess the likely success of this approach and where it should be implemented.

Cost: $500k to $2.5M depending on the area to be covered and required thickness.

Approach: A layer of sand is placed over areas where resuspension of bottom materials is most likely. The area to be covered will be defined by studies proposed in PhaseII. This approach requires that the Concept A tasks (reroute Rio Loco and construct wet pond) be implemented in order to be successful, otherwise the sand will eventually be covered with fine sediments as a result of high suspended sediment concentrations during significant rainfall events. Assuming that both Concepts are implemented this approach has a very high probability of generating significant improvements in water clarity throughout the water surrounding the Sugar Mill site.

- Dredging of the delta to remove the sediment down to a depth that reduces or eliminates the potential for re-suspension

Cost: $600k to $1.8M depending on the area to be dredged.

Approach: This approach represents an alternative to either breakwater construction or capping. It's selection and implementation will be dependent on the results of additional shear stress and wave prediction (hindcasting) analyses to be undertaken in Phase II. It has a relatively high likelihood of success, but, only deals with the resuspension of bottom materials in the vicinity of the delta versus the breakwater approach which also provides benefit in terms of reducing the input from the Rio Loco.

6 Las Pardas Beach

A general reconnaissance of the Las Pardas Beach site was completed. This included photography, the measurement of beach profiles (onshore and nearshore), and sand sample collection. The salinas area was also reviewed and considered in the analyses.

This reconnaissance, and related beach profile analyses, suggest that the Las Pardas Beach represents an excellent recreational beach. It has flat nearshore slopes and a sandy bottom out to depths in excess of 2m and beyond. It is unlikely that rip currents or other dangerous swimming conditions occur on this beach with the exception of during severe weather events with large wave conditions and related water level setup.

It will be important to minimize the introduction of new pollutants into the bay to maintain water quality as circulation is limited by the relatively small tidal circulation and flat nearshore slopes. More detailed modeling is required to verify this opinion and to determine the related acceptable level of development surrounding Las Pardas Beach.

The preliminary analysis undertaken to date suggests that the Las Pardas beach will overtop during even relatively small storm events. An example of the model output is provided in the Figure below:

Las Pardas Beach Profile Model Results FIGURE

This conclusion is based on both site observations and technical beach profile analysis and modeling. It is also supported by site observations in relation to the adjacent Salinas. It is therefore important that hotel and beach facilities be positioned properly to avoid damage due to both waves and increases in water level during storm events.

Additional, more complete site investigations are recommended to verify the observations noted during this preliminary diagnosis phase and to create adequate scientific information for the EIS submission. This should include additional beach cross section surveys, sand sample collection, and transects to be completed by a marine biologist. We strongly recommend that a qualified marine biologist visit the site during the next phase to complete the appropriate documentation of this site for the EIS submission.

7 Required EIS Studies

7.1 Objectives

The opinions and interpretations presented in this preliminary diagnosis are supported by limited information. Additional investigations are required to better define the sources

and processes that contribute to sediment suspension including:

The frequency of occurrence of re-suspension on the delta and adjacent sediments;

The frequency of occurrence of high sediment load conditions from the Rio Loco.

The diffusion and transport of these sediments throughout the bay.

Furthermore, the proposed next steps will also provide the information required to assess the level of performance and possible cost of the various conceptual alternatives. Additional concepts may also be developed a part of the work.

7.2 Required investigations

1. A list of required investigations and associated tasks is presented below:

   - Complete a geomorphic assessment and develop a sediment transport model of the lower reach watershed and river (i.e. below Lake Guanica) and evaluate possible solutions.

   - Obtain information from CSA on hydrology and hydraulics of the Rio Loco river and reservoir system upstream and including Lake Guanica;

   - Complete flow and suspended sediment measurements during a field campaign;

   - Investigate the possibility of deploying a silt curtain across the river to determione the effectiveness of this approach for low to medium flow conditions during the field campaign;

   - Complete a geomorphic survey of the river to identify the river bed profile, alignment, cross-sections, bed and bank sediments and areas of erosion and deposition;

   - Develop a hydraulic and sediment transport model of the lower reach of the river below Lake Guanica including any re-alignment, wetpond or wetland alternatives;

   - Develop the conceptual alternatives to the extent their performance (efficiency at intercepting sediment) can be evaluated and preliminary cost estimates can be developed.

2. Complete an assessment of sedimentation and resuspension processes on the bay and evaluate possible solutions. The required tasks are listed below:

   - Complete measurements and observations of current velocities, salinity,

temperature, suspended sediment, water quality, winds and tide levels seabed conditions;

- Develop a three dimensional hydrodynamic model of the bay to define the wind, wave, tide and density driven current patterns on the bay;

- Complete a wind-wave hindcast to define the locally generated wave conditions on the bay.

- Complete the development of a preliminary wave climate for the southwest coast of Puerto Rico and transform these waves into the bay;

- Undertake an analysis of the re-suspension potential for seabed sediments and verify these estimates using the measured and observed information collected in the field campaign.

- Assess the level of performance of the various alternatives and develop preliminary cost estimates.

A proposal outlining the tasks noted above and the related costs will be provided under separate cover.

7.3 Schedule

In order to meet the objective of a draft permit application by late 2001 it is absolutely ***essential that the required coastal / river studies be initiated by early to mid April*** at the latest. There are several reasons for this scheduling requirement.

Mid April through May represent one of the 'wet' seasons where rainfall and the associated runoff from the Rio Loco will affect water clarity. It is imperative for documenting existing conditions and for designing and costing solutions that field information related to this type of runoff event be collected. For example,

- The Corps of Engineers will expect seasonal field data which is presently unavailable and will need to include both the April/ May and August/November 'wet' seasons.
- Data collected during this period (mid April through May) will be used to calibrate proposed numerical models of water quality, tidal conditions etc. throughout Guanica Bay. The collection of this data during the fall 'wet' season would not provide adequate time to setup and calibrate the models as well as to prepare solutions which are dependent on the model results.
- The first step toward the objective of having seasonal data has been taken. The tide gauge originally installed for the preliminary diagnosis stage was left in place to provide long term tidal data at the Sugar Mill site.