TECHNICAL RESOURCES CENTER - P.C.C.
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Managerial Recommendations for the Lower Trinidad Project

1. Introduction

As a separate task order under the Program Management Advisory and Assistance Service Contract, the Program Manager Advisory Team (PMAT) have been requested to render a recommendation on the Lower Trinidad Project from which the ACP can make a managerial decision on the future conduct of additional studies. The recommendation is to be based upon the review of previous studies, project investigations and technical appraisals performed to evaluate its feasibility. In addition, the PMAT shall consider other critical non-technical elements of project development to render its managerial recommendation. The Task Order, however, is not intended for performing major new work or analysis on the Lower Trinidad Project.

2. Background

In consideration of the need to provide more water into the Canal system or better manage available water to meet existing system operating demands and provide for capacity expansion, the Canal Capacity Projects Division studied 30 individual project options at a Reconnaissance level of detail that were rated on the basis of technical viability, water yield, operational impacts, economic feasibility and environmental factors including socio-economic impacts. Economic feasibility included calculation of project first cost, investment cost, benefits and benefit/cost ratios. Of the 30 projects evaluated, a project configuration for the Lower Trinidad Project was evaluated that considered increased storage behind a dam that would be constructed in the Trinidad arm of Gatún Lake. The project consisted of a dam with a longitudinal axis length of about 4,100 meters and of 30 meters maximum height, to be constructed underwater on soft soil conditions characterized by the "Atlantic Muck" formation. Also, the project incorporated an additional spillway, a small lock and associated facilities. A Reconnaissance Report was prepared for this project and other project options by the United States Army Corps of Engineers (USACE) through its Mobile District, and submitted to the ACP in December 1999. Black and Veatch conducted the environmental and socio-economic reconnaissance review for this study. This project had also been studied in 1962 and 1963 by Tudor Engineering Company and Shannon and Wilson, Inc. but was not advanced beyond the initial study phase.

The projects considered in the Reconnaissance report were rated and the ACP later selected the most promising project alternatives for further study at the Feasibility Design level. The list of recommended project alternatives did not include the Lower Trinidad Project, as its ratings did not place it among the best project options.

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In 2001, the Lower Trinidad Project was reformulated and engineering analyses were made of the very soft foundation conditions. The reformulated project consists of the same basic dam arrangement as previously studied but now contains a pumped storage system to save the water that would normally be spilled from Gatun Reservoir into the Atlantic Ocean through the Gatun spillway. The reformulated project scheme consists of equal or higher water storage levels (as was originally contemplated) and the capacity for operating at levels below the minimum elevation of Gatun Reservoir through pumping. It does not contain a small lock to pass lake fishing traffic.

In order to equally compare this new project configuration, USACE-Mobile District and Black and Veatch were asked to perform project development and evaluation using the same basic framework of the original Reconnaissance Studies. The new Lower Trinidad project scheme was compared at the same level of detail and to the same rating factors as the original 30 projects. This project evaluation had the additional benefit of considering the foundation studies that were made by the ACP Geotechnical personnel to determine existing site conditions by geologic profile and calculation of expected settlements and design parameters for the foundation conditions. This project scheme also was studied in combination with the Indio River and the Caño Quebrado Dam projects to expand storage and increase water yield to the Canal operating system.

As part of the evaluation performed by USACE-Mobile at the Reconnaissance level, two engineering consultants retained by USACE-Mobile reviewed the report and provided their professional opinion on the merits of constructing this project. The study was completed and a report was presented to the ACP in January 2002, along with the technical opinion of the two independent consultants. Subsequently, the ACP requested its Geotechnical Advisory Board[1] to review all relevant technical documents associated with the evaluation of the Lower Trinidad Project, including additional analyses and presentations prepared by ACP staff. The Geotechnical Advisory Board expressed disappointment with the USACE work and recommended that the project be advanced to the feasibility phase to determine its viability for construction.

Because of the unique characteristics of this project, the effort and cost associated with conducting further feasibility studies, it is desirable to have the PMAT issue a managerial recommendation of the viability of the project and its potential for reaching the full design stage as a competing project with other available options to supply additional water to the Canal.

[1] ACP Geotechnical Advisory Board consists of James M. Duncan, Robert L. Schuster, William F. Marcuson III, Robert L. Wesson and Norbert R. Morgenstern.

3. Evaluation Process and References Reviewed

A multidisciplinary Review Team was organized to provide the managerial level review of the Lower Trinidad Project. The Review Team comprised environmental, geotechnical, and water resource specialists, supplemented by the base PMAT staff of environmental and engineering professionals.

The Review Team reviewed the available information, visited the proposed Lower Trinidad Dam site and reservoir area, attended a Workshop on December 4, 2002, participated in discussions with ACP staff, and visited the soils laboratory.

The ACP provided the following documents and information:

a. Increasing the Water Supply to the Panama Canal, Tudor Engineering, 1962
b. Tudor Report (including the Shannon and Wilson Report) 1963
c. Reconnaissance Report, December 1999, U.S. Army Corps of Engineers
d. Reconnaissance Report, Lower Trinidad, December 2001, U.S. Army Corps of Engineers
e. ACP Lower Trinidad Project Formulation and foundation geologic profile and analyses.
f. Consultant Reports on the Lower Trinidad Reconnaissance Report
g. ACP staff presentations to the ACP Geotechnical Advisory Board
h. ACP Geotechnical Advisory Board assessment.
i. Project location maps and available environmental and socio-economic information.

In addition to the above references, the study team also reviewed the presentation materials, data and scheme proposals presented by ACP at the December 4 Workshop.

4. The Lower Trinidad Project Description

The Lower Trinidad Dam Project has been studied since the 1960s. The Project concept was originally for the single purpose of water storage. Recently, the Trinidad Pumped Storage Concept has been introduced. This concept incorporates a pumping station that can transfer water between the proposed Trinidad Reservoir and Gatun Reservoir. The concept allows for partially separating the navigation lane from the storage/regulating function and allows the Gatun Reservoir to operate with a minimum level of fluctuation. Such control of the Gatun Reservoir level facilitates the maintenance of the draft required for navigation, and aims to avoid the requirement for ships to transit the locks light loaded.

The principal structures of the proposed Lower Trinidad Water Project, as currently, conceived by the ACP as a pumped-storage facility, include the following:

- Trinidad Dam. This dam would be located across the Trinidad arm of the existing reservoir. Such a dam would largely be constructed underwater and extend for a total length of about 4,100 meters. It would have a maximum height of about 30 meters and involve a total fill volume on the order of 20 million cubic meters. It would have a crest elevation of about El. 32.5 m

- Cano Quebrado Dams and Diversion Channel. These features would allow control over the Cano Quebrado Watershed, providing for maximum regulation of the water supply, and providing additional active storage of about 80 million cubic meters.

- Trinidad Reservoir. The dam would impound water in the Trinidad arm and the Cano Quebrado to a normal maximum level of El. 30.48 m, to maintain itself within the existing ACP property line. Between El. 30.48 and El. 22.86 m, an additional active storage of 1,140 million cubic meters would be provided. About another 4,700 ha of land would be inundated, largely vegetated (shrub-scrub, "matorral", and secondary growth, "rastrojos") reservoir shoreline and some low-lying pasturelands.

- Trinidad Pumping Station. The Project would include a Pumping Station that would allow water transfer in both directions.

- Trinidad Spillway. A spillway would be provided for flood passage capability. This would also tend to mitigate the undersized capacity of the existing Gatun spillway.

Previous reports have suggested that the Lower Trinidad Project as currently conceived would require about seven years to build.

As conceived, the Lower Trinidad Project would be part of an overall strategy to provide a complete and reliable water resource and navigation system for the Canal. Other alternative (or in some cases complementary) projects could include recycling, water savings basins, the Rio Indio Water Supply Project, and navigation channel deepening.

5. General Technical Review of the Lower Trinidad Project

The PMAT's technical review comments are presented below specifically on the conceptual design, design parameters, engineering analyses, constructibility, cost estimates and risk of overruns. The comments are focused primarily on the design concept proposed by the ACP, but the USACE assessment is also referenced where appropriate.

5.1 Conceptual Design

- The dam's cross-sectional design configuration proposed by ACP (i.e., with an average/equivalent slope of 8.3H:1V) is considered reasonable. It is anticipated that adequate stability of the proposed design can be achieved through the use of wick drains in the foundation soils, the dredging of the top very soft sediments, the placement of an initial drainage layer and other foundation improvement techniques. The 15H:1V slope scheme based on the USACE Mobile District's assessment appears to be overly conservative.

- ACP's design concept does not include the use of high strength geotextiles prior to the placement of the embankment fill. These geotextiles can provide very high tensile strengths, up to a couple of thousand lbs per inch. The use of high strength geotextiles provides the following advantages:
  (1) serving as a separator to protect the shallow foundation soil from being disturbed/degraded due to the placement of the fill (if bottom dumped),
  (2) avoiding the time-consuming and costly clam shell placement method suggested by the Mobile District's study,
  (3) increasing the slope stability during construction, thereby maximizing the side slopes and minimizing the required fill volume (particularly during the early stages of construction), and
  (4) reducing the amount of surficial soils to be pre-dredged (e.g., from the proposed 5 m to 2.5 m).
  High strength geotextiles have been successfully installed in similar water depths in Europe (refer to Appendix A), and have been installed for similar applications (prior to the installation of wick drains) such as LaGuardia Airport runway extension project in New York, except that the water depth in that case was much shallower (less than 5 m). Therefore the use of geotextiles is considered feasible, but approach and cost of geotextile installation in such deep-water conditions will need detailed evaluation by specialized contractors.

- The wick drain spacing proposed by ACP is about 10 m. This spacing is much wider than what has been generally used in practice and may have to be narrowed if soil strength properties or the soil consolidation rate are not as favorable as currently anticipated based on the 1963 Shannon and Wilson investigation. We expect that a wick drain spacing of around three meters may prove to be more appropriate.

- The construction concept indicates that wick drains would be placed <u>prior to</u> the placement of a crushed stone layer. Consequently, the drains would not be extended through the drainage layer, resulting in a potential retardation of the drainage path. However, if the crushed stone layer is placed first, then pushing the wick drains through the stone layer may be difficult. Consideration should be given to the use of

a thin sand/gravel size layer as the drainage material, so that the wick drains can be installed without difficulty and effective drainage can be achieved.

- Seismic design criteria and the related seismic design issues were not addressed. These are important issues that may affect the design and construction of the dam and therefore need to be addressed. Particularly, the performance goals required under the design ground motion level should be clearly and reasonably defined to avoid unrealistic design that may lead to unnecessary construction costs. Performance based or deformation-based design criteria should be developed for the project.

- The sand/gravel size drainage layer as well as the body of the dam may need to be densified to increase the material strength and minimize liquefaction potential under the design earthquake. ACP's design concept proposes the use of vibro-compaction for this purpose. Vibro-compaction techniques are generally most effective with relatively small sized granular fill materials (say to up 10 cm).The feasibility of using this technique in a very thick sand/stone mixture (with stone size up to 30 cm) should be further investigated. Generally, if the percentage of larger size stone is high (e.g. more than 30% of the fill having stone size larger than 25 cm), than vibro-compaction may not be feasible. Other cost effective ground improvement methods such as sand compaction piles could also be studied (equipment to install large diameter sand compaction piles up to 60 to 70 meters below water is available), although these are more commonly used in cohesive fill materials. On the other hand, if the dam materials consist primarily of rock fill, then liquefaction may not be an issue and densification may be unnecessary. However, the addition of an impervious core may be necessary. We consider that controlling the characteristics of the fill to minimize the need for in-situ densification may prove the most cost effective approach.

5.2 Soil Properties

- The typical soil column (stratigraphy) used by ACP in the analyses represents a more critical section, i.e., deeper soft soil profile than the average within the dam footprint area. It is conservative but reasonable.

- According to ACP's Workshop presentation, the typical range of vertical coefficient of consolidation (Cv) based on the lab test data is between 0.02 to 0.045 cm^2/min (corresponding to about 0.03 to 0.07 ft^2/day). Based on our experience with similar soils, this range of Cv values is considered reasonable and adequate for preliminary engineering. For the horizontal coefficient, C_h, a reasonable value can be assumed to be about 2 to 3 times that of the Cv.

- Engineering parameters, back-calculated based on data from the Gatun Lock South Approach Wall, however, indicate much higher Cv values (in the order of 0.13 to 0.37 cm^2/min). The reason for such a significant difference is unclear. Possible

causes may include differences in soil characteristics and the fact that a pile group supports the wall. Use of these high Cv values in calculating soil strength gain due to consolidation is not conservative and should not be used for design.

- The typical range of compression ratios computed from lab test data is between 0.25 and 0.3 (strain per log cycle of stress). The equivalent average compression ratios, back-calculated from the measured data from the South Approach wall, ranges from 0.28 to 0.33. These values are consistent with published data and the use of these values for performing long-term settlement calculations is considered appropriate.

- In deriving the deformation modulus value (i.e., the E value), five methods have been suggested by ACP. Among the five methods, methods 2 and 3 are based on correlations with SPT blow-counts (N-values). The resulting graph provided by ACP shows the blow-count N-values ranging from 3 to 49. These blow counts reported by Shannon and Wilson (1963) were CPT driving resistances and therefore cannot be used for SPT correlations. Furthermore, given the soft nature of the foundation soils, the anticipated SPT N-values should be in the range of 0 (weight of rod or weight of hammer) to 1.

- In Methods 2 and 5, the drained modulus was derived using the undrained modulus with a correction for the Poisson's effect. These methods in general lead to overestimation of drained modulus because the effect of consolidation on soil stiffness is not equivalent to the Poisson's effect.

- The 1963 Shannon and Wilson study indicates that the ratio of undrained shear strength to the effective overburden is in the range of 0.39 to 0.46. These numbers appear to be high and can lead to non-conservative derivation of undrained shear strength. For normally consolidated clay, the ratio can be correlated to the Plasticity Index (PI) of the soil. Using PI=70, the ratio is calculated to be 0.11+0.0037PI= 0.369. ACP has reported that the soil is somewhat over-consolidated and derived a strength ratio using $0.23(OCR)^m$, where OCR is the over-consolidation ratio and m=0.8. This method is also considered adequate provided that the OCR is reliably determined.

- In ACP's stability analyses, the shear strength properties of the embankment fill were assumed as follows:

  Zone 1 (crushed stone): friction angle= 35, cohesion=0
  Zone 2 : friction angle= 25, cohesion=100 psf
  Zone 3 : friction angle= 25, cohesion=100 psf
  Zone 4 : friction angle= 35, cohesion=500 psf

  The friction angles for Zones 2 and 3 material may have been underestimated, particularly if the material will be densified. The assumed characteristics of Zone 1 and 4 materials appear appropriate.

- Due to the uncertainty in soil properties (i.e., widely-scattered in soil testing results from previous studies), we consider it desirable to perform limited additional investigation using current cone penetrometer testing (CPT) techniques with excess pore pressure measurement (as well as dissipation tests) and seismic shear wave velocity measurements (i.e., seismic CPT). This type of field test is a fast and cost-effective operation, and can provide in-situ soil information for design and analysis, from both static and seismic design standpoints.

- We concur with the suggestion by the Geotechnical Advisory Board that before a decision can be made to adopt the proposed scheme, a test fill section is desirable to narrow down the uncertainties involved in the design and construction of the dam.

5.3 Settlement Analyses

- Various settlement predictions were made for end of construction and for the expected service life (say 50 years) of the dam. Given the current significant uncertainty in the rate of consolidation (see discussion about the coefficient of consolidation above) as well as the use of wick drains in the foundation soils, it is more important to have a reliable prediction in the total consolidation settlement than predicting the consolidation settlements at various stages during construction, although this will impact construction time and initial fill quantities. ACP predicted a total settlement due to primary consolidation of about 10.5 m. This prediction included 3.3 m of settlement in the very soft surficial material (upper 2.1 m). It should be noted that it is not reasonable that a 2.1 m soil layer would experience a settlement of 3.3 m. In addition, it is likely that this very soft upper soil will be pre-dredged. After deducting the 3.3 m, the resulting total settlement is about 7.3 m. We have performed a quick independent settlement analysis and the results indicate that the total primary consolidation settlement would be about 7.3 m at the centerline of the crest and about 6 meters at the mid-point along the averaged 8:3H:1V slope. In our opinion about 9 m of settlement at the centerline of the dam is a reasonable estimate at this conceptual engineering stage, considering the uncertainty in soil properties as well as the high organic content in the foundation soils.

5.4 Stability Analyses

- Three methods have been presented in ACP's stability analyses: (1) using drained strength, (2) using undrained strength parameters, and (3) using continuum finite element method (program PLAXIS) with modified Cam-Clay model for the foundation soils. The data provided by the ACP in the Workshop presentation are not sufficient for us to perform a detailed evaluation. It appears that Method 1 (using drained parameters) is not suitable for this type of analysis because the undrained behavior of the foundation soils during the various stages of construction cannot be

reliably quantified using drained parameters, unless pore water pressure generation is properly accounted for in the process.

- The general methodologies employed in Methods 2 and 3 are considered adequate. Nevertheless, the results from the three methods are not consistent and in some cases contradict each other. It is recommended that additional refined analyses using Methods 2 and 3 be carried out.

- Methods 1 and 2 show that the factors of safety increase when the reservoir is filled. Previous experience from analytical studies as well as actual case history data indicate that filling the reservoir is equivalent to imposing additional loads on the dam and therefore should reduce the safety margin of the dam's stability, not enhance it.

- In Method 2, it appears that the failure surface is assumed to be primarily circular in shape. It is not clear whether a block or wedge type potential failure mode along shallow depth has been investigated. In our experience such a failure mode tends to be more critical particularly in the early stages of construction when any significant soil strength gain at shallow depth has not yet been realized.

- The failure surfaces presented for stages 3 through 5 show that the most critical failure surfaces extend in general over a long length, from the toe of the embankment to behind the crest. It is not clear whether or not other localized failure surfaces have been investigated. At the end of stage 3, for example, the most critical failure surface may pass through the toe of the 3rd embankment lift rather than the toe of the embankment built in the 1st stage.

- Results from the stability analyses show that in some cases the factor of safety is marginally over 1.0. This is generally not acceptable in design practice. For a temporary construction condition we believe that a minimum factor of safety of 1.2 is required.

- Notwithstanding the review comments presented above it is believed that adequate stability of the proposed dam can be achieved through the use of wick drains, the high strength geotextiles, the improved strength properties of the embankment fill through vibro-compaction, or a combination of these and other ground improvement measures.

5.5 Constructibility of the Project

5.5.1 Foundations

- The proposed dam will be constructed in deep compressible soils. The staging and rate of construction achievable will depend on the rate of consolidation and resulting shear strength increase in the foundation soils.

- The consolidation of the foundation soils can be accelerated by using wick drains.

- Pre-dredging of the uppermost soft soils would eliminate settlements in that stratum, help reduce mud waves and generally improve the bearing capacity of the foundation. The extent of pre-dredging will be determined by the depth and extent of the uppermost soft layer along the dam site. The amount of pre-dredging may be reduced if high strength geotextiles are used. Pre-dredging of the uppermost soft foundation soils can be done hydraulically by ACP and disposed of in existing disposal sites.

- The use of high strength geotextile fabric where required,could improve the stability of the initial construction stages, reduce disturbance to the in situ soils and reduce the required quantity of fill materials.

- The large scale use of geotextiles in these conditions is not common and the installation approach and the likely costs should be further evaluated and field tested during the Test Fill installation if the use of geotextiles is under consideration. A sand / gravel layer should be provided above the geotextile for drainage and to assist in anchorage of the geotextile. This layer should be placed in a controlled manner (probably side dumped by barge) immediately following geotextile placement in an area.

- If the use of geotextiles is shown to be impracticable or proves not to be cost effective, then it should still prove feasible to construct the dam using pre-dredging and a sand/ gravel drainage layer, with wick drains as previously proposed, although the risk of foundation failure during construction may be increased, and consequently it may prove necessary to increase the construction period.

- The project is typical of major reclamation works on soft marine deposits with many successful precedents throughout the world, and as such is considered to be constructible.

5.5.2 Fill Material

- The body of the dam should ideally be constructed with coarse, durable, hard, rockfill material. In this manner, liquefaction potential may be minimized without the

necessity of underwater densification by vibro-compaction or other techniques. The rock gradation should be in the approximate range of 2.5 cm to 30 cm.

- The use of a rockfill dam will probably require the addition of an impervious core The core can be constructed using dredged silt and clay, as was done for the Gatun Dam, or alternatively a clay or bentonite cutoff could be trenched into the body of the dam. Additional stability, seepage, liquefaction potential, and settlement analyses are required to evaluate and refine this concept.

- The fill material may be obtained from a combination of sources including existing spoil stockpiles, new dredging and new land excavation. If the project is considered as a "stand-alone" project, then the most economical material source would be from nearby land excavation, as it would minimize transportation and handling costs. The assumption made by the Mobile District in their first estimate, i.e. fill material to be obtained from land excavation near the dam abutments, is reasonable, provided enough material is indeed available.

- The use of materials from an excavation undertaken as part of a Canal expansion program, may incur considerable handling, processing and transportation costs. The current study of disposal alternatives by Moffatt and Nichol will provide estimates of the transportation and handling costs for the Trinidad site compared to other spoil disposal options for spoil generated by Pacific side lock construction and channel dredging. The option of disposal of spoil material generated by Atlantic side lock construction should also be investigated.

- The engineering properties of the materials will account for all the design requirements including drainage, shear strength, seepage, and liquefaction potential. Selective use of appropriately processed materials within the embankment will save construction costs and reduce the extent of required densification effort (e.g., vibro-compaction). The potential benefits and costs of increased pre processing of materials compared to the cost of in situ improvement techniques requires further examination.

- Placement methods and rates would have significant impacts on construction costs and schedules, and bottom dumping by barge is considered the most appropriate method, following the foundation improvements discussed above. However, there may be components for which side dumping or clamshell placement may be necessary.

5.5.3 Construction Scheduling

- Three major factors affect construction scheduling; (1) the rate of consolidation and strength gain of the Atlantic Muck, (2) the needs for ground improvement such as use of wick drains, high strength geotextiles, and densification of the embankment fill, and (3) the availability and proximity of suitable fill sources and logistics of

transportation and placement. All of these factors require further study and evaluation before a definitive assessment can be made.

- The rate of consolidation of the foundation soils depends upon their permeability characteristics, and the effective performance of the wick drains and the first lift drainage layer.

- Since construction staging will depend on the consolidation rate of the foundation soils, the observational method would be employed by monitoring the actual field performance. This method has been routinely and successfully used in major construction projects on soft ground. Construction control through monitoring of field performance would eliminate undue construction delays and minimize risks of excessive deformations and bearing capacity failures during construction.

- The currently assumed construction period of seven years may be conservative, especially if wick drains are utilized. Ddepending on the availability of fill material, it should prove practicable to significantly reduce the construction period.

5.5.4 Project Delivery Framework

- The proposed observational method of construction requires extensive engineering evaluations of field performance and design reviews during construction and as such is not recommended for a design-build contract. The project would be best implemented under a conventional design-bid-build contract.

5.6 Construction Cost Estimates

- The two USACE construction cost estimates, $351 million in 1999 and $811 million ($830 million including Cano Quebrado) in 2002 differ significantly from ACP's estimate of $300 to $400 million. The significant increase in the 2002 USACE estimate over their first estimate is believed to be largely due to the change in the source of the fill material in their two estimates, from adjacent land excavation assumed in the first estimate, to the new dredging and excavation works as well as existing stockpiles assumed in the second estimate.

- Construction costs are extremely sensitive to the unit cost of fill material. Various estimates by the ACP and USACE Mobile District have ranged from a low of about $7 per m^3 to a high of about $23 per m^3. The most costly fill was that assumed by the 2002 Mobile District study based on fill transported from existing stockpiles from the Gaillard Cut widening, the new third lock excavation and additional quarry sources from Gaillard Cut. It is clearly most economical to obtain fill from the closest sources, as was assumed in Mobile District's 1999 study if the total cost of excavation and material transportation are to be included in the project costs.

Material costs including excavation, dredging, transportation, processing/crushing, and placement must be estimated based on local prices.

- The substantial difference in USACE and ACP estimates also results from the difference in the conceptual dam cross-sections that yield fill quantity takeoffs of about 30 million cubic meters and 21 million cubic meters respectively, a reduction of 30 percent. In our opinion, the conceptual dam cross section assumed by ACP is more reasonable than that assumed by the Mobile District and the difference in quantities should allow a significant reduction in the USACE cost estimate.

- The current work by Moffatt and Nichol on spoil disposal options will allow an improved assessment of the transportation costs for fill material.

- However the costs of the recommended foundation improvements are significant, and will significantly increase the cost of the dam above the norms for less difficult foundation conditions.

- The USACE estimates make an allowance of 50% of the base construction costs for engineering, supervision, administration, field overhead and contingency. For consistency of comparisons with other Reconnaissance Study level projects, and in the absence of detailed studies on the major cost elements, this percentage should be retained at this stage.

- Whilst it can be expected that the costs of the Trinidad project will reduce significantly from the most recent Reconnaissance level estimates (expected to reduce to the order of $ 600 million), the project is not expected to be cost competitive with the lower cost water supply options (e.g. Indio) on a stand-alone basis.

- It is anticipated that the additional studies recommended in this report will help reduce the differences in the existing cost estimates, and provide a more realistic and reliable estimate.

5.7 Beneficial Use of Spoil

- If the Trinidad project were to be undertaken as part of a major expansion of Canal capacity, the scheme could be considered as a beneficial use of spoil generated by Canal expansion. Under this scenario, the cost of excavation of fill material can be considered part of the expansion project rather than Trinidad project costs, and the fill transport and handling costs could be offset by the costs which would be incurred in disposing of the spoil elsewhere. In this case only the marginal additional cost of disposal of spoil to construct the Trinidad project as compared to other disposal options need be considered in comparing water supply alternatives. Therefore, as the costs of excavation and spoil disposal are a significant element of the Trinidad project

costs, the project could become far more cost competitive compared with other water resource schemes, with an estimated marginal additional cost less than $ 400 million.

- Another potential approach may be feasible if the Trinidad project was considered a long-range component of Canal expansion plans, and its implementation was not required for a number of years. In this case it may be practicable to significantly reduce the quantity of foundation improvement works (perhaps limiting to the removal of the top layer of very soft sediments) and to use the site as a spoil disposal site for excavation from Canal works. This could allow settlement and consolidation over a number of years prior to the building of a dam in the future, with further significant reductions of the cost of the project to below $ 250 million.

5.8 Risks of Overruns

- The two major risk factors are (1) excessive settlements, lateral deformations and local shear failures during construction which may require additional fill, and (2) a slower consolidation rate than that anticipated which may cause construction delays.

- Both of those risk factors can be minimized by establishing realistic engineering design parameters for the Atlantic Muck, providing contingency plans, and implementing the observational method during construction by means of an instrumentation and monitoring program.

- The Test Fill will help answer key questions that affect costs such as performance of wick drains, constructibility of the geotextile installation, the need for and effectiveness of vibro-compaction, and actual time of consolidation as measured in the field. These data obtained from actual field performance will provide reliable design parameters and help answer constructibility questions, reducing the risk of construction cost overruns.

6. Potential Environmental and Social Impact of the Lower Trinidad Project

The purpose of the Lower Trinidad Project is to ensure sufficient water supply to provide for present and future increases in lockages for shipping. None of the potential environmental issues of the Lower Trinidad Project are insurmountable or threaten this project's environmental viability. However, an environmental impact assessment (EIA) would be required to assess project impacts consistent with local requirements and those for international funding institutions.

The fact that the Lower Trinidad Project is contained in an arm of the existing Gatun Reservoir reduces the magnitude of most of its negative environmental impacts .

There are four principal environmental and social issues to be considered:

1. Forced Relocation;
2. Threatened and Endangered species;
3. Impact of the proposed Spillway for Trinidad Reservoir; and
4. Construction Impacts.

It is only the relocation of people who have settled within the areas to be flooded by the Lower Trinidad Reservoir that raises the Lower Trinidad Project to a World Bank Class A project, i.e., one that requires a complete Environmental Impact Assessment (EIA). It will be the most important issue of an EIA on this project.

These principal areas of environmental and social impact have been addressed by the ACP during their initial studies. If the Lower Trinidad Project is recommended for further study, additional efforts will be made in the environmental and social areas so as to continue to define the potential adverse impacts and to plan for their mitigation.

7. Water Resource Management Alternatives to the Lower Trinidad Project

7.1 Water Resource Perspectives

Numerous studies have presented evidence of continued growth in global shipping, increasing demand for Panama Canal Transits, and mounting pressure on present Canal water supplies. Each lock of the Panama Canal is 33.5 m wide by 305 m long and a single ship transit releases about 200,000 cubic meters of water to the oceans. This enormous dependence on water is currently met by the Gatun and Madden (Alajuela) Reservoirs. In addition, urban water use in the Canal area is approximately 800,000 cubic metres per day, or four (4) lockages.

The ACP is studying the addition of a third set of locks within the Master Planning framework to meet market demand, which would require additional water supplies. There are several water supply or water management options available to meet the future needs of the Panama Canal and municipal and industrial water users. The operating and commercial benefits of these options must be judged with the construction costs, environmental and social costs, and the considerable opportunity costs of financing the expansion.

During low water periods, the ACP restricts the draft available to ships transiting the Canal. At present demand levels (i.e., the "No Action" Alternative), shipping through the Canal would have been affected by water shortages (droughts) during parts of three of the last 30 years. In 1997-98, the year of the most recent and severe drought, ships were

required to reduce their fresh water draft from the normal of 12 meters to as little as 10.8 meters. Between 12 March and 20 May 1998, 2,612 transits occurred, and of these, 289 ships (11%) had to reduce their drafts to be able to transit the Canal.

7.2 Draft Reliability

The ACP has been studying and monitoring the reliability of historic performance in maintaining the draft provided for navigation operations. The ACP is committed to a high degree of reliability and currently uses a volumetric method to calculate the historic availability of the design draft as being 99.6 %. During extreme dry periods, sometimes attributable to the El Nino phenomenon, the ACP must inform shippers to light load so as to be able to transit with restricted draft.

The development of a water reliability strategy for the Canal is a key element of the Master Plan, and is ongoing. The detailed assessment of the performance of the alternative schemes is beyond the scope of this assessment, but some of the main performance features of the principal options are discussed below.

7.3 Water Resource Management Options

The Lower Trinidad Project is one of the options for increasing water supplies to the ACP operations. Numerous water resource options are under consideration, and principal alternatives or complementary projects to the Lower Trinidad Project include the following:

7.3.1 Water Savings Basins.

Water Savings Basins would be constructed with the new locks and could cost a total of $250 million to $400 million, depending on lock and basin configuration. The effectiveness of Water Savings Basins in reducing the water demand of the new locks would depend on lift configuration, basin configuration, and the number of lockages through these locks, including their use for multiple vessel lockages for sub-Panamax vessels.

As a matter of principle, international institutions such as the World Bank tend to support water demand management options in preference to new water supply options.

7.3.2 Deepen Gatun Navigation Channel to a Level of El. 8.3 metres.

This alternative involves an expansion of the current widening and deepening program to deepen the navigation channel from El 10.4 meters to EL 8.4 meters, thus increasing the live storage of Gatun Lake. This program is well understood and defined, and could be

performed by the ACP, supplemented by the addition of new equipment. This program could be implemented over seven years with a cost of the order of $400 million.

Like the Trinidad project, channel deepening is intended to maximize the use and performance of the existing catchment and Gatun storage system. The scheme has the significant operating advantage of allowing the transit of deeper draft vessels (15 meters plus) for much of the year when Gatun Lake is at its higher storage levels.

7.3.3 Rio Indio Water Supply Project.

This Project involves an 80-meter high dam on the Rio Indio and a 10-km long inter-basin transfer tunnel. It could be constructed in about four years and would cost about $250 million. The Indio scheme has the advantage of diverting water from a different watershed to Gatun Lake, thus making a new source of water available to the Canal.

7.3.4 Recycling System.

The recycling option would allow for pump-back of the brackish water from downstream of the lowest lock of the proposed new locks. The studies of recycling have not yet advanced to allow a reliable estimate of costs, although the expected costs are on the order of $100 million to $150 million.

Recycling would be used only when there was a risk of draft limitations coming into force, and would be probably used in conjunction with other water management or supply options. There are significant environmental concerns relating to salinity intrusion to be addressed prior to adoption of the scheme. The operating costs of recycling in dry years could be expected to be higher than other water resource management options. However this would be offset by lower capital costs.

7.4 Water Resource Management Performance.

Water resource projects are typically evaluated on the basis of incremental additional lockages that could be provided whilst maintaining the current levels of draft reliability. The detailed of the various water resource options is being analyzed as part of the assessment of the Canal draft reliability.

Based on the data currently available, all the principal options described above, including the Lower Trinidad Dam, would be able to provide sufficient water to allow an additional 13 to 15 lockages per day at the current reliability, or save water equivalent to this number of lockages depending on operating scenarios considered. The sensitivity of these estimates is closely related to the assumptions used in the analyses and simulations.

Therefore, based on the limited information available on the performance of the various options in allowing the ACP to maintain the target draft during dry periods, the

performance of Trinidad appears to be comparable to the other principal water supply options considered. A more detailed analysis covering a range of demands and operating scenarios is necessary to identify significant advantages / disadvantages under different climatic and operating regimes.

7.5 Compatibility of Options

The options are not mutually exclusive alternatives to the Lower Trinidad Project, but some possess potentially complementary features that can work well in combination with it. The ACP have developed scenarios with the Lower Trinidad project operating in conjunction with a reduced scale Indio project, water saving basins, and recycling systems.

The detailed assessment of water resource management options must consider the most effective combinations of alternatives and the most effective order in which to implement the options to optimize the performance of the Canal in the long term.

Draft is a key factor in establishing performance of combinations of options. Two draft scenarios for an expanded canal involve providing either 45 ft (13.7 m) of draft with six feet (1.8 m) of under keel clearance (UKC) or 50 ft (15.2 m) of draft with six feet of UKC. The 45-ft draft scenario could be implemented without further deepening of the channel. In such case, the minimum operating level of Gatun Lake would be 85 ft (25.9 m). Implementation of any of the potential water supply options would result in occasional draft restrictions at high levels of navigation demand. Figure 1 presents a comparison of the frequency and magnitude of draft restrictions at a water demand level (including municipal demand) of about 46.4 lockages/day (1.2 times the current demand). The performance of the existing system is compared with performance of the existing system working in conjunction with Lower Trinidad, Rio Indio or Channel Deepening.

The effect of project sequencing to meet increasing water demand is depicted in Figure 2 for a water demand of about 58.0 lockages/day (1.5 times the current demand). If channel deepening to an elevation of 27.5 ft (8.4 m) is performed first, and the maximum allowed vessel draft is maintained at 45 ft, then subsequent implementation of the Trinidad project, when compared to the Indio Project, would appear to provide limited benefits in terms of reducing the occurrence of significant draft restrictions. This appears to be due to the fact that Channel Deepening will provide sufficient storage to nearly fully control the runoff from the historic Canal watershed. The storage represented by Trinidad cannot be fully utilized because there often isn't enough runoff to refill the reservoir during a drought. Rio Indio represents a "new" source of water; thus, implementation of Indio is predicted to result in a pronounced reduction in draft restrictions. However, it should be noted that if the maximum allowable draft is increased to 50 ft, then five feet of storage in Gatun Lake would be "lost" due to operating level restrictions and Lower Trinidad would be expected to offer benefits of similar nature to those depicted in Figure 1.

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8. General Environmental and Socio-economic Comparisons of Water Supply Options

This environmental and socio-economic review is considering only four options that offer potential improvements in water availability for navigation purposes. They are: 1) Water Saving Basins ($250-400 million); 2) Deepen Gatun Navigation Channel ($350-400 million); 3) Lower Trinidad Project ($400-$800 million); and 4) Rio Indio Dam & Tunnel Project ($250 million). The Lower Trinidad Project would most likely include the Cano Quebrado components.

The options were evaluated with respect to both social and environmental considerations. Table 1 presents a summary of the comparison.

Table 1. Summary of Environmental and Socio-Economic Comparison

Item	Water Savings Basins	Gatun Channel Deepening	Lower Trinidad / Cano Quebrado Project	Rio Indio Dam and Tunnel Project
International Financing Required?	Yes	No	Yes	Yes
Forced Resettlement	No	No	<200 Families	~300 Families
Environmental Impacts	Low	Low	Moderate	High
Increase in Lockages	Variable with design	15	~14 with Cano Quebrado	15
Environmental Assessment Required?	No (Part of Locks EIA – Category A)	World Bank Category B	World Bank Category A	World Bank Category A
Material Sources	Some Fill and Concrete	Equipment Upgrade	20-30 Mm^3	10 Mm^3
Disposal of Excavated Material Required	Low: ~ 3 Mm^3	High: ~15 Mm^3	No	No
Permitting Requirements	None	None	ARI and ANAM	ANAM
Reservoir Fluctuations	Gatun 0.8 m	Gatun 2.7 m	Trinidad 8m Gatun 0.8 m	Indio 40 m Gatun 0.8 m
Area Inundated	0	0	4,720 ha (+713 ha for Caño Quebrado)	4,635 ha
Potential Endangered Species Impacts	Low	Low	Low	Moderate

From the environmental point of view the most desirable choice would involve the Water Savings Basins and/or Channel Deepening options. Channel Deepening has the important advantage that it can essentially be accomplished using Canal operating funds as part of ongoing cutting and dredging operations. Thus, it would not require going to the international markets for funding and consequently, it would not require an exhaustive EIA, which would potentially be subjected to the scrutiny of the international lending institutions.

The Channel Deepening project would take the bottom of the canal down from El. 10.4 m to El. 8.4 m over a period of about seven years. The dredged material would be disposed of at presently designated and approved sites within the Gatun Reservoir. An environmental assessment presently in preparation for deepening the channel from El 11.3 m to El. 10.4 m can be readily amended to accommodate the new phase of excavation. Channel Deepening will not require new environmental permitting.

Water saving basins would be constructed concurrently with the third lane of locks. Construction of water saving basins would occupy an additional 20-30 ha of terrestrial habitat near the site of each set of locks. The environmental impacts and permitting requirements for constructing water saving basins would be incorporated into the EIA for the new locks, thus avoiding the need for new studies or permits.

The remaining two options have much greater environmental and socio-economic impacts. A full accounting of environmental and social costs of the Rio Indio Dam and Tunnel Project or the Lower Trinidad Project is beyond the scope of this Managerial Review. For the purpose of this Managerial Review, the primary question concerning each of these projects is: "What are the probable environmental and socioeconomic issues?"

Both of these projects have different intensities of similar short- and long-term positive and negative impacts. Both will require Public Consultations as per the laws and regulations of the government of Panama, an Environmental Permit from ANAM (Autoridad Nacional del Ambiente), and a complete EIA based on the World Bank environmental guidelines. Both will require the construction of new and improved heavy-duty roads. Construction camps, staging sites, and quarries will have short-term impacts, which could become long-term impacts if, for example, drainage's are changed, access roads provide corridors to increased migration, etc. The flooding of agricultural lands may temper direct ecological costs but it exacerbates the social consequences and relocation issues. However, if it is necessary to clear forested areas to provide homesteads for resettlement purposes, environmental costs of the project could increase significantly.

The reservoir created by the Rio Indio Project will have much greater environmental and socio-economic impacts than that of the Lower Trinidad Project, even with the Caño Quebrado component. The Rio Indio Project would involve resettlement of entire communities; however, people displaced by the Lower Trinidad Project could likely be

resettled within their communities, which are located mostly outside the potential inundation zone.

The Lower Trinidad Project spillway will be an important environmental issue if it does not spill into the Gatun Reservoir. If it spills into another watershed, the EIA will be required to assess its negative impacts. The EIA for the Rio Indio Project would require an assessment of the impacts of the "adits" (i.e., access shafts) for the tunneling operation.

The Lower Trinidad Project, upon completion, would principally involve the raising and lowering of the water level of an arm of the existing Gatun Reservoir. The existing Gatun Reservoir was built for the sole purpose of providing water storage for the operation of the Panama Canal. It is only the forced relocation of people along the reservoir banks that elevates this project to a World Bank Category A project, i.e., one that requires an complete Environmental Impact Assessment. A preliminary review of "The IUCN Red List of Threatened Species" suggests that the Lower Trinidad Project may affect only the American Manatee (Trichechus manatus), which was introduced in the Rio Chagres in 1964.

The Rio Indio Project on the other hand, will involve expansion into the western watershed and the damming of a free-flowing river to create a new reservoir, with its concomitant flooding of new areas. It also will require the forced resettlement of local populations. These people are not squatters on project property, as appears to be the case for many in the Lower Trinidad Project area, but many of them may have or will soon obtain clear title to the property from which they will be forcibly relocated. The recent incorporation of responsibility for sustainable water resources development of the Western Watershed Region under ACP jurisdiction is a high profile source of potential conflict involving legal and social issues, which could give rise to international criticism of the project. The EIA for the Rio Indio Project would likely involve additional biological studies to determine the potential impact of the project on threatened or endangered species.

Thus, the negative environmental and socio-economic impacts of the Rio Indio Project will be considerably more complex than those of the Lower Trinidad Project. The Rio Indio Project will most likely be viewed by the international community as the first phase in a series of interconnecting projects, which could eventually result in construction of large water supply projects in two adjacent basins, Coclé del Norte and Caño Sucio/Miguel de la Borda.

9. Financial Considerations

A major water supply or water management project such as the Lower Trinidad Project may be financed and implement under a number of scenarios including:

- Maximize Use of Operating Revenues
- Capital Markets
- Project Finance

A full discussion of the financing options for water supply and Canal expansion is beyond the scope of this study, and will be addressed in detail in the preparation of the Master Plan.

The ACP could perform a portion of the works, prior to obtaining full funding from other sources, through the annual allocation of budget. The risk of this is that the final funding may never materialize and thus the initial construction spending would become sunk, non-recoverable costs. The dam, when completed, would still provide additional water to meet the incremental growth in market demand for the system.

Funding through the Capital markets or by Project Financing would involve the international finance community, who will pay close attention and be focused on the risks presented by all the elements of any proposed project, and risks presented by all ACP operations and plans in their entirety. Therefore the Trinidad Dam (or any water supply project proposed by ACP) will not be judged on its merits as a stand-alone project , but as part of the ACP system.

The Lower Trinidad Project does present special circumstances that will be carefully considered by the financial community, because the dam, although judged as technically feasible, does present significant technical challenges as outlined in Section 5 of this report.

The financial community would engage the services of technical and risk advisors to review and critique the proposed projects. The Lower Trinidad Project presents a number of significant risks to be addressed, which will impact on its potential for acceptance by the financial institutions . The following issues would receive considerable attention:

- The dam design will be crucial to the technical viability of the Lower Trinidad Project. The responsibility will be on the ACP to prove to the banking community that the design is acceptable and that the project can be built and will function as planned. We consider that a test fill section would be a requirement to support such design. Full exploration of all material sources,

confirming the quantity and quality of fill materials used in the design would also be required.

- The risk of construction delay would also be of great concern to the financial community. These issues would have to be mitigated through the inclusion of remedies in the terms of all construction contracts. The project would have to have be provided a significant schedule contingency (probably of more than one year) to prevent late completion impacting on ACP operations and revenues. Given the incremental nature of the growth of water demands prior to the construction of new locks, and the significant construction period required for new locks, it should be possible to allow a construction period with a a suitable schedule contingency for dam construction. Additionally, delay penalties would be required in construction contracts to cover the costs of delay to the ACP, including lost revenues to the ACP, additional interest charges, additional operating costs, and additional supervision costs. Given the nature of the works there would be considerable resistance by Contractors to such penalties, and enforcement may be a significant issue to be addressed.

- The risk of cost overruns would also be of great concern to the banking community. Again remedies would have to be included in the construction documentation. As indicated in Section 5, it is unlikely to envisage that a contractor would be willing to contemplate a lump-sum contract for the design and construction of the dam, thus leaving design risk and potential cost over runs at the risk of the ACP. The risks would be mitigated by executing a test fill section, incorporating an appropriate contingency fund, and by developing appropriate risk sharing and management strategies , including performance incentives and penalties for the contractor's performance.

In light of the above, the Lower Trinidad Project would appear to be more difficult to obtain the approval of the financial institutions than some of the other water supply options, which entail more conventional design and construction practices. However, this could also be partially offset by the lessened environmental and social impacts when compared to new developments in the Western Watershed, as outlined in Section 8. The risks of potential delays or additional costs associated with the social and environmental impacts and management would also be of great concern to the financial community

The above options and concerns should continue to be explored within the ongoing master planning efforts.

10. Summary of Principal Findings

The principal findings resulting from the review and evaluation of the Lower Trinidad Project are outlined below:

1. The Lower Trinidad Project has been studied several times in the past over many years, and considerable information is available. The quality and quantity of information is generally acceptable, however due to the extensive time gaps between studies and changing methodologies, there are some uncertainties and inconsistencies in the information.

2. In general, the proposed design and construction concept presented by the ACP and its Geotechnical Advisory Board is judged as technically feasible using techniques developed for major reclamation works on soft marine deposits, with many successful precedents throughout the world.

3. Notwithstanding the above, the dam presents significant technical and construction challenges, particularly relating to;

   - Characteristics of the Atlantic Muck Formation
   - Underwater construction conditions and methods, including the cost effective installation of geotextiles at depth if necessary
   - Source and quality requirements for the large quantities of fill,
   - Relationship of the dam to other ACP activities, particularly channel deepening and a third set of locks and their influence on material use and disposal.

4. The Lower Trinidad Project is judged to be the preferred Project over the Rio Indio Project from the environmental and social viewpoint. From the environmental and socio-economic perspective, the Water Savings Basins will have the least negative impacts of the alternative water projects considered. The Channel Deepening project will have some possible negative impacts due to the drilling and blasting which may affect the manatee, if present in the area. The Lower Trinidad Project may also have an impact on the manatee. The Lower Trinidad Project will have most of the same environmental and socio-economic issues as the Rio Indio Project. However, the magnitude of the negative environmental and socio-economic impacts of the Rio Indio Project may make it more difficult to obtain international funding. The fact that the Lower Trinidad Project is in the existing Gatun Reservoir rather than an expansion into the western watershed is the single most important consideration from the environmental point of view. The people displaced by the Lower Trinidad Project will most likely be relocated within their same communities above the inundation zone but the Indio Project requires the resettlement of entire communities to another area.

5. The Lower Trinidad Project, to El. 30.5 m, is located within the current ACP land boundaries, and would appear to be more readily implemented than other major storage projects, such as the Rio Indio Project, which is located outside of the traditional ACP watershed. Consequently, until the Lower Trinidad Project costs are conclusively judged to be prohibitive or the Rio Indio Project is judged to be feasible from an environmental and social standpoint, it would be premature to discard the Lower Trinidad Dam Project from further consideration.

6. The cost of the project may prove to be prohibitively high in comparison to other viable water projects. Previous cost estimates for the Trinidad Dam range from $350 million to $800 million. The upper range appears to be based on very conservative and/or overly simplified design and construction assumptions and is judged to be high. The cost estimate is highly dependent on the total volume of fill, the material source, and the material quality requirements. We estimate that the cost of the scheme with the foundation improvements as described above, as a stand-alone project, would be of the order of $ 600 million.

7. Alternatively, if the project is undertaken as part of a major Canal expansion, it can be considered as a potential beneficial use spoil from that program, thus allowing project costs to be assessed on the marginal additional cost of the scheme above other spoil disposal options. This would assist in making the Trinidad scheme far more cost competitive with other water resource options.

8. The Geotechnical Advisory Board has outlined a list of steps and an approach to better define the design concept and the attendant cost estimate for the Lower Trinidad Project. Their approach was judged as both reasonable and logical, but it would involve a relatively large commitment of people and resources of the ACP.

11. Summary of Principal Recommendations

The recommended action items are outlined below:

1. The ACP should not at this stage proceed with a full feasibility study of the Lower Trinidad Project.

2. However, the ACP should continue further investigation into the Lower Trinidad Project. The goal of additional investigations would be to better define the conceptual design of the Lower Trinidad Project, and the estimate of capital costs, to a level of detail that would facilitate an objective comparison of the Lower Trinidad Project with the other water resource management options available to the ACP.

3. At this stage the study should be limited to about four to six months to suit the requirements of the Master Plan preparation, and be focused on several of the action items that were identified by the Geotechnical Advisory Board. Such a study would include the following:
    a. Limited programs of cone penetrometer tests along the dam footprint to better define and confirm the strength characteristics of the proposed foundation.
    b. Identification of potential sources of fill material.
    c. Development of performance based seismic design criteria.
    d. Consolidation of current ideas and designs into a probable Conceptual Design for the dam section to allow an accurate assessment of the overall material requirements.
    e. Definition of suitable construction methods, including sequencing and staging of the operations.
    f. Preparation of a detailed preliminary estimation of costs, including assessment of the project as a beneficial use of spoil.
    g. Preparation of report and schedules to document the results.

4. As part of the alternatives analysis process, the ACP should make further objective comparisons of comprehensive water supply development scenarios, with the improved cost data on the Lower Trinidad Project, and decide the next steps - which could involve discarding the Project from further consideration or implementing a full Feasibility Study.

5. If, following further investigation and analysis of alternatives, a decision is made to proceed with a Feasibility study, it should include the design of a Test Fill Section which would be later implemented to obtain data of sufficient quality and quantity to minimize uncertainties, mitigate risks, and facilitate bidders including reasonable contingencies within their bid prices.

6. Environmental assessment of the Lower Trinidad project should be deferred until such time as a decision is made to proceed to a full feasibility study. If the decision is made to proceed with a feasibility study, an environmental assessment should be conducted simultaneously, and in close coordination or integrated with, the technical feasibility study.