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SECTION 36

Lower Rio Trinidad 22.9m to 30.5m

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

Synopsis

The development plan for the Lower Rio Trinidad Dam Project presented herein considers creating a dam and lake on the Trinidad basin, within the Panama Canal watershed at Gatun Lake, southwest of Gatun Locks. Under normal flow conditions water passes from Lower Rio Trinidad Lake to Gatun Lake through a gated spillway. Water may be pumped between Gatun Lake and Lower Rio Trinidad Lake by a pumping station installed near the east end of the Lower Rio Trinidad Dam. During the flood season, excess water can be pumped from Gatun Lake to Lower Rio Trinidad Lake. During the dry season, water stored in Lower Rio Trinidad Lake can be pumped from Lower Rio Trinidad Lake to Gatun Lake. Water impounded in Lower Rio Trinidad Lake adds storage to the Panama Canal system of lakes and reduces spilling at the Gatun spillway. The water may be used as needed to support canal operations.

The Rio Trinidad watershed is located on the western side of the Panama Canal watershed. The proposed dam site is located within Gatun Lake across the Lower Rio Trinidad Lake arm near the town of Escobal. The proposed dam extends from Punta Mala on the west shore of Gatun Lake to Guacha Island, and then straight across to the eastern shore of the Rio Trinidad Lake arm, just south of the South Range Point lighthouse. This alignment follows closely the proposed path found in the Study and Report on Increasing the Water Supply of the Panama Canal (referred to as the Tudor Report), prepared by Tudor Engineering Company, San Francisco, California 1962, for the Panama Canal Company. Plate 36 - 1 shows the location of the proposed Lower Rio Trinidad Dam project. The structures for the proposed Lower Rio Trinidad project should consist of a rock fill dam constructed by underwater deposition of fill materials, a gated spillway constructed in the dry on Guacha Island, and a large pumping plant constructed in the dry on Tern Island. The spillway should have 11 gate bays, each measuring 18.3 m wide. The pumping plant should contain 6 large diesel engine driven hydraulic pumps configured to allow pumping in either direction. The total project first costs of the proposed Lower Rio Trinidad Dam project are estimated to be $811,400,000.

This project poses great construction difficulties because of the extremely large quantities of underwater fill required for construction of the dam. It requires extensive drilling and site investigation prior to construction and, because of the uncertainties inherent with this type of construction, extensive unforeseen costs may be encountered during construction. Also, the spillway and pumping plant must be constructed in island settings where the structures and appurtenances practically engulf the island areas. This poses extreme space limitations on the construction effort and is very costly.

The proposed Lower Rio Trinidad Dam project should contribute to the hydrologic reliability of the Panama Canal, enhancing its ability to serve its customers by reducing the need for imposing draft restrictions, and resulting light loading of vessels during periods of low water availability. The existing hydrologic reliability of the Panama Canal, based on the period of record from January 1948 through December 1999, and current demands (38.68 lockages) is approximately 99.6 percent. The hydrologic reliability, with the demand increasing to 120 percent of the current level (46.42 lockage), is 98.8 percent. With construction of the proposed Lower Rio Trinidad project under the scenarios presented, the existing high hydrologic reliability may be continued as demand for lockages increases by 6.7 percent (3.67 lockages) above current demand levels for Scenario 1 and 23 percent (8.99 lockages) for Scenario 2 above current demand levels.

Site Selection

The proposed Lower Rio Trinidad Dam site was recommended in previous reports. Project definition and description developed with a view toward maximizing the water impounded, while minimizing the volume of material required for construction of the dam, as well as minimizing the number of saddle dams required to contain the lake.

The site chosen for the proposed Lower Rio Trinidad Dam is approximately 10 km south of Gatun Locks and 14 km southwest of the navigation channel. The proposed dam location is approximately 4 km northeast the town of Escobal. This site can accommodate construction of a dam with a maximum operating lake level at EL. 30.48 m MSL. Flood storage accommodations are between EL. 30.48 and 31.09 m MSL.

Hydrologic Considerations

The Lower Rio Trinidad flows northward from the Continental Divide to the Gatun Lake. The headwater of the watershed begins at EL. 1,000 m MSL, approximately 75 km inland, and falls to 26 m MSL at Gatun Lake. The distribution of the average annual rainfall over the Rio Trinidad watershed varies from a high of 2,200 mm in the western part of the watershed to 2,000 mm on the eastern side of the watershed. The proposed Lower Rio Trinidad Lake site receives runoff from approximately 750 km^2 of the upper portion of the watershed. Rainfall runoff produces an average annual flow of 32 CMS at the proposed dam site.

The discharge at the Lower Rio Trinidad Dam site was obtained by drainage area ratio to the established record for Gatun. The Gatun Lake runoff is based on records developed by the U.S. Army Corps of Engineers Hydrologic Engineering Center and the PCC in a separate study.

Since the Lower Rio Trinidad Lake is located within Gatun Lake the monthly evaporation rates established for Gatun Lake are considered appropriate for the evaporation rates of Trinidad Lake.

Geologic Considerations

The proposed Lower Rio Trinidad Dam site was investigated in 1962 by Geo-Recon, Inc. of Seattle, Washington, as part of the Tudor report. The investigation consisted of seismic velocity and electrical resistivity profiles in conjunction with four test borings (all located in the lake and drilled by the Panama Canal Company). The results of the geophysical surveys reportedly compared well with the logs of the test borings in the deep-water areas (up to 23 m deep) of Gatun Lake. In June 1963, Tudor Engineering submitted a report including additional foundation investigations. The foundation investigations were made by the firm Shannon & Wilson, Inc., Soil Mechanics and Foundation Engineers, from Seattle, Washington, and consisted of 77 cone penetrometer borings, 24 classification borings, 11 undisturbed sample borings, and 6 field vane shear borings. The investigations submitted by Shannon & Wilson, Inc. were recently reanalyzed in Geology of the Proposed Dam Across Trinidad Arm of Gatun Lake, by Mr. Pastora Franceschi S., for the Geotechnical Section of the Panama Canal Authority.

In the lake areas, the investigations disclosed that overburden material included recent lake deposits, Atlantic Muck Formation, alluvial deposits, and residual deposits. Between the west shore and Guacha Island these deposits consist of soft to very soft clay, silt, sand, and peat (Atlantic Muck Formation) overlying soft to hard deposits of clay, silt, sand, and gravel derived both from alluvial deposition and the weathering of bedrock. The upper two phases of the Atlantic Muck Formation, judged to be the most compressible portion of the formation, was found to have an average thickness of about 18.3 m and a maximum thickness of 22.9 m. Recent, soft lake deposits ranging from 1.2 to 2.4 m thick were found overlying the Atlantic Muck Formation. In the length between Guacha Island and Tern Island, the Atlantic Muck Formation was either not found, or was very thin. In this area, Recent-aged soft sediments (averaging 2 m thick) were found to overlay residual soil and weathered rock. Atlantic Muck Formation, where present, occurred between the Recent-aged material and the residual soil, and was a maximum 5 m thick. Between Tern Island and the east mainland, only recent lake sediments (1.5 m thick) overlying residual clay were found above the conglomerate of the Bohio Formation.

Guacha, Tern and Booby Islands, all located within Gatun Lake, were each found to have an overlying stratum of soft overburdened and weathered rock of variable thickness. In general, firm bedrock was found available below EL. 22.9 m MSL and the islands were judged to offer suitable foundation conditions for control structures.

Firm bedrock under both the land and the lake was found to consist of low velocity sedimentary rock composed primarily of sandstone and the Bohio Formation. Two areas containing abrupt changes in bedrock velocities were located during the survey. One of the areas was a narrow zone located on Guacha Island that was interpreted as a possible shear zone in rock of similar type. The second area was an abrupt change in bedrock velocity on Tern Island that was interpreted as a possible fault contact between two formations, or between different lithologic units of the same formation. The top of the bedrock on land was interpreted from the geophysical results to be weathered to below lake level. The core borings in the lake determined the weathered zone of bedrock to range from 1.2 to 3.1 m in thickness.

Satisfactory foundation conditions exist for construction of a pumping station, and a spillway at the Lower Rio Trinidad Dam site. Serious consideration, however, must be given to problems that could cause the anticipated settlement and instability of the embankment materials. Additionally, it is assumed that all concrete aggregates may be obtained from commercial sources.

Lake Operation

Two operating scenarios were considered each with two operating mechanisms to transfer water from Lower Rio Trinidad Lake to Gatun Lake for canal operations.

- Scenario 1 -The first consists of allowing the water surface of Rio Trinidad Lake to fluctuate from the normal operating lake level at EL. 30.48 m MSL down to the minimum operating lake level at Gatun Lake, EL. 25.91 m MSL. Thereafter, the Lower Rio Trinidad Lake may be drawn down by pumping, allowing further fluctuation from the normal minimum Gatun operating lake level at EL. 25.91 m MSL down to the minimum Lower Rio Trinidad Lake level, EL. 22.86 m MSL.
- Scenario 2 –The second consists of allowing the water surface of Rio Trinidad Lake to fluctuate from the normal operating lake level at EL. 30.48 m MSL down to the minimum

operating lake level at Gatun Lake, EL. 24.84 m MSL. Thereafter, the Lower Rio Trinidad Lake may be drawn down by pumping, allowing further fluctuation from the normal minimum Gatun operating lake level at EL. 24.84 m MSL down to the minimum Lower Rio Trinidad Lake level, EL. 22.86 m MSL.

Both operating scenarios provide an additional 1139.5 MCM of usable storage. The maximum flood level at Lower Rio Trinidad Lake would at EL. 31.09 m MSL. Flood storage accommodations are available between EL. 22.86 and 31.09 m MSL by seasonally varying the elevation of the Lower Rio Trinidad Lake, first by natural means, and then by pumping from Gatun Lake. The Lower Rio Trinidad Lake rule curve was designed to function similarly to the rule curve for Madden Lake. Table 36 - 1 shows the lake levels for the two affected pools.

Table 36-1 Lake Operating Levels

	Scenario 1		Scenario 2	
Lake Level (m MSL)	**Lower Rio Trinidad**	**Gatun**	**Lower Rio Trinidad**	**Gatun**
Normal Operating Lake Level	30.48	26.67	30.48	26.67
Minimum Operating Lake Level	22.86	25.91	22.86	24.84
Maximum Flood Lake Level	31.09	27.13	31.09	27.13

Project Features

GENERAL

The structures for the proposed Lower Rio Trinidad Dam project should consist of a rock fill dam, a large pumping plant, and a gated spillway; modification of one existing saddle dam and construction of two additional saddle dams are also required. The following paragraphs provide a description of the proposed structures and improvements for the Lower Rio Trinidad Dam project. Plate 36 - 2 shows the dam site in upstream right bank perspective and indicates the location of the spillway and pumping facilities.

Design was performed only to the extent necessary to establish, with reasonable accuracy, the principal dimensions, elevations, and costs of the proposed project. Separate documentation was provided to the PCC that contained assumptions and design calculations for the reconnaissance level investigations of these structures. If this project is carried into the planning studies, optimization of the project features and improvements must be accomplished.

EMBANKMENTS

Lower Rio Trinidad Dam

The proposed dam consists of an embankment with the top at EL. 31.50 m MSL and with a crest width of 13 m with a final crest of 7 m upon completion of all settlement of the embankment and bridge work. The left abutment of the embankment will be located at Universal

Transverse Mercator Grid, Zone 17, Clark 1866 Spheroid Coordinates 1015858 north and 614864 east. The right abutment will be 1013937 north and 618229 east coordinates. The normal lake elevation is 30.48 m while the ground surface elevations along the axis of the dam vary from El. 2 m in the lake bottom to 39 m on Guacho Island and 38m on Tern Island. The Gatun Lake subgrade supporting the embankment occupies a broad flat valley having sides, which slope, upward from the valley at grades up to 40 percent. Water depths are 21.3 to 26.3 m over 80 percent of the site. The Atlantic Muck Formation, consisting of very soft organic clays, silts and peats varying in thickness from 7.6 m to 48.7 m, underlies approximately two thirds of the alignment subgrade. The Atlantic Muck Formation in the old river channel is further underlain by soft silts, sand and clay strata.

The critical challenge for design, espoused by the Tudor Report and others, is the depth of subgrade degradation during the initial fill placements. The materials will lose much of its natural strength when disturbed and will only regain strength after the effects of consolidation of a surcharge fill. However, complete restoration of strength can only be assumed to a depth of 5 to 7 meters. If the effects of the subgrade disturbance extend appreciably deeper, then an extremely weak material will be under the more stable subgrade and surcharge creating a condition of lateral instability.

Due to the inability to accurately analyze this condition, a test fill was performed on the western end of the alignment. In early 1963, 1,000-cy bottom-dump barges deposited some 168,000 cy of blasted rock from the cut widening project, extending some 305 m. 155 m of the fill was placed to a height of 11 m while the remaining 150 m was filled to 5 m. The differential heights were use to simulate initial and intermediate fill placement effects. Divers were then used to observe the performance of the fills placed along the alignment. The mechanisms of failure within the subgrade were caused by impact and static loadings. The impact of the initial placements caused severe destruction of the surface materials creating lateral displacements up to 5 m. However, when a continuous blanket of fill had been established and subsequent fill was placed, then conventional failures such as slip circle shear failures and horizontal shears creating large mud waves outward from embankment were observed. Therefore, to predict the behavior of the embankment during construction and for the long term, it is imperative that a foundation mat be established to such a depth to prevent subgrade rupture with subsequent fill placement. The Tudor report recommended that a 5 m thick minimum crushed rock blanket with maximum sizes of 20 cm be placed initially to act as the supporting blanket. Special barge dumping methods were to be employed so loads would not fall as an integral mass, which would create destructive forces on the subgrade. These recommendations were detailed by the Tudor report.

The placement of a large hydraulic structure on a deep-seated weak foundation is the most challenging of geotechnical endeavors. It is virtually impossible to analyze with great deal of certainty and the owner must be prepared to accept possible additional costs during construction and long term maintenance due to the potential for lateral instabilities and high degrees of settlement. The Tudor Report has predicted some 2.5 to 3 m of predicted settlement below the crest elevation for a construction duration of 7 years and an additional 2.5 to 3 m of maximum settlement below the crest for the 50-year service life of the project. These settlements are predicted where the Atlantic Muck and underlying compressible materials are the thickest. These movements are reduced as the fill approaches the mainlands and the two islands. This implies that significant differential settlements are predicted within these approaches as well. The key to any successful construction and maintenance of this embankment will be to establish a blanket mat atop the subgrade where subsequent fill can be economically placed without fear of rupturing the foundation to greater depths. Any significant lateral failure of the embankment during construction or productive use will render that alignment unsuitable. Additional embankment sections must be established upstream or downstream to reestablish the embankment section to the proper elevation. This repair will take considerable time and prevent its use as a road. These recommendations are presented for ultimate costs considerations in comparison to alternatives with a greater degree of performance certainty.

The divers observed that the test fill had trouble placing the fill in the correct locations within the alignment and the lift thickness varied significantly over the fill cross section. It is imperative that the blanket fill be placed intact with the least subgrade disturbance, in order for the embankment to act as monolithic mass. Therefore, the initial 5 m of fill will be barged to the site and placed by lowering a clamshell to the subgrade surface. The positioning of the barges must be strictly controlled by survey positioning systems established on land. The initial fill should have a maximum size of 20 cm and the percent fines should be controlled to remain fairly intact during placement. Materials with a significant size differential and a large fine content can create weak shear zones with the embankment. The subsequent fill materials above this zone can be placed by bottom dumped barges or clamshells from El. 8 m to El. 21 m. The material above El. 21 m must be placed by clamshell due to the draft and door operations of the barges. These materials will be more random in gradation having a maximum size of 30 cm and a greater degree of fines. The materials placed below El. 27 m will assume a side slope of 1 V:15 H. A 15 m berm will be constructed and the materials will continue to be placed by clam shell and spread with a dozer to El. 31.5 , assuming a side slope of 1V:3H and a crest width of 13 m. The flatter side slopes are needed to distribute bearing pressures and to reduce the lateral displacements. This configuration should also reduce the construction and total settlements predicted by the Tudor report and provide acceptable factors of safety for lateral stability during fill placement. The side slope berms and extra crest width will facilitate the future fill placements of up to 3 m over the life of the project. The road surface atop the dam embankment will remain gravel surfaced for the foreseeable future due to future fill placements. The dam will be approximately 30 m high, and the overall length 4,473 m. The top of the dam will be 5 m above the normal Gatun Lake level. The total volume of fill material required to construct and maintain the main dam to El. 31.5 m is approximately 29,550,850 M^3. Water access from the main channel to Guacha and Tern Islands will be built during construction. After access roads have been constructed, fill placements from the east mainland to Tern and Gaucha Islands could be delivered by truck and placed by end-dumping from the east mainland. This technique could prove beneficial if a material source was found near the Gatun Lock area. The side slopes and overall embankment configuration was offered for ease of calculation, to reduce the foundation pressure on the soft subgrade and to account for the lateral displacement of embankment materials. The increased foundation base should help the structure survive a relatively minor seismic event.

The methods of subgrade stabilization and embankment strengthening offered in the PowerPoint presentations from the ACP Engineering Division are examples of many ideas for enhancing the performance of the embankment during construction and post construction. The use of wick drains have been an effective tool for accelerating consolidations under a mass loading. It is believed that the Atlantic Muck materials will not readily transmit water to the drains, therefore the spacing of the drains must be much closer than that implied and the effectiveness of the drains will be restricted to the top 15 to 20 feet of the foundation subgrade. The drains must be effectively tied into the foundation blanket for continuity of the drainage path. There are concerns about the use of vibro-flotation or stone columns techniques above the mat. The mat will not effectively dampen these compaction forces and some rupture of the mat could be possible. A safer reinforcing technique could be the use of reinforcing within the embankment section, such as high strength geogrids placed in layers. All reinforcing techniques are expensive but could be offset by the reduction in fill quantities ultimately required. Any reinforcing selected for use in production must be part of a comprehensive test fill program to demonstrate its effectiveness.

The Tudor Report identified considerable leakage to be expected from the completed embankment. Since loss of any water from storage is a significant reduction in benefits, the seepage must be prevented. Therefore a bentonite slurry trench should be installed within the centerline of the embankment. The trench will be a minimum of 3 feet wide and extend to several meters below the original lake bottom. The trench can be excavated using rockmill techniques. Since the embankment will undergo significant settlement, both total and differential, it is likely that the trench will be sheared and will require replacement within the deeper portions of the lake during the life of the project.

Saddle Dams

As noted in the Tudor Report, the existing Caño Saddle Dam No. 4, located along the western shoreline of the Trinidad Arm of Gatun Lake, needs to be raised and/or strengthened to accommodate the higher lake levels. Immediately to the north of this location, two additional smaller saddle dams are required. All saddle dams must be built to provide a minimum top elevation of 31.50 m MSL. The total volume of fill material required for these three dams is approximately 50,000 M^3, based on a crest width of 13 m. The Caño Quebrado dam must be constructed as a saddle dam to contain the Lower Rio Trinidad Pool.

The actual side slopes and crest widths would be determined during further study and are contingent upon the need for vehicular access across the embankment, the size and quality of the rock fill, and the detailed design of the embankment. A typical section of the embankment at the saddle dams and main dam would be similar to that shown for the embankments for the Rio Indio project, contained herein.

SPILLWAY

Under normal flow conditions water should pass from Lower Rio Trinidad Lake to Gatun Lake through a gated spillway. This spillway should have 11 gate bays separated/flanked by 3 m wide reinforced concrete piers (12 piers in all) which provide support for the gates and access to the gate operating machinery, as well as for a roadway bridge over the top of the spillway. Each of the 11 spillway gates should have a nominal width of 18.33 m and a height of 5.48 m to provide 0.3 m freeboard above the maximum lake operating level. The overall length of the spillway, from out-to-out of the end piers is 237.67 m. The spillway sills shall be placed at the minimum lake operating level for Gatun Lake, EL. 25.91 m MSL for this scenario.

A bridge across the tops of the spillway piers would be constructed as a part of the roadway across the top of the dam. The roadway must be approximately 7 m wide thus allowing for two-way traffic and providing ready access to the spillway gate operating machinery.

For this study, stop logs for servicing the gates, guides, etc. may be placed either from the roadway or from barges using floating cranes. Also, it should be noted that, with the spillway sill at the prescribed level, stoplogs are required both upstream and downstream to allow work to be done on the gates and sills in the dry.

The spillway would be situated along the axis of the dam approximately centered in Guacha Island. This allows the construction to be performed completely within a dry construction cut requiring a minimum of construction dewatering. Once the concrete structures are completed, the entrance and exit channels to the spillway can be opened.

PUMPING PLANT

A large pumping plant is included in this scenario at the Lower Rio Trinidad dam. This pumping facility provides for pumping in two directions, allowing Lower Rio Trinidad Lake to be drawn down to a level below that of Gatun Lake during extremely dry months, and providing the capability of pumping excess water from Gatun Lake into Lower Rio Trinidad Lake during flood season. Water thus stored would be available for navigation during the dry season. The pumping plant is configured to provide pumping to EL. 33.53 m MSL in Lower Rio Trinidad Lake. For the purpose of this study the pumping plant is located in the northwest segment of Tern Island. See Table 36-2 for the controlling head and flow data used for this study.

This plant should consist of six 1407 horsepower (HP) pumps, each capable of pumping slightly more than 62 cubic meters per second (CMS) for a total plant pumping capacity of 373 CMS at a total dynamic head of 4.6 m. The pumping units would be mounted in a reinforced concrete housing and arranged in a row perpendicular to the axis of the dam, with intake and outlet channels on either side. The channels would be separated from the Lower Rio Trinidad and Gatun Lakes by large concrete walls containing low level sluiceways and gates for controlling flows into and away from the pumping plant. For this study these sluiceways are configured to provide average entry velocities of approximately 2.35 meters per second (MPS). The lower portions of the channels would be excavated through rock and configured so as to maintain relatively low velocities. Therefore these channels require no special armoring of walls or inverts for scour protection. As configured for this study, the outlet channel invert would be at approximate EL. 20 .09 m MSL, or 13.5 m below the centerline of the pump outlets. This provides sufficient water depth at maximum pumping to buffer the erosive effects of the very large outflows required. The inflow channel invert is set at EL. 17.07 m MSL to provide submergence for the hydraulic pump intakes at minimum intake water level, EL. 22.86 m MSL.

In conjunction with this facility a roadway bridge would be required to connect the pumping station structure to the banks on either side of the intake and exit channels thus continuing the roadway across the facility. This bridge should also provide both operational and maintenance access to the pumping plant. As configured for this study, the bridge must have two 15 m long spans with steel girders and a concrete bridge deck on each side of the pumping station. It shall have a 7 m wide travel way and include one bridge bent including a cap, two round columns and a spread footing located within each channel section.

Table 36-2 Pumping Data

Pumping Cycle	**Head** (m)	**Average Daily Flow** (M^3/sec)
Lower Rio Trinidad (EL. 22.86) to Gatun Lake (EL. 25.91)	3.05	127.43
Gatun Lake (EL. 26.67) to Lower Rio Trinidad (EL. 30.48)	3.81	56.64

IMPOUNDMENT

The lake formed by the proposed Lower Rio Trinidad Dam under this scenario should have a normal operating lake EL. of 30.48 m MSL. The surface area at the normal operating lake level would be approximately 18,169 hectacres (ha). At the maximum flood level, EL. 31.09 m MSL, the surface area would be approximately 18,835 ha. With the minimum operating level at EL. 22.86 m MSL, the surface area would be approximately 9,019 ha. It should be noted that the current operating levels of Gatun Lake vary up to EL. 26.67 m MSL; therefore areas below the maximum Gatun Lake level are already subject to inundation.

CLEARING AND / OR GRUBBING

Clearing and grubbing are required for all areas above the existing Gatun Lake that are required for construction of the dam (embankments and spillway), access roads, and disposal and staging areas. For the Rio Trinidad Lake area, clearing is required for the 700 ha in the lake area between the maximum operating lake level of Gatun Lake and EL. 30.48 m MSL.

ACCESS ROUTE

Access to the lake site and the various construction sites was evaluated from the main population centers, Colon on the Atlantic coast and Panama City on the Pacific coasts.

The route from Colon is westward across the Panama Canal and then generally southwestward along existing roads that follow the westernmost boundary of Gatun Lake to Cape Mala, near the western abutment of the dam. A very short access road is required from the existing road to the dam site. This route would require crossing the Panama Canal near the Gatun Locks using the existing lock gate bridge. This bridge is narrow and operates only intermittently since canal operations take precedence over roadway traffic. It may be undersized and may possibly lack the load carrying capacity needed for the heavy construction materials and equipment loads anticipated. Access routes would be supplied from the southeast with roads built from the Cerro Cama and Lagarterta areas north and east with 10 km of roadways and 1 km of bridges.

Access to the spillway and pump station construction sites would be by water since these structures would be placed on Guacha Island and Tern Island. It has been considered that a water access route for conveyance of much, if not all, of the construction equipment and materials may be used. This should require that offloading facilities be constructed near the west abutment of the dam, on Guacha Island, and near the eastern abutment site in the vicinity of South Range Point.

Since much of the construction for this project would be in the existing lake or on islands in the lake, it is concluded that both land and water access is required. Plate_36_1 shows the general location of the proposed features and the possible land and water access available or to be provided.

Sources of Construction Material

The bottom 5 m layer of the dam embankments shall be constructed with material less than 8 in maximum size, and with no more than 5 percent passing the #200 screen. Such a material would require crushing and processing across a grizzly to remove oversize rock, and washing to remove fines. Material for this bottom layer must be reasonably well graded to prevent the removal of the finer fraction by piping. The overlying main portion of the embankment would be constructed with (-12 in) sized material. This material should also require crushing and processing across a grizzly to remove oversize rock.

The majority of the materials used for the embankment construction should be obtained from upland sources adjacent to the Gaillard Cut, transported to the site by barge and clam shelled along the proposed embankment alignment. The initial materials should be obtained from the existing disposal sites for the Gaillard Cut widening above Pedro Miguel Locks. Based on the information received from Autoridad Del Canal De Panama (ACP), these sites contain approximately 5.5 million M^3 of suitable excavated rock. However, this rock was not stockpiled in an orderly manner and some is randomly mixed with unsuitable material and some is covered with unsuitable material. All the rock materials, from whatever source, would need to be crushed, graded and loaded on trucks for transport to a loading facility adjacent to the canal at the Cucaracha Reach on the east side, or the mouth of the Mandinga River on the west side. These loading facilities should require being excavated into the bank area and bulkheaded for crane support and barge placement. Working stockpiles should be maintained next to the transfer points to facilitate the loading process. Additional materials within the immediate area should come from the Third Locks excavation adjacent to the Pedro Miguel Locks. These materials would be drilled and blasted in place, excavated and transported to one of the transfer facilities for processing. Additional materials would come from newly developed quarry sources in areas such as Hodges Hill, Escabor Hill, Contractor Hill, and others within 10 km of the transfer points. Each of these new sources would require extensive excavation to remove the overburden and soft rock materials. These materials would be stockpiled adjacent to the work area for restoration once the rock fill materials have been acquired. The suitable rock materials would be blasted, crushed and graded and trucked to the transfer points. All material would be loaded onto barges, transported to the dam site and clam shelled within the dam limits.

Cement is available within the Republic of Panama. Rock obtained from developed quarries may be used to produce concrete aggregates on-site, or they may be obtained from commercial quarries. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) need to be fabricated outside the Republic of Panama and imported for final assembly and installation at the proposed dam site.

Real Estate Requirements

The proposed Lower Rio Trinidad Lake is located within the former Panama Canal Zone and is presently managed and controlled by the ACP; therefore, acquisition of lands for the lake area is not required. Construction of this proposed project requires acquisition of approximately 800 ha for other than lake inundation areas. Table 36-3 shows the amount of land required for the various project features. Real estate for access roads is included in the estimated quantities for the other items listed in the table. The ACP provided the estimated cost of the land for the proposed project.

Table 36-3 Real Estate Requirements

Project Feature	Land Required (ha)
Lake	0
Dam Site	0
Staging Area	200
Housing and Facilities	200
Disposal Area	400
Total	**800**

Relocations

The proposed Lower Rio Trinidad Lake project is located within the existing Panama Canal Zone. Structures and facilities established along the waters edge in the Trinidad arm between the existing Gatun Lake levels and EL. 30 m MSL need to be relocated or modified. This includes a major portion of the town of Escobal. Additionally, there are a few small communities and isolated individual structures along the lakeshore with very limited access by land.

Development Sequence

Planning studies to evaluate the alternative features of each proposed project must be accomplished. Each potentially viable project must be evaluated to assure that the plan presented provides all of the features required to function. Each project must be assessed as to its effectiveness in providing navigation water to the Panama Canal, with due recognition of any secondary benefits. Environmental assessments of the proposed projects need to be made to assure environmental acceptability of the project features. These environmental assessments begin during the planning studies phase and continue during the final design, advertising and award phases. Environmental coordination begins with planning studies and continues through completion of construction. After completion of the final design, plans and specifications must be prepared for the advertising and award phase.

Project implementation begins with land acquisition and construction of the access facilities. Lands for the housing and facilities project feature, which includes the access roads, need to be acquired initially. Lands for the dam site, staging area, disposal area, and lake can then be acquired.

Access roads, equipment, and materials offloading docks, etc. would be constructed for the dam site and structure sites. A small boat channel must be dredged to route boat traffic around to the east side of Guacha Island during construction of the western leg of the dam. Boat traffic must be prevented once the fill materials have been placed across the open waters.

Socio-economic programs must begin shortly before construction of the dam. The relocation of the small settlements and isolated structures must also be accomplished. Socio-economic programs to assist those individuals impacted by the construction of the proposed project should continue throughout the construction phase.

Construction of the dam begins with the clearing and grubbing of the construction sites at Guacha and Tern Islands and the clearing of the perimeter of the Lower Rio Trinidad Lake area. Some construction within Gatun Lake needs to be accomplished with floating plants. Materials used for the embankment construction should be obtained from upland sources, transported to the site by barge and clam shelled along the proposed embankment alignment. The material may be obtained from the disposal areas used for the excavation of the recently completed widening of the Gaillard Cut above Pedro Miguel Lock. Additional sources would be from hillsides adjacent to the disposal areas and the third locks project site next to Pedro Miguel Locks. The remainder of the materials should come from areas within 10 km of the transfer points within the Gaillard Cut. All materials, regardless of location would require processing by crushing, grading and transporting to the transfer point. The materials should then be loaded onto barges, transported to the project site, and clamshelled into place up to its prescribed top elevation. The slopes and top elevation should require redressing and additional placement of materials due to settlement.

Limited cofferdams would be required to accomplish construction of the spillway and pumping station. These efforts may be accomplished simultaneously. Following completion of the pumping plant and spillway, the channels connecting these structures to the lake areas upstream and downstream may be excavated. Where possible, materials removed from these sites would be placed directly into the dam.

Once the western leg of the dam, pumping station and spillway are completed, the eastern leg may be constructed, thus completing the dam. The pool may then be raised. Upon completion of this phase of construction, all facilities must undergo trial operations, before being commissioned for service.

Considering the construction methods required by this project and the nature of the work, it is estimated that development of this project may be completed in approximately 13 years, from initial planning to lake filling. Figure 36 - 1 depicts the development sequence of the various project features.

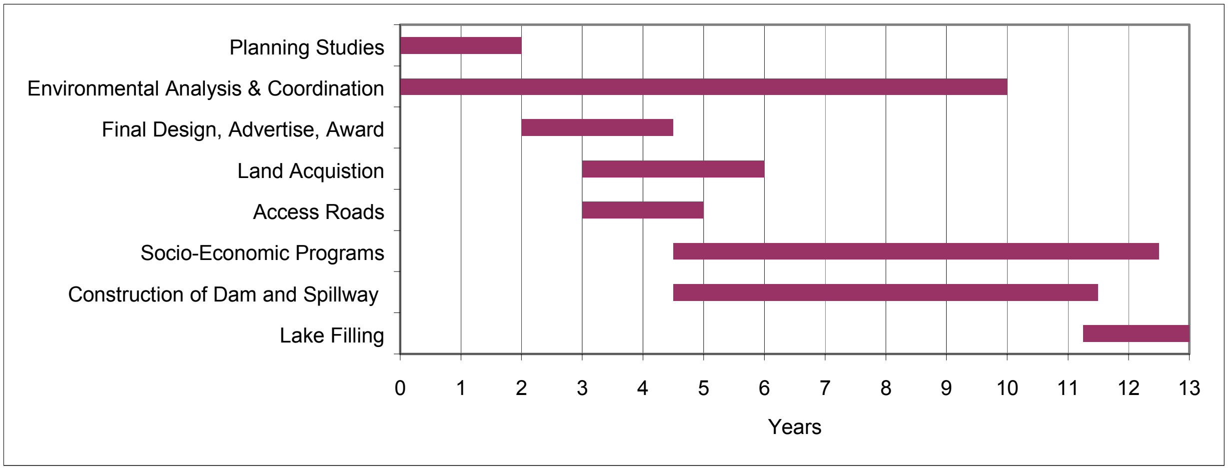


Figure 36 - 1 Development Sequence – Lower Trinidad

Hydrologic Reliability

In order to determine the effect of the proposed Lower Rio Trinidad Lake on the hydrologic reliability of the Panama Canal, the existing HEC-5 model was modified to include the Lower Rio Trinidad Lake with pumpback operation. The existing Gatun Lake parameters (surface areas, storages, and local inflows) are reduced by the proportion that Lower Rio Trinidad Lake should capture.

HEC-5 model simulations were conducted for both the existing canal system and the system operating with the proposed Lower Rio Trinidad Lake providing water to the Panama Canal watershed. The simulations considered proportionally increasing demands up to 180 percent of current demand levels. The simulation considered 50.5 years (January 1948 through July 1998) of hydrologic record, including the worst drought on record, which occurred in 1998. Figure 32-2 presents the resulting hydrologic reliability for two configurations with demands increasing up to 180 percent of current demands. These configurations are:

- Existing system,
- Scenario 1 (Lower Rio Trinidad Lake fluctuating between the normal operating lake level at EL. 30.48 m MSL and the minimum operating lake level at EL. 22.86 m MSL with pumping capability to and from Gatun Lake and Gatun Lake fluctuating between the normal operating lake level at EL. 26.67 m MSL and the minimum operation lake level at EL. 25.91 m),
- Scenario 2 (Lower Rio Trinidad Lake fluctuating between the normal operating lake level at EL. 30.48 m MSL and the minimum operating lake level at EL. 22.86 m MSL with pumping capability to and from Gatun Lake and Gatun Lake fluctuating between the normal operating lake level at EL. 26.67 m MSL and the minimum operation lake level at EL. 24.84 m).

The horizontal axis along the bottom
Figure 36 - 2 of reflects demands as a ratio of the five-year average from 1993 to 1997, and the axis along the top reflects demands in lockages (assuming 55 million gallons per lockage).

Figure 36 - 2 illustrates the existing hydrologic reliability of the Panama Canal (shown in red). Based on the period of 52 years, the hydrologic reliability is approximately 99.6 percent; hydrologic reliability changes to 86.3 percent with a demand ratio of 1.8. The hydrologic reliability, with a demand ratio of 1.0, is 99.90 percent for operating Scenario 1, and the hydrologic reliability, with a demand ratio of 1.8, is 89.29 percent. With operating Scenario 2, the hydrologic reliability with a demand ratio of 1.0 would be 100 percent, and the hydrologic reliability with a demand ratio of 1.8 would be 90.65 percent. Table 36 - 7 displays the number of lockages associated with various levels of reliability.

Without additional water supplies, the hydrologic reliability of the canal system should decrease. With the construction of the proposed Lower Rio Trinidad Dam project using Scenario Operation 1, the existing high hydrologic reliability may be continued as demand for water increases by 6.7 percent (3.67 lockages) above current demand levels. . Scenario 2 would allow increases up to 23 percent (8.99 lockages) above current demand levels.

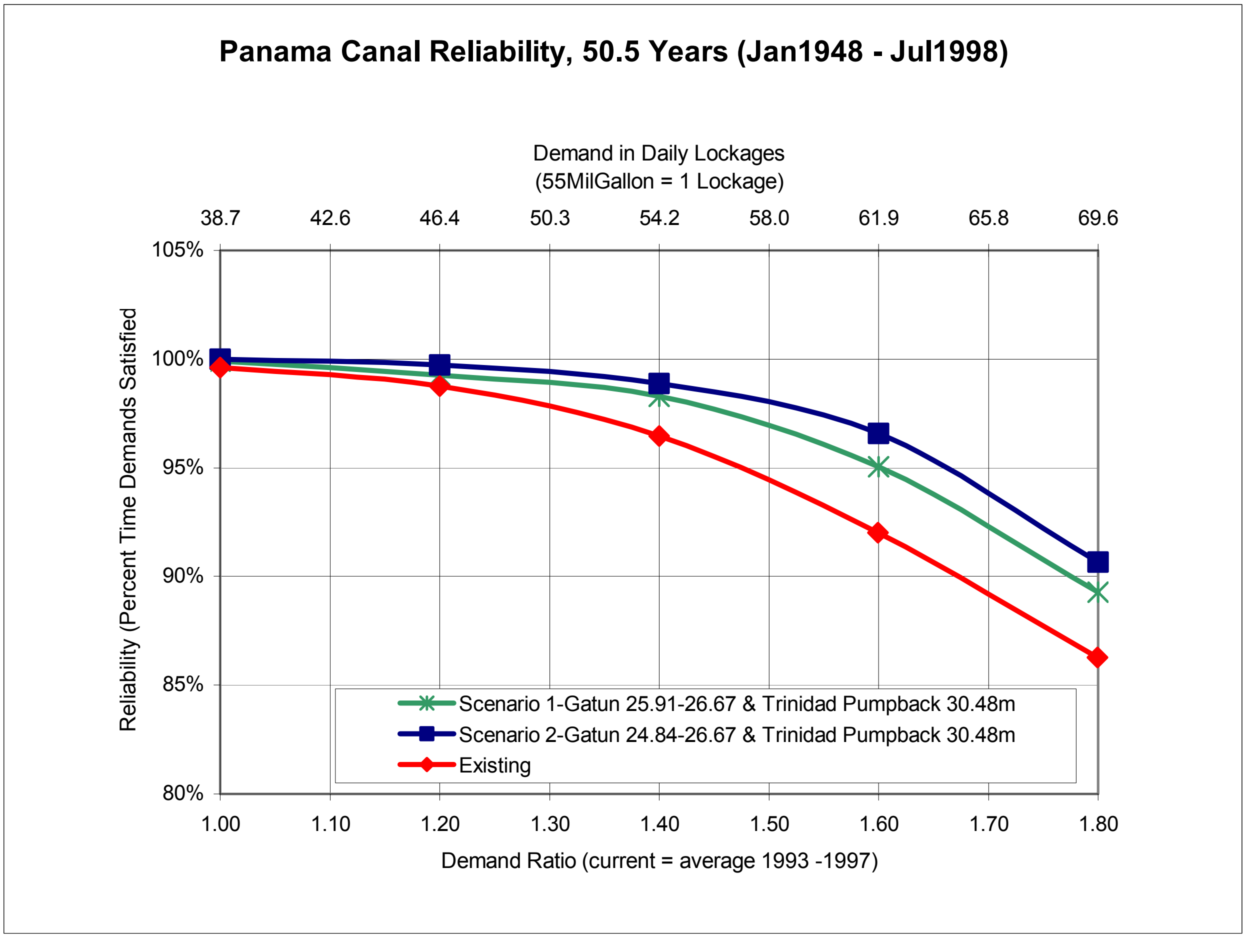


Figure 36 - 2 Panama Canal Hydrologic Reliability

Project Costs

GENERAL

The quantities estimated for the various items of work required in the construction of this project have been derived from the layouts shown on Plates 36 - 3 through 36 - 5. The unit prices applied to these quantities are based on: historical information from previous estimates prepared for similar construction by the PCC; estimates for similar construction in the Mobile District; information gathered from Mobile District Construction Division personnel in Panama; and the book Feasibility Studies For Small Scale Hydropower Additions, A Guide Manual, written by The Hydrologic Engineering Center of the U.S. Army Corps of Engineers.

Supervision and administration is estimated to be 6 percent of the construction cost items, and engineering and design is estimated to be 12 percent. An allowance of 2 percent of the construction cost items is allowed for field overhead (construction camp, contractor facilities, etc.). An allowance of 25 percent is included for contingencies.

FIRST COSTS

The total project first costs are estimated to be $811,400,000. Table 36-4 provides a summary of the first costs for the principal features. Separate documentation provided to the PCC includes a detailed cost estimate containing the sub-features of the work.

Table 36-4 Summary of Project First Costs

Item	Costs ($)
Lands and Relocations	2,000,000
Access Roads	9,574,000
Clearing and / or Grubbing	556,250
Cofferdam	850,000
Dam	491,824,842
Spillway	8,891,206
Saddle Dams	2,143,390
Pumping Station	22,999,637
Transmission Lines	2,090,000
Subtotal	540,929,325
E&D, S&A, Field Overhead	108,185,865
Contingencies	162,278,798
Total Project First Cost	811,393,988 Approximately 811,400,000

OPERATION AND MAINTENANCE

Staff
A staff should operate and maintain the proposed Lower Rio Trinidad Dam project during the day and then run the facility remotely at night. The full-time staff should consist of a total force of 9, including a station manager, a multi-skilled supervisor, 2 leaders (Electronics/Instrumentation, Electrical/Mechanical), 4 craftsmen and a laborer. A part-time staff would be required for two to three months each year to perform general maintenance and overhaul of the project. The part-time staff may consist of three mechanics and three electricians. The annual staffing costs are estimated to be $350,000.

Ordinary Maintenance
Ordinary maintenance and care of the project is required and includes minor repair materials, lubricants and other supplies needed by project staff. It is estimated that the costs of ordinary maintenance is $18,000 per year for the access road, and $100,000 per year for the main project facilities. Fuel consumption for the pumps is estimated to be $648,000 yearly. This estimate considers the growth in demand for water over time and the variability of inflows to Gatun Lake, and the proposed Lower Rio Trinidad Dam project. An estimated $150,000 would be needed for rock placement to account for settling of the embankment. The total ordinary maintenance is $916,000 yearly.

Major Replacements
The average service life of gates, electrical equipment, pumps, trash racks and other features is less than the total useful life of the proposed project, which is 100 years. To estimate the major replacement costs during the 50-year planning period, it is assumed that specific items should not change in price. No allowance is made for salvageable fixed parts. Table 36-5 presents the service life, number of times each component may be replaced, the future costs of each item, and the present worth of the replacement costs for the major components. Based on these values, the present worth of the proposed replacements is $2,214,500, and the average annual replacement costs is $267,000.

Table 36-5 Major Replacement Costs

Component	Service Life (years)	Number of Times Replaced During Planning Period	Future Costs ($)	Present Worth of Replacement Costs ($)
Roads	50	1	12,435,000	43,000
Bridges	50	1	1,800,000	6,200
Pump Station				
Pumps	25	2	21,006,000	654,200
Sluice Gates	50	1	1,275,525	4,400
Sluice Trash Racks	50	1	458,850	1,600
Electrical Controls	25	2	2,100,000	65,400
Fuel Tanks, etc.	50	1	450,000	1,600
Misc Equip & Comm.	25	2	3,183,000	99,100
Slurry Trench	25	2	39,000,000	1,214,500
Spillway				
Bridge Girders	50	1	365,271	1,300
Tainter Gates	50	1	1,980,000	6,900
Tainter Gate Hoists	50	1	1,320,000	4,600
Tainter Gate Op Sys.	50	1	360,000	1,200
Stoplogs	50	1	475,950	1,600
Misc. Mech. Items	25	2	1,500,000	46,700
Electrical Controls	25	2	1,650,000	51,400
Transmission Lines	50	1	3,135,000	10,800
Total			92,494,596	2,214,500
Average Annual Replacement Costs				267,000

Annual Costs

The first costs for the proposed Lower Rio Trinidad Dam project are estimated to be $811,400,000. These total project first costs are distributed across the development period using generalized curves for contractor earnings for large, heavy construction jobs. Interest on the total project first costs is computed from mid-year throughout the 13-year development period from initiation of Planning and Design until the lake is filled. Interest during construction at 12 percent is $658,745,000 for the proposed Lower Rio Trinidad Dam project. These costs are added to the total project first costs for total project investment costs of $1,470,139,000. A capital recovery factor for the 50-year planning period is applied to get the annual average investment costs of $177,029,000. Annual operation and maintenance costs are added. Major replacement costs are estimated and converted to an annual cost by discounting the future replacement costs of major components of the project back to completion of the project construction. Table 36-6 contains a summary of the $178,562,000 total annual costs.

Table 36-6 Summary of Annual Costs

Item	Costs ($)
Total Project First Costs	811,394,000
Interest During Construction	658,745,000
Total Project Investment Costs	1,470,139,000
Annual Average Investment Costs	177,029,000
Operation and Maintenance Costs	
Staff Costs	350,000
Ordinary Maintenance Costs	916,000
Major Replacement Costs	267,000
Total Average Annual Costs	178,562,000

Annual Benefits

NAVIGATION

The procedures and assumptions used in estimating the benefits are described in Volume One, Section 4. The following paragraphs present the results of the economic investigations for the proposed Lower Rio Trinidad Dam project. The 50-year period of the economic analyses is 2014 to 2063.

Either of the operating scenarios for the proposed Lower Rio Trinidad Dam project should increase the reliability of water to accommodate the total daily number of lockages demanded. The manner in which Lake Gatun is operated is the difference between Scenario 1 and 2. With Scenario 1, the minimum elevation of Lake Gatun is restricted to a higher elevation. With Scenario 2, the current operation of Lake Gatun is unchanged. Table 36-7 lists the increases in the hydrologic reliability of providing the sum of the demands for both navigation and M&I water supply keyed to years. The hydrologic reliability percentages are obtained from the data used to develop Figure 36-2. The 99.6 percent level of reliability for this proposal is used to estimate the water supply benefits for navigation. The net change in reliability is used to estimate the reliability benefits for navigation and M&I water uses.

Table 36-7 Panama Canal Hydrologic Reliability (Based on Period of Record from January 1948 to July 1998)

Current Demand Ratio	Year	Demand in Daily Average Number of Lockages (Navigation and M&I)	Hydrologic Reliability		
			Existing System (%)	With Lower Rio Trinidad Scenario 1 [1/]	With Lower Rio Trinidad Scenario 2 [2/]
1	2000	38.68 [3/]	99.60	99.90	100.0
	2010	45.11	98.91	99.38	99.79
1.2		46.42	98.76	99.27	99.74
	2015	46.82	98.64	99.24	99.70
	2020	47.61	98.41	99.12	99.61
	2025	48.52	98.14	99.00	99.50
	2030	49.55	97.83	98.87	99.39
	2035	50.72	97.48	98.72	99.26
	2040	52.02	97.10	98.55	99.11
	2045	53.49	96.65	98.37	98.94
1.4		54.15	96.45	98.28	98.87
	2050	55.13	95.89	97.87	98.58
	2055	56.98	94.83	96.85	98.04
	2060	59.05	93.65	96.85	97.86
	2065	61.37	92.32	95.26	96.75
1.6		61.89	92.02	95.04	96.59
	2070	63.97	90.47	93.49	94.99
1.8		69.63	86.27	89.29	90.65

[1/] The lake behind the Lower Rio Trinidad Dam should fluctuate from the normal operating lake level at EL. 30.48 m MSL down to the minimum operating lake level at EL. 22.86 m MSL. The operation of Lake Gatun would change to a normal operating lake level at EL. 26.67 m MSL down to the minimum operating lake level at EL. 25.91 m MSL.

[2/] The lake behind the Lower Rio Tinidad Dam would remain the same and, the operation of Lake Gatun would remain the same as in the without project condition.

[3/] 2000 Daily Demand is Average of 1993-1997.

With the proposed Lower Rio Trinidad Dam project, water supply shortages for navigation should continue. The demand for the M&I purposes should always be met first. As these demands grow, the amount of water available to meet the demands for navigation should decrease. Thus, the benefits for the additional water supply are estimated at the value for navigation. With the addition of the proposed Lower Rio Trinidad Dam project, these shortages would be less frequent. With a hydrologic reliability of 99.6 percent, the proposed project should increase the amount of water supplied by approximately 3.67 equivalent lockages. The 99.6 percent hydrologic reliability should occur after the year 2006 with an equivalent daily average number of lockages of 42.54. Benefits for these amounts of additional water would be attributable to navigation since the amount of M&I water demanded would be provided first. Therefore, all shortages shall be attributable to navigation. The benefits are estimated using the toll revenue per lockage and the increased daily average number of lockages. The average annual benefits for water supply for Scenario 1 are $75,619,000, and $178,172,000 for

Scenario 2. Table 36-8 provides the estimate of daily shortages under the existing system, the remaining daily shortages with the proposed Lower Rio Trinidad Dam project in operation, the annual benefits for meeting shortages and the average annual benefits.

Table 36-8 Benefits for Additional Water Supply for Navigation

Year	Daily Shortages In Lockages Under Existing System	Remaining Daily Shortages Scenario 1	Remaining Daily Shortages Scenario 2	Annual Benefits For Navigation Scenario 1 ($)	Annual Benefits For Navigation Scenario 2 ($)
2014	8.00	4.33	0	74,905,291	163,238,182
2020	8.93	5.26	0	75,705,072	184,110,449
2030	10.87	7.20	1.88	75,705,072	185,427,895
2040	13.34	9.67	4.35	75,705,072	185,427,895
2050	16.45	12.78	7.46	75,705,072	185,427,895
2063	20.36	16.69	11.37	75,705,072	185,427,895
Average Annual Benefits				75,619,000	178,172,000
With Scenario 1, the system should provide a total of 42.35 lockages at the 99.6 percent level of reliability or 3.67 more lockages than the existing system. With Scenario 2, the system should provide a total of 47.67 lockages at the 99.6 percent level of reliability or 8.99 more lockages than the existing system.					

With the proposed Lower Rio Trinidad Dam project, the reliability of the system to provide all of the water demanded by navigation and M&I water would be improved. Using the increase in hydrologic reliability, the forecast number of vessels converted to a daily average number of lockages, the toll revenue for each average lockage, and a project discount rate of 12 percent, the average annual benefits for navigation reliability attributable to the proposed Scenario 1 of the Lower Rio Trinidad Dam project is $6,681,000. For Scenario 2 the average annual benefits would be $10,741.000. Table 36-9 provides the forecast daily average number of lockages, the forecast value per daily lockage, the annual benefits for increased reliability, and the average annual benefits.

Table 36-9 Average Annual Reliability Benefits For Navigation

Year	Daily Average Number of Lockages	Value Per Lockage ($)	Annual Benefits For Navigation Scenario 1 ($)	Annual Benefits For Navigation Scenario 2 ($)
2014	40.0	2,236,000	4,609,000	8,218,000
2020	40.0	2,260,000	5,840,000	9,885,000
2030	40.0	2,260,000	8,579,000	12,861,000
2040	40.0	2,260,000	12,059,000	16,643,000
2050	40.0	2,260,000	16,312,000	22,163,000
2063	40.0	2,260,000	21,649,000	31,676,000
Average Annual Benefits			6,681,000	10,741,000

M&I WATER SUPPLY

The future demand figure of water supply for M&I purposes is based upon the growth in population. The PCC provided a forecast for the area surrounding the Panama Canal. The current usage is estimated at 4.0 equivalent lockages per day (an equivalent lockage is 55 million gallons of water). One equivalent lockage is added to the forecast to account for the burgeoning tourist industry, beginning in the year 2010. The increased reliability of the system to provide water supply for navigation similarly provides the same increase in reliability to provide water for M&I purposes. Using the increased hydrologic reliability of the system with the addition of the proposed Lower Rio Trinidad Dam project, the current costs to the PCC to process finished water of $0.69 per 1,000 gallons, the number of daily lockages demanded, and a project discount rate of 12 percent, the average annual benefits for M&I reliability is $1,002,000 for Scenario 1. Under Scenario 2, the average annual benefits would be $1,575,000. Table 36-10 presents the population forecast, the resulting number of equivalent lockages per day, and the benefits for M&I water supply.

Table 36-10 Average Annual Reliability Benefits For M&I Water Supply

Year	Population	Equivalent Lockages per Day	Annual M&I Water Supply Benefits Scenario 1 ($)	Annual M&I Water Supply Benefits Scenario 2 ($)
2014	1,880,000	6.00	524,000	933,000
2020	2,141,000	7.61	747,000	1,264,000
2030	2,688,000	9.55	1,378,000	2,066,000
2040	3,384,000	12.02	2,433,000	3,358,000
2050	4,259,000	15.13	4,143,000	5,629,000
2063	5,751,800	20.44	7,863,000	11,518,000
Average Annual Benefits			1,002,000	1,575,000

HYDROPOWER

The amount of hydropower energy that may be produced by the system of Gatun Lake and Madden Lake should decline over time as the demands for navigation and M&I water supply increase. With the inclusion of the proposed Lower Rio Trinidad Dam project, the system should lose megawatt hours of hydropower due to the changes in operation of the system. The value for hydropower energy used in this analysis is $0.070 / kWh. On an average annual basis, the proposed Scenario 1 project should have losses of ($2,866,000). Scenario 2 would also lose some generation of hydropower energy, but those losses would amount to $2,416,000 on an average annual basis. Table 36-11 provides the net losses of megawatt hours of hydropower generation and the resulting losses in average annual benefits.

Table 36-11 Average Annual Benefits For Hydropower Generation

Year	Net Generation (MWh) Scenario 1 [1/]	Net Generation (MWh) Scenario 2 [1/]	Annual Benefits For Hydropower Scenario 1 ($)	Annual Benefits For Hydropower Scenario 2 ($)
2014	(40,529)	(33.875)	(2,841,000)	(2,371,000)
2020	(40,789)	(34,300)	(2,855,000)	(2,400,000)
2030	(41,307)	(35,028)	(2,892,000)	(2,452,000)
2040	(41,966)	(35,953)	(2,938,000)	(2,517,000)
2050	(42,859)	(37,329)	(3,000,000)	(2,613,000)
2063	(44,622)	(40,460)	(3,129,000)	(2,832,000)
Average Annual Benefits			(2,866,000)	(2,416,000)

[1/] Lose of net generation of Gatun and Madden hydropower plants with the operation of the Lower Rio Trinidad Dam project.

SUMMARY OF ANNUAL BENEFITS

As shown in Table 36-12, total average annual benefits for Scenario 1 and 2 of the proposed Lower Rio Trinidad Dam project would be $80,436,000 and $188,072,000, respectively.

Table 36-12 Summary of Annual Benefits

Benefit Category	Average Annual Benefits Scenario 1 ($)	Average Annual Benefits Scenario 2 ($)
Navigation – Water Supply	75,619,000	178,172,000
Navigation – Reliability	6,681,000	10,741,000
M&I - Reliability	1,002,000	1,575,000
Hydropower	(2,866,000)	(2,416,000)
Total	80,436,000	188,072,000

To perform an analysis of benefits versus costs, a common point in time was selected. This common point is at the completion of filling the Lower Rio Trinidad Dam project (the end of the year 2013). Thus, the 50-year period for the economic analyses of the proposed project is 2014 through 2063. Once average annual benefits and costs are estimated, the ratio of benefits to costs and the net benefits (net of costs) were computed. In the first instance, the analysis determines the feasibility of the proposal. The net benefits determine which proposal among several provides the greatest value for the investment dollars. Since there is no cost to change the operation of Lake Gatun, the cost for both scenarios is the same. Table 36-13 displays the benefit to cost ratio and the net benefits for Scenarios 1 and 2.

Table 36-13 Economic Evaluation

Item	Value Scenario 1 ($)	Value Scenario 2 ($)
Average Annual Benefits	80,436,000	188,072,000
Average Annual Costs	178,562,000	178,562,000
Benefit to Cost Ratio	0.5	1.1
Net Benefits	(98,126,000)	9,510,000

Internal Rate of Return

An internal rate of return analysis for this proposed project has been performed. To accomplish this analysis, the annual construction costs are used as the investment, and the undiscounted benefits are used as return cash flows. The internal rate of return for Scenario 1 would be 7.0 percent. The internal rate of return for Scenario 2 would be 12.8 percent.

Socio-Economic Impacts

The description of the environmental setting is based on field observations made while conducting reconnaissance throughout the Gatun Lake and Lower Rio Trinidad area in company with ACP personnel. Autoridad Nacional del Ambiente (ANAM), ACP, Asociacion Nacional para la Conservacion de la Naturaleza (ANCON), Electrical Transmission Agency, Smithsonian Tropical Research Institute (STRI), and Directorate of Mineral Resources personnel were interviewed to gain information on site characteristics and potential activities that could affect the project. In addition, extrapolations of the 2000 census data were used, and a review of the Informe de Cobertura Boscosa 1992 were used to determine the extent of forest cover.

Environmental Setting

The Lower Rio Trinidad project will provide additional storage of water for Gatun Lake and 3.67 additional lockages per day on a continual basis. The structures for the proposed Lower Rio Trinidad project would consist of a rockfill dam, a pumping station, a gated spillway, and access/maintenance roads. The Lower Rio Trinidad project area covers 19,613 hectares within Gatun Lake. The terrain in this sparsely populated area ranges from rolling hills to low-lying land near Gatun Lake. Lower Rio Trinidad is located west of the Panama Canal, and flows northward from the Continental Divide into Gatun Lake. Its watershed above the dam is approximately 741 km^2. The incremental impoundment area, which covers approximately 3,968 ha, consists of approximately 50 percent forested land, 30 percent pasture land (used by ranchers), 10 percent cropland, and 10 percent newly slashed and burned land. Gatun Lake's normal pool level is 26.7 meters. The lake level during field observations (August 2001) was approximately 25.4 meters.

LAND USE

The Lower Rio Trinidad project area encompasses the southwestern portion of Gatun Lake and areas along the shores. The towns of Escobal (population – 1,653), Nuevo Provenir (population – 121), Cuipo (population – 249), Ciricito (population – 72), La Arenosa (population – 242), La Garterita (population – 138), La Gartera (population – 348) and a few small isolated developments are in the area to be flooded or partially flooded.

The shores of the Lower Rio Trinidad portion of Gatun Lake have been partially deforested. Approximately 65 percent of the lakeshore is forested, mostly with secondary growth. The remainder is occupied by farms and ranches of various sizes, as well as plantations of teak and African mahogany. Farm crops include maize, rice, beans, sugar, coffee, mangos, pineapples, and tobacco. Ranchers raise cows, horses, chickens, hogs, and tilapia. Some of the farmers and ranchers operate commercial enterprises; others rely on cash crops and subsistence farming.

INFRASTRUCTURE

The largest settlement visited during site investigations was the town of Escobal which includes businesses, schools, churches, cemeteries and medical centers, and can be reached by paved roadways that are in good condition. A new and improved roadway (Highway 35) is in the project area near Escobal. Other establishments in the project area - Nuevo Provenir; Cuipo; Ciricito; La Arenosa; La Garterita; La Gartera; and a few small isolated establishments - have elementary schools, small cemeteries, churches and meeting centers, medical clinics, and a few small businesses (i.e. general stores). The towns and villages depend on Gatun Lake or groundwater wells for their potable water supply. Each community also had docks, small ports, and other boat access areas. Goods are transported by boat. No treatment of community waste is provided. Wastewater from showers and washing is discharged into the environment; some of it may eventually reach the Lower Rio Trinidad portion of Gatun Lake. Disposal of domestic waste is the responsibility of individual homeowners: some homes have septic tanks, others have an outdoor latrine (a hole in the ground). These waste disposal methods can contribute to health problems, such as hepatitis, dysentery, dermatitis, intestinal parasites, and respiratory illnesses. No major industries or poultry or beef processing plants are located in the project area. The project area is traversed by unpaved horseback riding trails that link the various communities and by dirt roads used by the ACP for maintenance. Because of the relatively isolated location of the project area, these roads are extremely important to the residents for transportation, community cohesion, commerce, and communication with neighboring communities.

TERRESTRIAL HABITAT

The terrestrial habitat along the Lower Rio Trinidad portion of Gatun Lake consists of tropical forest ecosystems with large secondary growth and patches of primary forest. About 65 percent of the land along the Lower Rio Trinidad portion of Gatun Lake is covered with forests that could support diverse wildlife populations. The Lower Rio Trinidad portion of Gatun Lake also contains islands inhabited by wildlife. Some of the wildlife species do not interact with species on the mainland; others migrate between the island and the mainland. The species interrelationships are of great interest to scientists studying tropical ecosystems. Slash and burn activities have opened tracts of land for farming and cattle grazing; however, the majority of the lakeshore is forested to the edge of the water. The lakeshores are used by migratory species as wintering, breeding, and feeding grounds. The complex and diverse tropical ecosystems offer habitat to a variety of wildlife communities and may provide critical habitat to many native species.

ANIMALS ON ENDANGERED LIST

ANAM, by Resolution 002-80, enacted on June 7, 1995, declared 33 mammals, 39 birds, and 11 reptiles and amphibians as being in danger of becoming extinct in Panama. Although none have been identified to date, some of the listed species on the threatened list might be found in the project area. The manatee is an aquatic mammal known to inhabit Gatun Lake around Barro Colorado Island, however, its occurrence within the project area is unknown.

AQUATIC HABITAT

Gatun Lake, one of the largest manmade lakes in the world, was created during construction of the Panama Canal. It contains many types of aquatic habitat and its depth, and water quality varies widely. There are various submerged topographical features, including inundated forests, and in areas distant from the shipping lanes, the water is clear. The Lower Rio Trinidad portion of Gatun Lake provides habitat for a variety of wildlife species, both resident and migratory, as well as for both native and introduced fish and other aquatic species.

WETLANDS

Areas that contain hydric soils and hydrophytic plant communities, and that are subject to hydrologic conditions are termed wetlands. Wetlands in the Lower Rio Trinidad project area are shallow water habitat and areas subject to frequent flooding. Shallow water areas along the banks of the Lower Rio Trinidad portion of Gatun Lake receive sunlight to a depth of approximately 1 meter. Sunlight stimulates growth of submergent, emergent, or floating mats of aquatic vegetation. Wetlands occur in topography where water remains pooled long enough to allow development of hydric soil conditions and wetland plant communities. Wetlands in the project area are stressed by runoff that carries sediments, municipal waste, agricultural waste, and debris from slash and burn areas.

AIR QUALITY

Air quality in the project area is generally good, except during the slash and burn activities. At the end of the dry season in March or early April, both primary forest and secondary growth areas are burned to clear land for agricultural use. The smoke and ash generated during this period may be transported by winds to the Lower Rio Trinidad and Gatun Lake. Air quality monitoring has not been implemented within the project area.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

Barro Colorado Island is an international center for tropical research and one of the first biological reserves established in the Neotropics. From 1923 through 1940, a scientific committee of the National Academy of Sciences administered the biological reserve/laboratory. In 1940, by an Act of the United States Congress, the facility was renamed the Panama Canal Zone Biological Area, and in 1946, the responsibility for its maintenance was assigned to the Smithsonian Institution. With the Panama Canal Treaty Implementation in 1977, the island was granted the category of National Monument and to date it continues to be managed by the Smithsonian Institute. It should also be noted that most of the Atlantic region of Panama is within the interest and objectives of the Mesoamerican Biological Corridor, an international project to conserve biodiversity.

Environmental Impacts

TERRESTRIAL HABITAT

The impacts of the project on the terrestrial habitat in the Lower Rio Trinidad portion of Gatun Lake could be substantial. The boundary between two types of habitats, in this case between a forest and a lake, is called an ecotone. Ecotones are inhabited by a mixture of species from the neighboring habitats, but are unique, with high species diversity. At the proposed normal lake operating levels between 22.9 and 30.5 meters, erosion of the shoreline may be substantial. Terrestrial habitat areas that would be inundated above the 26.7 meters (existing level) to the 30.5 meters proposed normal pool level cover 18,169 hectares. A dam structure, access roads, and pump station would permanently impact terrestrial habitat areas. Wildlife species that are able to relocate will be competing with similar species for resources. Wildlife species that are not able to relocate will not survive the project activities. As a result, competition for natural resources in the surrounding habitat areas will increase. This is considered a secondary impact to terrestrial habitat areas outside the proposed zone of inundation and construction.

ANIMALS ON ENDANGERED LIST

The severity of impacts on endangered species cannot be determined at this time, because it is not known which of the listed species occur within the proposed project area; however, it is expected that some species on the endangered list will be found in the region. Some endangered and/or threatened species may use the Lower Rio Trinidad portion of Gatun Lake for some or all parts of their life cycle.

WATER QUANTITY

The impacts of the project on water quantity would be substantial. The increased volume of water could have negative impacts to lakeshore communities as well as on existing ecosystems. The same is true if the lake level is lowered to 22.9 meters.

WATER QUALITY

Impacts of the project on water quality are unknown. Damming the Lower Rio Trinidad could increase the amounts of nutrients and debris in this portion of Gatun Lake. A pilot plant for a tilapia farm is located in the project area and may be impacting water quality. The rate at which nutrients and debris enter the lake will determine the severity of the project's impact on water quality. Project implementation could cause an increase in turbidity, which will interfere with photosynthesis and could deprive plants and other aquatic species of sunlight. Aquatic plants and organisms serve to maintain water quality. The dam would interfere with the circulation of freshwater throughout the Gatun Lake environment. Species inhabiting specific depths could be impacted when lake depth increases to 30.5 meters and/or decreased to 22.9 meters.

DOWNSTREAM AQUATIC FAUNAL HABITAT

The impacts of the project on aquatic faunal habitat could be substantial. The project may impact the breeding and nursery habitat of many aquatic species. Impacts detrimental to fish spawning grounds may include sudden increase or decrease in turbidity, nutrient content, or depth of the water, altering the conditions needed for a successful fish hatch. Plant populations may decrease as a result of fluctuations in water depth, clarity, and quality. Invertebrate populations may decline which would reduce the food supply for fish and other aquatic species.

FUTURE LAKE AQUATIC PLANT COMMUNITY

The impacts of the project on future aquatic plant communities will depend on water quality and stability of water levels. Plant species in the Lower Rio Trinidad portion of Gatun Lake could be impacted by fluctuations in water levels. Aquatic plant communities could be affected during project implementation; but would probably re-establish themselves after conditions stabilize.

AQUATIC FAUNA INHABITING AFFECTED AREAS

The proposed project could have substantial impacts on aquatic fauna inhabiting the Lower Rio Trinidad and its tributaries. Some unavoidable, adverse environmental impacts that could occur should be identified and minimized by appropriate mitigation measures to be discussed in a feasibility study. Gatun Lake has populations of peacock bass and tilapia, both of which are introduced species that have adapted well. However, several native riverine species that formerly occupied the impoundment have disappeared.

WETLANDS

The impacts to wetlands could be significant. As the present wetlands are inundated, they could become aquatic habitats. Project activities may lead to increases and/or decreases in water depth, sedimentation, and turbidity, which could hamper the biological processes of the wetlands and decrease their productivity. Such changes could be detrimental to the health and sustainability of the Lower Rio Trinidad portion of Gatun Lake. Fish and other aquatic species use shallow water areas as spawning grounds as well as habitat for juvenile aquatic species. Since the juveniles of many aquatic species survive in shallow waters of the wetlands until they are large enough to venture out into deeper water, these areas are vital to the sustainability of this portion of Gatun Lake, including the Lower Rio Trinidad area.

AIR QUALITY

During project implementation, emissions from construction equipment and from the local slash and burn activities could cause deterioration of air quality in the project area. After project implementation, the air quality may be impacted by the normal operation of the pumping station.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

The potential impacts on cultural resources and historic properties cannot be defined. Prior to project implementation, surveys should be conducted to locate cultural resource and historic properties, and the important sites would be preserved or salvaged as appropriate.

SOCIO-ECONOMIC IMPACTS

The socio-economic impacts of the project could be substantial. The relocation of the town of Escobal and other small lakeshore communities would be an important change. The average monthly income of families in the project area ranges from less than $100 to $200 per month. No indigenous groups are known to reside in the affected area. Land use would be greatly influenced by the inundation of pastures and agricultural lands to expand the impoundment. The relocation of farming and ranching activities would have an effect, because approximately 10 percent of the land in the impoundment area is used for farming and ranching. After the water level is raised, additional agricultural land could be lost as a result of turning former isthmuses into islands. The incremental surface area of the proposed lake is 3,968 ha, with another 1,044 ha for the dam and construction areas including permanent disposal sites.

During construction, the influx of workers could create a temporary demand for additional housing, which could result in an increase in housing values near the dam site. However, after completion of the project, the workers could leave, the housing demands could drop, and the housing values could return to pre-construction levels. Currently, all residents have access to public schools and health centers. During construction, these services should continue to be available, and additional public and community services may be offered. After construction, these services would return to the normal level.

To construct the dam, some existing roads, would be improved and some new roads would be built. However, some roads, both paved and unpaved within the impoundment area would be eliminated, which would change traffic patterns and could cause some communities to lose overland transportation, communication, cohesion, and commerce with other communities. During construction, the traffic volumes over both new and existing roads systems would increase; however following completion of construction, the traffic volumes could decline. Noise levels would increase during construction and could negatively impact noise-sensitive receptors; after construction, noise levels may remain elevated as a result of the pump station.

The communities that receive people displaced by the project could be negatively impacted by overcrowding and by competition for jobs, land, and working areas. Construction of the dam would permanently displace people and disrupt community cohesion as a result of division of communities, separation of families, and loss of livelihood. Following completion of the impoundment, tourism in the affected region, including sport fishing and ecotourism, could increase.

Additional Environmental Information Required

This section identifies the aspects for which additional data are required to evaluate the scope and magnitude of the potential effects of the Lower Rio Trinidad alternative in further detail. These aspects are discussed by impact category.

SOCIO-ECONOMIC IMPACTS

- Conduct a Socio-Economic Impact Assessment (SIA). The SIA would consist of three tasks: scoping, assessment, and mitigation and monitoring. The following information should be developed:
  - Business, Industrial, and Agricultural Activities.
  - Employment.
  - Land Use.
  - Property Values.
  - Public and Community Facilities and Services (including utilities and schools).
  - Transportation.
  - Housing.
  - Health (vector routes).
  - Population.
  - Community Cohesion.
  - Recreational Resources.

TERRESTRIAL AND AQUATIC HABITAT

- Prepare site-specific habitat maps to ensure that all major types of aquatic habitat are identified and quantified.
- Conduct field studies to locate rare and unique types of habitat, such as wetlands, primary forests, roosting sites, foraging areas, old growth, and migration flyways.
- Determine the present quality and ecosystem value of existing habitats within the Gatun Lake project area.
- Coordinate with local experts to identify and evaluate aquatic and terrestrial habitat areas.
- Prepare a species inventory for each part of the site identifying their status as native or exotic and whether they are threatened and/or endangered species.
- Conduct additional research into water currents and estimate turbidity levels to evaluate impacts to the shallow areas along Barro Colorado Island.
- Investigate the cumulative effects of natural flow diversions.

ANIMALS ON THE ENDANGERED LIST

- Compile habitat maps to help assess the availability and quality of suitable habitats for the animals on the endangered and/or threatened species list.

- Establish field procedures for assessing wildlife habitat values.
- Conduct site surveys to determine the presence of selected species or their habitats.
- Develop candidate mitigation measures for the appropriate project alternatives to be considered in the Conceptual Phase.
- Coordinate with local experts on the presence of endangered species.

WATER QUALITY

- Since only limited water quality data are available for the Gatun Lake area, compile information on total suspended solids, conductivity, total dissolved solids, dissolved oxygen, nutrients, pH, and coliform bacteria.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

- Information regarding cultural resources and historic properties in the project area is incomplete. Additional studies should be conducted to identify any such resources and/or properties.

Evaluation Matrices

This section to be added in Final product.

Table 36-14 Developmental Effects

Evaluation Criteria	Function	Measure [1/]	Importance [2/]	Composite [3/]
Water Contribution (Water Yield)	Meets M&I Demands	4	10	40
	Supplements Existing System	0	10	0
	Satisfies Future Canal Needs/Expansion	0	10	0
	Additional Hydropower Potential	0	5	0
Technical Viability	Design Constraints	2	5	12
	Feasibility of Concept	2	5	12
Operational Issues	Compatibility	8	5	48
	Maintenance Requirements	4	2	8
	Operational Resources Required	4	2	8
Economic Feasibility	Net Benefits	0	9	0
	Total			128

[1/] Measure - A numerical from 0 to 10 value representing the degree or level the alternative satisfies the criteria. Value of 10 indicates the most significant beneficial impact and 0 the most significant adverse impact.
[2/] Importance - A weighting factor from 0 to 10 to balance the significance of a criteria to the others.
[3/] Composite - the product of the measure and importance.

Table 36-15 Environmental Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Terrestrial Habitat	5	8	40
Animals on Extinction List	5	10	50
Water Quantity Impacts – Lake	9	10	90
Water Quantity Impacts -- Downstream	5	7	35
Water Quality	5	10	50
Downstream Aquatic Fauna Habitat	5	8	40
Future Lake Aquatic Plant Community	7	8	56
Aquatic Faunal Inhabiting Affected Area and Upstream Tributaries	5	5	25
Potential for Fishing on Lake	5	6	30
Wetlands	4	4	16
Air Quality	5	3	15
Cultural Resources and Historic Properties	5	10	50
Total			497

[1/] Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
[2/] Importance - 1 to 10 increasing in importance.
[3/] Composite - the product of the measure and importance.

Table 36-16 Socio-Economic Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Land Use	4	7	28
Relocation of People	4	10	40
Relocation of Agricultural/Ranching Activities	5	6	30
Post-Construction Business	6	5	30
Post-Construction on Existing Employment	5	5	25
Property Values During Construction	5	4	20
Property Values Post-Construction	5	5	25
Public/Community Services During Construction	6	4	24
Public/Community Services Post-Construction	5	8	40
Traffic Volumes over Existing Roadway System During Construction	4	5	20
Traffic Volumes over New Roadway System Post-Construction	5	5	25
Noise-Sensitive Resources or Activities	5	4	20
Communities Receiving Displaced People	5	8	40
Community Cohesion	5	8	40
Tourism	7	5	35
Total			442

[1/] Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
[2/] Importance - 1 to 10 increasing in importance.
[3/] Composite - the product of the measure and importance.

Pertinent Data

Table_36_17**Error! Reference source not found.** presents pertinent data for the proposed Lower Rio Trinidad project.

Table 36-17 Pertinent Data

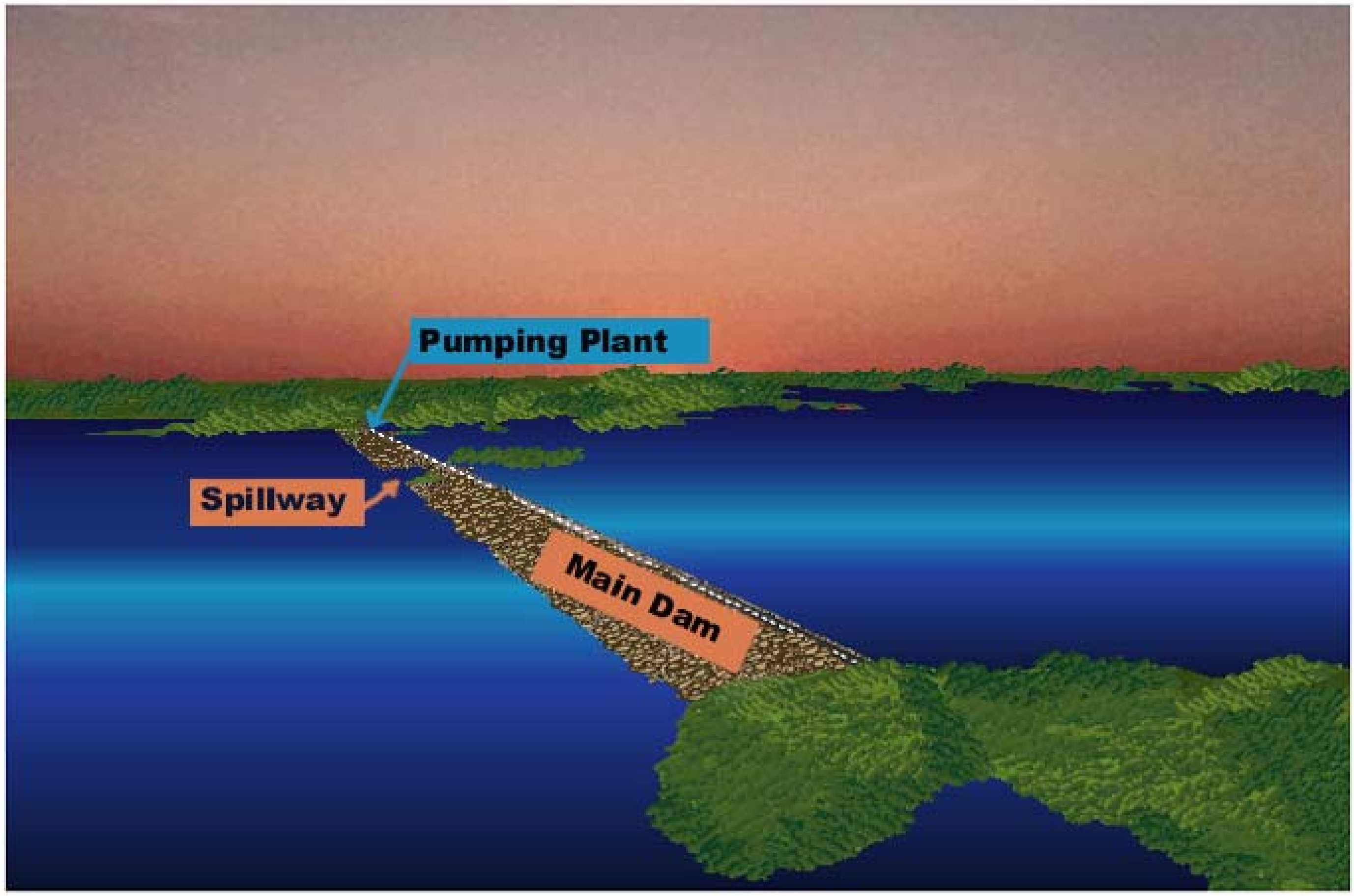
GENERAL	**Gatun**	**Trinidad**
Dam Site, above Gatun Dam	km	10 km
Drainage Area above Dam Site	2597.5 km^2	741 km^2
Average Annual Flow at Dam Site	60 CMS	30 CMS
LAKE (Scenario 1)		
Elevation of Maximum Operating Lake Level	26.67 m MSL	30.48 m MSL
Elevation of Maximum Flood Storage Lake Level	26.74 m MSL	31.09 m MSL
Elevation of Minimum Operating Lake Level	25.91 m MSL	22.86 m MSL
Useable Storage between Max. and Min. levels	214MCM	1139.5 MCM
Area at Maximum Operating Lake Level	29,410 ha	18,169 ha
Area at Maximum Flood Storage Lake Level	29,775 ha	18,835 ha
Area at Minimum Operating Lake Level	28,987 ha	9,019 ha
Top Clearing Elevation	31 m MSL	30.48 m MSL
Lower Clearing Elevation	26 m MSL	26 m MSL
LAKE (Scenario 2)		
Elevation of Maximum Operating Lake Level	26.67 m MSL	30.48 m MSL
Elevation of Maximum Flood Storage Lake Level	26.74 m MSL	31.09 m MSL
Elevation of Minimum Operating Lake Level	24.84 m MSL	22.86 m MSL
Useable Storage between Max. and Min. levels	417 MCM	1139.5 MCM
Area at Maximum Operating Lake Level	29,410 ha	18,169 ha
Area at Maximum Flood Storage Lake Level	29,775 ha	18,835 ha
Area at Minimum Operating Lake Level	28,497 ha	9,019 ha
Top Clearing Elevation	31 m MSL	30.48 m MSL
Lower Clearing Elevation	26 m MSL	26 m MSL
EMBANKMENTS		
Dam - Rock Fill Embankment		
Top Elevation of Dam	32 m MSL	31.5 m MSL
Fixed Crest Width	13 m	13 m
Height above Lowest Foundation	15 m	25 m
Overall Length of Dams	varies m	4473 m
SPILLWAY		
Type of Spillway	Gated Ogee	Gated Ogee
Number of Gates	14	11
Width of Gates	13.72 m	18.33 m
Net Length	192.02 m	201.17 m
Total Length	246.27 m	238m
Elevation of Crest	21.03 m MSL	25.91 m MSL
Maximum Discharge	5150 CMS	3794 CMS

LOWER TRINIDAD DAM

Project Location Map

Plate 36 - 1 Project Location Map

LOWER TRINIDAD



Site Plan

Plate 36 - 2 Site Plan

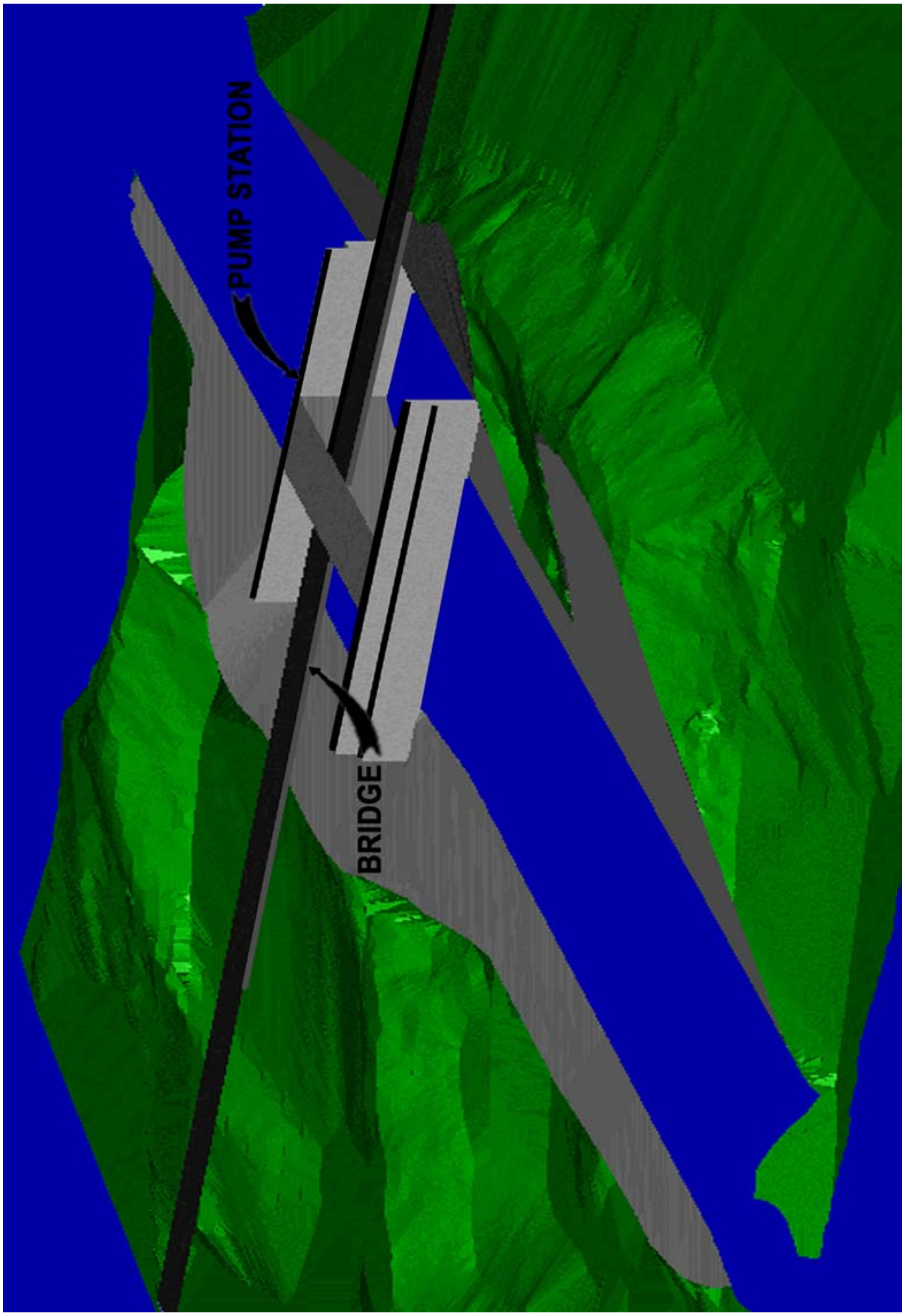


Plate 36 - 3 Pumping Plant Plan

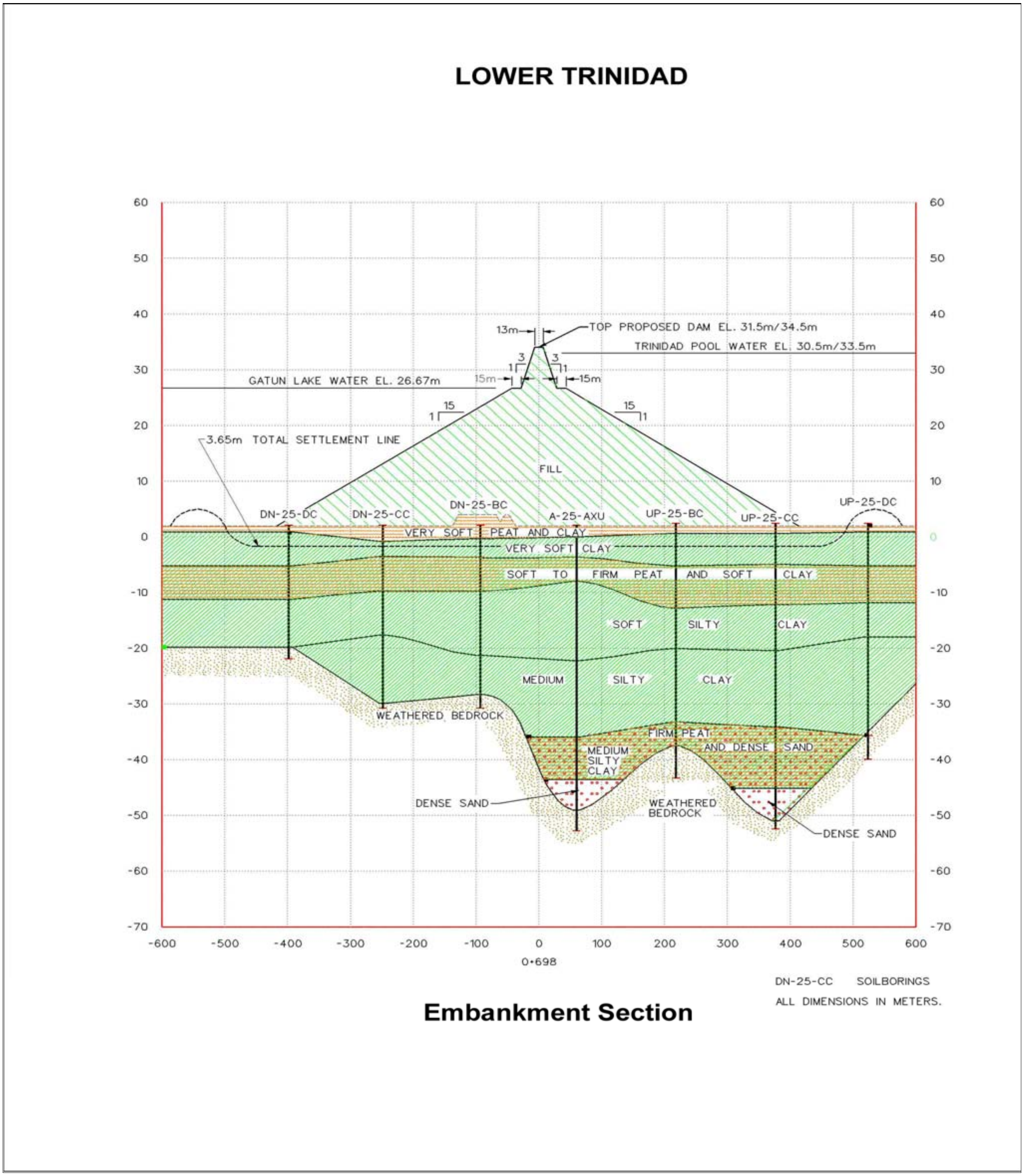
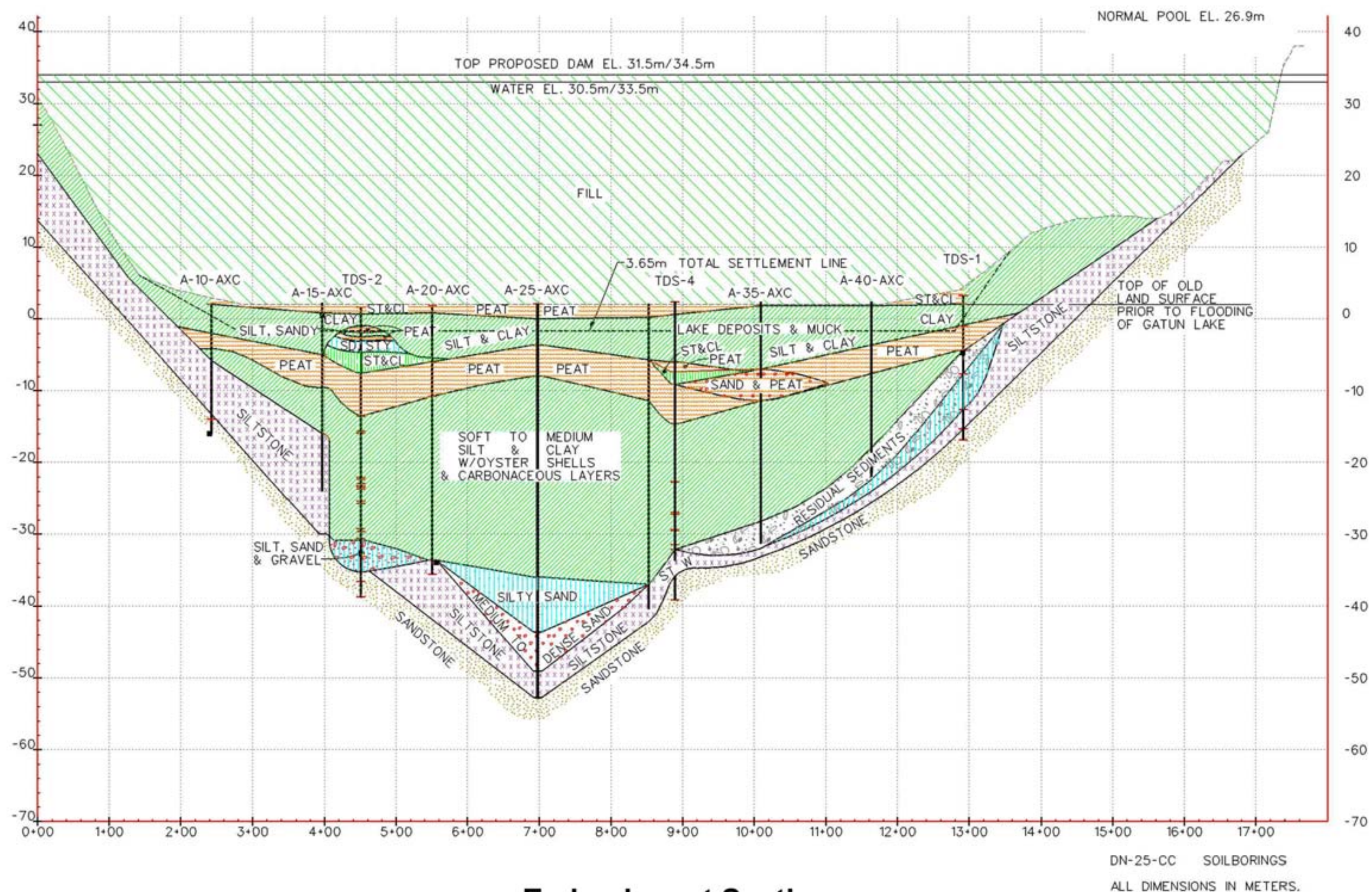


Plate 36 - 4 Embankment Cross Section

LOWER TRINIDAD



Embankment Section

Plate 36 - 5 Embankment Longitudinal Section

SECTION 37

Lower Rio Trinidad 22.9m to 30.5m
Rio Indio 50m to 80m

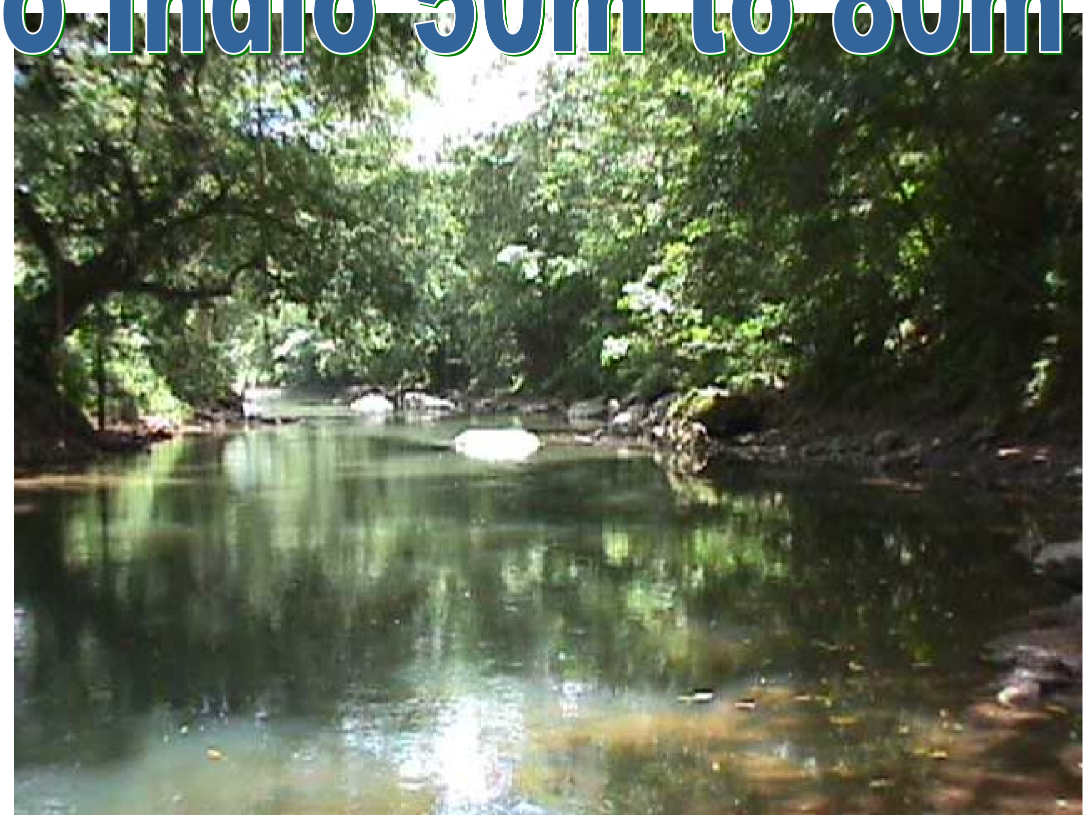


TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

Synopsis

The development plan presented creating a dam and a lake on the Rio Trinidad basin within the Panama Canal watershed at Gatun Lake, southwest of Gatun Locks and an additional dam on the Rio Indio to the west of Lake Gatun. Water impounded in Lower Rio Trinidad Lake should add storage to the Panama Canal system of lakes, water impounded at the Rio Indio site can also provide additional water to the Panama Canal system, since it can transferred via a tunnel from the adjacent watershed to the upper reaches of the Lower Rio Trinidad Lake . Under normal flow conditions water should pass from Lower Rio Trinidad Lake to Gatun Lake through a gated spillway. Water may also be pumped between Gatun Lake and Lower Rio Trinidad Lake by pumping station installed near the east end of the Lower Rio Trinidad Dam. During the flood season, excess water can pumped from Gatun Lake to Lower Rio Trinidad Lake. During the dry season, water stored in Lower Rio Trinidad Lake may be pumped to Gatun Lake. The water can be used as needed to support canal operations.

The Rio Trinidad watershed is located on the western side of the Panama Canal watershed. The proposed dam site is located within Gatun Lake across the Rio Trinidad Lake arm near the town of Escobal. The proposed dam extends from Punta Mala on the west shore of Gatun Lake to Guacha Island, and then straight across to the eastern shore of the Rio Trinidad Lake arm, just south of the South Range Point lighthouse. This alignment follows closely the proposed path in the Study and Report on Increasing the Water Supply of the Panama Canal (referred to as the Tudor Report), prepared by Tudor Engineering Company, San Francisco, California 1962, for the Panama Canal Company. Plate 37 - 1 shows the location of the proposed Lower Rio Trinidad Dam project. The structures for the proposed Lower Rio Trinidad project should consist of a rock fill dam constructed by underwater deposition of fill materials, a gated spillway constructed in the dry on Guacha Island, and a large pumping plant constructed in the dry on Tern Island. The spillway should have 11 gate bays, each measuring 18.3 m wide. The pumping plant should contain 6 large diesel engine driven hydraulic pumps configured to allow pumping in either direction. The total project first costs of the proposed Lower Rio Trinidad Dam project are estimated to be $811,400,000.

The Rio Indio watershed is located adjacent to the western side of the Panama Canal watershed. The proposed Rio Indio Dam site is approximately 25 km inland from the Atlantic Ocean and near the mountain named Cerro Tres Hermanas. Plate 37 - 1 illustrates the location of the proposed Rio Indio Dam project. The structures for this project should consist of a rock fill dam, two saddle dams, an uncontrolled ogee spillway, inter-basin transfer facilities, two hydropower plants, and other outlet works. The tunnel should transfer water from Rio Indio Lake to the Panama Canal watershed as needed for canal operations. The total project first cost of the proposed Rio Indio Dam project is estimated at $245,868,000.

This project poses great construction difficulties because of the extremely large quantities of underwater fill required for construction of the dam. It requires extensive drilling and site investigation prior to construction and, because of the uncertainties inherent with this type of construction; extensive unforeseen costs may be encountered during construction. Also, the spillway and pumping plant must be constructed in island settings where the structures and appurtenances practically engulf the island areas. This poses extreme space limitations on the construction effort and is very costly.

The proposed Lower Rio Trinidad Dam project, in conjunction with the Rio Indio Dam project, should contribute greatly to the hydrologic reliability of the Panama Canal. The project should also increase the ACP's ability to serve its customers by reducing draft restrictions and the light loading of vessels, especially during periods of low water availability. The existing hydrologic reliability of the Panama Canal, based on the period of record from January 1948 through July 1998 and current demands (38.68 lockages), is approximately 99.6 percent. The hydrologic reliability with the demand increasing to 120 percent of the current level (46.42 lockage) is 98.8 percent. With construction of the proposed Lower Rio Trinidad and Rio Indio Dam projects, the existing high hydrologic reliability may be continued as demand for lockages increases up to 44.7 percent above current demand levels (17.29 lockages).

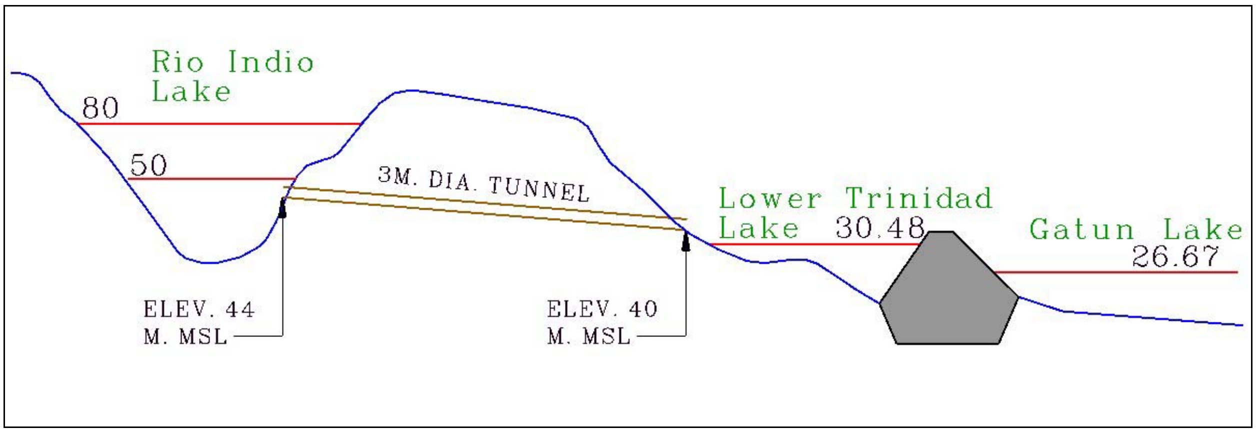


Figure 37 - 1 System Profile

Site Selection

The proposed Lower Rio Trinidad Dam site was recommended in Section 36. Project definition and description developed with a view toward maximizing the water impounded, while minimizing the volume of material required for construction of the dam.

The site chosen for the proposed Lower Rio Trinidad Dam is approximately 10 km south of Gatun Locks and 14 km southwest of the navigation channel. The dam location is 4 km northeast the town of Escobal. This site can accommodate construction of a dam with a maximum operating lake level at EL. 30.5 m MSL. Flood storage accommodations are between EL. 30.5 and 28.7 m MSL.

The proposed Rio Indio Dam site was chosen to maximize the water impounded, while minimizing the volume of material required for construction of the dam and the number of saddle dams required. To maximize the water impounded, it is desirable to locate the dam as far downstream in the Rio Indio watershed as possible. The ideal location is where the surrounding hillsides are relatively steep and high, and the valley is relatively narrow. However, the downstream portion of the Rio Indio watershed does not contain any sites that meet these criteria, as it is comprised of rolling hills and valleys.

The site chosen for the proposed Rio Indio Dam is approximately 25 km inland from the Atlantic Ocean and near the mountain named Cerro Tres Hermanas. This site can accommodate construction of a dam with a normal operating lake level at EL. 80 m MSL and a maximum flood lake level at EL. 82.5 m MSL.

Hydrologic Considerations

Rio Trinidad

The Rio Trinidad flows northward from the Continental Divide to the Gatun Lake. The headwater of the watershed begins at EL. 1,000 m MSL, approximately 75 km inland, and falls to El. 26 m MSL at Gatun Lake. The distribution of the average annual rainfall over the Rio Trinidad watershed varies from a high of 2,200 mm in the western part of the watershed to 2,000 mm on the eastern side of the watershed. The proposed Lower Rio Trinidad Lake receives runoff from approximately 750 km^2 of the upper portion of the watershed. Rainfall runoff produces an average annual flow of 32 CMS at the proposed dam site.

The discharge rate at the Lower Rio Trinidad Dam site is obtained by observing the drainage area ratio established for Gatun. The Gatun Lake runoff is based on records developed by the U.S. Army Corps of Engineers Hydrologic Engineering Center and the ACP in a separate study.

Since the Lower Rio Trinidad Lake is located within Gatun Lake, the monthly evaporation rates established for Gatun Lake are considered appropriate for the evaporation rates of Lower Rio Trinidad Lake.

Rio Indio

The Rio Indio flows northward from the Continental Divide to the Atlantic Ocean. The headwaters of the watershed begin at EL. 1,000 m MSL, approximately 75 km inland, and fall to MSL at its mouth. The distribution of the average annual rainfall over the Rio Indio watershed varies from a high of 4,000 mm at the coast to a low of 2,500 mm in the middle watershed area. It increases again to over 3,000 mm in the Continental Divide. The proposed Rio Indio Lake receives runoff from approximately 381 km^2 of the upper portion of the watershed. Rainfall runoff produces an average annual flow of 25 CMS at the proposed dam site.

The calculated discharge at the Rio Indio Dam site is extrapolated, recorded, and correlated stream flow data of the Boca de Uracillo hydrologic station. This station began operation in 1979 and is located on the Rio Indio, approximately 2.5 km upstream from the dam site. Data established from a statistical correlation with the discharge data of the Rio Ciri Grande at Los Canones, using standard hydrologic techniques, completed missing data and increased the period of record. Utilization of the double mass curve method satisfactorily verified the consistency of the data measured and correlated.

Because of the proximity of Rio Indio to Gatun Lake, and because of the absence of site-specific information, the monthly evaporation rates established for Gatun Lake are considered appropriate for the evaporation rates of Rio Indio Lake.

Geologic Considerations

Rio Trinidad

The proposed Lower Rio Trinidad Dam site was investigated in 1962 by Geo-Recon, Inc. of Seattle, Washington, as part of the Tudor report. The investigation consisted of seismic velocity and electrical resistivity profiles in conjunction with four test borings (all located in the lake and drilled by the Panama Canal Company [PCC]). The results of the geophysical surveys reportedly compared well with the logs of the test borings in the deep-water areas (up to 23 m deep) of Gatun Lake. In June 1963, Tudor Engineering submitted a report including additional foundation investigations. The foundation investigations were made by the firm Shannon & Wilson, Inc., Soil Mechanics and Foundation Engineers, from Seattle, Washington, and consisted of 77 cone penetrometer borings, 24 classification borings, 11 undisturbed sample borings, and 6 field vane shear borings. The investigations submitted by Shannon & Wilson, Inc were recently reanalyzed in Geology of the Proposed Dam Across Trinidad Arm of Gatun Lake, by Mr. Pastora Franceschi S., for the Geotechnical Section of the Panama Canal Authority.

In the lake areas, the investigations disclosed that overburden material included recent lake deposits, Atlantic Muck Formation, alluvial deposits, and residual deposits. Between the west shore and Guacha Island these deposits consist of soft to very soft clay, silt, sand and peat (Atlantic Muck Formation) overlying soft to hard deposits of clay, silt, sand and gravel derived both from alluvial deposition and the weathering of bedrock. The upper two phases of the Atlantic Muck Formation, judged to be the most compressible portion of the formation, was found to have an average thickness of about 18.3 m and a maximum thickness of 22.9 m. Recent, soft lake deposits ranging from 1.2 to 2.4 m thick were found overlying the Atlantic Muck Formation. In the length between Guacha Island and Tern Island, the Atlantic Muck Formation was either not found, or was very thin. In this area, Recent-aged soft sediments (averaging 2 m thick) were found to overlay residual soil and weathered rock. Atlantic Muck Formation, where present, occurred between the Recent-aged material and the residual soil, and was a maximum 5 m thick. Between Tern Island and the east mainland, only recent lake sediments (1.5 m thick) overlying residual clay were found above the conglomerate of the Bohio Formation.

Guacha, Tern and Booby Islands, all located within Gatun Lake, have an overlying stratum of soft overburdened and weathered rock of variable thickness. In general, firm bedrock is available below EL. 22.9 m MSL and the islands offer suitable foundation conditions for control structures.

Firm bedrock under both the land and the lake consists of low velocity sedimentary rock composed primarily of sandstone and the Bohio Formation. Two areas containing abrupt changes in bedrock velocities were located during the survey. One of the areas is a narrow zone located on Guacha Island that is a possible shear zone in rock of similar type. The second area has an abrupt change in bedrock velocity on Tern Island that is interpreted as a possible fault contact between two formations, or between different lithologic units of the same formation. The top of the bedrock on land was interpreted from the geophysical results to be weathered to below lake level. The core borings in the lake determined the weathered zone of bedrock to range from 1.2 to 3.1 m in thickness.

Satisfactory foundation conditions exist for construction of a pumping station, and a spillway at the Lower Rio Trinidad site. Serious consideration, however, must be given to problems that would be caused by the anticipated settlement and instability of the embankment materials.

Rio Indio

The proposed Rio Indio Dam project is located in an area of the Isthmus of Panama underlain by Oligocene-aged sedimentary rocks of the Caimito Formation. Three members of the Caimito Formation are recognized: the lower, the middle and the upper. The deposits of each of these members are mainly marine, but are lithologically heterogeneous. The lower member is composed of conglomerate and tuffaceous sandstone. The middle member consists chiefly of tuffaceous sandstone, some of which is calcareous, and lenticular limestone. The upper, principal member consists of tuff, agglomeratic tuff, tuffaceous siltstone, and discontinuous sandy tuffaceous limestone. In general, all members are hard, thinly to thickly bedded, and closely to moderately jointed. The lower member weathers to greater depths. A summary of test data developed in 1966, as part of the studies for a sea level canal, listed compressive strengths for samples of Caimito Formation material varying between 79,450 and 5,955,257 kg/m^2. The same 1966 studies assigned an allowable bearing capacity of 195,300 kg/m^2 for the material of the Caimito Formation.

The report required an investigative visit to the proposed site for the Rio Indio Dam. The investigation found moderately hard siltstone, fitting the description of strata of the principal member of the Caimito Formation, exposed along the riverbed at the proposed site. This siltstone makes an acceptable foundation for an earth and rock fill dam. It is unacceptable for use as concrete aggregate and only marginally acceptable for use as fill in some of the less important zones of an earth and rock fill dam. Because of dense vegetation, it is unknown whether sedimentary or volcanic material underlies the ridges that form the proposed abutments. Further development of this project requires drilling cores in each abutment during planning studies to identify the abutment material and its general suitability for construction use. In addition, the cores must be of sufficient depth to check for the occurrence of any soluble limestone strata that may underlie the dam foundation.

The proposed inter-basin transfer tunnel connecting the Rio Indio Lake to the Panama Canal watershed is probably located very near the contact of the Caimito Formation and the overlying Miocene volcanic rocks. Many springs occur in the area of the proposed tunnel inlets and outlets, caused by groundwater flowing in volcanic rock above impervious strata of the Caimito Formation. In addition, a 1921 drawing shows two coal mines in the general area of the tunnel inlets. Further development of this project requires drilling cores near the proposed tunnel inlets and outlets early during planning studies to determine the general relationship between the tunnel alignments and the sedimentary/volcanic rock contact, coal or peat beds, and the water table.

In the absence of detailed geologic mapping for the proposed Rio Indio Dam site, a degree of extrapolation is necessary. Available general geologic mapping and general data were the basis of predictions that rock, encountered at a shallow depth and of sufficient quality can serve as foundation for the dam and appurtenant structures. Furthermore, assumptions for this report are: excavation should produce sufficient rock for fill; and the immediate area contains adequate impervious materials and concrete aggregate for use in the construction.

Lake Operation

The operating scenario considered in this study for periods when water would be transferred from Lower Rio Trinidad Lake to Gatun Lake for canal operations is detailed in Section 37 – 1. The following is a reiteration of the tabulated pool levels contained in that narrative.

Table 37 - 1 Lake Operating Options

Lake Level (m MSL)	Lower Rio Trinidad	Gatun
Normal Operating Lake Level	30.48	26.67
Minimum Operating Lake Level	22.86	25.91
Maximum Flood Lake Level	31.09	27.13

The operating scenario for periods that require water transferal from Rio Indio Lake to the Panama Canal watershed for canal operations allows the water surface of the lake to fluctuate from the normal operating lake level at EL. 80 m MSL down to a minimum operating lake level at EL. 50 m MSL and provides 993,000,000 M^3 of usable storage. The maximum flood lake level is at EL. 82.5 m MSL. The volume between the maximum flood lake level and the normal operating lake level would be used to store floodwaters and reduce peak flood flows. Areas along the Rio Indio, downstream of the dam, should experience some reduction in flooding. Table 37-2 shows the lake levels for this operating scenario.

Table 37 - 2 Lake Operating Options

Lake Level (m MSL)	Rio Indio
Normal Operating Lake Level	80
Minimum Operating Lake Level	50
Maximum Flood Lake Level	82.5

Project Features

GENERAL

The structures for the proposed Lower Rio Trinidad Dam project should consist of a rock fill dam, a large pumping plant, and a gated spillway; modification of one existing saddle dam and construction of two additional saddle dams. The following paragraphs provide a description of the proposed structures and improvements for the Lower Rio Trinidad Dam project. Plate 37-2 shows the dam site in upstream right bank perspective and indicates the location of the spillway and pumping facilities.

The structures for the proposed Rio Indio Dam project should consist of a rock fill dam, two saddle dams, an uncontrolled ogee spillway, inter-basin transfer facilities, two hydropower plants, and outlet works. Plate 37-2 depicts the site plan.

Design is performed only to the extent necessary to establish, with reasonable accuracy, the principal dimensions, elevations, and costs of the proposed project. Separate documentation was provided to the ACP that contained assumptions and design calculations for the reconnaissance level investigations of these structures. If this project is carried into the planning studies, optimization of the project features and improvements must be accomplished.

EMBANKMENTS

Dams

Lower Rio Trinidad Dam
The proposed dam consists of an embankment with the top at EL. 31.50 m MSL and with a crest width of 13 m with a final crest of 7 m upon completion of all settlement of the embankment and bridge work. The left abutment of the embankment will be located at Universal Transverse Mercator Grid, Zone 17, Clark 1866 Spheroid Coordinates 1015858 north and 614864 east. The right abutment will be 1013937 north and 618229 east coordinates. The normal lake elevation is 30.48 m while the ground surface elevations along the axis of the dam vary from El. 2 m in the lake bottom to 39 m on Guacho Island and 38m on Tern Island. The Gatun Lake subgrade supporting the embankment occupies a broad flat valley having sides, which slope, upward from the valley at grades up to 40 percent. Water depths are 21.3 to 26.3 m over 80 percent of the site. The Atlantic Muck Formation, consisting of very soft organic clays, silts and peats varying in thickness from 7.6 m to 48.7 m, underlies approximately two thirds of the alignment subgrade. The Atlantic Muck Formation in the old river channel is further underlain by soft silts, sand and clay strata.

The critical challenge for design, espoused by the Tudor Report and others, is the depth of subgrade degradation during the initial fill placements. The materials will lose much of its natural strength when disturbed and will only regain strength after the effects of consolidation of a surcharge fill. However, complete restoration of strength can only be assumed to a depth of 5 to 7 meters. If the effects of the subgrade disturbance extend appreciably deeper, then an extremely weak material will be under the more stable subgrade and surcharge creating a condition of lateral instability.

Due to the inability to accurately analyze this condition, a test fill was performed on the western end of the alignment. In early 1963, 1,000-cy bottom-dump barges deposited some 168,000 cy of blasted rock from the cut widening project, extending some 305 m. 155 m of the fill was placed to a height of 11 m while the remaining 150 m was filled to 5 m. The differential heights were use to simulate initial and intermediate fill placement effects. Divers were then used to observe the performance of the fills placed along the alignment. The mechanisms of failure within the subgrade were caused by impact and static loadings. The impact of the initial placements caused severe destruction of the surface materials creating lateral displacements up to 5 m. However, when a continuous blanket of fill had been established and subsequent fill was placed, then conventional failures such as slip circle shear failures and horizontal shears creating large mud waves outward from embankment were observed. Therefore, to predict the behavior of the embankment during construction and for the long term, it is imperative that a foundation mat be established to such a depth to prevent subgrade rupture with subsequent fill placement. The Tudor report recommended that a 5 m thick minimum crushed rock blanket with maximum sizes of 20 cm be placed initially to act as the supporting blanket. Special barge dumping methods were to be employed so loads would not fall as an integral mass, which would create destructive forces on the subgrade. These recommendations were detailed by the Tudor report.

The placement of a large hydraulic structure on a deep-seated weak foundation is the most challenging of geotechnical endeavors. It is virtually impossible to analyze with great deal of certainty and the owner must be prepared to accept possible additional costs during construction and long term maintenance due to the potential for lateral instabilities and high degrees of settlement. The Tudor Report has predicted some 2.5 to 3 m of predicted settlement below the crest elevation for a construction duration of 7 years and an additional 2.5 to 3 m of maximum settlement below the crest for the 50-year service life of the project. These settlements are predicted where the Atlantic Muck and underlying compressible materials are the thickest. These movements are reduced as the fill approaches the mainlands and the two islands. This implies that significant differential settlements are predicted within these approaches as well. The key to any successful construction and maintenance of this embankment will be to establish a blanket mat atop the subgrade where subsequent fill can be economically placed without fear of rupturing the foundation to greater depths. Any significant lateral failure of the embankment during construction or productive use will render that alignment unsuitable. Additional embankment sections must be established upstream or downstream to reestablish the embankment section to the proper elevation. This repair will take considerable time and prevent its use as a road. These recommendations are presented for ultimate costs considerations in comparison to alternatives with a greater degree of performance certainty.

The divers observed that the test fill had trouble placing the fill in the correct locations within the alignment and the lift thickness varied significantly over the fill cross section. It is imperative that the blanket fill be placed intact with the least subgrade disturbance, in order for the embankment to act as monolithic mass. Therefore, the initial 5 m of fill will be barged to the site and placed by lowering a clamshell to the subgrade surface. The positioning of the barges must be strictly controlled by survey positioning systems established on land. The initial fill should have a maximum size of 20 cm and the percent fines should be controlled to remain fairly intact during placement. Materials with a significant size differential and a large fine content can create weak shear zones with the embankment. The subsequent fill materials above this zone can be placed by bottom dumped barges or clamshells from El. 8 m to El. 21 m. The material above El. 21 m must be placed by clamshell due to the draft and door operations of the barges. These materials will be more random in gradation having a maximum size of 30 cm and a greater degree of fines. The materials placed below El. 27 m will assume a side slope of 1 V:15 H. A 15 m berm will be constructed and the materials will continue to be placed by clam shell and spread with a dozer to El. 31.5 , assuming a side slope of 1V:3H and a crest width of 13 m. The flatter side slopes are needed to distribute bearing pressures and to reduce the lateral displacements. This configuration should also reduce the construction and total settlements predicted by the Tudor report and provide acceptable factors of safety for lateral stability during fill placement. The side slope berms and extra crest width will facilitate the future fill placements of up to 3 m over the life of the project. The road surface atop the dam embankment will remain gravel surfaced for the foreseeable future due to future fill placements. The dam will be approximately 30 m high, and the overall length 4,473 m. The top of the dam will be 5 m above the normal Gatun Lake level. The total volume of fill material required to construct and maintain the main dam to El. 31.5 m is approximately 29,550,850 M^3. Water access from the main channel to Guacha and Tern Islands will be built during construction. After access roads have been constructed, fill placements from the east mainland to Tern and Gaucha Islands could be delivered by truck and placed by end-dumping from the east mainland. This technique could prove beneficial if a material source was found near the Gatun Lock area. The side slopes and overall embankment configuration was offered for ease of calculation, to reduce the foundation pressure on the soft subgrade and to account for the lateral displacement of embankment materials. The increased foundation base should help the structure survive a relatively minor seismic event.

The methods of subgrade stabilization and embankment strengthening offered in the powerpoint presentations from the ACP Engineering Division are examples of many ideas for enhancing the performance of the embankment during construction and post construction. The use of wick drains have been an effective tool for accelerating consolidations under a mass loading. It is believed that the Atlantic Muck materials will not readily transmit water to the drains, therefore the spacing of the drains must be much closer than that implied and the effectiveness of the drains will be restricted to the top 15 to 20 feet of the foundation subgrade. The drains must be effectively tied into the foundation blanket for continuity of the drainage path. There are concerns about the use of vibro-flotation or stone columns techniques above the mat. The mat will not effectively dampen these compaction forces and some rupture of the mat could be possible. A safer reinforcing technique could be the use of reinforcing within the embankment section, such as high strength geogrids placed in layers. All reinforcing techniques are expensive but could be offset by the reduction in fill quantities ultimately required. Any reinforcing selected for use in production must be part of a comprehensive test fill program to demonstrate its effectiveness.

The Tudor Report identified considerable leakage to be expected from the completed embankment. Since loss of any water from storage is a significant reduction in benefits, the seepage must be prevented. Therefore a bentonite slurry trench should be installed within the centerline of the embankment. The trench will be a minimum of 3 feet wide and extend to several meters below the original lake bottom. The trench can be excavated using rockmill techniques. Since the embankment will undergo significant settlement, both total and differential, it is likely that the trench will be sheared and will require replacement within the deeper portions of the lake during the life of the project.

Rio Indio Dam

The Rio Indio Dam would be constructed as an embankment, with the top at EL. 83.5 m MSL and with a crest width of 13 m. The left abutment of the embankment would be located at Universal Transverse Mercator Grid, Zone 17, Clark 1866 Spheroid Coordinates 994408 north and 589644 east. The right abutment would be 994801 north and 590432 east coordinates. The embankment would be constructed with an impervious earth and rock fill core encased in rock fill, and the final side slopes would be 2 horizontal on 1 vertical. The dam at its highest point shall be approximately 73.5 m high - the overall length 891 m. Further study should determine the actual side slopes and crest width and contingent upon the need for vehicular access across the embankment, the size and quality of the rock fill, and the detailed design of the embankment. Plate 37 - 3 presents a typical section of the embankment at the dam, incorporating upstream and downstream cofferdams within the section.

Foundation grouting would be required across the entire base of the dam and up a portion of the valley walls. A blend of bentonite and native fill materials in a core trench may provide seepage cutoff in the embankment foundations. A concrete or bentonite cutoff wall can also provide seepage cutoff.

Saddle Dams

As noted in the Tudor Report, the existing Caño Saddle Dam No. 4, located along the western shoreline of the Trinidad Arm of Gatun Lake, needs to be raised and/or strengthened to accommodate the higher lake levels. Immediately to the north of this location, two additional smaller saddle dams are required. All saddle dams must be built to provide a minimum top elevation of 31.50 m MSL. The total volume of fill material required for these three dams is approximately 50,000 M^3, based on a crest width of 13 m.

Two saddle dams are required to complete the lake impoundment at Rio Indio. For this study, both saddle dams are configured with an impervious earth and rock fill core encased in rock fill, and the final side slopes would be 2 horizontal on 1 vertical. The top of the saddle dams would be set at EL. 83.5 m MSL, a crest width of 13 m. The length of the north saddle dam shall be 255 m, while the length of the south saddle dam would be 272 m.

The actual side slopes and crest widths would be determined during further study and are contingent upon the need for vehicular access across the embankment, the size and quality of the rock fill, and the detailed design of the embankment.

SPILLWAYS

Lower Rio Trinidad

Under normal flow conditions water should pass from Lower Rio Trinidad Lake to Gatun Lake through a gated spillway. This spillway should have 11 gate bays separated/flanked by 3 m wide reinforced concrete piers (12 piers in all). These provide support for the gates, and access to the gate operating machinery, as well as for a roadway bridge over the top of the spillway. Each of the 11 spillway gates should have a nominal width of 18.33 m and a height of 5.48 m to provide 0.3 m freeboard above the maximum lake operating level. The overall length of the spillway, from out-to-out of the end piers is 237.67 m. The spillway sills shall be placed at the minimum lake operating level for Gatun Lake, EL. 25.91 m MSL.

A bridge across the tops of the spillway piers would be constructed as a part of the roadway across the top of the dam. The roadway must be approximately 7 m wide thus allowing for two-way traffic and providing ready access to the spillway gate operating machinery.

For this study, stop logs for servicing the gates, guides, etc. may be placed either from the roadway or from barges using floating cranes. Also, it should be noted that, with the spillway sill at the prescribed level, stoplogs are required both upstream and downstream to allow work to be done on the gates and sills in the dry.

The spillway would be situated along the axis of the dam approximately centered in Guacha Island. This allows the construction to be performed completely within a dry construction cut requiring a minimum of construction dewatering. Once the concrete structures are completed, the entrance and exit channels to the spillway can be opened.

Rio Indio
An uncontrolled ogee spillway with a length of 120 m and a crest at EL. 80 m MSL is required. The spillway crest would be 3.5 m below the EL. of the top of the dam. The maximum discharge from the spillway would be 920 CMS at a maximum flood lake level at EL. 82.5 m MSL. The spillway design discharge is equivalent to a 1 in 1,000 frequency unregulated flow at the dam site. The spillway would be located within the abutment adjacent to the left end of the dam and consist of a mass concrete sill section embedded in the natural rock. A sloped and/or stepped, natural rock cut tailrace channel should return flow to the existing stream. The tailrace channel shall extend from the sill section to its confluence with the natural stream some distance downstream from the toe of the dam. The task of dissipating energy at the downstream end of the tailrace channel requires excavation of a stilling basin into the rock adjacent to the natural channel. See Plate 37 - 2 for the location of the spillway and Plate 37 - 5 for a typical section at the spillway.

PUMPING PLANT

A large pumping plant is included in this scenario at the Lower Rio Trinidad dam. This pumping facility provides for pumping in two directions, allowing Lower Rio Trinidad Lake to be drawn down to a level below that of Gatun Lake during extremely dry months, and providing the capability of pumping excess water from Gatun Lake into Lower Rio Trinidad Lake during the flood season. Water thus stored would be available for navigation during the dry season. The pumping plant is configured to provide pumping to EL. 33.53 m MSL in Lower Rio Trinidad Lake. For the purpose of this study the pumping plant is located in the northwest segment of Tern Island. See Table 36-3 for the controlling head and flow data used for this study.

This plant should consist of six 1407 HP pumps, each capable of pumping slightly more than 62 CMS for a total plant pumping capacity of 373 CMS at a total dynamic head of 4.6 m. The pumping units would be mounted in a reinforced concrete housing and arranged in a row perpendicular to the axis of the dam, with intake and outlet channels on either side. The channels would be separated from the Lower Rio Trinidad and Gatun Lakes by large concrete walls containing low-level sluiceways and gates for controlling flows into and away from the pumping plant. These sluiceways are configured to provide average entry velocities of approximately 7.7 MPS. The channels are configured to provide this velocity or less and require no special armoring of walls or inverts for scour protection. The channel invert would be at EL. 20 m MSL, or 13.5 m. below the centerline of the pump outlets. This may provide sufficient water depth at maximum pumping to buffer the erosive effects of the very large outflows required.

In conjunction with this facility a roadway bridge would be required to connect the pumping station structure to the banks on either side of the intake and exit channels thus continuing the roadway across the facility. This bridge should also provide both operational and maintenance access to the pumping plant. As configured for this study, the bridge must have two 15 m long spans with steel girders and a concrete bridge deck on each side of the pumping station. It shall have a 7 m wide travel way and include one bridge bent including a cap, two round columns and a spread footing, located within each channel section.

Table 37-3 Pumping Data

Pumping Cycle	**Head** (m)	**Average Daily Flow** (M^3/sec)
Lower Rio Trinidad (EL. 22.86) to Gatun Lake (EL. 25.91)	3.05	127.43
Gatun Lake (EL. 26.67) to Lower Rio Trinidad (EL. 30.48)	3.81	56.64

IMPOUNDMENT

The lake formed by the proposed Lower Rio Trinidad Dam should have a normal operating lake elevation. of 30.48 m MSL. The surface area at the normal operating lake level would be approximately 18,169 ha. At the maximum flood level, EL. 31.09 m MSL, the surface area would be approximately 18,835 ha. With the minimum operating level at EL. 22.86 m MSL, the surface area would be approximately 9,019 ha. It should be noted that the current operating levels of Gatun Lake vary up to EL. 26.67 m MSL; therefore areas below the maximum Gatun Lake level are already subject to inundation.

The lake formed by the proposed Rio Indio Dam should have a normal operating lake level at EL. 80 m MSL. The surface area at the normal operating lake level is approximately 4,280 ha. At the maximum flood lake level, EL. 82.5 m MSL, the surface area would be approximately 4,440 ha. With the minimum operating lake level at EL. 50 m MSL, the surface area would be approximately 2,360 ha.

CLEARING AND/OR GRUBBING

Clearing and grubbing are required for all areas above the existing Gatun Lake that would be used for construction of the dam (embankments, spillway and pumping plant), access roads, and disposal and staging areas. For the Rio Trinidad Lake area, clearing is required for the 700 ha in the lake area between the maximum operating lake level of Gatun Lake and EL. 30.48 m MSL.

For the Rio Indio Lake, clearing is required in all areas necessary for construction of the dam (embankments and spillway), inter-basin transfer facilities, outlet works, hydropower plants and access roads. Only the 650 ha in the lake area between the normal operating lake level at EL. 80 m MSL and the minimum operating lake level at EL. 50 m MSL should require clearing. Disposal and staging areas require both clearing and grubbing. The transmission lines should also require clearing.

INTER-BASIN TRANSFER FACILITIES

The project should include excavation of a tunnel beneath the common watershed divide to connect the proposed Rio Indio Lake to the Panama Canal watershed in the Lower Rio Trinidad Pool. The finished tunnel would be concrete lined, 3 m in diameter, and approximately 5.2 km in length. This tunnel should have an inlet invert at EL. 44 m MSL and an outlet invert at EL. 40 m MSL. The maximum capacity of the tunnel is 37.1 CMS. In estimating the effort required to construct this tunnel it is assumed that rock stabilization, including rock bolting, is required over much of the tunnel length. The tunnel outlet shall be on the Rio Ciricito approximately 5 km upstream from Gatun Lake. A gate structure, located at the tunnel outlet, should control flow through the tunnel. The channel of Rio Circito downstream of the outlet requires enlargement to provide sufficient flow capacity to the lake, as well as some surface armoring to prevent erosion. The tunnel discharge would be oriented to mitigate the erosion potential. The tunnel would be under pressure continually. Allowances for maintenance of the tunnel, and for rapid tunnel closure when required, necessitate construction of a gate/stoplog structure at the inlet. In the process of stopping flow through the tunnel, a water hammer effect may occur; if such an event occurs, then construction of a series of surge protection shafts may be necessary. These shafts require relatively minor surface structures for safety purposes. Plate 37-1 shows the location of the tunnel outlet, and Plate 37 - 4 depicts a profile of the tunnel.

HYDROPOWER PLANTS

The flows that are excess to the needs of the Panama Canal operation at the proposed Rio Indio Dam should support installation of a 25 MW hydropower plant, with a plant factor of 0.5 at the dam and a 5 MW hydropower plant at the inter-basin transfer tunnel outlet. This plant should receive flow from a Y off the main tunnel. The 25 MW hydropower plant should have two 12.5 MW units. These facilities are designed and configured to function as part of the national power grid. A 115 kV transmission line is required to carry the energy to a GHD connection near La Chorrera. Plate 37 - 2 shows the location of the hydropower plant at the dam, and Plate 5 - 7 shows the details at the hydropower plants.

OUTLET WORKS

An outlet works system is required to provide diversion of the Rio Indio flows during construction, to supply flows for production of hydropower, to allow for emergency drawdown of the lake, and to allow minimum flow to pass through the dam.

This outlet works system shall include a single intake structure. This structure would be configured to allow passage of channel flows up to the required level of protection during construction. Once diversion is no longer needed for construction, the structure can used to control the flows for hydropower and emergency drawdown. It also should have separate controlled water intakes at various elevations to allow flows to be withdrawn from the lake and to optimize the quality of the water passed as minimum flow. The hydropower intake may also be elevated to prevent silt from entering the power units.

This system should consists of an 8 m by 8 m horseshoe-shaped tunnel passing through the dam abutment, a gated intake structure located in the lake, an outlet channel downstream, and various gate structures and water conduits, as depicted in Plates 37 - 8 and 37 - 9. The diversion tunnel would be 1,500 m in length; it should have an inlet invert at EL. 10 m MSL and an outlet invert at EL. 7 m MSL. The diversion tunnel serves in combination with the cofferdam to protect the construction area from floods up to a 10 percent frequency. A 10 percent frequency flood should deliver a peak flow of approximately 680 CMS at the site without regulation from the dam. A separate 1.2 m diameter conduit, required for minimum flow, would be installed beneath the floor of this tunnel. The minimum flow conduit would be 800 m should length; it should have an inlet invert at EL. 8 m MSL and an outlet invert at EL. 5 m MSL. The capacity of the minimum flow conduit would be 2.5 CMS. A bulkhead structure is required at the tunnel outlet to close the construction diversion and to divert flows from the lake into the hydropower conduit(s). The closure would be configured so that it can removed in the event that the Rio Indio Lake had to be drawn down.

ACCESS ROUTE

Lower Rio Trinidad
Access to the Lower Rio Trinidad lake site and the various construction sites was evaluated from the main population centers, Colon on the Atlantic coast and Panama City on the Pacific coasts.

The route from Colon is westward across the Panama Canal and then southwestward along existing roads that follow the westernmost boundary of Gatun Lake to Cape Mala, near the western abutment of the dam. A very short access road is required from the existing road to the dam site. This route requires crossing the Panama Canal near the Gatun Locks using the existing lock gate bridge. This bridge is narrow and operates only intermittently since canal operations take precedence over roadway traffic. It may be undersized and may lack the load carrying capacity needed for heavy construction materials and equipment loads anticipated.

Access to the spillway and pumping plant construction sites would be by water since these structures are to be placed on Guacha and Tern Islands, respectively. A water access route was considered for conveyance of much, if not all, of the construction equipment and materials. This requires the construction of offloading facilities near the west abutment of the dam, on Guacha Island, and near the eastern abutment site in the vicinity of South Range Point.

Since much of the construction for this project would be in the existing lake or on islands in the lake, it is concluded that both land and water access is required. Plate_37_1 shows the general location of the proposed features and the possible land and water access available or to be provided.

Rio Indio
For access to the Rio Indio site it is concluded that the route from Panama City westward across the Bridge of the Americas, then southwestward along the Inter-American Highway, and then westward along existing roads to Ciri Grande, may be best. This route requires that the road between Panama City and Ciri Grande be upgraded over much of its length and the route west

of Ciri Grande must traverse the mountains. The proposed access road would be 26 km in length, and bridges and / or culverts would be required at 15 streams. Plate 37-1 shows the portion of the proposed access road from Ciri Grande to the construction sites.

In addition to providing dam construction access, this new corridor into the country west of the Panama Canal benefit those living in the region, providing access to the main centers of commerce in the southern part of the country. It should also provide continuous access along the new power transmission lines from the dam site to the connection with the power grid.

Sources of Construction Material

Lower Rio Trinidad

The bottom 5 m layer of the dam embankments shall be constructed with material less than 8 in. maximum size, and with no more than 5 percent passing the #200 screen. Such a material should require crushing and processing across a grizzly to remove oversize rock, and washing to remove fines. Material for this bottom layer must be reasonably well graded so as to prevent the removal of the finer fraction by piping. The overlying main portion of the embankment would be constructed with (-12 in.) sized material. This material should also require crushing and processing across a grizzly to remove oversize rock.

The majority of the materials used for the embankment construction would be obtained from upland sources adjacent to the Gaillard Cut, transported to the site by barge and clam shelled along the proposed embankment alignment. The initial materials would be obtained from the existing disposal sites for the Gaillard Cut widening above Pedro Miguel Locks. Based on the information received from the ACP, these sites contain approximately 5.5 million M^3 of suitable excavated rock. However, this rock is not stockpiled in an orderly manner, is randomly mixed with unsuitable material and is covered with unsuitable material. All the rock materials, from whatever source, would need to be crushed, graded and loaded on trucks for transport to a loading facility adjacent to the canal at the Cucaracha Reach on the east side, or the mouth of the Mandinga River on the west side. These loading facilities should require excavation into the bank area and bulkheaded for crane support and barge placement. Working stockpiles would be maintained next to the transfer points to facilitate the loading process. Additional materials within the immediate area should come from the Third Locks excavation adjacent to the Pedro Miguel Locks. These materials would be drilled and blasted in place, excavated, and then transported to one of the transfer facilities for processing. Additional materials should come from newly developed quarry sources in areas such as Hodges Hill, Escabor Hill, Contractor Hill, and others within 10 km of the transfer points. Each of these new sources should require extensive excavation to remove the overburden and soft rock materials. These materials would be stockpiled adjacent to the work area for restoration once the rock fill materials have been acquired. The suitable rock materials would be blasted, crushed and graded, and trucked to the transfer points. All material would be loaded onto barges, transported to the dam site and clam shelled within the dam limits.

Cement is available within the country. Rock obtained from developed quarries may be used to produce concrete aggregates on-site, or they may be obtained from commercial quarries. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) need to be fabricated outside the Republic of Panama and imported for final assembly and installation at the proposed dam site.

Rio Indio
Rock removed from the spillway site can used as fill in the embankment portion of the dam. Impervious materials might be obtained from outside the project area; however, for this study it is assumed that these materials would be available locally in sufficient quantity to supply the project needs. If further study indicates that impervious materials are unavailable locally, then other materials, such as roller compacted concrete, would be considered for construction of the dam.

Cement is available within the Republic of Panama. Rock obtained from developed quarries may be used to produce concrete aggregates on-site, or they may be obtained from commercial quarries. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) need to be fabricated outside the country and imported for final assembly and installation at the proposed dam site.

Real Estate Requirements

The proposed Lower Rio Trinidad Lake site is located within the former Panama Canal Zone and is presently managed and controlled by the ACP. Construction of this project requires acquisition of approximately 800 ha. Table 37 - 4 shows the amount of land required for the various project features. Real estate for access roads is included in the estimated quantities for the other items listed in the table. The ACP provided the estimated cost of the land for the proposed project.

Table 37 - 4 Rio Trinidad Real Estate Requirements

Project Feature	Land Required (ha)
Lake	0
Dam Site	0
Staging Area	200
Housing and Facilities	200
Disposal Area	400
Total	800

The proposed Rio Indio Dam project is located in the Cocle, Colon, and Panama Provinces. Construction of this project requires the acquisition of approximately 5,600 ha. Table 37 - 5 shows the amount of land required for the various project features. Real estate for access roads is included in the estimated quantities for this other items listed in the table.

Table 37 - 5 Rio Indio Real Estate Requirements

Project Feature	Land Required (ha)
Lake	4,600
Dam Site	200
Staging Area	200
Housing and Facilities	200
Disposal Area	400
Total	5,600

Relocations

The proposed Lower Rio Trinidad Lake site is located within the existing former Panama Canal Zone. Structures and facilities established along the waters edge in the Rio Trinidad arm, between the existing Gatun Lake levels and EL. 30 m MSL, need to be relocated or modified. This includes a major portion of the town of Escobal. Additionally, there are a few small communities and isolated individual structures along the lakeshore with very limited access by land.

The proposed Rio Indio Lake site is located in a sparsely settled region with few roads and utilities. This area is devoted primarily to subsistence farming and ranching. Structures and individuals located in the lake area below EL. 85 m MSL require relocation because of the normal lake inundation, and to secure land on the lake perimeter for flood considerations. The required relocations include the five towns (El Limon, Los Uveros, La Boca de Urcelillo, Aguila, and Tres Hermanas), approximately 30 other small settlements, and numerous isolated structures. The five towns all have elementary schools, churches, electricity, and limited telephone coverage.

Development Sequence

Lower Rio Trinidad
Each of the component lake projects is designed and constructed as a stand-alone facility. If the Upper Rio Indio facilities are constructed first and placed into service before the Lower Rio Trinidad facilities, the interbasin transfer tunnel can used to navigational advantage while the Lower Rio Trinidad Dam project is being completed. During the interim, the Rio Indio Dam project can also help control flooding on the Lower Rio Indio and can contribute to the electric power output of the country.

The development sequence for each individual project follows roughly the same progression. This progression is summarized below with pertinent site-specific notations as appropriate.

Each project must be evaluated to assure that the plan presented includes all of the features required to function. Each project must be assessed as to its effectiveness in providing navigation water to the Panama Canal, with due recognition of any secondary benefits. Environmental assessments of the proposed projects need to be made to assure environmental acceptability of the project features. These environmental assessments begin during the planning studies phase and continue into the final design, advertising and award phases. Environmental coordination begins with planning studies and continues through the completion of construction. After completion of the final design, plans and specifications must be prepared for the advertising and award phase.

Project implementation begins with land acquisition and construction of the access facilities. Lands for the housing and facilities project feature, which includes the access roads, need to be acquired initially. Lands for the dam site, staging area, disposal area, and lake can then be acquired.

Socio-economic programs must begin shortly before construction of the dam. The relocation of the small settlements and isolated structures must be accomplished. Socio-economic programs to assist those individuals impacted by the construction of the proposed project should continue throughout the construction phase.

Rio Indio
Construction of the Rio Indio Dam begins with the clearing and grubbing of the construction sites and clearing the perimeter of the lake area. Materials used for the embankment construction can obtained from upland sources then transported to the site.

Upstream and downstream cofferdams are required for construction of the Rio Indio Dam and appurtenant facilities. These shall be configured to form a portion of the finished dam.

Limited cofferdams would be required to accomplish construction of the spillway and pumping station. These efforts may be accomplished simultaneously. Following completion of the pumping plant and spillway, the channels connecting these structures to the lake areas upstream and downstream may be excavated. Where possible, materials removed from these sites would be placed directly into the dam.

Once the western leg of the dam, pumping station and spillway are completed, the eastern leg may be constructed, thus completing the dam. The pool may then be raised. Upon completion of this phase of construction, all facilities must undergo trial operations, before being commissioned for service.

Considering the construction methods required and the nature of the work, it is estimated that development of the Lower Rio Trinidad and Rio Indio Dam projects may be completed in approximately the time spans indicated in Figures 37-2 and 37-3, below, from initial planning to lake filling. Assuming that the development of the two projects is overlapped by 1 year the total development time is approximately 22 years.

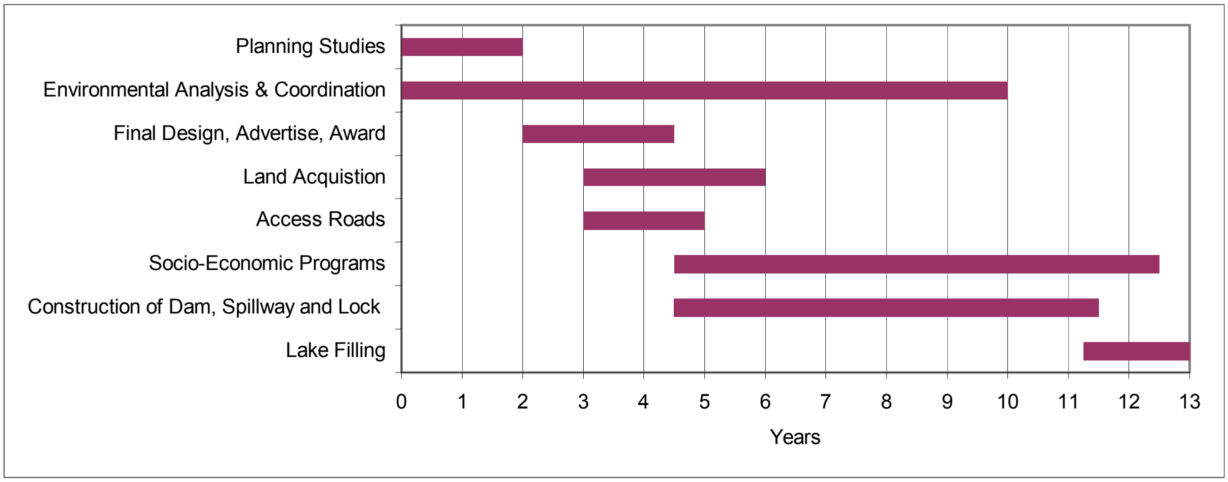


Figure 37 - 2 Development Sequence – Lower Rio Trinidad

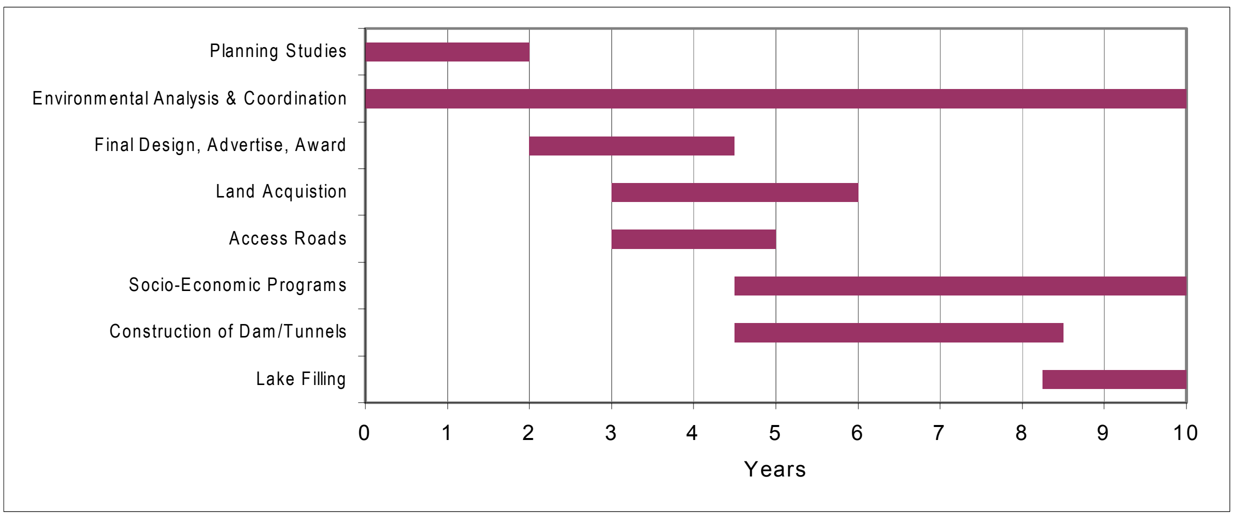


Figure 37 - 3 Development Sequence – Rio Indio

Hydrologic Reliability

In order to determine the effect of the proposed Lower Rio Trinidad and Rio Indio Lakes on the hydrologic reliability of the Panama Canal, the existing HEC-5 model is modified to include the Lower Rio Trinidad Lake with pumpback operation and diversion from Rio Indio Lake. The existing Gatun Lake parameters (surface areas, storages, and local inflows) are reduced by the proportion that Lower Rio Trinidad Lake should capture.

HEC-5 model simulations are conducted for both the existing canal system and the Scenario 2 operating system providing water to the Panama Canal watershed. The simulations considered proportionally increasing demands to 180 percent of current demand levels. The period of simulation considered 52-years (January 1948 through December 1999) of hydrologic record. Figure 37 - 4 Panama Canal Hydrologic Reliability presents the resulting hydrologic reliability for two configurations with demands increasing to 180 percent of current demands. These configurations were:

- Existing system,
- Scenario 2 – Rio Indio Lake fluctuating between the normal operation lake at EL. 80 m MSL and the minimum operation lake level at EL. 50 m MSL, with a 3 m diversion tunnel; Lower Rio Trinidad Lake fluctuating between the normal operating lake level at EL. 30.48 m MSL and the minimum operating lake level at EL. 22.86 m MSL with pumping capability to and from Gatun Lake; and Gatun Lake fluctuating between the normal operating lake level at EL. 26.67 m MSL and the minimum operation lake level at EL. 25.91 m MSL.

The horizontal axis along the bottom of Figure 37 - 4 Panama Canal Hydrologic Reliability reflects demands as a ratio of the five-year average from 1993 to 1997, and the axis along the top reflects demands in lockages (assuming 55 million gallons per lockage).

As shown in Figure 37 - 4 Panama Canal Hydrologic Reliability, the existing hydrologic reliability of the Panama Canal, based on the period of record of 52 years, is approximately 99.6 percent, while the hydrologic reliability with a demand ratio of 1.8 is 86.3 percent. This period of hydrologic record includes the worst drought of the area, which occurred in 1998. The hydrologic reliability with a demand ratio of 1.0 is 100 percent for operating Scenario 2, and the hydrologic reliability with a demand ratio of 1.8 is 97.23 percent. Table 37 - 6 displays the number of lockages associated with various levels of reliability.

Without additional water supplies, the hydrologic reliability of the canal system should decrease. With the construction of the proposed Lower Rio Trinidad Pumpback and Rio Indio Dams projects, the existing high hydrologic reliability can continued as demand for water increases by 44.7 percent (17.29 lockages) above current demand levels.

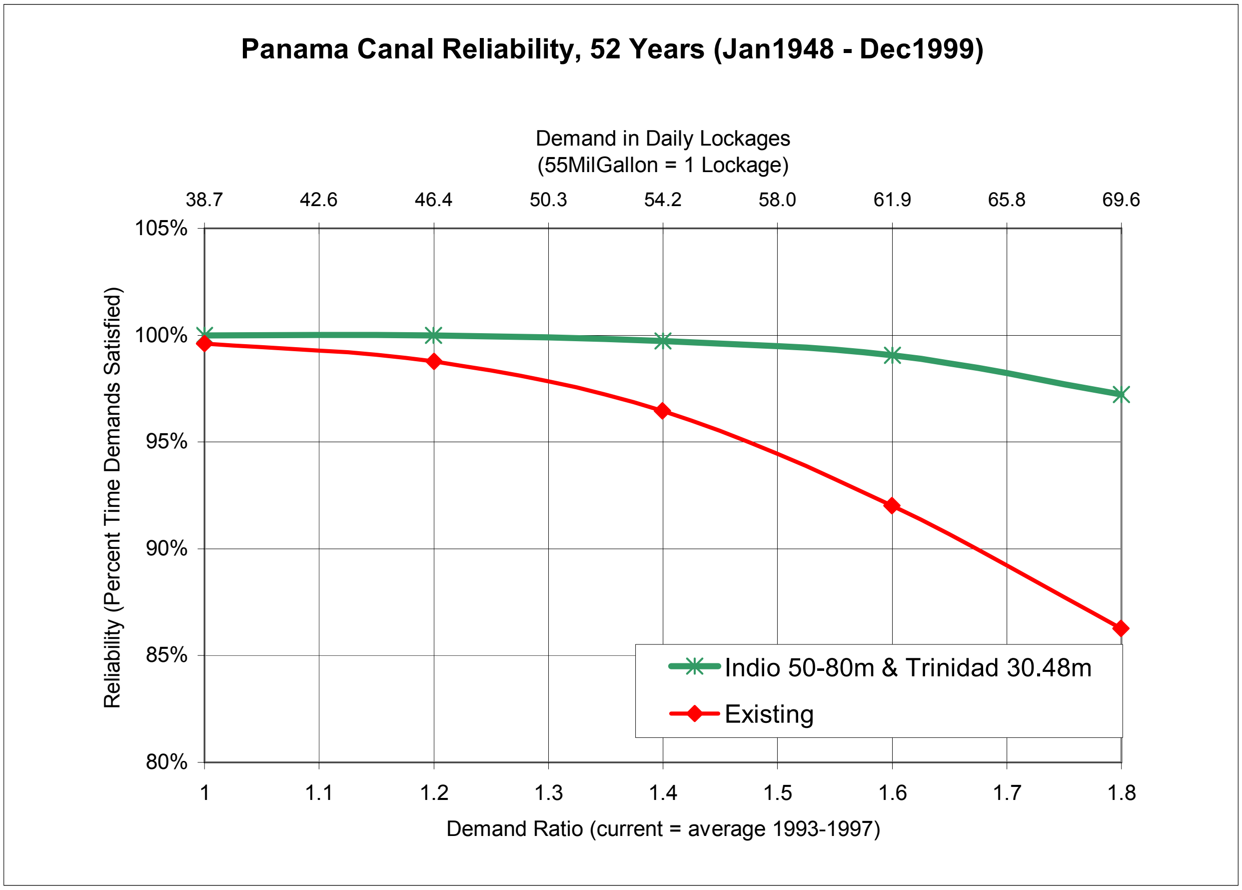


Figure 37 - 4 Panama Canal Hydrologic Reliability

Project Costs

GENERAL

The quantities estimated for the various items of work required for the construction of this project are derived from the layouts shown on Plate 37-2. The unit prices applied to these quantities are based on: historical information from previous estimates prepared for similar construction by the ACP; estimates for similar construction in the Mobile District; information gathered from Mobile District Construction Division personnel in Panama; and the book Feasibility Studies For Small Scale Hydropower Additions, A Guide Manual, written by The Hydrologic Engineering Center of the U.S. Army Corps of Engineers.

Engineering and design is estimated to be 12 percent while supervision and administration is estimated to be 6 percent of the construction cost items. An allowance of 2 percent of the construction cost items is allowed for field overhead (construction camp, contractor facilities, etc.). An allowance of 25 percent is included for contingencies.

FIRST COSTS

The total project first costs are estimated to be $1,057,262,000. Table 37 - 6 provides a summary of the first costs for the principal features. Separate documentation provided to the ACP includes a detailed cost estimate containing the sub-features of the work.

Table 37 - 6 Summary of Project First Costs

	Lower Rio Trinidad	Rio Indio
Item	**Costs ($)**	**Costs ($)**
Lands and Relocations	2,000,000	14,000,000
Access Roads	9,574,000	8,030,000
Clearing and / or Grubbing	556,250	3,566,250
Cofferdam	850,000	4,850,665
Dam	491,824,842	22,723,329
Spillway	8,891,206	43,387,450
Intake	N/A	7,701,295
Saddle Dams	2,143,390	4,241,143
Pumping Station	22,999,637	N/A
Diversion Tunnel	N/A	14,732,944
Interbasin Transfer Tunnel	N/A	11,595,800
Transfer Intake Indio-Gatun	N/A	365,258
Hydropower Plants	N/A	22,118,125
Transmission Lines	2,090,000	6,600,000
Subtotal	540,929,325	163,912,258
E&D, S&A, Field Overhead	108,185,865	32,782,452
Contingencies	162,278,798	49,173,677
Total Project First Cost	811,393,988 Approximately 811,400,000	245,868,387 Approximately 245,868,000

OPERATION AND MAINTENANCE

Staff

A staff should operate and maintain the proposed Lower Rio Trinidad Dam project during the day and then run the facility remotely at night. The full-time staff should consist of a total force of 9, including a station manager, a multi-skilled supervisor, 2 leaders (Electronics/Instrumentation, Electrical/Mechanical), 4 craftsmen and a laborer. A part-time staff would be required for two to three months each year to perform general maintenance and overhaul of the project. The part-time staff may consist of three mechanics and three electricians. The annual staffing costs are estimated to be $350,000. Staff costs for the proposed Rio Indio project are estimated to be $500,000.

Ordinary Maintenance

Ordinary maintenance and care of the project is required and includes minor repair materials, lubricants and other supplies. A cost estimate of ordinary maintenance is $18,000 per year for the access road, and $100,000 per year for the main project facilities. Fuel consumption is estimated at $648,000 yearly. This estimate considers the growth in demand for water over time and the variability of inflows to Gatun Lake, and the proposed Lower Rio Trinidad Dam project. An estimated $150,000 would be needed for rock placement to account for settling of the embankment. The total ordinary maintenance is $916,000 yearly. The ordinary maintenance for the proposed Rio Indio project is estimated to be $320,000.

Major Replacements

The average service life of gates, electrical equipment, pumps, trash racks and other features is less than the total useful life of the project (100 years). To estimate the major replacement costs during the 50-year planning period, it is assumed that specific items should not change in price. No allowance is made for salvageable fixed parts. Table 37-7 lists the service life, number of times each component may be replaced, the future costs of each item, and the present worth of the replacement costs for the major components. Based on these values, the present worth of the proposed replacements is $2,124,500, and the average annual replacement cost is $267,000. The average annual replacement cost for the proposed Rio Indio project is estimated to be $91,000.

Table 38 - 7 Major Replacement Costs

Component	**Service Life** (years)	**Number of Times Replaced During Planning Period**	**Future Costs** ($)	**Present Worth of Replacement Costs** ($)
Roads	50	1	12,435,000	43,000
Bridges	50	1	1,800,000	6,200
Pump Station				
Pumps	25	2	21,006,000	654,200
Sluice Gates	50	1	1,275,525	4,400
Sluice Trash Racks	50	1	458,850	1,600
Electrical Controls	25	2	2,100,000	65,400
Fuel Tanks, etc.	50	1	450,000	1,600
Misc Equip & Comm.	25	2	3,183,000	99,100
Slurry Trench	25	2	39,000,000	1,214,500
Spillway				
Bridge Girders	50	1	365,271	1,300
Tainter Gates	50	1	1,980,000	6,900
Tainter Gate Hoists	50	1	1,320,000	4,600
Tainter Gate Op Sys.	50	1	360,000	1,200
Stoplogs	50	1	475,950	1,600
Misc. Mech. Items	25	2	1,500,000	46,700
Electrical Controls	25	2	1,650,000	51,400
Transmission Lines	50	1	3,135,000	10,800
Total			92,494,596	2,214,500
Average Annual Replacement Costs				267,000

Annual Costs

The project first costs for the proposed Lower Rio Trinidad Dam project are estimated to be $811,400,000. The total project first costs that include the $245,868,000 costs for the Rio Indio Dam project (see Volume One, Section 5) are estimated to be $1,057,262,000. These total project first costs are distributed across the development period using generalized curves for contractor earnings for large, heavy construction jobs. Interest on the proposed Rio Indio Dam project first costs are computed from mid-year throughout the 22-year development period from initiation of Planning and Design until the Lower Rio Trinidad area is filled. Interest during construction for the Lower Rio Trinidad Dam project is computed from mid-year throughout its 12-year development period until lake filling is complete. The interest during construction at 12 percent is $658,745,000 for Lower Rio Trinidad, and $1,222,371,000 for Rio Indio for a total interest during construction of $1,881,116,000. These costs are added to the total project first costs for total project investment costs of $2,938,378,000. A capital recovery factor for the 50-year planning period is applied to get the annual average investment costs of $353,830,000. Annual operation and maintenance costs are added. Major replacement costs are estimated and converted to an annual cost by discounting the future replacement costs of major components of the project back to completion of the project construction. Table 37-8 contains a summary of the $356,274,000 total annual costs.

Table 37 - 8 Summary of Annual Costs

Item	Costs ($)
Total Project First Costs - Lower Rio Trinidad	811,394,000
Total Project First Costs – Rio Indio	245,868,000
Interest During Construction – Lower Rio Trinidad	658,745,000
Interest During Construction – Rio Indio	1,222,371,000
Total Project Investment Costs	2,938,378,000
Annual Average Investment Costs	353,830,000
Operation and Maintenance Costs	
Staff Costs – Lower Rio Trinidad	350,000
Staff Costs – Rio Indio	500,000
Ordinary Maintenance Costs – Lower Rio Trinidad	916,000
Ordinary Maintenance Costs – Rio Indio	320,000
Major Replacement Costs – Lower Rio Trinidad	267,000
Major Replacement Costs – Rio Indio	91,000
Total Average Annual Costs	356,274,000

Annual Benefits

NAVIGATION

The procedures and assumptions used in estimating the benefits are described in Volume One, Section 4. The following paragraphs present the results of the economic investigations for the proposed Lower Rio Trinidad and Rio Indio Dam projects. The 50-year period for the economic analyses of this proposal is 2024 to 2073.

The proposed Lower Rio Trinidad and Rio Indio Dam projects should increase the reliability of water to the total daily number of lockages demanded. Table 37-9 provides the increase in the hydrologic reliability of providing the sum of the demands for both navigation and M&I water supply keyed to years. The hydrologic reliability percentages obtained from the data are used to develop Figure 37 - 4. The 99.6 percent level of reliability for this proposal is used to estimate the water supply benefits for navigation. The net change in reliability is used to estimate the reliability benefits for navigation and M&I water uses.

Table 37 - 9 Panama Canal Hydrologic Reliability
(Based on Period of Record from January 1948 to July 1998)

Current Demand Ratio	Year	Demand in Daily Average Number of Lockages (Navigation and M&I)	Hydrologic Reliability	
			Existing System (%)	With Lower Rio Trinidad and Rio Indio [1/] (%)
1	2000	38.68 [2/]	99.60	100.00
	2010	45.11	98.91	100.00
1.2		46.42	98.76	100.00
	2015	46.82	98.64	99.99
	2020	47.61	98.41	99.96
	2025	48.52	98.14	99.93
	2030	49.55	97.83	99.89
	2035	50.72	97.48	99.85
	2040	52.02	97.10	99.80
	2045	53.49	96.65	99.75
1.4		54.15	96.45	99.73
	2050	55.13	95.89	99.65
	2055	56.98	94.83	99.49
	2060	59.05	93.65	99.31
	2065	61.37	92.32	99.11
1.6		61.89	92.02	99.06
	2070	63.97	90.47	98.57
1.8		69.63	86.27	97.23

[1/] The lake behind the Lower Rio Trinidad Dam should fluctuate from the normal operating lake level at EL. 30.48 m MSL down to the minimum operating lake level at EL. 22.86 m MSL and the lake behind the Rio Indio Dam should fluctuate from the normal operating lake level at EL. 80 m MSL down to the minimum operating lake level at EL. 50 m MSL.

[2/] 2000 Daily Demand is Average of 1993-1997

With the proposed Lower Rio Trinidad and Rio Indio Dam projects, water supply shortages for navigation should continue. The demand for M&I purposes should always be met first. As these demands grow, the amount of water available to meet the demands for navigation should decrease. Thus, the benefits for the additional water supply are estimated at the value for navigation. With the addition of the proposed Lower Rio Trinidad and Rio Indio Dam projects, these shortages would be less frequent. With a hydrologic reliability of 99.6 percent, the project increases the amount of water supplied by approximately 17.29 equivalent lockages. The 99.6 percent hydrologic reliability should occur after the year 2052, with an equivalent daily average number of lockages 55.97. Benefits for these amounts of additional water would be attributable to navigation since the amount of M&I water demanded would be provided first. Therefore, all shortages are attributable to navigation. The benefits are estimated using the toll revenue per lockage and the increased daily average number of lockages. The average annual benefits for water supply are $232,760,000. Table 37-10 (Create link)provides the estimate of daily shortages under the existing system, the remaining daily shortages with the proposed Lower Rio Trinidad and Rio Indio Dam projects in operation, the annual benefits for meeting shortages and the average annual benefits.

Table 37 - 10 Benefits for Additional Water Supply for Navigation

Year	Daily Shortages In Lockages Under Existing System	Remaining Daily Shortages	Annual Benefits For Navigation ($)
2023	9.51	0.00	196,137,742
2030	10.87	0.00	224,201,428
2040	13.34	0.00	275,146,640
2050	16.45	0.00	339,265,866
2060	20.36	3.08	356,474,569
2070	25.29	8.00	356,474,569
Average Annual Benefits			232,760,000
With the Lower Rio Trinidad Dam project operating between 22.86 and 30.48 m and the Rio Indio Dam project operating between 50 and 80 m, the system should provide a total of 55.97 lockages at the 99.6 percent level of reliability or 17.29 more lockages than the existing system.			

With the Lower Rio Trinidad and Rio Indio Dam projects, the reliability of the system to provide all of the water demanded by navigation and M&I water would be improved. Using the increase in hydrologic reliability, the forecast number of vessels converted to a daily average number of lockages, the toll revenue for each average lockage, and a project discount rate of 12 percent, the average annual benefits for navigation reliability attributable to the proposed Lower Rio Trinidad and Rio Indio Dam projects is $18,372,000. Table 37 - 11 provides the forecast daily average number of lockages, the forecast value per daily lockage, the annual benefits for increased reliability, and the average annual benefits.

Table 37 - 11 Average Annual Reliability Benefits For Navigation

Year	Daily Average Number of Lockages	Value Per Lockage ($)	Annual Benefits For Navigation ($)
2023	40.0	2,260,000	14,049,000
2030	40.0	2,260,000	17,008,000
2040	40.0	2,260,000	22,380,000
2050	40.0	2,260,000	30,950,000
2060	40.0	2,260,000	40,792,000
2070	40.0	2,260,000	66,820,000
Average Annual Benefits			18,372,000

M&I WATER SUPPLY

The future demand figure of water supply for M&I purposes is based upon growth in population. The ACP provided a forecast for the area surrounding the Panama Canal. The current usage is estimated at 4.0 equivalent lockages per day (an equivalent lockage is 55 million gallons of water). One equivalent lockage is added to the forecast to account for the burgeoning tourist industry, beginning in the year 2010. The increased reliability of the system to provide water supply for navigation similarly provides the same increase in reliability to provide water for M&I purposes. Using the increased hydrologic reliability of the system with the addition of the proposed Lower Rio Trinidad Dam project, the current costs to the ACP to process finished water ($0.69 per 1,000 gallons), the number of daily lockages demanded, and a project discount rate of 12 percent, the average annual benefits for M&I reliability is $1,002,000. Table 37-12 presents the population forecast, the resulting number of equivalent lockages per day, and the benefits for M&I water supply.

Table 37 - 12 Average Annual Reliability Benefits For M&I Water Supply

Year	Population	Equivalent Lockages per Day	Annual M&I Water Supply Benefits ($)
2023	2,294,000	8.15	1,933,000
2030	2,688,000	9.55	2,732,000
2040	3,384,000	12.02	4,516,000
2050	4,259,000	15.13	7,861,000
2060	5,360,000	19.05	13,050,000
2070	6,746,000	23.97	26,906,000
Average Annual Benefits			3,351,000

HYDROPOWER

The amount of hydropower energy that can be produced by the system of Gatun Lake and Madden Lake should decline over time as the demands for navigation and M&I water supply increase. With the inclusion of the Lower Rio Trinidad project, the system will loose hydropower generation at Gatun Lake and Madden Lake due to the change in the operation of the system. With the inclusion of the Rio Indio Dam project, however, the system can produce additional megawatt hours of hydropower for a net gain in hydropower generation. The value for hydropower energy used in this analysis is $0.070 / kWh. On an average annual basis, the proposed project should have benefits of $3,156,000. The estimated net additional megawatt hours of hydropower generation and the resulting benefits are tabulated in Table 37-13.

Table 37 - 13 Average Annual Benefits For Hydropower Generation

Year	Net Generation [1] (MWh)	Annual Benefits For Hydropower ($)
2023	47,329	3,313,000
2030	45,686	3,198,000
2040	42,786	2,995,000
2050	38,897	2,723,000
2060	33,346	2,334,000
2070	25,650	1,796,000
Average Annual Benefits		3,156,000
[1/] Lose of net generation of Gatun and Madden hydropower plants with the operation of the Lower Rio Trinidad Dam project.		

SUMMARY OF ANNUAL BENEFITS

As shown in Table 37 - 14 , total average annual benefits for the proposed Lower Rio Trinidad and Rio Indio Dam projects would be $257,639,000.

Table 37 - 14 Summary of Annual Benefits

Benefit Category	Average Annual Benefits ($)
Navigation – Water Supply	232,760,000
Navigation – Reliability	18,372,000
M&I – Reliability	3,351,000
Hydropower	3,156,000
Total	257,639,000

To perform an analysis of benefits versus costs, a common point in time is selected. This common point is at the completion of filling of the project, the end of the year 2022. In these analyses, it is important to note that the average annual benefits or average annual costs are the amortized value of the sum of the present worth of either the benefits or costs at the point of comparison. The development sequence for the proposed Lower Rio Trinidad and Rio Indio Dam projects would be to develop the Rio Indio Dam project first (2001 – 2010) and then the Lower Rio Trinidad Dam project (2009 – 2022).

The benefits attributable to the proposed Rio Indio Dam project begin to accrue in 2010 when the reservoir is filled. The operation of Gatun Lake during the construction of the proposed Lower Rio Trinidad Dam project would be the same as described in Volume One, Section 5. The Rio Indio Dam project benefits for the period 2011 to 2022 is escalated by the project discount rate, 12 percent, in order to estimate the total present worth of $4,446,416,000 in the year 2022. The average annual benefits for the proposed Rio Indio Dam project accruing during the construction of the proposed Lower Rio Trinidad Dam project are estimated to be $535,423,000.

To estimate the interest during construction, similar calculations are made for the costs of each proposed project. For the proposed Rio Indio Dam project, interest during construction is taken from year 2001 to year 2022 and the interest during construction for the proposed Lower Rio Trinidad Dam project is from the year 2009 to the year 2022.

The sequence of development of the two projects is crucial to the estimate of average annual benefits and costs. If the Lower Rio Trinidad Dam project is developed first, then the average annual costs double in size and the average annual benefits reduce to less than half of the values that are estimated for the development sequence of Rio Indio and then Lower Rio Trinidad. This occurs because the first costs for the Lower Rio Trinidad Dam project are four times the cost for the Rio Indio Dam project ($812M vs. $245M). The estimate of interest during construction changes from approximately $4B to $2B. Likewise, the Rio Indio Dam project provides approximately 80 percent of the total average annual benefits of the combined projects ($212M of $258M). The estimate of benefits for the first project during the period of construction of the other project changes from $150M to $600M.

Total average annual benefits and average annual costs were then estimated, and the ratio of benefits to costs and the net benefits (net of costs) are computed. In the first instance, the analysis determines the feasibility of the proposal. The net benefits determine which proposal among several provides the greatest value for the investment dollars. Table 37 - 15 provides the benefit to cost ratio and the net benefits.

Table 37 - 15 Economic Evaluation

Item	Value ($)
Average Annual Benefits	
Lower Rio Trinidad	257,639,000
Rio Indio	535,423,000
Total Average Annual Benefits	793,062,000
Average Annual Costs	
Lower Rio Trinidad	178,562,000
Rio Indio	177,712,000
Total Average Annual Costs	356,274,000
Benefit to Cost Ratio	2.2
Net Benefits	436,788,000

Internal Rate of Return

An internal rate of return analysis for this proposed project was performed. To accomplish this analysis, the annual construction costs are used as the investment, and the undiscounted benefits are used as return cash flows. The internal rate of return would be 24.3 percent.

Socio-Economic Impacts

The description of the environmental setting is based on field observations made while conducting field reconnaissance throughout Gatun Lake, specifically the Lower Rio Trinidad and Rio Indio areas with ACP personnel. Autoridad Nacional del Ambiente (ANAM), ACP, Asociacion Nacional para la Conservacion de la Naturaleza (ANCON), Electrical Transmission Agency, Smithsonian Tropical Research Institute (STRI), and Directorate of Mineral Resources personnel were interviewed to gain information on site characteristics and potential activities that could affect the project. In addition, extrapolations of the 2000 census data were used, and a review of the Informe de Cobertura Boscosa 1992 were used to determine the extent of forest cover.

Environmental Setting

This alternative combines three projects, the Lower Rio Trinidad (lake level 22.9 - 30.5 m) and Rio Indio (lake level 50 - 80 m). This project will provide additional storage of water for Gatun Lake and 17.29 additional lockages per day on a continual basis. The project area consists of 19,613 ha within Gatun Lake and 5,600 ha within the Rio Indio watershed. The area near Gatun Lake is sparsely populated and has a topography consisting of rolling hills, low regions near Gatun Lake. Near Rio Indio, the area is sparsely populated with terrains and a topography consisting of steep hills as well as coastal regions. The Lower Rio Trinidad and Rio Indio are west of the Panama Canal and flows northward from the Continental Divide into Gatun Lake. The watershed above Lower Rio Trinidad and the Rio Indio dam projects covers approximately 741 km^2.and 381 km^2respectively. The incremental impoundment area which covers approximately 3,968 consists of approximately 50 percent of forested land, 30 percent of pasture land (used by ranchers), 10 percent of cropland, and 10 percent of newly slashed and burned land. Gatun Lake's normal pool level is 26.7 m. The lake level during field observations (August 2001) was approximately 25.4 m.

LAND USE

The Lower Rio Trinidad project area encompasses the southwestern portion of Gatun Lake and areas along its shores. The areas to be flooded or partially flooded include the village of Escobal (population – 1,653), Nuevo Provenir (population – 121), Cuipo (population – 249), Ciricito (population – 72), La Arenosa (population – 242), La Garterita (population – 138), La Gartera (population – 348), and a few small isolated developments.

Some areas along the shores of the Lower Rio Trinidad have been deforested. Approximately 65 percent of the lakeshore areas are forested, mostly with secondary growth. Farms and ranches of various sizes as well as plantations of teak and African mahogany occupy the remaining land. Farm crops include maize, rice, beans, sugar, coffee, mangos, pineapples, and tobacco. Ranchers raise cows, horses, chickens, hogs, and tilapia. Some of the farmers and ranchers operate commercial enterprises, others rely on cash crops and subsistence farming. No significant ore deposits or mineral resources are located in the project area.

Approximately 2,300 people inhabits the Rio Indio project area; they live in the towns of Tres Hermanas (population – 200), Los Cedros (population – 80), El Coquillo (popoulation – 150), El Limon (population – 140), Los Uveros (population – 140), and La Boca de Uracillo (population – 110), and in nearly 30 smaller settlements. Downstream from the dam site at El Limon there are 14 communities with a combined population of approximately 600. The largest of these is La Boca del Rio Indio with a population of more than 150.
Farms and ranches of various sizes, as well as some teak plantations, occupy approximately 60 percent of the land in the Rio Indio project area. Farm crops include maize, rice, beans, sugar, coffee, and tobacco. Ranches raise horses, cows, chickens, and hogs. Some of the farmers and ranchers run small commercial enterprises, or rely on cash crop and subsistence farming.

INFRASTRUCTURE

During site investigations in the Lower Trinidad area, the town of Escobal was the largest settlement visited. Escobal has businesses, schools, churches, cemeteries, medical centers, residences, and paved roadways of good condition. A new and improved roadway (Highway 35) is adjacent to the project area near Escobal. Other establishments in the project area - Nuevo Provenir; Cuipo; Ciricito; La Arenosa; La Garterita; La Gartera - and a few small isolated establishments have elementary schools, small cemeteries, churches and meeting centers, medical clinics, and a few small businesses (i.e. general stores). The towns and villages depend on Gatun Lake or groundwater wells for their potable water supply. Each community also had docks, small ports, and other boat access facilities. Goods are transported from one town to another by boat. No treatment of community waste is provided. Wastewater from showers and washing is discharged into the environment; some of it may eventually reach the Lower Rio Trinidad portion of Gatun Lake. Disposal of domestic waste is the responsibility of individual homeowners; some homes have septic tanks, while others have an outdoor latrine (a hole in the ground). There are some health problems, such as hepatitis, dysentery, dermatitis, intestinal parasites, and respiratory illnesses, which are attributable to the present waste disposal methods. No major industries or poultry or beef processing plants are located in the project area. The project area is traversed by unpaved horseback riding trails that link the various communities and by unpaved roads used by the ACP for maintenance. Because of the relatively isolated location of the project area, these roads are extremely important to the residents for transportation, community cohesion, commerce, and communication with neighboring communities.

In the Rio Indio project area, towns of El Limon, El Silencio, San Cristobal, and Piedra Amarilla have elementary schools. Several towns have cemeteries, churches, and medical centers. All these towns obtain water from rivers or groundwater wells. Some have electricity (from small generators) and limited telephone service. No treatment of community waste is provided.

Wastewater from showers and washing is discharged into the environment; some of it might eventually reach Rio Indio and its tributaries. Disposal of domestic waste is the responsibility of individual homeowners; each home has an outdoor latrine. There are some known health problems, such as hepatitis, diarrhea, dermatitis, intestinal parasites, and respiratory illnesses which are attributed to the present waste disposal methods. No known major industries or poultry or beef processing plants are located in the project area. The only roads in the project area are unpaved and poorly maintained, and are usable only in the dry season (mid-December through March). The roads are rarely graded and receive little attention from either the Ministry of Public Works or the local government. Because of the relatively isolated location of the project area, these roads are extremely important to the residents for transportation, community cohesion, commerce, and communication with neighboring communities.

TERRESTRIAL HABITAT

The terrestrial habitat in the Lower Rio Trinidad project area of Gatun Lake consists of tropical forest ecosystems, mostly secondary growth forests with patches of primary forest. About 65 percent of the land along the Lower Rio Trinidad of Gatun Lake is forested and probably supports diverse wildlife populations. The Lower Rio Trinidad areas of Gatun Lake also contain islands inhabited by wildlife. Some of the wildlife species do not interact with species on the mainland; others migrate between the island and the mainland. The species interrelationships are of great interest to scientists studying tropical ecosystems. Slash and burn activities have opened tracts of land for farming and cattle grazing; however, the majority of the lakeshore is forested to the edge of the water. Terrestrial areas are used by migratory species as wintering, breeding, and feeding grounds. The complex and diverse tropical ecosystems offer habitat to connect a variety of wildlife communities and may provide critical wildlife habitat to many native species.

In Rio Indio, forests along the river that could support diverse wildlife populations cover about 90 percent of the areas along the Rio Indio and its tributaries. The forests also extend to the mountainous areas above the Rio Indio impoundment. As a result of slash and burn activities, there are no large contiguous tracts of forests at lower elevations in the impoundment.

ANIMALS ON ENDANGERED LIST

ANAM, Resolution 002-80, enacted on June 7, 1995, declared 33 mammals, 39 birds, and 11 reptiles and amphibians as being in danger of becoming extinct in Panama. Although their presence has not been confirmed to date, some of the species on the threatened list might be found in the project area. The manatee is an aquatic mammal known to inhabit Gatun Lake around the Barro Colorado Island; however, it has not been sighted in the project area.

AQUATIC HABITAT

Gatun Lake, one of the world’s largest manmade lakes, was created during the construction of the Panama Canal. The lake’s water depth and quality vary widely. Aquatic habitat ranges from inundated forests to clear water in areas distant from shipping lanes. The Lower Rio Trinidad areas of Gatun Lake provide habitat for a variety of wildlife species, both resident and migratory, as well as for both native and introduced fish and other aquatic species.

Rio Indio in the project area has characteristics typical of streams in mountainous regions. Its water is clean and cool, and its bottom ranges from sand to boulders, with numerous riffles, runs, and pools. Tributaries to Rio Indio include four major streams: Rio El Torno, Rio Uracillo, Rio Teria, and Rio Riacito, and 20 smaller streams. The river is approximately 16 km long, its width ranges from 3 m (in the dry season) to 10 m. The tributaries appear to support some fish communities; however, information about these is limited.

WETLANDS

Areas that contain hydric soils and hydrophytic plant communities, and that are subject to hydric conditions are termed wetlands. Wetlands occur in topographic areas where water remains pooled long enough to produce hydric soil conditions and wetland plant communities. Wetlands in the Lower Rio Trinidad project area consist of shallow water habitat and lands subject to frequent flooding. Shallow water areas along the banks of the Lower Rio Trinidad area of Gatun Lake receive sunlight to approximately 1 m. Sunlight stimulates growth of submergent, emergent, or floating mats of aquatic vegetation. Wetlands in the project area are stressed as a result of sediments, municipal waste, agricultural runoff, and other debris carried in the runoff.

Wetlands in the Rio Indio project area consist of forested riparian habitat and are limited by their relatively steep topography. The width of the riparian habitat within the impoundment area varies from approximately 5 to 50 m. Approximately 90 percent of the streams both above and below the dam site along the Rio Indio and its tributaries are bordered by forested riparian habitat.

AIR QUALITY

Air quality in the project area is generally good, except during the slash and burn activities. At the end of the dry season in March or early April, areas of forest and secondary growth are burned and cleared for agricultural use. During this period, the air is filled with smoke and ash, which may be transported by winds to the Lower Rio Trinidad area of Gatun Lake. Based on observations in the Rio Indio project area, approximately 10 percent (or 400 ha) of forested land is burned annually. Air quality monitoring has not been implemented within the project area.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

Barro Colorado Island is an international center for tropical research and one of the first biological reserves established in the Neotropics. From 1923 through 1940, a scientific committee of the U.S. National Academy of Sciences administered the biological reserve/laboratory. In 1940, by an Act of the United States Congress, the facility was renamed the Panama Canal Zone Biological Area, and in 1946, the responsibility for its maintenance was assigned to the Smithsonian Institution. With the Panama Canal Treaty Implementation in 1977, the island was granted the category of National Monument and to date it continues to be managed by the Smithsonian Institute. It should also be noted that most of the Atlantic region of Panama is within the interest and objectives of the Mesoamerican Biological Corridor, an international project to conserve biodiversity.

In the pre-Columbian period, Rio Indio was a language frontier; that is, the inhabitants on each side of the river spoke a different native language. During the Spanish colonial period, the river served as a political boundary; thus, the project area has a high potential to be rich in archaeological and historical remains.

Environmental Impacts

TERRESTRIAL HABITAT

The impacts of the project on terrestrial habitat in the Lower Rio Trinidad area of Gatun Lake could be substantial. The boundary between two types of habitats, in this case between a forest and a lake, is called an ecotone. Ecotones are inhabited by a variety of species from neighboring habitats, and are unique, with high species diversity. Considering the proposed operating levels for both impoundments, between 22.9 - 30.5 m, as the normal zone of operation, erosion of the shoreline may be substantial as pool levels rise and fall. Terrestrial habitat that would be inundated above the 26. 7 m (existing level) to the 30.5 m proposed normal pool level consists of 18,169 ha for the Lower Rio Trinidad project. The placement of a dam structure, access roads, and pump stations would permanently impact terrestrial habitat. Wildlife species that are able to relocate to suitable areas will compete with similar species for resources. Wildlife species that are not able to relocate will not survive. As a result, competition for natural resources in surrounding habitat areas will increase. This is considered a secondary impact to terrestrial habitat outside the proposed zone of inundation and construction.

The terrestrial impacts of the Rio Indio project, which is located in area of relatively high quality forest habitat, would be substantial. With the creation of the lake, the migratory routes of some species could be adversely affected. Forested areas along lower elevations would be lost as a result of the impoundment. The only forests that would remain near the Rio Indio reservoir and its drainage basin would be confined to the higher elevations, where the vegetation and species may be completely different from those found on lower elevations. Natural communities are linked together by complex interactions and relationships among various species, therefore impacts to upper forested areas may occur resulting from the inundation of the lower forests.

ANIMALS ON ENDANGERED LIST

The severity of impacts on endangered species cannot be determined at this time, because although it is expected that some of the listed species are found in the region, it is not known which of the listed species inhabit the proposed project area. Some endangered and/or threatened species may use the Lower Rio Trinidad areaa of Gatun Lake during some or all parts of their life cycle.

WATER QUANTITY

The impacts of the Lower Trinidad project on water quantity would be substantial. The increase in the volume of water could have negative impacts to lakeshore communities as well as on existing ecosystems. The same is true if the lake level is lowered and maintained at 22.9 m.

The impacts of the Rio Indio project area on water quality would also be substantial. The volume of water will increase, making fresh water available in the surrounding areas during the dry season. The impacts downstream from the dam would be significant. Sediment loads would be deposited upstream from the dam as water velocity slows. Downstream from the dam the water will be released at an increased velocity, causing erosion of banks and river bottoms. Seasonal flooding could be significantly reduced. It would also be possible to periodically release water in appropriate amounts to avoid problems with water quality and temperature downstream. The cumulative impacts downstream from the dam site depend on the amount of water being released.

WATER QUALITY

Project impacts on water quality are not known. Damming the Lower Rio Trinidad could increase the amounts of nutrients and debris in this portion of Gatun Lake. A pilot plant tilapia farm is in the project area and may affect water quality. The rate at which nutrients and debris enter the lake will determine the severity of the impact on water quality. Project implementation could cause an increase in turbidity, which would interfere with photosynthesis and deprive plants and other aquatic species from sunlight. Aquatic plants and organisms serve to maintain water quality. The dam would interfere with the circulation of freshwater throughout the Gatun Lake environment. Species inhabiting specific depths could be impacted when lake depth increases to 30.5 m and/or decreases to 22.9 m.

The impacts of the Rio Indio project on water quality could be positive. The people living downstream from the dam and around the impoundment would have access to a water supply of higher quality. Water quality in the impoundment area would differ from water released downstream from the dam. If the water in the impoundment area does not circulate or turn over periodically, it could become anoxic. A change in temperature, dissolved oxygen, turbidity, or pH could change water quality.

DOWNSTREAM AQUATIC FAUNAL HABITAT

The impacts of the project on aquatic faunal habitat could be substantial. The project may affect the breeding and nursery habitat of many aquatic species. Impacts to fish spawning areas may be detrimental when turbidity, nutrient content, and depth of the water suddenly increase or decrease, by altering the conditions needed for a successful fish hatch. Plant populations may decrease as a result of fluctuating water depths, clarity, and quality. Invertebrate populations may decline, which could reduce the food supply for fish and other aquatic species.

Impacts to downstream aquatic faunal communities in the Rio Indio project area could be substantial, because the dam structure will prevent their migration throughout the riverine habitat. The dam structure would be designed for multi-level releases to maintain a water level downstream from the dam site. The dam should act as a large sediment trap; thus, the released water would have low turbidity, which would result in better visibility and increased predation on the fish species. Aquatic faunal habitats downstream would be deprived of the beneficial nutrients and silts that were transported in the sediment. Native riverine fish species may be negatively impacted as a result of the project; the extent of the impact is not known.

FUTURE LAKE AQUATIC PLANT COMMUNITY

The impacts of the project on future aquatic plant communities depend on water quality and stability of water levels. Plant species in the Lower Rio Trinidad portion of Gatun Lake could be impacted by fluctuating water levels. Aquatic plant communities could be impacted during project implementation; however, they could re-establish themselves after conditions stabilize.

The severity of impacts from the Rio Indio project will depend on water level fluctuations. Since water levels are anticipated to fluctuate widely, large portions of the shores would be covered with mud, where neither aquatic nor terrestrial plants could thrive.

AQUATIC FAUNA INHABITING AFFECTED AREAS

The proposed project impacts could have some unavoidable, adverse environmental impacts on aquatic fauna in the Lower Rio Trinidad and associated rivers and tributaries. These impacts should be identified and minimized with appropriate mitigation measures to be discussed in a feasibility level study. Gatun Lake has populations of peacock bass and tilapia, both introduced species that have adapted well. However, several native riverine species that formerly occupied the impoundment have disappeared.

The impacts of the Rio Indio project on aquatic fauna in the Rio Indio and its upstream tributaries could be substantial, since the habitat area would change from riverine to lacustrine. Some aquatic species would continue to inhabit the area; however, non-native fish species would become dominant in the impoundment area and native riverine species would be pushed upstream or extirpated. Other manmade lakes in the Republic of Panama have been stocked with peacock bass and tilapia, both of which have adapted well. The impoundment area would probably be stocked with these species to promote sport fishing and to provide the local communities with fish for food.

WETLANDS

The impacts to wetlands could be significant. Inundation of wetlands could cause them to become aquatic habitat. The changes in water depth caused by the project may lead to increased or decreased sedimentation and turbidity which could hamper the biological processes in the wetlands and decrease their productivity. Such impacts could be detrimental to the health and sustainability of the Lower Rio Trinidad area of Gatun Lake. Fish and other aquatic species use shallow water areas as spawning grounds as well as habitat for their juvenile aquatic species, that survive in the shallow waters of the wetlands until they are large enough to venture into deeper water. These wetlands are vital to the sustainability of this portion of Gatun Lake, including the Lower Rio Trinidad area.

The impacts to wetlands both upstream and downstream from the Rio Indio project area could be significant. Owing to the topography of the project area, a number of wetlands could be impacted. It is possible that although the reservoir level will fluctuate, new wetlands could develop in the littoral zones. Downstream from the dam site, wetlands along the minimal flow zone would survive; however, wetlands that depend on seasonal flooding for survival may be adversely affected.

AIR QUALITY

During project implementation, emissions from construction equipment, as well as from the slash and burn activities could cause deterioration of air quality. After project implementation, the air quality may be impacted by the operation of the power generation facility and the pumping stations.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

The potential impacts on cultural resources and historic properties from the Rio Indio project can be defined and mitigated, in particular, in the La Boca de Uracillo area, which is near previously identified archaeological sites. The project area is relatively large and is known to contain pre-Columbian sites; therefore, the presence of cultural resources and historic properties is highly probable. Prior to construction, surveys to locate cultural resources and historic properties would be conducted, and the important sites would be preserved or salvaged as appropriate.

SOCIO-ECONOMIC IMPACTS

The socio-economic impacts of the project could be substantial. The relocation of the towns and other small communities along the lakeshore would be an important issue. The average monthly income of families in the project area ranges from less than $100 to $200 per month. No indigenous groups are known to reside in the impact area. Land use would be greatly impacted by the inundation of pastures and agricultural lands to expand the impoundment. The relocation of agricultural and ranching activities would be an important issue, because approximately 10 percent of the land in the impoundment area is used for farming and ranching. After the water level is raised, additional agricultural land could be lost as a result of creation of islands that were once isthmuses. The incremental surface area of the proposed Lower Trinidad lake is 3,968 ha; another 1,066 ha from the Lower Trinidad project and 760 ha from the Rio Indio project will be occupied by the dam and construction areas, including permanent disposal areas.

During construction, the influx of workers could create a temporary demand for additional housing, which could result in an increase in housing values near the dam site. However, after completion of the project, the workers could leave, the housing demands could drop, and the housing values could return to pre-construction levels. Currently, all residents have access to public schools and health centers. During construction, these services should continue to be available, and additional public and community services may be offered. After construction, these services would return to the normal level.

To construct the dam, some existing roads would be improved and some new roads would be built. However, some paved and unpaved roads within the impoundment area would be eliminated, which would change traffic patterns and could cause some communities to lose overland transportation, communication, cohesion, and commerce with other communities. During construction, the traffic volumes over both new and existing roads systems would increase; however, following completion of construction, the traffic volumes could decline. Noise levels would temporarily increase during construction and could negatively impact noise-sensitive receptors, however, after construction noise levels may remain elevated as a result of the power generation facility and pump stations.

The communities that receive people displaced by the project could be negatively impacted by overcrowding and by competition for jobs, land, and working areas. Construction of the dams would permanently displace people and disrupt community cohesion through the division of communities, separation of families, and loss of livelihood. Following completion of the impoundment, tourism trade in the affected region, including sport fishing and ecotourism, could increase.

Additional Environmental Information Required

This section identifies the subject areas for which additional data are required to evaluate in further detail, the scope and magnitude of the potential effects of the Lower Rio Trinidad and Rio Indio alternative. The subject areas are discussed by impact category.

SOCIO-ECONOMIC IMPACTS

- Conduct a SIA. The SIA would consist of three tasks: scoping, assessment, and mitigation and monitoring. The following information should be developed:
    - Business, Industrial, and Agricultural Activities;
    - Employment;
    - Land Use;
    - Property Values;
    - Public and Community Facilities and Services (including utilities and schools);
    - Transportation;
    - Housing;
    - Health (vector routes);
    - Population;
    - Community Cohesion; and,
    - Recreational Resources.

TERRESTRIAL AND AQUATIC HABITAT

- Prepare site-specific habitat maps to ensure that the major types of aquatic habitat are identified and quantified.
- Conduct field studies to locate rare and unique habitats such as wetlands, primary forests, roosting sites, foraging areas, old growth, and migration flyways.
- Determine the present quality and ecosystem value of existing habitats within the Gatun Lake project area.
- Coordinate with local experts to identify and evaluate aquatic and terrestrial habitat areas.
- Prepare species inventory lists for each site area, identifying their status as native or exotic and whether they are threatened and/or endangered species.
- Conduct additional research into water currents and estimated turbidity levels to evaluate impacts to the shallow areas along Barro Colorado Island.
- Address cumulative effects caused by natural flow diversions.

ANIMALS ON THE ENDANGERED LIST

- Compile habitat maps to assess the availability and quality of suitable habitats for the animals on the endangered and/or threatened species list.
- Establish field methodology to assess wildlife habitat values.
- Conduct site surveys to determine the presence of selected species or their habitats.
- Develop candidate mitigation measures for the appropriate project alternatives to be considered in the Conceptual Phase.
- Coordinate with local experts on the presence of endangered species.

WATER QUALITY

- Since limited water quality data are available for the Gatun Lake area, compile information on total suspended solids, conductivity, total dissolved solids, dissolved oxygen, nutrients, pH, and coliform bacteria.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

- Information regarding cultural resources and historic properties in the project area is incomplete. Additional evaluation studies should be completed to identify any such resources and/or properties.

Evaluation Matrices

Table 37 - 16 Developmental Effects

Evaluation Criteria	Function	Measure [1/]	Importance [2/]	Composite [3/]
Water Contribution (Water Yield)	Meets M&I Demands	10	10	100
	Supplements Existing System	10	10	100
	Satisfies Future Canal Needs/Expansion	0	10	0
	Additional Hydropower Potential	1	5	5
Technical Viability	Design Constraints	2	6	12
	Feasibility of Concept	2	6	12
Operational Issues	Compatibility	8	6	48
	Maintenance Requirements	4	2	8
	Operational Resources Required	4	2	8
Economic Feasibility	Net Benefits	10	9	90
Total				383

[1/] Measure - A numerical from 0 to 10 value representing the degree or level the alternative satisfies the criteria. Value of 10 indicates the most significant beneficial impact and 0 the most significant adverse impact.
[2/] Importance - A weighting factor from 0 to 10 to balance the significance of a criteria to the others.
[3/] Composite - the product of the measure and importance.

Table 37 - 17 Environmental Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Terrestrial Habitat	3	8	24
Animals on Extinction List	2	10	20
Water Quantity Impacts – Lake	8	10	80
Water Quantity Impacts – Downstream	4	7	28
Water Quality	5	10	50
Downstream Aquatic Fauna Habitat	3	8	24
Future Lake Aquatic Plant Community	6	8	48
Aquatic Faunal Inhabiting Affected Area and Upstream Tributaries	4	5	20
Potential for Fishing on Lake	6	6	36
Wetlands	3	4	12
Air Quality	5	3	15
Cultural Resources and Historic Properties	3	10	30
Total			387

[1/] Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
[2/] Importance - 1 to 10 increasing in importance.
[3/] Composite - the product of the measure and importance.

Table 37 - 18 Socio-Economic Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Land Use	1	7	7
Relocation of People	2	10	20
Relocation of Agricultural/Ranching Activities	2	6	12
Post-Construction Business	6	5	30
Post-Construction on Existing Employment	6	5	30
Property Values During Construction	7	4	28
Property Values Post-Construction	5	5	25
Public/Community Services During Construction	6	4	24
Public/Community Services Post-Construction	5	8	40
Traffic Volumes over Existing Roadway System During Construction	3	5	15
Traffic Volumes over New Roadway System Post-Construction	5	5	25
Noise-Sensitive Resources or Activities	4	4	16
Communities Receiving Displaced People	1	8	8
Community Cohesion	1	8	8
Tourism	6	5	30
Total			318

[1/] Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
[2/] Importance - 1 to 10 increasing in importance.
[3/] Composite - the product of the measure and importance.

Pertinent Data

Table 37 - 19 presents pertinent data for the proposed Lower Rio Trinidad Dam project.

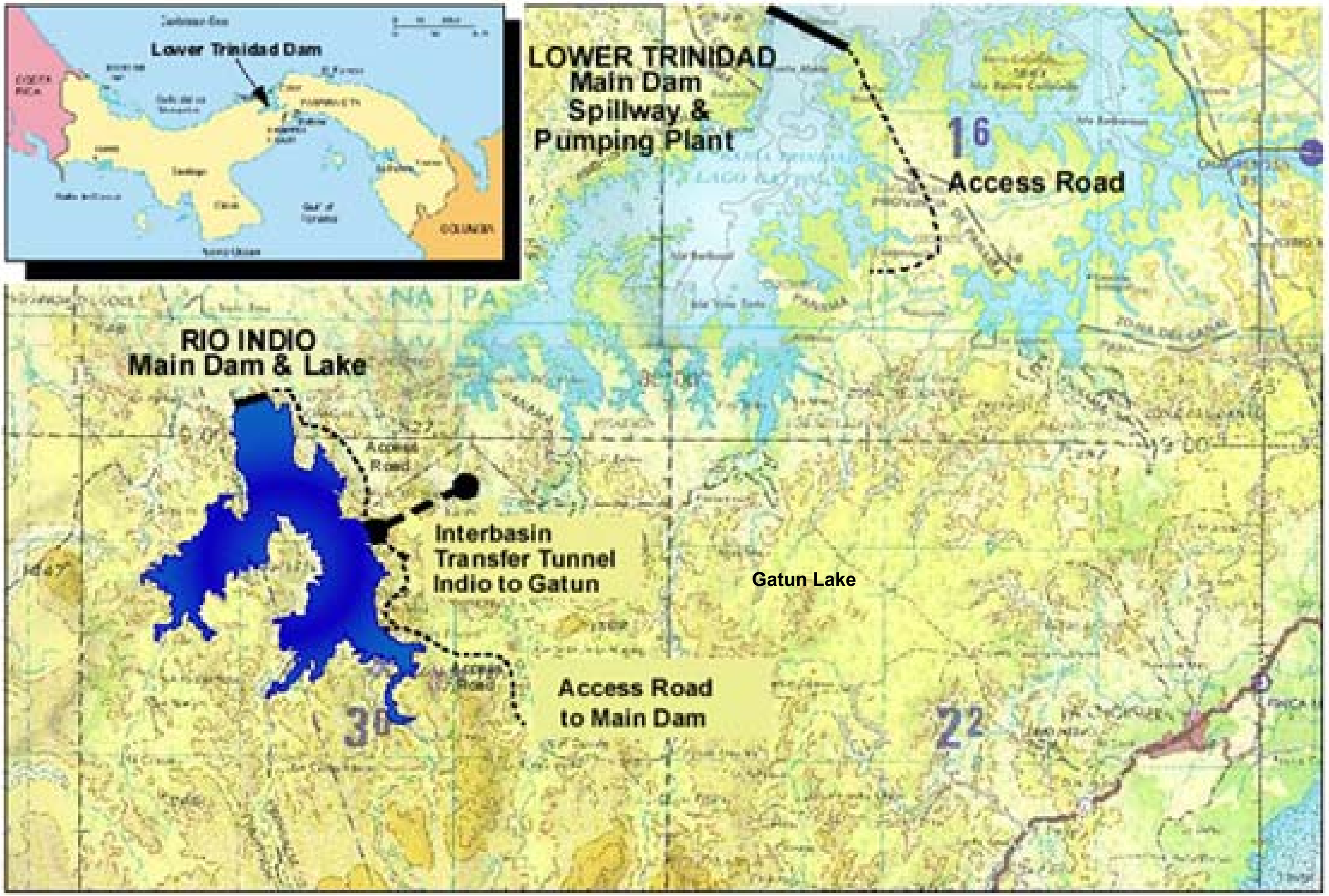
Table 37 - 19 Pertinent Data for Operating Scenario 2

GENERAL	**Gatun**	**Trinidad**	**Rio Indio**
Dam Site, above Gatun Dam		10 km	
Drainage Area above Dam Site	2597.5 km^2	741 km^2	381 km^2
Average Annual Flow at Dam Site	60 CMS	30 CMS	25 CMS
LAKE			
EL. of Maximum Operating Lake Level	26.67 m MSL	30.48 m MSL	80 m MSL
EL. of Maximum Flood Storage Lake Level	26.74 m MSL	31.09 m MSL	82.5 m MSL
EL. of Minimum Operating Lake Level	25.91 m MSL	22.86 m MSL	50 m MSL
Useable Storage between Max. and Min. levels	214.1 MCM	1139.5 MCM	993 MCM
Area at Maximum Operating Lake Level	29,410 ha	18,169 ha	4,280 ha
Area at Maximum Flood Storage Lake Level	29,775 ha	18,835 ha	4,440 ha
Area at Minimum Operating Lake Level	28,987 ha	9,019 ha	2,360 ha
Top Clearing EL.	30.5 m MSL	30.48 m MSL	80 m MSL
Lower Clearing EL.	22.9 m MSL	22.9 m MSL	50 m MSL
EMBANKMENTS			
Dam – Rock Fill Embankment			
Top EL. of Dam	32 m MSL	31.5 m MSL	83.5m
Fixed Crest Width	13 m	13 m	13m
Height above Lowest Foundation	15 m	25 m	73.5m
Overall Length of Dam	varies m	4473 m	891m
SPILLWAY			
Type of Spillway	Gated Ogee	Gated Ogee	Uncontrolled Ogee
Number of Gates	14	11	-
Width of Gates	13.72 m	18.33 m	-
Net Length	192.02 m	201.17 m	-
Total Length	246.27 m	237.75 m	120 m
EL. of Crest	21.03 m MSL	25.91 m MSL	80.0 m MSL
Maximum Discharge	5150 CMS	3794 CMS	920 CMS

RIO INDIO ONLY	
INTER-BASIN TRANSFER TUNNEL	
Tunnel diameter	3 m
Tunnel length	5.2 km
Inlet invert	60 m MSL
Outlet invert	40 m MSL
Tunnel capacity	37.1 CMS
HYDROPOWER PLANTS	
Dam	
Type of hydropower plant construction	Reinforced concrete
Number of units	2
Capacity of each unit	12.5 MW
Inter-basin Transfer Tunnel	
Type of hydropower plant construction	Reinforced concrete
Number of units	1
Capacity of unit	5 MW
CONSTRUCTION / POWERHOUSE DIVERSION	
Diversion length	1,500 m
Horseshoe tunnel dimensions	8 m X 8 m
Inlet invert	10 m
Outlet invert	7 m
MINIMUM FLOW CONDUIT	
Conduit diameter	1.2 m
Conduit length	800 m
Inlet invert	10 m
Outlet invert	8 m
Conduit capacity	2.5 CMS
EMBANKMENTS	
Dam	
Type of dam	Rock fill embankment
Top EL. of dam	83.5 m
Fixed crest width	13 m
Height	73.5 m
Overall length of dam	891 m
Saddle dam (North)	
Type of saddle dam	Earth / rock fill embankment
Top EL. of saddle dam	83.5 m MSL
Fixed crest width	13 m
Overall length of saddle dam	255 m
Saddle dam (South)	
Type of saddle dam	Earth / rock fill embankment
Top EL. of saddle dam	83.5 m MSL
Fixed crest width	13 m
Overall length of saddle dam	272 m

Plate 37 - 1 Project Location Map

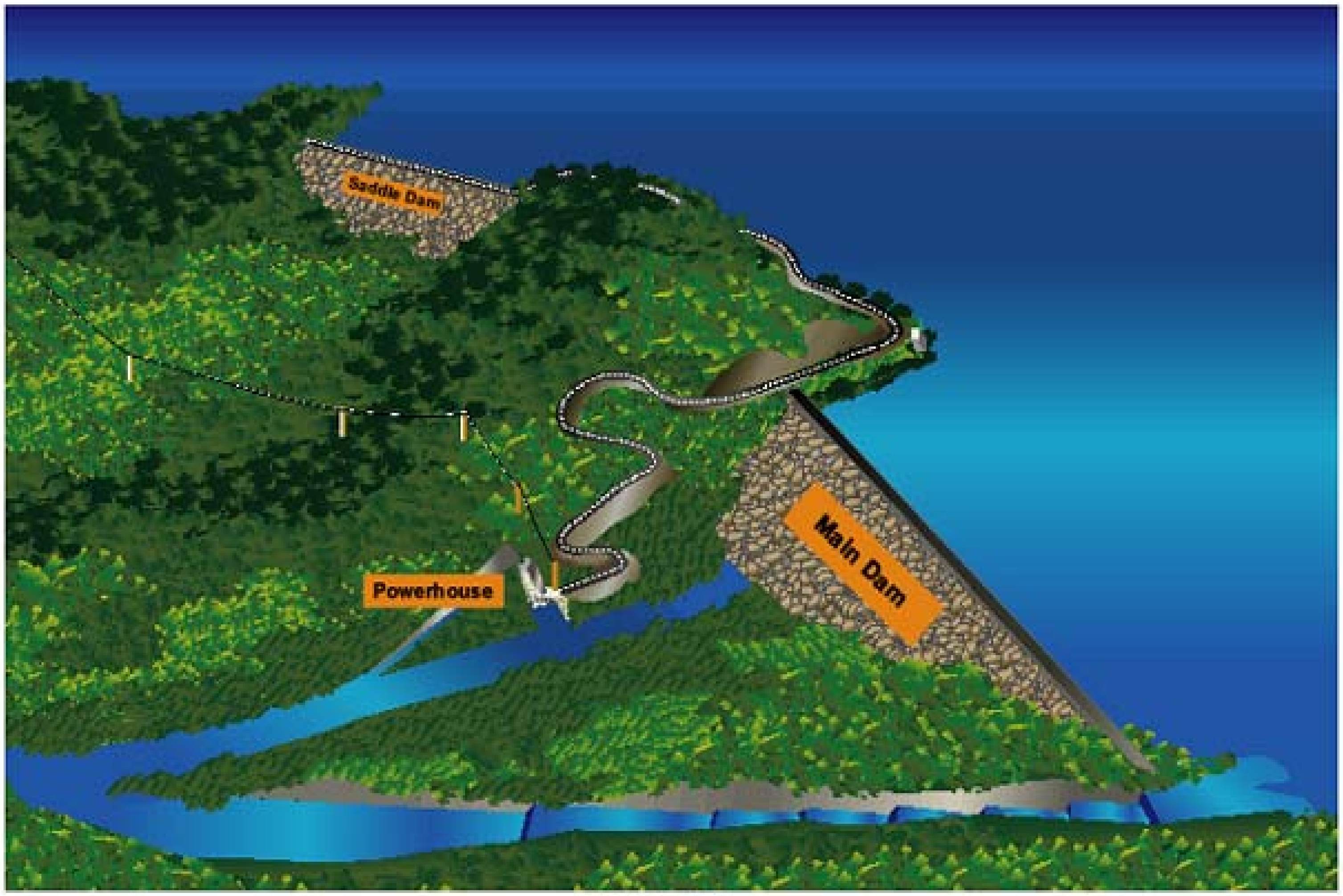
LOWER TRINIDAD / RIO INDIO



Project Location Map

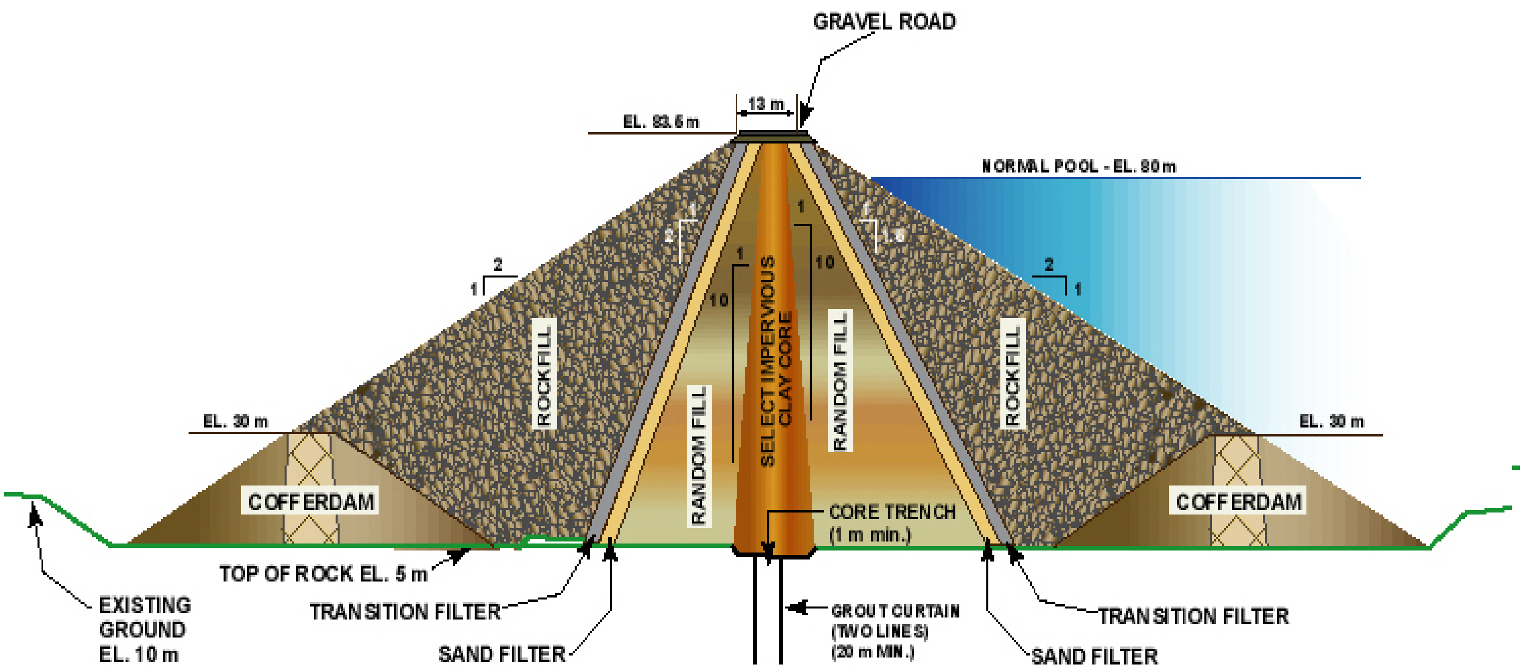
Plate 37 - 2 Site Plan

RIO INDIO



Site Plan

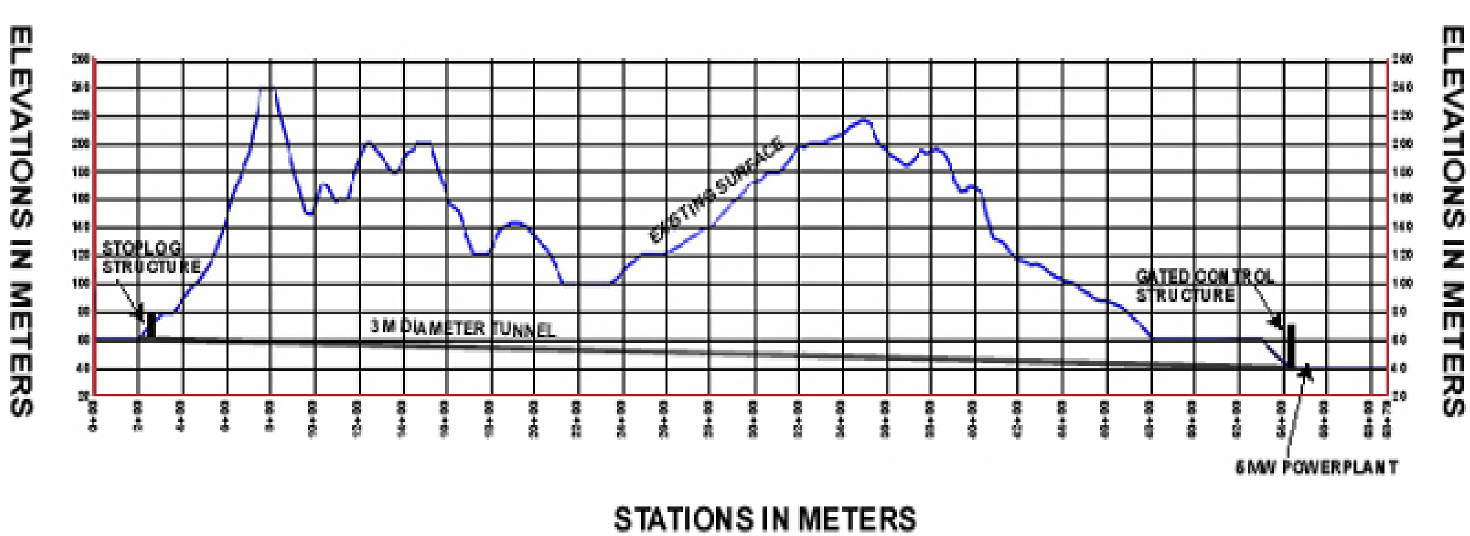
Plate 37 - 3 Typical Section at Embankment – Rio Indio



Typical Section

Typical Section at Embankment

Plate 37 - 4 Interbasin Transfer Tunnel Profile – Rio Indio



TYPICAL SECTION

Interbasin Transfer Tunnel Profile

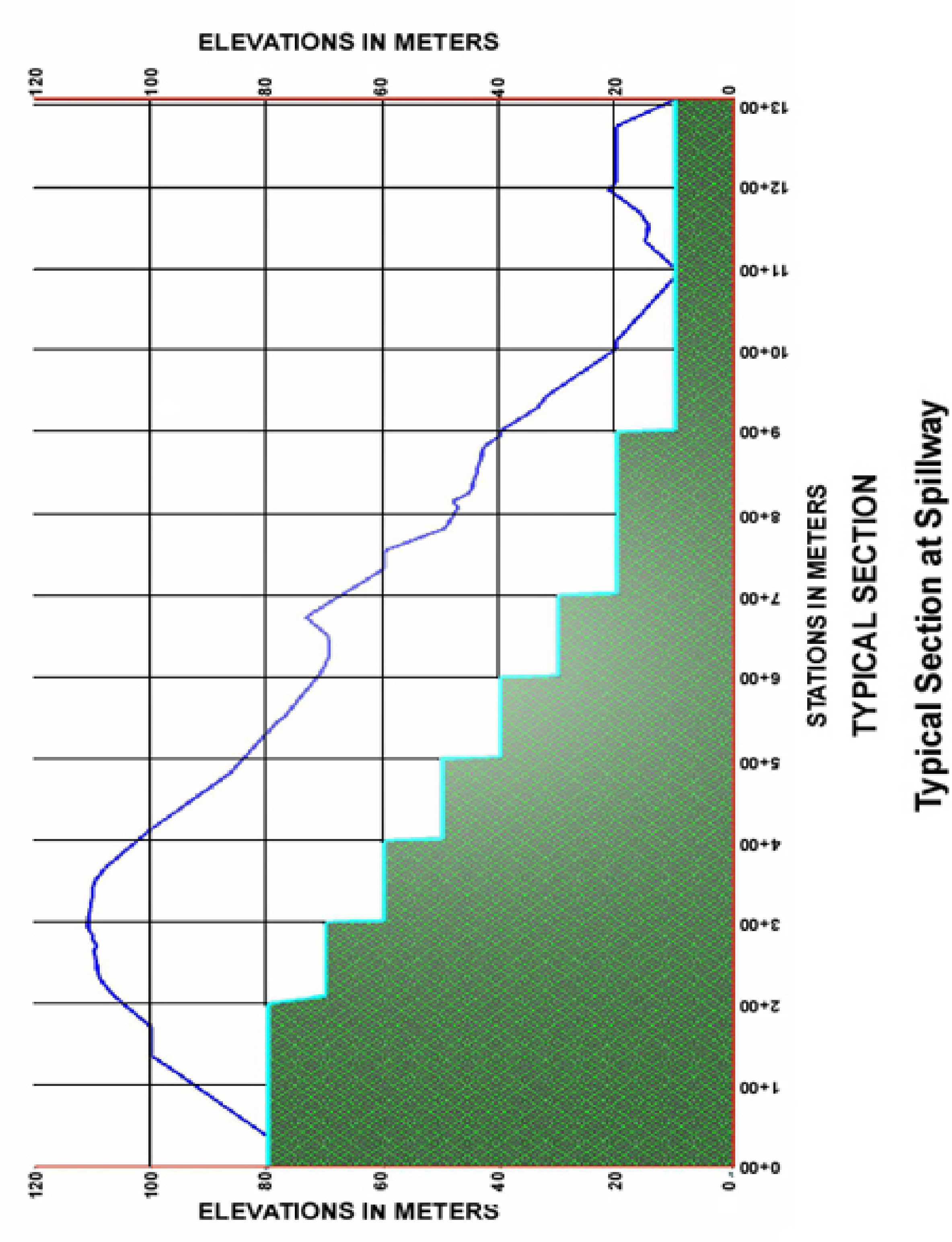


Plate 37 - 5 Typical Section at Spillway – Rio Indio

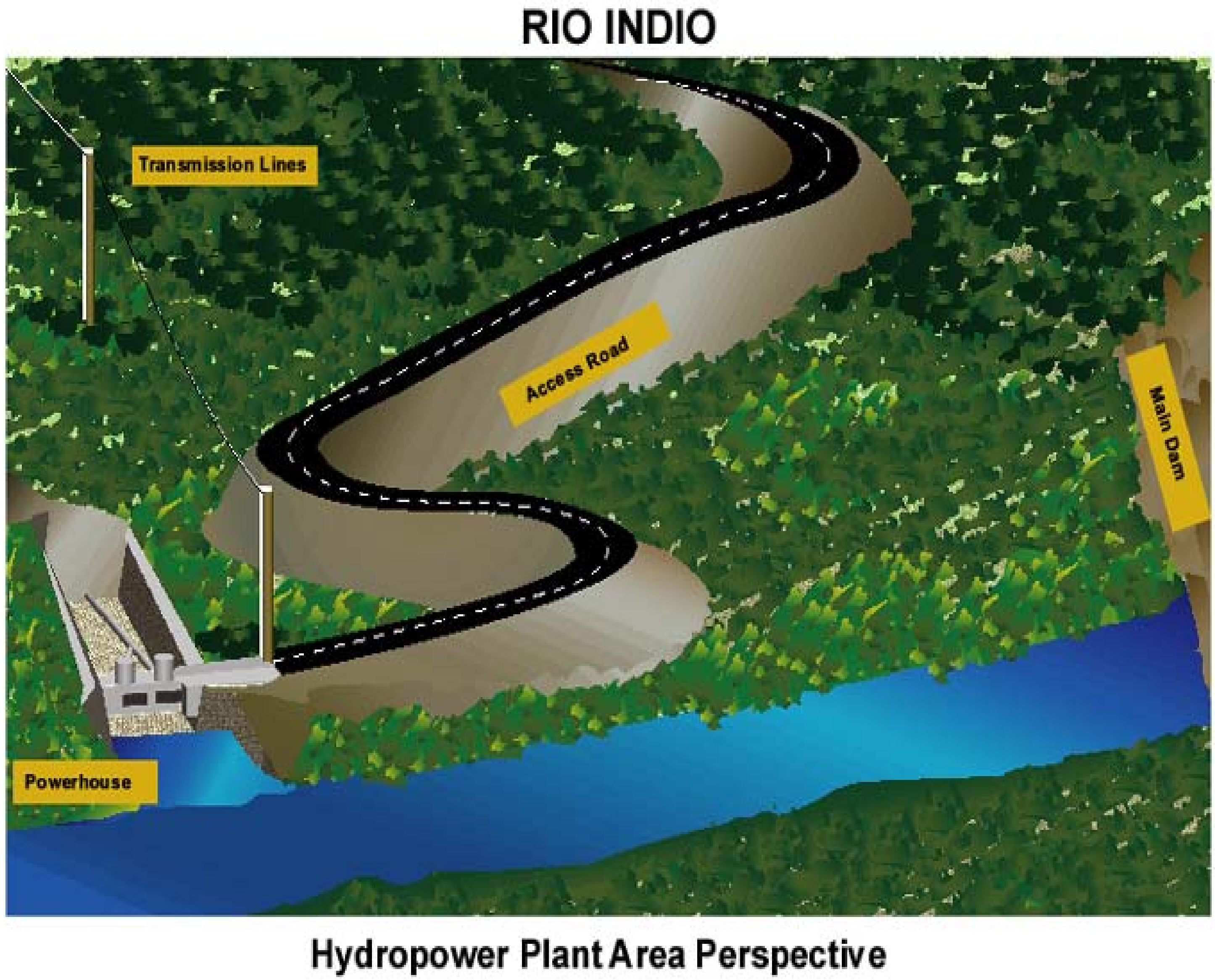
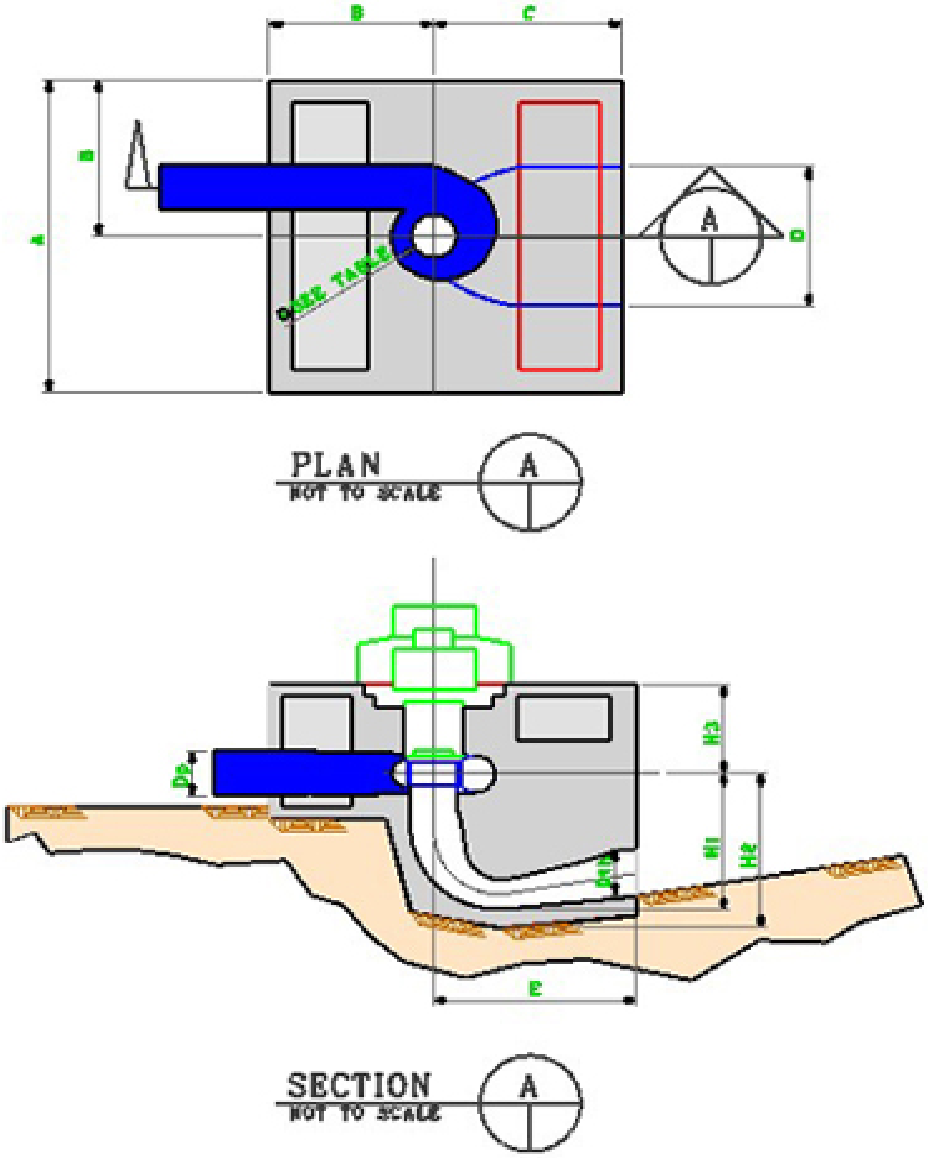


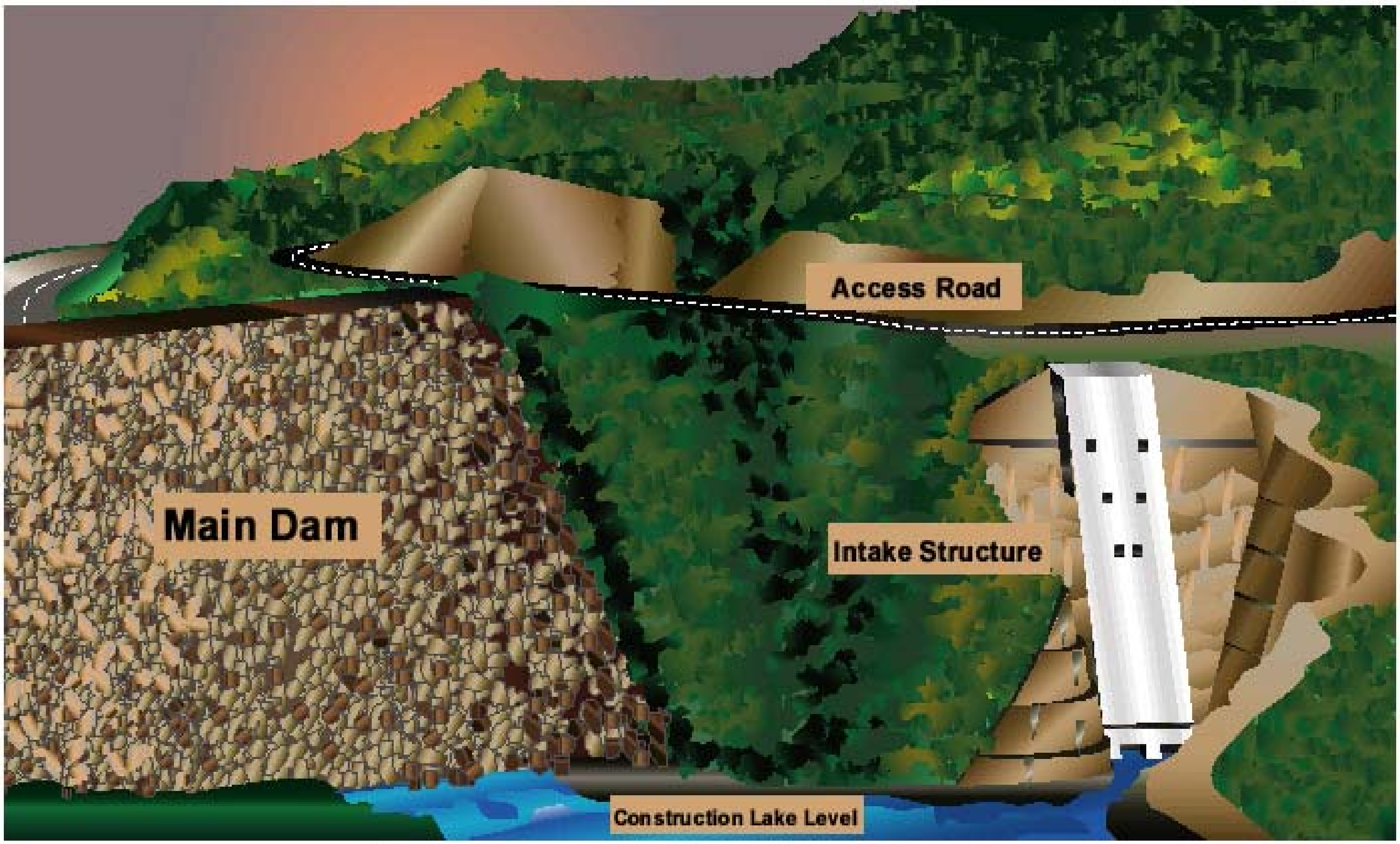
Plate 37 - 6 Hydropower Plant Area Perspective – Rio Indio



RIO INDIO DAM POWER FACILITIES									
UNIT	A	B	C	D	E	Dp	H1	H2	H3
Dth					(Meters)				
BASIN TRANSFER UNIT									
1.04	11.79	4.49	4.15	3.32	4.15	1.55	2.9	3.51	2.44
UNITS 1 AND 2									
1.68	12.34	4.72	6.71	5.36	6.71	2.53	4.69	5.30	2.44

Plate 37 - 7 Rio Indio Dam Power Facilities

RIO INDIO



Intake Structure Area Perspective

Plate 37 - 8 Intake Structure Area Perspective

SECTION 38

Lower Rio Trinidad 22.9m to 30.5m
Upper Rio Indio 50m

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

Synopsis

The development plan presented herein considers creating a dam and a lake on the Trinidad basin within the Panama Canal watershed at Gatun Lake southwest of Gatun Locks and creating of a dam on the Upper Rio Indio to the west of Lake Gatun. Water impounded in Lower Rio Trinidad Lake should add storage to the Panama Canal system of lakes. Water impounded at the Upper Rio Indio site can be transferred via a tunnel to Lower Rio Trinidad Lake. Under normal flow conditions water passes from Lower Rio Trinidad Lake to Gatun Lake through a gated spillway. Water can also be pumped between Gatun Lake and Lower Rio Trinidad Lake via a pumping station installed near the east end of the Lower Rio Trinidad Dam. During the flood season, excess water may be pumped from Gatun Lake to Lower Rio Trinidad Lake. During the dry, season water stored in Lower Rio Trinidad Lake can be pumped to Gatun Lake. The water may also be used as needed to support canal operations.

The Rio Trinidad watershed is located on the western side of the Panama Canal watershed. The proposed dam site is located within Gatun Lake across the Rio Trinidad Lake arm near the town of Escobal. The proposed dam extends from Punta Mala on the west shore of Gatun Lake to Guacha Island, and then straight across to the eastern shore of the Rio Trinidad Lake arm, just south of the South Range Point lighthouse. This alignment follows closely the proposed path found in the Study and Report on Increasing the Water Supply of the Panama Canal (referred to as the Tudor Report), prepared by Tudor Engineering Company, San Francisco, California 1962, for the Panama Canal Company. Plate 38 - 1 shows the location of the proposed Lower Rio Trinidad Dam project. The structures for the proposed Lower Rio Trinidad project should consist of a rock fill dam constructed by underwater deposition of fill materials, a gated spillway constructed in the dry on Guacha Island, and a large pumping plant constructed in the dry on Tern Island. The spillway should have 11 gate bays, each measuring 18.3 m wide. The pumping plant should contain 6 large diesel engine driven hydraulic pumps configured to allow pumping in either direction. The total project first costs of the proposed Lower Rio Trinidad Dam project are estimated to be $811,400,000.

The Upper Rio Indio watershed is located adjacent to the western side of the Panama Canal watershed. The proposed Upper Rio Indio dam site is approximately 29 km inland from the Atlantic Ocean and 4 km upstream from the confluence of the Rio Indio and Rio Uracillo. Plate 38-1 shows the location of the proposed Upper Rio Indio project. The structures for this project consist of a rock fill dam, an uncontrolled ogee spillway, inter-basin transfer facilities, 2 hydropower plants, and other outlet works. The tunnel should transfer water from Rio Indio Lake to the Upper Trinidad Lake continually where it would be stored for canal operations. The total project first cost of the proposed Upper Rio Indio project is estimated at $199,177,000.

This project poses great construction difficulties because of the extremely large quantities of underwater fill required for construction of the dam. It requires extensive drilling and site investigation prior to construction and, because of the uncertainties inherent with this type of construction; extensive unforeseen costs may be encountered during construction. Also, the spillway and pumping plant must be constructed in island settings where the structures and appurtenances practically engulf the island areas. This poses extreme space limitations on the construction effort and is very costly.

The proposed Lower Rio Trinidad Dam project, in conjunction with the Rio Indio Dam project, should contribute greatly to the hydrologic reliability of the Panama Canal. The project should also increase the ACP's ability to serve its customers by reducing draft restrictions and the light loading of vessels, especially during periods of low water availability. The existing hydrologic reliability of the Panama Canal, based on the period of record from January 1948 through July 1998 and current demands (38.68 lockages), is approximately 99.6 percent. The hydrologic reliability with the demand increasing to 120 percent of the current level (46.42 lockage) is 98.8 percent. With construction of the proposed Lower Rio Trinidad and Rio Indio Dam projects, the existing high hydrologic reliability may be continued as demand for lockages increases to 18.3 percent above current demand levels (up to 7.06 lockages).

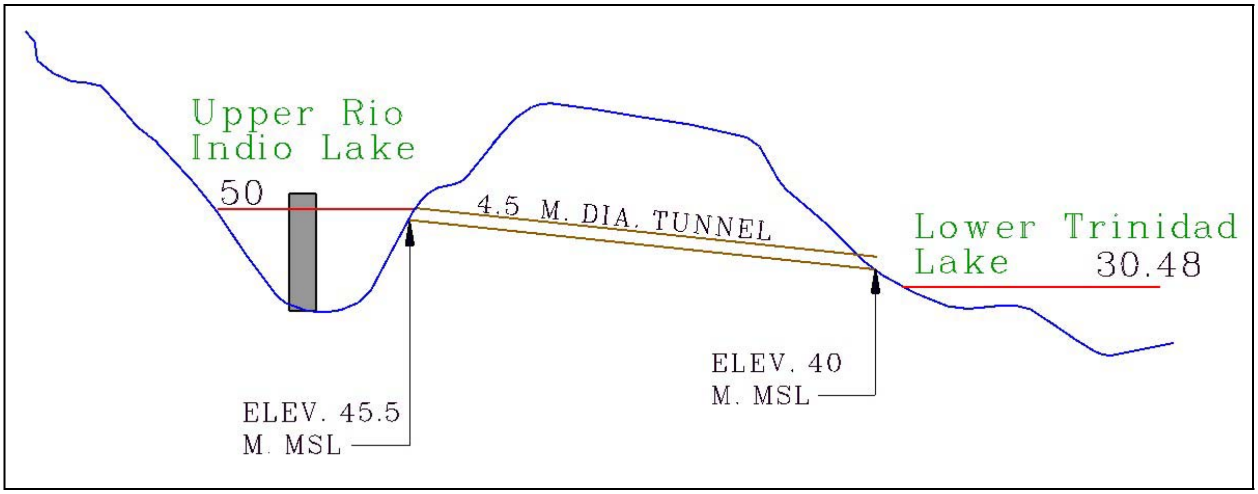


Figure 38 - 1 System Profile

Site Selection

Project definition and description developed with a view toward maximizing the water impounded, while minimizing the volume of material required for construction of the dam. The site chosen for the proposed Lower Rio Trinidad Dam is 10 km south of Gatun Locks and 14 km southwest of the navigation channel. The dam would be approximately 4 km northeast the town of Escobal. This site can accommodate construction of a dam with a maximum operating lake level at EL. 30.48 m MSL. Flood storage accommodations are between EL. 30.48m and 31.09 m MSL.

The proposed Upper Rio Indio dam site was chosen with a view toward maximizing the water impounded, while minimizing the volume of material required for construction of the dam, thus minimizing the number of saddle dams required to contain the lake, and minimizing the impact on the existing populated areas in the Lower Rio Indio Basin. It is desirable to locate the dam immediately above the confluence of the Rio Trinidad and the Rio Uracillo, as far downstream in the upper arm of the Rio Indio watershed as possible. In choosing a site for the dam, the ideal location is where the surrounding hillsides are relatively steep and high, and the valley relatively narrow, features which the site chosen affords.

The proposed Upper Rio Indio dam site is 29 km inland from the Atlantic Ocean and 4 km upstream from the confluence of the Rio Indio and the Rio Uracillo. This site can accommodate construction of a dam with a normal operating lake level at EL. 50 m MSL and a maximum flood lake level at EL. 53 m MSL.

Hydrologic Considerations

Rio Trinidad
The Rio Trinidad flows northward from the Continental Divide to Gatun Lake. The headwater of the watershed begins at EL. 1,000 m MSL, approximately 75 km inland, and falls to 26 m MSL at Gatun Lake. The distribution of the average annual rainfall over the Rio Trinidad watershed varies from a high of 2,200 mm in the western part of the watershed to 2,000 mm on the eastern side of the watershed. The proposed Lower Trinidad Lake receives runoff from approximately 750 km^2 of the upper portion of the watershed. Rainfall runoff produces an average annual flow of 32 CMS at the proposed dam site.

The discharge rates at the Lower Rio Trinidad dam site are obtained by observing the drainage area ratio established for Gatun. The Gatun Lake runoff is based on records developed by the U.S. Army Corps of Engineers Hydrologic Engineering Center and the ACP in a separate study.

Since the Lower Trinidad Lake is located within Gatun Lake the monthly evaporation rates established for Gatun Lake are considered appropriate for the evaporation rates of Lower Trinidad Lake.

Upper Rio Indio
The Rio Indio flows northward from the Continental Divide to the Atlantic Ocean. The headwaters of the watershed begin at EL. 1,000 m MSL, approximately 75 km inland, and fall to MSL at its mouth. The distribution of the average annual rainfall over the Rio Indio watershed varies from a high of 4,000 mm at the coast to a low of 2,500 mm in the middle watershed area. It increases again to over 3,000 mm in the Continental Divide. The proposed Indio Lake receives runoff from approximately 256 km^2 of the upper portion of the watershed. Rainfall runoff produces an average annual flow of 16.8 CMS at the proposed dam site.

The calculated discharge at the Upper Rio Indio dam site is extrapolated, recorded, and correlated stream flow data of the Boca de Uracillo hydrologic station. This station began operation in 1979 and is located on the Rio Indio, approximately 6 km downstream from the dam site. Data is established from a statistical correlation with the discharge data of the Rio Indio at Limon, approximately 3 km downstream from the dam site, using standard hydrologic techniques, completed missing data and increased the period of record. Utilization of the double mass curve method satisfactorily verified the consistency of the data measured and correlated.

Because of the proximity of Rio Indio to Gatun Lake, and because of the absence of site specific information, the monthly evaporation rates established for Gatun Lake are considered appropriate for the evaporation rates of Indio Lake.

Geologic Considerations

Rio Trinidad

The proposed Lower Rio Trinidad Dam site was investigated in 1962 by Geo-Recon, Inc. of Seattle, Washington, as part of the Tudor report. The investigation consisted of seismic velocity and electrical resistivity profiles in conjunction with four test borings (all located in the lake and drilled by the Panama Canal Company). The results of the geophysical surveys reportedly compared well with the logs of the test borings in the deep-water areas (up to 23 m deep) of Gatun Lake. In June 1963, Tudor Engineering submitted a report including additional foundation investigations. The foundation investigations were made by the firm Shannon & Wilson, Inc., Soil Mechanics and Foundation Engineers, from Seattle, Washington, and consisted of 77 cone penetrometer borings, 24 classification borings, 11 undisturbed sample borings, and 6 field vane shear borings. The investigations submitted by Shannon & Wilson, Inc were recently reanalyzed in Geology of the Proposed Dam Across Trinidad Arm of Gatun Lake, by Mr. Pastora Franceschi S., for the Geotechnical Section of the Panama Canal Authority.

In the lake areas, the investigations disclosed that overburden material included recent lake deposits, Atlantic Muck Formation, alluvial deposits, and residual deposits. Between the west shore and Guacha Island these deposits consist of soft to very soft clay, silt, sand and peat (Atlantic Muck Formation) overlying soft to hard deposits of clay, silt, sand and gravel derived both from alluvial deposition and the weathering of bedrock. The upper two phases of the Atlantic Muck Formation, judged to be the most compressible portion of the formation, was found to have an average thickness of about 18.3 m and a maximum thickness of 22.9 m. Recent, soft lake deposits ranging from 1.2 to 2.4 m thick were found overlying the Atlantic Muck Formation. In the length between Guacha Island and Tern Island, the Atlantic Muck Formation was either not found, or was very thin. In this area, Recent-aged soft sediments (averaging 2 m thick) were found to overlay residual soil and weathered rock. Atlantic Muck Formation, where present, occurred between the Recent-aged material and the residual soil, and was a maximum 5 m thick. Between Tern Island and the east mainland, only recent lake sediments (1.5 m thick) overlying residual clay were found above the conglomerate of the Bohio Formation.

Guacha, Tern and Booby Islands, all located within Gatun Lake, have an overlying stratum of soft overburdened and weathered rock of variable thickness. In general, firm bedrock is available below EL. 22.9 m MSL and the islands offer suitable foundation conditions for control structures.

Firm bedrock under both the land and the lake consists of low velocity sedimentary rock composed primarily of sandstone and the Bohio Formation. Two areas containing abrupt changes in bedrock velocities were located during the survey. One of the areas is a narrow zone located on Guacha Island that is a possible shear zone in rock of similar type. The second area has an abrupt change in bedrock velocity on Tern Island that is interpreted as a possible fault contact between two formations, or between different lithologic units of the same formation. The top of the bedrock on land was interpreted from the geophysical results to be weathered to below lake level. The core borings in the lake determined the weathered zone of bedrock to range from 1.2 to 3.1 m in thickness.

Satisfactory foundation conditions exist for construction of a pumping station, and a spillway at the Lower Rio Trinidad site. Serious consideration, however, must be given to problems that would be caused by the anticipated settlement and instability of the embankment materials.

Upper Rio Indio

The proposed Upper Rio Indio project is located in an area of the Isthmus of Panama underlain by Oligocene-aged sedimentary rocks of the Caimito Formation. Three members of the Caimito Formation are recognized: the lower, the middle and the upper. The deposits of each of these members are mainly marine, but are lithologically heterogeneous. The lower member is composed of conglomerate and tuffaceous sandstone. The middle member consists chiefly of tuffaceous sandstone, some of which is calcareous, and lenticular limestone. The upper, principal member consists of tuff, agglomeratic tuff, tuffaceous siltstone, and discontinuous sandy tuffaceous limestone. In general, all members are hard, thinly to thickly bedded, and closely to moderately jointed. The lower member weathers to greater depths. A summary of test data developed in 1966, as part of the studies for a sea level canal, listed compressive strengths for samples of Caimito Formation material varying between 79,450 and 5,955,257 kg/m^2. The same 1966 studies assigned an allowable bearing capacity of 195,300 kg/m^2 for the material of the Caimito Formation. The abutments at the project site may consist of Miocene volcanic rocks, possibly of the Tucue Formation.

It is believed that the Caimito Formation material should make an acceptable foundation for an earth and rock fill dam, however, it is be unacceptable for use as concrete aggregate and only marginally acceptable for use as fill. Further development of this project should require drilling of cores early during the planning studies to identify the foundation and abutment materials and to determine their general suitability for use as construction material. In addition, the cores should be of sufficient depth to check for the occurrence of any soluble limestone strata that may underlie the dam foundation.

The proposed inter-basin transfer tunnel connecting the Rio Indio Lake to the Panama Canal watershed is also located very near the contact of the Caimito Formation and the overlying Miocene volcanic rocks. Groundwater flowing in volcanic rock above impervious strata of the Caimito Formation may cause problems. Further development of this project should require drilling of cores near the proposed tunnel inlets and outlets early during planning studies to determine the general relationship between the tunnel alignments, the sedimentary/volcanic rock, and the water table.

In the absence of detailed geologic mapping for the proposed Upper Rio Indio dam site, a degree of extrapolation is necessary. Available general geologic mapping and general data are the basis of predictions that rock, encountered at a shallow depth and of sufficient quality, could serve as foundation for the dam and appurtenant structures. Furthermore, assumptions for this report are: the required excavation should make available sufficient rock for fill, and the immediate area contains available impervious materials and concrete aggregate for use in the construction of the proposed project.

Lake Operation

The operating scenario considered in this study for periods when water would be transferred from Lower Trinidad Lake to Gatun Lake for canal operations is detailed in Section 36 – Lower Rio Trinidad. Following is a reiteration of the tabulated pool levels contained in that narrative.

Table 38 - 1 Lake Operating Options

Lake Level (m MSL)	Lower Trinidad	Gatun
Normal Operating Lake Level	30.48	26.67
Minimum Operating Lake Level	22.86	25.91
Maximum Flood Lake Level	31.09	27.13

Under this scenario the Upper Rio Indio Lake would be operate in a "run-of-the–river" mode, transferring all flows above the invert of the interbasin transfer tunnel, EL. 45.5 m MSL, to the Lower Trinidad Lake for storage and subsequent use for navigation. This transfer of water between Upper Rio Indio and Lower Trinidad Lakes would be made via a tunnel constructed beneath the divide separating the two basins. The tunnel shall be sized to carry all but the greatest flood flows from the Upper Rio Indio basin. The maximum flood flows would be passed over the fixed crest spillway to the lower Rio Indio. Table 38-2 shows the lake levels affecting the Upper Rio Indio design for this scenario.

Table 38 - 2 Lake Operating Levels

Lake Level (m MSL)	Upper Rio Indio
Normal Operating Lake Level	50
Minimum Operating Lake Level	45.5
Maximum Flood Lake Level	52.0

Project Features

GENERAL

The structures for the Lower Rio Trinidad project should consist of a rock fill dam, a large pumping plant, and a gated spillway. Modification of one existing saddle dam and construction of two additional saddle dams should also be required. Plate 38 - 2 shows the dam site in downstream left bank perspective and indicates the location of the spillway and pumping facilities.

The structures for the proposed Upper Rio Indio project consist of a rock fill dam, an uncontrolled ogee spillway, inter-basin transfer facilities, two hydropower plants, and outlet works. The site plan and details would be similar to those presented in Section 37, Plate 37-2, for the lower Rio Indio Site.

Design was performed only to the extent necessary to establish, with reasonable accuracy, the principal dimensions, elevations, and costs of the proposed project. Separate documentation was provided to the ACP that contained assumptions and design calculations for the reconnaissance level investigations of these structures. If this project is carried into the planning studies, optimization of the project features and improvements must be accomplished.

The following paragraphs provide a description of the proposed structures and improvements for these projects.

EMBANKMENTS

Dams

Lower Trinidad Dam
The proposed dam consists of an embankment with the top at EL. 31.50 m MSL and with a crest width of 13 m with a final crest of 7 m upon completion of all settlement of the embankment and bridgework. The left abutment of the embankment will be located at Universal Transverse Mercator Grid, Zone 17, Clark 1866 Spheroid Coordinates 1015858 north and 614864 east. The right abutment will be at 1013937 north and 618229 east coordinates. The normal lake elevation is 30.48 m while the ground surface elevations along the axis of the dam vary from El. 2 m MSL in the lake bottom to 39 m on Guacho Island and 38 m on Tern Island. The Gatun Lake subgrade supporting the embankment occupies a broad flat valley having sides, which slope, upward from the valley at grades up to 40 percent. Water depths are 21.3 to 26.3 m over 80 percent of the site. The Atlantic Muck Formation, consisting of very soft organic clays, silts and peats varying in thickness from 7.6 m to 48.7 m, underlies approximately two thirds of the alignment subgrade. The Atlantic Muck Formation in the old river channel is further underlain by soft silts, sand and clay strata.

The critical challenge for design espoused by the Tudor Report and others is the depth of subgrade degradation during the initial fill placements. The materials will lose much of its natural strength when disturbed and will only regain strength after the effects of consolidation of a surcharge fill. However, complete restoration of strength can only be assumed to a depth of 5 to 7 m. If the effects of the subgrade disturbance extend appreciably deeper, then an extremely weak material will be under the more stable subgrade and surcharge creating a condition of lateral instability.

Because of the inability to accurately analyze this condition, a test fill was performed on the western end of the alignment. In early 1963, 1,000-cy bottom-dump barges deposited some 168,000 cy of blasted rock from the cut widening project, extending some 305 m. 155 m of the fill was placed to a height of 11 m while the remaining 150 m was filled to 5 m. The differential heights were use to simulate initial and intermediate fill placement effects. Divers were then used to observe the performance of the fills placed along the alignment. The mechanisms of failure within the subgrade were caused by impact and static loadings. The impact of the initial placements caused severe destruction of the surface materials creating lateral displacements up to 5 m. However, when a continuous blanket of fill had been established and subsequent fill was placed, then conventional failures such as slip circle shear failures and horizontal shears creating large mud waves outward from embankment were observed. Therefore, to predict the behavior of the embankment during construction and for the long term, it is imperative that a foundation mat be established to such a depth to prevent subgrade rupture with subsequent fill placement. They recommended that a 5 m thick minimum crushed rock blanket with maximum sizes of 20 cm be placed initially to act as the supporting blanket. Special barge dumping methods were to be employed so loads would not fall as an integral mass, which would create destructive forces on the subgrade. These recommendations were offered to the Tudor Engineering Company for use in their final study report.

The placement of a large hydraulic structure on a deep-seated weak foundation is the most challenging of geotechnical endeavors. It is virtually impossible to analyze with great deal of certainty and the owner must be prepared to accept possible additional costs during construction and long term maintenance due to the potential for lateral instabilities and high degrees of settlement. The Tudor Report has predicted some 2.5 to 3 m of predicted settlement below the crest elevation for a construction duration of 7-years and an additional 2.5 to 3 m of maximum settlement below the crest for the 50-year service life of the project. These settlements are predicted where the Atlantic Muck and underlying compressible materials are the thickest. These movements are reduced as the fill approaches the mainlands and the two islands. This implies that significant differential settlements are predicted within these approaches as well. The key to any successful construction and maintenance of this embankment will be to establish a blanket mat atop the subgrade where subsequent fill can be economically placed without fear of rupturing the foundation to greater depths. Any significant lateral failure of the embankment during construction or productive use will render that alignment unsuitable. Additional embankment sections must be established upstream or downstream to reestablish the embankment section to the proper elevation. This repair will take considerable time and prevent its use as a road. Based on these considerations, our recommendations were presented for ultimate costs considerations in comparison to alternatives with a greater degree of performance certainty.

The divers observed that the test fill had trouble placing the fill in the correct locations within the alignment and the lift thickness varied significantly over the fill cross section. It is imperative that the blanket fill be placed intact with the least subgrade disturbance in order for the embankment to act as monolithic mass. Therefore, the initial 5 m of fill will be barged to the site and placed by lowering a clamshell to the subgrade surface. The positioning of the barges must be strictly controlled by survey positioning systems established on land. The initial fill should have a maximum size of 20 cm and the percent fines should be controlled to remain fairly intact during placement. Materials with a significant size differential and a large fine content can create weak shear zones with the embankment. The subsequent fill materials above this zone can be placed by bottom dumped barges or clamshells from El. 8 m MSL to El. 21 m MSL. The material above El. 21 m MSL must be placed by clamshell due to the draft and door operations of the barges. These materials will be more random in gradation having a maximum size of 30 cm and a greater degree of fines. The materials placed below El. 27 m MSL will assume a side slope of 1 V:15 H. A 15 m berm will be constructed and the materials will continue to be placed by clam shell and spread with a dozer to El. 31.5 m MSL, assuming a side slope of 1V:3H and a crest width of 13 m. The flatter side slopes are needed to distribute bearing pressures and to reduce the lateral displacements. This configuration should also reduce the construction and total settlements predicted by the Tudor report and provide acceptable factors of safety for lateral stability during fill placement. The side slope berms and extra crest width will facilitate the future fill placements of up to 3 m over the life of the project. The road surface atop the dam embankment will remain gravel surfaced for the foreseeable future due to future fill placements. The dam will be approximately 30 m high, and the overall length 4,473 m. The top of the dam will be 5 m above the normal Gatun Lake level. The total volume of fill material required to construct and maintain the main dam to El. 31.5 m MSL is approximately 29,550,850 M^3 .

Water access from the main channel to Guacha and Tern Islands will be built during construction. After access roads have been constructed, fill placements from the east mainland to Tern and Gaucha Islands could be delivered by truck and placed by end-dumping from the east mainland. This technique could prove beneficial if a material source was found near the Gatun Lock area. The side slopes and overall embankment configuration was offered for ease of calculation, to reduce the foundation pressure on the soft subgrade and to account for the lateral displacement of embankment materials. The increased foundation base should help the structure survive a relatively minor seismic event.

The methods of subgrade stabilization and embankment strengthening offered in the powerpoint presentations from the ACP Engineering Division are examples of many ideas for enhancing the performance of the embankment during construction and post construction. The use of wick drains have been an effective tool for accelerating consolidations under a mass loading. However, the Atlantic Muck materials will not readily transmit water to the drains, therefore the spacing of the drains must be much closer than that implied and the effectiveness of the drains will be restricted to the top 15 to 20 feet of the foundation subgrade. The drains must be effectively tied into the foundation blanket for continuity of the drainage path. There are concerns about the use of vibro-flotation or stone columns techniques above the mat. The mat will not effectively dampen these compaction forces and some rupture of the mat could be possible. A safer reinforcing technique could be the use of reinforcing within the embankment section, such as high strength geogrids placed in layers. All reinforcing techniques are expensive but could be offset by the reduction in fill quantities ultimately required. Any reinforcing selected for use in production must be part of a comprehensive test fill program to demonstrate its effectiveness.

The Tudor Report identified considerable leakage to be expected from the completed embankment. Since loss of any water from storage is a significant reduction in benefits, the seepage must be prevented. Therefore a bentonite slurry trench should be installed within the centerline of the embankment. The trench will be a minimum of 3 feet wide and extend to several meters below the original lake bottom. The trench can be excavated using rockmill techniques. Since the embankment will undergo significant settlement, both total and differential, it is likely that the trench will be sheared and will require replacement within the deeper portions of the lake during the life of the project.

Saddle Dams

As noted in the Tudor Report, the existing Caño Saddle Dam No. 4, located along the western shoreline of the Trinidad Arm of Gatun Lake, needs to be raised and/or strengthened to accommodate the higher lake levels. Immediately to the north of this location, two additional smaller saddle dams are required. All saddle dams must be built to provide a minimum top El. 31.50 m MSL. The total volume of fill material required for these three dams is approximately 50,000 M^3, based on a crest width of 13 m.

The actual side slopes and crest widths would be determined during further study and are contingent upon the need for vehicular access across the embankment, the size and quality of the rock fill, and the detailed design of the embankment. A typical section of the embankment at the saddle dams and main dam would be similar to that shown for the embankments for the Upper Rio Indio project, Volume One of the parent document to this report.

SPILLWAYS

Lower Trinidad

Under normal flow conditions water should pass from Lower Rio Trinidad Lake to Gatun Lake through a gated spillway. This spillway should have 11 gate bays, separated/flanked by 3 m wide reinforced concrete piers (12 piers in all). These provide support for the gates, and access to the gate operating machinery, as well as for a roadway bridge over the top of the spillway. Each of the 11 spillway gates should have a nominal width of 18.33 m and a height of 5.48 m to provide 0.3 m freeboard above the maximum lake operating level. The overall length of the spillway, from out-to-out of the end piers is 237.67 m. The spillway sills shall be placed at the minimum lake operating level for Gatun Lake, EL. 25.91 m MSL.

A bridge across the tops of the spillway piers would be constructed as a part of the roadway across the top of the dam. The roadway must be approximately 7 m wide thus allowing for two-way traffic and providing ready access to the spillway gate operating machinery.

For this study, stop logs for servicing the gates, guides, etc. may be placed either from the roadway or from barges using floating cranes. Also, it should be noted that, with the spillway sill at the prescribed level, stoplogs are required both upstream and downstream to allow work to be done on the gates and sills in the dry.

Rio Indio

At Upper Rio Indio, an uncontrolled ogee spillway, with a length of 113.11 m and a crest at EL. 50 m MSL, is required. The spillway crest would be 3 m below the elevation of the top of the dam. The maximum discharge from the spillway would be 618 CMS at a maximum flood lake level at EL. 52 m MSL. The spillway design discharge is equivalent to a 1 in 1,000 frequency unregulated flow at the dam site. The spillway site is located within the abutment adjacent to the left end of the dam and should consist of a mass concrete sill section embedded in the natural rock. A sloped and/or stepped, natural rock cut tailrace channel would transfer flow to the adjacent Rio Uracillo tributary. The tailrace channel extends from the sill section to its confluence with the Rio Uracillo. The task of dissipating energy at the downstream end of the tailrace channel requires excavation of a stilling basin into the rock adjacent to the natural channel. See Plate38 - 2 for the location of the spillway and Plate 38 - 4 for a typical section at the spillway.

PUMPING PLANT

A large pumping plant is included in this scenario at the Lower Rio Trinidad dam. This pumping facility provides for pumping in two directions, allowing Lower Rio Trinidad Lake to be drawn down to a level below that of Gatun Lake during extremely dry months, and providing the capability of pumping excess water from Gatun Lake into Lower Rio Trinidad Lake during the flood season. Water thus stored would be available for navigation during the dry season. The pumping plant is configured to provide pumping to EL. 33.53 m MSL in Lower Rio Trinidad Lake. For the purpose of this study the pumping plant is located in the northwest segment of Tern Island. See Table 36-3 for the controlling head and flow data used for this study.

This plant should consist of six 1407 HP pumps, each capable of pumping slightly more than 62 CMS for a total plant pumping capacity of 373 CMS at a total dynamic head of 4.6 m. The pumping units would be mounted in a reinforced concrete housing and arranged in a row perpendicular to the axis of the dam, with intake and outlet channels on either side. The channels would be separated from the Lower Rio Trinidad and Gatun Lakes by large concrete walls containing low-level sluiceways and gates for controlling flows into and away from the pumping plant. These sluiceways are configured to provide average entry velocities of approximately 7.7 MPS. The channels are configured to provide this velocity or less and require no special armoring of walls or inverts for scour protection. The channel invert would be at EL. 20 m. MSL, or 13.5 m. below the centerline of the pump outlets. This may provide sufficient water depth at maximum pumping to buffer the erosive effects of the very large outflows required.

In conjunction with this facility a roadway bridge would be required to connect the pumping station structure to the banks on either side of the intake and exit channels thus continuing the roadway across the facility. This bridge should also provide both operational and maintenance access to the pumping plant. As configured for this study, the bridge must have two 15 m long spans with steel girders and a concrete bridge deck on each side of the pumping station. It shall have a 7 m wide travel way and include one bridge bent including a cap, two round columns and a spread footing, located within each channel section.

Table 38 - 3 Pumping Data

Pumping Cycle	**Head** (m.)	**Average Daily Flow** (M^3/sec)
Lower Trinidad (Elev. 22.86) to Gatun Lake (Elev. 25.91)	3.05	127.43
Gatun Lake (Elev. 26.67) to Lower Trinidad (Elev. 30.48)	3.81	56.64

IMPOUNDMENT

The lake formed by the proposed Lower Rio Trinidad Dam should have a normal operating lake El. 30.48 m MSL. The surface area at the normal operating lake level would be approximately 18,169 ha. At the maximum flood level, EL. 31.09 m MSL, the surface area would be approximately 18,835 ha. With the minimum operating level at EL. 22.86 m MSL, the surface area would be approximately 9,019 ha. It should be noted that the current operating levels of Gatun Lake vary up to EL. 26.67 m MSL; therefore areas below the maximum Gatun Lake level are already subject to inundation.

The lake formed by the proposed Upper Rio Indio Dam should have a normal operating lake level at EL. 50 m MSL. The surface area is 863.8 ha. At the maximum flood lake level, EL. 52 m MSL, the surface area is 897.6 ha. With the minimum operating lake level at EL. 45.5 m MSL, the surface area is 732 ha.

CLEARING AND/OR GRUBBING

Clearing and grubbing is required for all areas above the existing Gatun Lake that are required for construction of the dam (embankments and spillway), access roads, and disposal and staging areas. For the Trinidad Lake area, clearing is required for the 3,700 ha in the lake area between the maximum operating lake level of Gatun Lake and EL. 30.48 m MSL.

For the Upper Rio Indio Lake, clearing is required in all areas necessary for construction of the dam (embankments and spillway), inter-basin transfer facilities, outlet works, hydropower plants, access roads. Disposal and staging areas require clearing and grubbing. Only the 900 ha in the lake area between the normal operating lake level, EL. 50 m MSL, and the minimum operating lake level, EL. 45.5 m MSL, require clearing. The transmission lines also require clearing.

INTER-BASIN TRANSFER FACILITIES

The project should include excavation of a tunnel beneath the common watershed divide to connect the proposed Rio Indio Lake to the Panama Canal watershed in the Lower Rio Trinidad Pool. The finished tunnel would be concrete lined, 4.5 m in diameter, and approximately 7.6 km in length. This tunnel should have an inlet invert at EL. 44.5 m MSL and an outlet invert at EL. 40 m MSL. The maximum capacity of the tunnel is 37.9 CMS. In estimating the effort required to construct this tunnel, it is assumed that rock stabilization, including rock bolting, is required over much of the tunnel length. The tunnel outlet shall be on the Rio Ciricito 24 km upstream from Gatun Lake. A gate structure, located at the tunnel outlet, should control flow through the tunnel. The channel of Rio Circito downstream of the outlet requires enlargement to provide sufficient flow capacity to the lake, as well as some surface armoring to prevent erosion. The tunnel discharge would be oriented to mitigate the erosion potential. The tunnel would be under pressure continually. Allowances for maintenance of the tunnel, and for rapid tunnel closure when required, necessitate construction of a gate/stoplog structure at the inlet. In the process of stopping flow through the tunnel, a water hammer effect may occur; if such an event occurs, then construction of a series of surge protection shafts may be necessary. These shafts require relatively minor surface structures for safety purposes. Plate 38-1 shows the location of the tunnel outlet, and Plate 38 - 4 depicts a profile of the tunnel.

HYDROPOWER PLANTS

In order to use the flows that are excess to the needs of the Panama Canal operation at the proposed Upper Rio Indio Dam a 5 MW hydropower plant would be installed at the dam. Also, a 2 MW hydropower plant would be installed at the downstream end of the inter-basin transfer tunnel. This plant receives flow from a Y off the main tunnel. These facilities are designed and configured to function as part of the national power grid. A 115 kV transmission line is required to carry the energy to a GHD connection near La Chorrera. Plate 38 - 6 shows the location of the hydropower plant at the dam, and Plate 38 - 7 shows the details at the hydropower plants.

OUTLET WORKS

The installation at Lower Trinidad requires no outlet works for construction nor for operation after project completion. All transfer of water would be made at Gatun lake level until actual closure of the dam. Once the dam and its appurtenant structures are complete, water transfers between the Lower Trinidad Lake and Gatun Lake can be made as described in Lake Operation above.

An outlet works system is required to provide for diversion of the Rio Indio flows during construction. This water passage can also be used to supply flows for production of hydropower, to allow for emergency draw down of the lake, and to allow minimum flow to pass through the dam after completion of the project.

This outlet works system would be included in a single intake structure. This structure would be configured to allow passage of channel flows up to the required level of protection during construction. Once diversion is no longer needed for construction, the structure can be used to control the flows for hydropower and emergency draw down. It should also have separate controlled water intakes at various elevations to allow flows to be withdrawn from the lake to optimize the quality of the water passed. The hydropower intake should also be elevated to prevent silt from entering the power units.

This system should consists of an 8 m by 8 m horseshoe-shaped tunnel passing through the dam abutment, a gated intake structure located in the lake, an outlet channel downstream, and various gate structures and water conduits, as depicted in Plates 37 - 8 and 37 - 9. The diversion tunnel would be 1,500 m in length; it should have an inlet invert at EL. 10 m MSL and an outlet invert at EL. 7 m MSL. The diversion tunnel serves in combination with the cofferdam to protect the construction area from floods up to a 10 percent frequency. A 10 percent frequency flood should deliver a peak flow of approximately 680 CMS at the site without regulation from the dam. A separate 1.2 m diameter conduit, required for minimum flow, would be installed beneath the floor of this tunnel. The minimum flow conduit would be 800 m should length; it should have an inlet invert at EL. 8 m MSL and an outlet invert at EL. 5 m MSL. The capacity of the minimum flow conduit would be 2.5 CMS. A bulkhead structure is required at the tunnel outlet to close the construction diversion and to divert flows from the lake into the hydropower conduit(s). The closure would be configured so that it can removed in the event that the Rio Indio Lake had to be drawn down.

ACCESS ROUTE

Lower Trinidad Lake
Access to the lake site and the various construction sites was evaluated from the main population centers, Colon on the Atlantic coast and Panama City on the Pacific coasts.

The route from Colon is westward across the Panama Canal and then southwestward along existing roads that follow the westernmost boundary of Gatun Lake to Cape Mala, near the western abutment of the dam. A very short access road is required from the existing road to the dam site. This route requires crossing the Panama Canal near the Gatun Locks using the existing lock gate bridge. This bridge is narrow and operates only intermittently since canal operations take precedence over roadway traffic. It may be undersized and may lack the load carrying capacity needed for heavy construction materials and equipment loads anticipated.

Access to the spillway and pumping plant construction sites would be by water since these structures are to be placed on Guacha and Tern Islands, respectively. A water access route was considered for conveyance of much, if not all, of the construction equipment and materials. This requires the construction of offloading facilities near the west abutment of the dam, on Guacha Island, and near the eastern abutment site in the vicinity of South Range Point.

Since much of the construction for this project would be in the existing lake or on islands in the lake, it is concluded that both land and water access is required. Plate 36-1 shows the general location of the proposed features and the possible land and water access available or to be provided.

Rio Indio
For access to the Rio Indio site it is concluded that the route from Panama City westward across the Bridge of the Americas, then southwestward along the Inter-American Highway, and then westward along existing roads to Ciri Grande, may be best. This route requires that the road between Panama City and Ciri Grande be upgraded over much of its length and the route west of Ciri Grande must traverse the mountains. The proposed access road would be 26 km in length, and bridges and / or culverts would be required at 15 streams. Plate 37-1 shows the portion of the proposed access road from Ciri Grande to the construction sites.

In addition to providing dam construction access, this new corridor into the country west of the Panama Canal benefit those living in the region, providing access to the main centers of commerce in the southern part of the country. It should also provide continuous access along the new power transmission lines from the dam site to the connection with the power grid.

Sources of Construction Material

Lower Rio Trinidad
The bottom 5 m layer of the dam embankments shall be constructed with material less than 8 in. maximum size, and with no more than 5 percent passing the #200 screen. Such a material should require crushing and processing across a grizzly to remove oversize rock, and washing to remove fines. Material for this bottom layer must be reasonably well graded so as to prevent the removal of the finer fraction by piping. The overlying main portion of the embankment would be constructed with (-12 in.) sized material. This material should also require crushing and processing across a grizzly to remove oversize rock.

The majority of the materials used for the embankment construction would be obtained from upland sources adjacent to the Gaillard Cut, transported to the site by barge and clam shelled along the proposed embankment alignment. The initial materials would be obtained from the existing disposal sites for the Gaillard Cut widening above Pedro Miguel Locks. Based on the information received from the ACP, these sites contain approximately 5.5 million M^3 of suitable excavated rock. However, this rock is not stockpiled in an orderly manner, is randomly mixed with unsuitable material and is covered with unsuitable material. All the rock materials, from whatever source, would need to be crushed, graded and loaded on trucks for transport to a loading facility adjacent to the canal at the Cucaracha Reach on the east side, or the mouth of the Mandinga River on the west side. These loading facilities should require excavation into the bank area and bulkheaded for crane support and barge placement. Working stockpiles would be maintained next to the transfer points to facilitate the loading process. Additional materials within the immediate area should come from the Third Locks excavation adjacent to the Pedro Miguel Locks. These materials would be drilled and blasted in place, excavated, and then transported to one of the transfer facilities for processing. Additional materials should come from newly developed quarry sources in areas such as Hodges Hill, Escabor Hill, Contractor Hill, and others within 10 km of the transfer points. Each of these new sources should require extensive excavation to remove the overburden and soft rock materials. These materials would be stockpiled adjacent to the work area for restoration once the rock fill materials have been acquired. The suitable rock materials would be blasted, crushed and graded and trucked to the transfer points All material would be loaded onto barges, transported to the dam site and clam shelled within the dam limits.

Cement is available within the country. Rock obtained from developed quarries may be used to produce concrete aggregates on-site, or they may be obtained from commercial quarries. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) need to be fabricated outside the Republic of Panama and imported for final assembly and installation at the proposed dam site.

Upper Rio Indio
Rock removed from the spillway site can used as fill in the embankment portion of the dam. Impervious materials might be obtained from outside the project area; however, for this study it is assumed that these materials would be available locally in sufficient quantity to supply the project needs. If further study indicates that impervious materials are unavailable locally, then other materials, such as roller compacted concrete, would be considered for construction of the dam.

Cement is available within the Republic of Panama. Rock obtained from developed quarries may be used to produce concrete aggregates on-site, or they may be obtained from commercial quarries. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) need to be fabricated outside the country and imported for final assembly and installation at the proposed dam site.

Real Estate Requirements

The proposed Lower Rio Trinidad Lake site is located within the former Panama Canal Zone and is presently managed and controlled by the ACP. Construction of this project requires acquisition of approximately 800 ha. Table 38 - 4 shows the amount of land required for the various project features. Real estate for access roads is included in the estimated quantities for the other items listed in the table. The ACP provided the estimated cost of the land for the proposed project.

Table 38 - 4 Real Estate Requirements

Project Feature	Land Required (ha)
Lake	0
Dam Site	0
Staging Area	200
Housing and Facilities	200
Disposal Area	400
Total	800

The proposed Upper Rio Indio project would be located in the Cocle, Colon, and Panama Provinces. Construction of this proposed project would require acquisition of approximately 1900 ha. Table 38 - 5 shows the amount of land required for the various project features. Real estate for access roads is included in the estimated quantities for the other items listed in the table.

Table 38 - 5 Real Estate Requirements

Project Feature	Land Required (ha)
Lake	900
Dam Site	200
Staging Area	200
Housing and Facilities	200
Disposal Area	400
Total	1,900

Relocations

The Lower Trinidad Lake would be located within the existing former Panama Canal Zone. Structures and facilities established along the waters edge in the Trinidad arm between the existing Gatun Lake levels and EL. 30 m MSL would need to be relocated or modified. This would include a major portion of the town of Escobal. Additionally, there are only a few small communities and isolated individual structures along the lake shore with very limited access by land.

The Upper Rio Indio Lake would be located in a sparsely settled region with few roads and utilities. This area is devoted primarily to subsistence farming and ranching. Structures and individuals located in the lake area below EL. 55 m MSL would require relocation because of the normal lake inundation and the need to secure the lake perimeter for flood considerations. The required relocations would include the towns in the lake area Los Uveros, and Tres Hermanas, approximately 12 other small settlements (just a few structures), and numerous isolated structures. The two towns all have elementary schools, churches, electricity, and limited telephone coverage.

Development Sequence

Each of the component lake projects is designed and constructed as a stand-alone facility. If the Rio Indio facilities are constructed first and placed into service before the Lower Rio Trinidad facilities, the interbasin transfer tunnel can used to navigational advantage while the Lower Rio Trinidad Dam project is being completed. During the interim, the Rio Indio Dam project can also help control flooding on the Lower Rio Indio and can contribute to the electric power output of the country.

The development sequence for each individual project follows roughly the same progression. This progression is summarized below with pertinent site-specific notations as appropriate.

Each project must be evaluated to assure that the plan presented includes all of the features required to function. Each project must be assessed as to its effectiveness in providing navigation water to the Panama Canal, with due recognition of any secondary benefits. Environmental assessments of the proposed projects need to be made to assure environmental acceptability of the project features. These environmental assessments begin during the planning studies phase and continue into the final design, advertising and award phases. Environmental coordination begins with planning studies and continues through the completion of construction. After completion of the final design, plans and specifications must be prepared for the advertising and award phase.

Project implementation begins with land acquisition and construction of the access facilities. Lands for the housing and facilities project feature, which includes the access roads, need to be acquired initially. Lands for the dam site, staging area, disposal area, and lake can then be acquired.

Socio-economic programs must begin shortly before construction of the dam. The relocation of the small settlements and isolated structures must be accomplished. Socio-economic programs to assist those individuals impacted by the construction of the proposed project should continue throughout the construction phase.

Construction of the Rio Indio Dam begins with the clearing and grubbing of the construction sites and clearing the perimeter of the lake area. Materials used for the embankment construction can obtained from upland sources then transported to the site.

Upstream and downstream cofferdams would be required for construction of the Upper Rio Indio Dam and appurtenant facilities. These would be configured so as to form a portion of the finished dam.

Upstream and downstream cofferdams are required for construction of the Rio Indio Dam and appurtenant facilities. These shall be configured to form a portion of the finished dam.

Limited cofferdams would be required to accomplish construction of the spillway and pumping station. These efforts may be accomplished simultaneously. Following completion of the pumping plant and spillway, the channels connecting these structures to the lake areas upstream and downstream may be excavated. Where possible, materials removed from these sites would be placed directly into the dam.

Once the western leg of the dam, pumping station and spillway are completed, the eastern leg may be constructed, thus completing the dam. The pool may then be raised. Upon completion of this phase of construction, all facilities must undergo trial operations, before being commissioned for service.

Considering the construction methods required and the nature of the work, it is estimated that development of the Lower Rio Trinidad and Rio Indio Dam projects may be completed in approximately the time spans indicated in Figures 38-2 and 38-3, below, from initial planning to lake filling. Assuming that the development of the two projects is overlapped by 1 year the total development time is approximately 22 years.

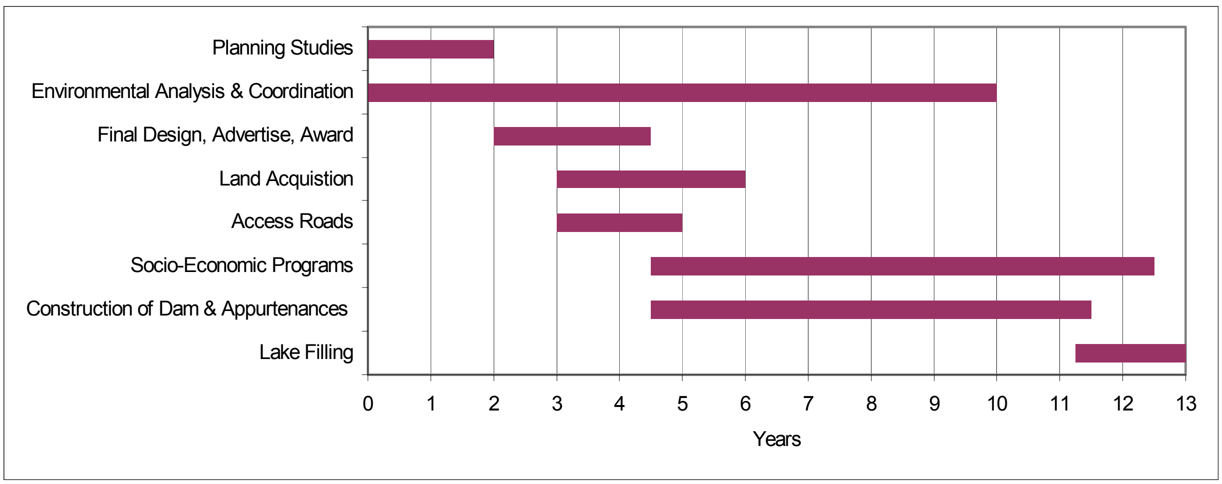


Figure 38 - 2 Development Sequence – Rio Trinidad

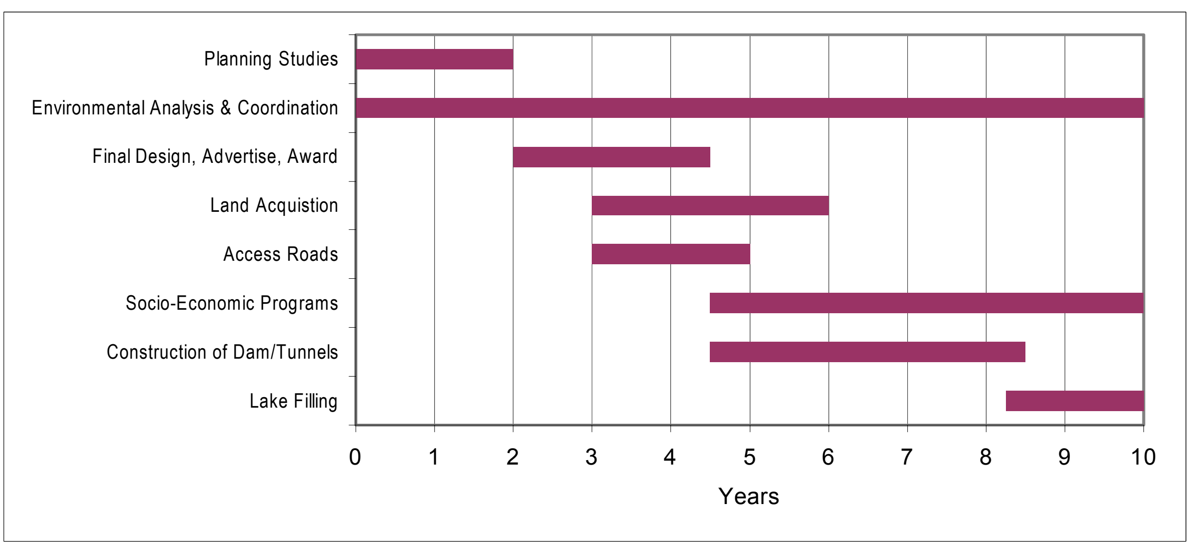


Figure 38 - 3 Development Sequence – Upper Rio Indio

Hydrologic Reliability

In order to determine the effect of the proposed Lower Rio Trinidad and Rio Indio Lakes on the hydrologic reliability of the Panama Canal, the existing HEC-5 model is modified to include the Lower Rio Trinidad Lake with pumpback operation and diversion from Rio Indio Lake. The existing Gatun Lake parameters (surface areas, storages, and local inflows) are reduced by the proportion that Lower Rio Trinidad Lake should capture.

HEC-5 model simulations are conducted for both the existing canal system and the Scenario 3 operating system providing water to the Panama Canal watershed. The simulations considered proportionally increasing demands to 180 percent of current demand levels, see \
Figure 38 - 4. The period of simulation considered 52 years (January 1948 through December 1999) of hydrologic record. These configurations are:

- Existing system,
- Scenario 3 – Indio Lake has a normal operating level of El. 50 m MSL and should operate as a "run-of-river" dam, transferring flows to Lower Trinidad via 4.5 m interbasin transfer tunnel; Lower Trinidad Lake fluctuating between the normal operating lake level, EL. 30.48 m MSL, and the minimum operating lake level, EL. 22.86 m MSL, with pumping capability to and from Gatun Lake; and Gatun Lake fluctuating between the normal operating lake level, EL. 26.67 m MSL and the minimum operation lake level, EL. 25.91 m MSL.

The horizontal axis along the bottom of Figure 38 - 4
Figure 38 - 4 reflects demands as a ratio of the 5-year average from 1993 to 1997, and the axis along the top reflects demands in lockages (assuming 55 million gallons per lockage. The existing hydrologic reliability of the Panama Canal, based on the period of record of 52 years, is approximately 99.6 percent, while the hydrologic reliability, with a demand ratio of 1.8, is 86.3 percent. This period of record includes the worst drought on record in Panama, which occurred in 1998. The hydrologic reliability with a demand ratio of 1.0 is 100 percent for Scenario 3, and the hydrologic reliability, with a demand ratio of 1.8, is 92.89 percent. Table 38 - 6 displays the number of lockages associated with various levels of reliability.

Without additional water supplies, the hydrologic reliability of the canal system should decrease. With the construction of the proposed Lower Rio Trinidad Pumpback Dam and Rio Indio Dam projects, using Scenario 3 operation, the existing high hydrologic reliability can be continued as demand for water increases up to 18.3 percent (7.06 lockages) above current demand levels.

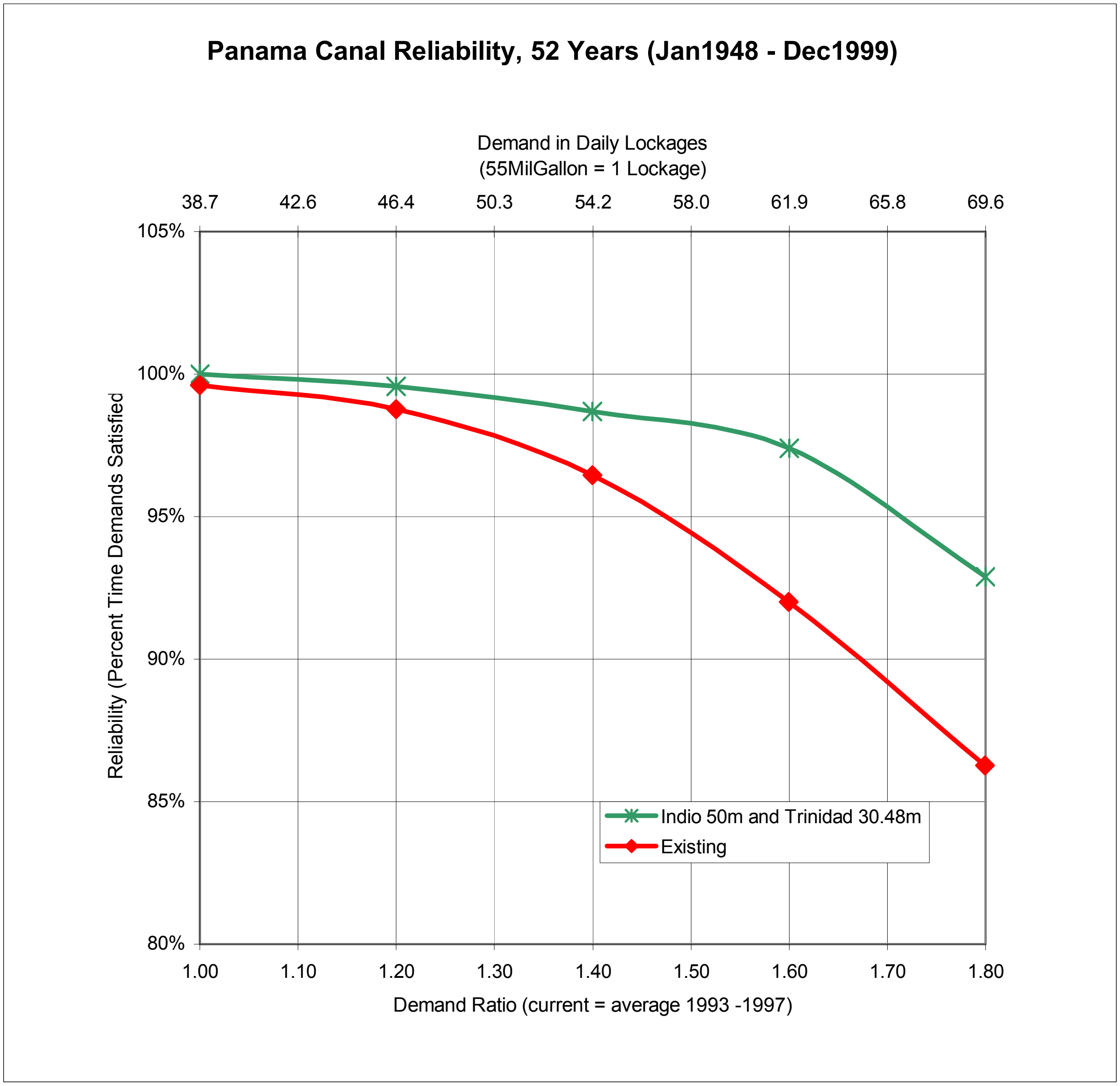


Figure 38 - 4 Panama Canal Hydrologic Reliability

Project Costs

GENERAL

The quantities estimated for the various items of work required for the construction of this project are derived from the layouts shown on Plate 38-1. The unit prices applied to these quantities are based on: historical information from previous estimates prepared for similar construction by the ACP; estimates for similar construction in the Mobile District; information gathered from Mobile District Construction Division personnel in Panama; and the book

Feasibility Studies For Small Scale Hydropower Additions, A Guide Manual, written by The Hydrologic Engineering Center of the U.S. Army Corps of Engineers.

Engineering and design is estimated to be 12 percent while supervision and administration is estimated to be 6 percent of the construction cost items. An allowance of 2 percent of the construction cost items is allowed for field overhead (construction camp, contractor facilities, etc.). An allowance of 25 percent is included for contingencies.

FIRST COSTS

The total project first costs are estimated at $1,010,571,000. Table 38 - 6 provides a summary of the first costs for the principal features. Separate documentation provided to the ACP includes a detailed cost estimate containing the sub-features of the work.

Table 38 - 6 Summary of First Costs

Item	Lower Trinidad Costs ($)	Rio Indio Costs ($)
Lands and Relocations	2,000,000	4,750,000
Access Roads	9,574,000	7,810,000
Clearing and / or Grubbing	556,250	2,957,500
Cofferdam	850,000	4,850,665
Dam	491,824,842	15,226,374
Spillway	8,891,206	42,070,303
Intake	N/A	7,701,295
Saddle Dikes	2,143,390	N/A
Pumping Station	22,999,637	N/A
Diversion Tunnel	N/A	4,714,622
Interbasin Transfer Tunnel	N/A	27,806,250
Transfer Intake Indio-Gatun	N/A	371,194
Hydropower Plants	N/A	7,926,380
Transmission Lines	2,090,000	6,600,000
Subtotal	540,929,325	132,784,583
E&D, S&A, Field Overhead	108,185,865	26,556,917
Contingencies	162,278,798	39,835,375
Total Project First Cost	811,393,988 Approximately 811,400,000	199,176,875 Approximately 199,177,000

OPERATION AND MAINTENANCE

Staff

A staff would operate and maintain the proposed Lower Rio Trinidad project during the day and then run the facility remotely. The full-time staff would ultimately consist of a total force of 9 who would include a station manager, a multi-skilled supervisor, 2 leaders (Electronics / Instrumentation, Electrical and Mechanical), 4 craftsmen and a laborer. A part-time staff would be required for two to three months each year to perform general maintenance and overhaul of the proposed project. The part-time staff would consist of three mechanics and three electricians. The annual costs of the staff are estimated to be $350,000. The annual costs of the staff for the proposed Rio Indio project are estimated to be $500,000.

Ordinary Maintenance

Ordinary maintenance and care is required and includes minor repair materials, lubricants and other supplies needed by project staff. It is estimated that the costs of ordinary maintenance is $18,000 per year for the access road and $100,000 per year for the main project facilities. Fuel consumption for the pumps is estimated at $648,000. This estimate considers the growth in demand for water over time and the variability in inflows to Gatun Lake, as well as the proposed Lower Trinidad project. An estimated $150,000 would be needed for rock placement to account for settling of the project. The total ordinary maintenance is $916,000. The ordinary maintenance for the proposed Rio Indio project is estimated to be $320,000.

Major Replacements

The average service life of gates, electrical equipment, pumps, trash racks and other features would be less than the total useful life of the project (100 years). To estimate the major replacement costs necessary during the 50-year planning period for this proposed project, it is assumed that specific items should cost the same as at present. No allowance is made for salvageable fixed parts. Table 38 - 7 presents the service life, number of times each component should be replaced during the 50-year planning period, the future costs of each item, and the present worth of the replacement costs for the major components for the proposed Rio Indio project. Based on these values, the present worth of the proposed replacements is $273,000 and the average annual replacement costs is $33,000. The average annual replacement cost for the proposed Lower Rio Trinidad project is estimated to be $267,000.

Table 38 - 7 Major Replacement Costs

Component	Service Life (years)	Number of Times Replaced During Planning Period	Future Costs ($)	Present Worth of Replacement Costs ($)
Roads	50	1	8,250,000	28,500
Bridges	50	1	3,375,000	11,700
Intakes				
Head Gates	50	1	801,900	2,800
Minimum Flow Gates	50	1	90,000	300
Stoplogs	50	1	378,300	1,300
Trash Racks	25	2	121,500	400
Access Stairs	50	1	66,750	200
Hydropower Plant				
Turbines & Generators	33	1	4,798,200	114,000
Station Elec. Equip.	33	1	1,713,600	40,700
Switchyard Equipment	33	1	1,193,400	28,400
Misc. Plant Equipment	33	1	440,640	10,500
Transmission Lines	50	1	9,900,000	34,300
Total			31,129,290	273,000
Average Annual Replacement Costs				33,000

Annual Costs

The project first costs for the proposed Lower Rio Trinidad project are estimated at $811,400,000. The total project first costs, including the $199,177,000 costs for the Rio Indio project, are estimated at $1,010,571,000. These total project first costs are distributed across the development period using generalized curves for contractor earnings for large, heavy construction jobs. Interest on the proposed Rio Indio project first costs is computed from mid-year throughout the 22-year development period. Interest during construction for the Lower Trinidad project is computed from mid-year throughout its 13-year development period until lake filling is complete. The interest during construction at 12 percent is $658,745,000 for Lower Trinidad, and $1,001,634,000 for Rio Indio - for a total interest during construction of $1,660,379,000. These costs are added to the total project first costs for total project investment costs of $2,670,950,000. A capital recovery factor for the 50-year planning period is applied to get the annual average investment costs of $321,627,000. Annual operation and maintenance costs are added. Major replacement costs are estimated and converted to an annual cost by discounting the future replacement costs of major components of the project back to completion of the project construction. Table 38 - 8 contains a summary of the $324,013,000 total annual costs.

Table 38 - 8 Summary of Annual Costs

Item	Costs ($)
Total Project First Costs - Lower Trinidad	811,394,000
Total Project First Costs – Rio Indio	199,177,000
Interest During Construction – Lower Trinidad	658,745,000
Interest During Construction – Rio Indio	1,001,634,000
Total Project Investment Costs	2,670,950,000
Annual Average Investment Costs	321,627,000
Operation and Maintenance Costs	
Staff Costs – Lower Trinidad	350,000
Staff Costs – Rio Indio	500,000
Ordinary Maintenance Costs – Lower Trinidad	916,000
Ordinary Maintenance Costs – Rio Indio	320,000
Major Replacement Costs – Lower Trinidad	267,000
Major Replacement Costs – Rio Indio	33,000
Total Average Annual Costs	324,013,000

Annual Benefits

NAVIGATION

The procedures and assumptions used in estimating the benefits are described in Volume One, Section 4. The following paragraphs present the results of the economic investigations for the proposed Lower Rio Trinidad and Rio Indio Dam projects. The 50-year period for the economic analyses of this proposal is 2024 to 2073.

The proposed Lower Rio Trinidad and Rio Indio Dam projects should increase the reliability of water to the total daily number of lockages demanded. Table 38-9 provides the increase in the hydrologic reliability of providing the sum of the demands for both navigation and M&I water supply keyed to years. The hydrologic reliability percentages obtained from the data are used to develop \
Figure 38 - 4. The 99.6 percent level of reliability for this proposal is used to estimate the water supply benefits for navigation. The net change in reliability is used to estimate the reliability benefits for navigation and M&I water uses.

Table 38 - 9 Panama Canal Hydrologic Reliability
(Based on Period of Record from January 1948 to July 1998)

Current Demand Ratio	Year	Demand in Daily Average Number of Lockages (Navigation and M&I)	Hydrologic Reliability	
			Existing System (%)	With Lower Rio Trinidad and Rio Indio [1/] (%)
1	2000	38.68 [2/]	99.60	100.0
	2010	45.11	98.91	99.64
1.2		46.42	98.76	99.56
	2015	46.82	98.64	99.53
	2020	47.61	98.41	99.43
	2025	48.52	98.14	99.32
	2030	49.55	97.83	99.21
	2035	50.72	97.48	99.07
	2040	52.02	97.10	98.92
	2045	53.49	96.65	98.76
1.4		54.15	96.45	98.68
	2050	55.13	95.89	98.52
	2055	56.98	94.83	98.11
	2060	59.05	93.65	98.11
	2065	61.37	92.32	97.48
1.6		61.89	92.02	97.39
	2070	63.97	90.47	95.05
1.8		69.63	86.27	88.68

[1/] The lake behind the Lower Trinidad Dam would fluctuate from the normal operating lake level at EL. 30.48 m MSL down to the minimum operating lake level at EL. 22.86 m MSL and the lake behind the Rio Indio Dam would operate at EL. 50 m MSL.

[2/] 2000 Daily Demand is Average of 1993-1997

With the proposed Lower Rio Trinidad and Rio Indio projects, water supply shortages for navigation should continue. The demand for the M&I purposes should always be met first. As these demands grow, the amount of water available to meet the demands for navigation should decrease. Thus, the benefits for the additional water supply are estimated at the value for navigation. With the addition of the proposed Lower Trinidad and Rio Indio projects, these shortages would be less frequent. With a hydrologic reliability of 99.6 percent, the proposed project should increase the amount of water supplied by 7.06 equivalent lockages. The 99.6 percent hydrologic reliability should occur after the year 2013, with an equivalent daily average number of lockages of 45.74. Benefits for these amounts of additional water are attributable to navigation since the amount of M&I water demanded would be provided first. Therefore, all shortages are attributable to navigation. The benefits are estimated using the toll revenue per lockage and the increased daily average number of lockages. The average annual benefit for water supply is $145,539,000. Table 38 - 10 provides the estimate of daily shortages under the existing system, the remaining daily shortages with the proposed Lower Trinidad and Rio Indio projects in operation, the annual benefits for meeting shortages and the average annual benefits.

Table 38 - 10 Benefits for Additional Water Supply for Navigation

Year	Daily Shortages In Lockages Under Existing System	Remaining Daily Shortages	Annual Benefits For Navigation ($)
2023	9.51	2.45	145,539,000
2030	10.87	3.81	145,539,000
2040	13.34	6.28	145,539,000
2050	16.45	9.39	145,539,000
2060	20.36	13.31	145,539,000
2070	25.29	18.23	145,539,000
Average Annual Benefits			145,539,000
With the Lower Trinidad project operating between 22.86 and 30.48 m and the Rio Indio project operating at 50 m, the system should provide a total of 45.74 lockages at the 99.6 percent level of reliability or 7.06 more lockages than the existing system.			

With the proposed Lower Rio Trinidad and Rio Indio projects, the reliability of the system to provide all of the water demanded by navigation and M&I water would be improved. Using the increase in hydrologic reliability, the forecast number of vessels converted to a daily average number of lockages, the toll revenue for each average lockage, and a project discount rate of 12 percent, the average annual benefits for navigation reliability attributable to the proposed Lower Trinidad and Rio Indio projects is $12,332,000. Table 38 - 11 provides the forecast daily average number of lockages, the forecast value per daily lockage, the annual benefits for increased reliability, and the average annual benefits.

Table 38 - 11 Average Annual Reliability Benefits For Navigation

Year	Daily Average Number of Lockages	Value Per Lockage ($)	Annual Benefits For Navigation ($)
2023	40.0	2,260,000	9,281,000
2030	40.0	2,260,000	11,357,000
2040	40.0	2,260,000	15,126,000
2050	40.0	2,260,000	21,661,000
2060	40.0	2,260,000	29,872,000
2070	40.0	2,260,000	37,755,000
Average Annual Benefits			12,332,000

M&I WATER SUPPLY

The future demand for water supply for M&I purposes is based upon the growth in population. The ACP provided a forecast for the area surrounding the Panama Canal. The current usage is estimated at 4.0 equivalent lockages per day; an equivalent lockage is 55 million gallons of water. One equivalent lockage is added to the forecast to account for the burgeoning tourist industry, beginning in the year 2010. The increased reliability of the system to provide water for navigation provides the same increase in reliability to provide water for M&I purposes. Using the increased hydrologic reliability of the system with the addition of the proposed Lower Trinidad and Rio Indio projects, the current costs to the ACP to process water ($0.69 per 1,000 gallons), the number of daily lockages demanded, and a project discount rate of 12 percent, the average annual benefits for M&I reliability are $2,254,000. Table 38 - 12 displays the population forecast, the resulting number of equivalent lockages per day, and the benefits for M&I water supply.

Table 38 - 12 Average Annual Reliability Benefits For M&I Water Supply

Year	Population	Equivalent Lockages per Day	Annual M&I Water Supply Benefits ($)
2023	2,294,000	8.15	1,277,000
2030	2,688,000	9.55	1,824,000
2040	3,384,000	12.02	3,052,000
2050	4,259,000	15.13	5,501,000
2060	5,360,000	19.05	9,557,000
2070	6,746,000	23.97	15,202,000
Average Annual Benefits			2,254,000

HYDROPOWER

The amount of hydropower energy that can be produced by the system of Gatun Lake and Madden Lake should decline over time as the demands for navigation and M&I water supply increase. With the inclusion of the Lower Rio Trinidad project, the system will loose hydropower generation at Gatun Lake and Madden Lake due to the change in the operation of the system. The inclusion of the Rio Indio Dam project, however, will not produce enough additional megawatt hours of hydropower to offset those losses in hydropower generation. Thus, the system will have a net decrease in hydropower production. The value for hydropower energy used in this analysis is $0.070 / kWh. On an average annual basis, the proposed project should have losses of ($1,053,000). Table 38 - 13 provides the net additional megawatt hours of hydropower generation and the resulting benefits.

Table 38 - 13 Average Annual Benefits For Hydropower Generation

Year	Net Generation [1] (MWh)	Annual Benefits for Hydropower ($)
2023	(14,945)	(1,046,000)
2030	(14,929)	(1,045,000)
2040	(14,902)	(1,043,000)
2050	(15,515)	(1,086,000)
2060	(18,063)	(1,264,000)
2070	(25,326)	(1,773,000)
Average Annual Benefits		(1,053,000)
[1/] Net generation of Gatun, Madden and Indio above generation of Gatun and Madden hydropower plants.		

SUMMARY OF ANNUAL BENEFITS

As shown in Table 38 - 14, total average annual benefits for the proposed Lower Trinidad and Rio Indio projects are $159,072,000.

Table 38 - 14 Summary of Annual Benefits

Benefit Category	Average Annual Benefits ($)
Navigation – Water Supply	145,539,000
Navigation – Reliability	12,332,000
M&I - Reliability	2,254,000
Hydropower	(1,053,000)
Total	159,072,000

To perform an analysis of benefits versus costs, a common point in time is selected. This common point is at the completion of filling of the project, the end of the year 2022. In these analyses, it is important to note that the average annual benefits or average annual costs are the amortized value of the sum of the present worth of either the benefits or costs at the point of comparison. The development sequence for the proposed Lower Rio Trinidad and Rio Indio Dam projects would be to develop the Rio Indio Dam project first (2001 – 2010) and then the Lower Rio Trinidad Dam project (2009 – 2022).

The benefits attributable to the proposed Rio Indio Dam project begin to accrue in 2010 when the reservoir is filled. The operation of Gatun Lake during the construction of the proposed Lower Rio Trinidad Dam project would be the same as described in Volume One, Section 5. The Rio Indio Dam project benefits for the period 2011 to 2022 is escalated by the project discount rate, 12 percent, in order to estimate the total present worth of $1,270,111,000 in the year 2022. The average annual benefits for the proposed Rio Indio project accrued during the construction of the proposed Lower Trinidad project are estimated at $152,943,000.

To estimate the interest during construction, similar calculations are made for the costs of each proposed project. For the proposed Rio Indio project, interest during construction is taken from year 2001 to year 2022 and the interest during construction for the proposed Lower Trinidad project was taken from the year 2009 to the year 2022.

The sequence of development of the two projects is crucial to the estimate of average annual benefits and costs. If the Lower Rio Trinidad Dam project is developed first, then the average annual costs double in size and the average annual benefits reduce to less than half of the values that are estimated for the development sequence of Rio Indio and then Lower Rio Trinidad. This occurs because the first costs for the Lower Rio Trinidad Dam project are four times the cost for the Rio Indio Dam project ($812M vs. $245M). The estimate of interest during construction changes from approximately $4B to $2B. Likewise, the Rio Indio Dam project provides approximately 80 percent of the total average annual benefits of the combined projects ($212M of $258M). The estimate of benefits for the first project during the period of construction of the other project changes from $150M to $600M.

Total average annual benefits and average annual costs were then estimated, and the ratio of benefits to costs and the net benefits (net of costs) are computed. In the first instance, the analysis determines the feasibility of the proposal. The net benefits determine which proposal among several provides the greatest value for the investment dollars. Table 38 - 15 provides the benefit to cost ratio and the net benefits.

Table 38 - 15 Economic Evaluation

Item	Value ($)
Average Annual Benefits	
Lower Trinidad	159,072,000
Rio Indio	152,943,000
Total Average Annual Benefits	312,015,000
Average Annual Costs	
Lower Trinidad	178,562,000
Rio Indio	145,451,000
Total Average Annual Costs	324,013,000
Benefit to Cost Ratio	0.96
Net Benefits	(11,998,000)

Internal Rate of Return

An internal rate of return analysis for this proposed project was performed. To accomplish this analysis, the annual construction costs are used as the investment, and the undiscounted benefits are used as return cash flows. The internal rate of return is 11.8 percent.

Socio-Economic Impacts

The description of the environmental setting is based on field observations made while conducting field reconnaissance throughout Gatun Lake, specifically the Lower Rio Trinidad and Rio Indio areas with ACP personnel. Autoridad Nacional del Ambiente (ANAM), ACP, Asociacion Nacional para la Conservacion de la Naturaleza (ANCON), Electrical Transmission Agency, Smithsonian Tropical Research Institute (STRI), and Directorate of Mineral Resources personnel were interviewed to gain information on site characteristics and potential activities that could affect the project. In addition, extrapolations of the 2000 census data were used, and a review of the Informe de Cobertura Boscosa 1992 were used to determine the extent of forest cover.

Environmental Setting

This alternative combines two projects which would function in tandem with Gatun Lake, The Lower Rio Trinidad (lake level 22.9 - 30.5 m) and Upper Rio Indio (lake level 50 m). This project would provide additional storage of water for Gatun Lake and 7.06 additional lockages per day on a continual basis. The structures for the proposed Lower Trinidad portion of the project would consist of a rockfill dam, a pumping station, a gated spillway, and access/maintenance roads. The project area consists of 18,169 ha within Gatun Lake. The area near Gatun Lake is sparsely populated and has a topography consisting of rolling hills, low regions near Gatun Lake. The Rio Indio portion of the project would consist of a rock fill dam, outlet works, unregulated spillway, an interbasin transfer tunnel, two hydropower facilities, and required access and maintenance roads and power transmission lines. The project area would require approximately 1,898 ha along the eastern leg of the Upper Rio Indio. Near Rio Indio, the area is sparsely populated with terrains and a topography consisting of steep hills as well as coastal regions. The Lower Rio Trinidad and Rio Indio are west of the Panama Canal and flows northward from the Continental Divide into Gatun Lake. The watershed above the Lower Rio Trinidad and the Rio Indio dam project covers approximately 741 km^2 and 256 km^2 respectively. The incremental impoundment area, which covers approximately 3,968 ha, consists of approximately 50 percent forested land, 30 percent pasture land (used by ranchers), 10 percent cropland, and 10 percent newly slashed and burned land. Gatun Lake's normal pool level is 26.7 m. The lake level during field observations (August 2001) was approximately 25.4 m.

LAND USE

The Lower Rio Trinidad project area encompasses the southwestern portion of Gatun Lake and areas along its shores. The areas to be flooded or partially flooded include the town of Escobal (population – 1,653), Nuevo Provenir (population – 121), Cuipo (population – 249), Ciricito (population – 72), La Arenosa (population – 242), La Garterita (population – 138), La Gartera (population – 348), and a few small isolated establishments.

Some areas along the shores of the Lower Rio Trinidad have been deforested. Approximately 65 percent of the lakeshore areas are forested, mostly with secondary growth. Farms and ranches of various sizes as well as plantations of teak and African mahogany occupy the remaining land. Farm crops include maize, rice, beans, sugar, coffee, mangos, pineapples, and tobacco. Ranchers raise cows, horses, chickens, hogs, and tilapia. Some of the farmers and ranchers operate commercial enterprises, others rely on cash crops and subsistence farming. No significant ore deposits or mineral resources are located in the project area.

Approximately 2,300 people inhabits the Rio Indio project area; they live in the towns of Tres Hermanas (population – 200), Los Cedros (population – 80), El Coquillo (popoulation – 150), El Limon (population – 140), Los Uveros (population – 140), and La Boca de Uracillo (population – 110), and in nearly 30 smaller settlements. Downstream from the dam site at El Limon there are 14 communities with a combined population of approximately 600. The largest of these is La Boca del Rio Indio with a population of more than 150.

Farms and ranches of various sizes, as well as some teak plantations, occupy approximately 60 percent of the land in the project area. Farm crops include maize, rice, beans, sugar, coffee, and tobacco. Ranches raise horses, cows, chickens, and hogs. Some of the farmers and ranchers run small commercial enterprises, or rely on cash crop and subsistence farming.

INFRASTRUCTURE

During site investigations in the Lower Trinidad area, the town of Escobal was the largest settlement visited. Escobal has businesses, schools, churches, cemeteries, medical centers, residences, and paved roadways of good condition. A new and improved roadway (Highway 35) is adjacent to the project area near Escobal. Other establishments in the project area are - Nuevo Provenir; Cuipo; Ciricito; La Arenosa; La Garterita; La Gartera - and a few small isolated establishments. These communities have elementary schools, small cemeteries, churches and meeting centers, medical clinics, and a few small businesses (i.e. general stores). The towns and villages depend on Gatun Lake or groundwater wells for their potable water supply. Each community also had docks, small ports, and other boat access facilities. Goods are transported from one town to another by boat. No treatment of community waste is provided. Wastewater from showers and washing is discharged into the environment; some of it may eventually reach the Lower Rio Trinidad portion of Gatun Lake. Disposal of domestic waste is the responsibility of individual homeowners: some homes have septic tanks, while others have an outdoor latrine (a hole in the ground). There are some health problems, such as hepatitis, dysentery, dermatitis, intestinal parasites, and respiratory illnesses which are attributable to the present waste disposal methods. No major industries or poultry or beef processing plants are located in the project area. The project area is traversed by unpaved horseback riding trails that link the various communities and by unpaved roads used by the ACP for maintenance. Because of the relatively isolated location of the project area, these roads are extremely important to the residents for transportation, community cohesion, commerce, and communication with neighboring communities.

In the Rio Indio project area, towns of El Limon, El Silencio, San Cristobal, and Piedra Amarilla have elementary schools. Several towns have cemeteries, churches, and medical centers. All these towns obtain water from rivers or groundwater wells. Some have electricity (from small generators) and limited telephone service. No treatment of community waste is provided. Wastewater from showers and washing is discharged into the environment; some of it might eventually reach Rio Indio and its tributaries. Disposal of domestic waste is the responsibility of individual homeowners; each home has an outdoor latrine. There are some known health problems, such as hepatitis, diarrhea, dermatitis, intestinal parasites, and respiratory illnesses which are attributed to the present waste disposal methods. No known major industries or poultry or beef processing plants are located in the project area. The only roads in the project area are unpaved and poorly maintained, and are usable only in the dry season (mid-December through March). The roads are rarely graded and receive little attention from either the Ministry of Public Works or the local government. Due to the relatively isolated location of the project area, these roads are extremely important to the residents for transportation, community cohesion, commerce, and communication with neighboring communities.

TERRESTRIAL HABITAT

The terrestrial habitat in the Lower Rio Trinidad project area of Gatun Lake consists of tropical forest ecosystems, mostly secondary growth forests with patches of primary forest. About 65 percent of the land along the Lower Rio Trinidad of Gatun Lake is forested and probably supports diverse wildlife populations. The Lower Rio Trinidad areas of Gatun Lake also contain islands inhabited by wildlife. Some of the wildlife species do not interact with species on the mainland; others migrate between the island and the mainland. The species interrelationships are of great interest to scientists studying tropical ecosystems. Slash and burn activities have opened tracts of land for farming and cattle grazing; however, the majority of the lakeshore is forested to the edge of the water. Terrestrial areas are used by migratory species as wintering, breeding, and feeding grounds. The complex and diverse tropical ecosystems offer habitat to connect a variety of wildlife communities and may provide critical wildlife habitat to many native species.

In Rio Indio, forests along the river that could support diverse wildlife populations cover about 90 percent of the areas along the Rio Indio and its tributaries. The forests also extend to the mountainous areas above the Rio Indio impoundment. As a result of slash and burn activities, there are no large contiguous tracts of forests at lower elevations in the impoundment.

ANIMALS ON ENDANGERED LIST

ANAM by its Resolution 002-80 on June 7, 1995 declared 33 mammals, 39 birds, and 11 reptiles and amphibians as being in danger of becoming extinct in Panama. Although their presence has not been confirmed to date, some of the listed species of interest on the threatened list might be found in the project area. The manatee is an aquatic mammal known to inhabit Gatun Lake around the Barro Colorado Island; however, it has not been sighted in the project area.

AQUATIC HABITAT

Gatun Lake, one of the world's largest manmade lakes, was created during the construction of the Panama Canal. The lake's water depth and quality vary widely. Aquatic habitat ranges from inundated forests to clear water in areas distant from shipping lanes. The Lower Rio Trinidad areas of Gatun Lake provide habitat for a variety of wildlife species, both resident and migratory, as well as for both native and introduced fish and other aquatic species.

Rio Indio in the project area has characteristics typical of streams in mountainous regions. Its water is clean and cool, and its bottom ranges from sand to boulders, with numerous riffles, runs, and pools. Tributaries to Rio Indio include four major streams: Rio El Torno, Rio Uracillo, Rio Teria, and Rio Riacito, and 20 smaller streams. The river is approximately 16 km long, its width ranges from 3 m (in the dry season) to 10 m. The tributaries appear to support some fish communities; however, information about these is limited.

WETLANDS

Areas that contain hydric soils and hydrophytic plant communities, and that are subject to hydric conditions are termed wetlands. Wetlands occur in topographic area where water remains pooled long enough to produce hydric soil conditions and wetland plant communities. Wetlands in the Lower Rio Trinidad project area consist of shallow water habitat and lands subject to frequent flooding. Shallow water areas along the banks of the Lower Rio Trinidad area of Gatun Lake receive sunlight to approximately 1 meter. Sunlight stimulates growth of submergent, emergent, or floating mats of aquatic vegetation. Wetlands in the project area are stressed as a result of sediments, municipal waste, agricultural runoff, and other debris carried in the runoff.

Wetlands in the Rio Indio project area consist of forested riparian habitat and are limited by their relatively steep topography. The width of the riparian habitat within the impoundment area varies from approximately 5 to 50 meters. Approximately 90 percent of the streams both above and below the dam site along the Rio Indio and its tributaries are bordered by forested riparian habitat.

AIR QUALITY

Air quality in the project area is generally good, except during the slash and burn activities. At the end of the dry season in March or early April, areas of forest and secondary growth are burned and cleared for agricultural use. During this period, the air is filled with smoke and ash, which may be transported by winds to the Lower Rio Trinidad area of Gatun Lake. Based on observations in the Rio Indio project area, approximately 10 percent (or 400 hectares) of forested land is burned annually. Air quality monitoring has not been implemented within the project area.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

Barro Colorado Island is an international center for tropical research and one of the first biological reserves established in the Neotropics. From 1923 through 1940, a scientific committee of the U.S. National Academy of Sciences administered the biological reserve/laboratory. In 1940, by an Act of the United States Congress, the facility was renamed the Panama Canal Zone Biological Area, and in 1946, the responsibility for its maintenance was assigned to the Smithsonian Institution. With the Panama Canal Treaty Implementation in 1977, the island was granted the category of National Monument and to date it continues to be managed by the Smithsonian Institute.It should also be noted that most of the Atlantic region of Panama is within the interest and objectives of the Mesoamerican Biological Corridor, an international project to conserve biodiversity.

In the pre-Columbian period, Rio Indio was a language frontier; that is, the inhabitants on each side of the river spoke a different native language. During the Spanish colonial period, the river served as a political boundary; thus, the project area has a high potential to be rich in archaeological and historical remains.

Environmental Impacts

TERRESTRIAL HABITAT

The impacts of the project on terrestrial habitat in the Lower Rio Trinidad area of Gatun Lake could be substantial. The boundary between two types of habitats, in this case between a forest and a lake, is called an ecotone. Ecotones are inhabited by a variety of species from neighboring habitats, and are unique, with high species diversity. Considering the proposed operating levels for both impoundments, between 22.9 - 30.5 m, as the normal zone of operation, erosion of the shoreline may be substantial as pool levels rise and fall. errestrial habitat that would be inundated above the 26. 7 m (existing level) to the 30.5 m proposed normal pool level consists of 18,169 ha for the Lower Rio Trinidad project. The placement of a dam structure, access roads, and pump stations would permanently impact terrestrial habitat. Wildlife species that are able to relocate to suitable areas will compete with similar species for resources. Wildlife species that are not able to relocate will not survive. As a result, competition for natural resources in surrounding habitat areas will increase. This is considered a secondary impact to terrestrial habitat outside the proposed zone of inundation and construction.

The terrestrial impacts of the Rio Indio project, which is located in area of relatively high quality forest habitat, would be substantial. With the creation of the lake, the migratory routes of some species could be adversely affected. Forested areas along lower elevations would be lost as a result of the impoundment. The only forests that would remain near the Rio Indio reservoir and its drainage basin would be confined to the higher elevations, where the vegetation and species may be completely different from those found on lower elevations. Natural communities are linked together by complex interactions and relationships among various species, therefore impacts to upper forested areas may occur resulting from the inundation of the lower forests.

ANIMALS ON ENDANGERED LIST

The severity of impacts on endangered species cannot be determined at this time, because although it is expected that some of the listed species are found in the region, it is not known which of the listed species inhabit the proposed project area. Some endangered and/or threatened species may use the Lower Rio Trinidad areaa of Gatun Lake during some or all parts of their life cycle.

WATER QUANTITY

The impacts of the Lower Trinidad project on water quantity would be substantial. The increase in the volume of water could have negative impacts to lakeshore communities as well as on existing ecosystems. The same is true if the lake level is lowered and maintained at 22.9 m.

The impacts of the Rio Indio project area on water quality would also be substantial. The volume of water will increase, making fresh water available in the surrounding areas during the dry season. The impacts downstream from the dam would be significant. Sediment loads would be deposited upstream from the dam as water velocity slows. Downstream from the dam the water will be released at an increased velocity, causing erosion of banks and river bottoms. Seasonal flooding could be significantly reduced. It would also be possible to periodically release water in appropriate amounts to avoid problems with water quality and temperature downstream. The cumulative impacts downstream from the dam site depend on the amount of water being released.

WATER QUALITY

Project impacts on water quality are not known. Damming the Lower Rio Trinidad could increase the amounts of nutrients and debris in this portion of Gatun Lake. A pilot plant tilapia farm is in the project area and may affect water quality. The rate at which nutrients and debris enter the lake will determine the severity of their impact on water quality. Project implementation could cause an increase in turbidity, which would interfere with photosynthesis and deprive plants and other aquatic species from sunlight. Aquatic plants and organisms serve to maintain water quality. The dam would interfere with the circulation of freshwater throughout the Gatun Lake environment. Species inhabiting specific depths could be impacted when lake depth increases to 30.5 m and/or decreases to 22.9 m.

The impacts of the Rio Indio project on water quality could be positive. The people living downstream from the dam and around the impoundment would have access to a water supply of higher quality. Water quality in the impoundment area would differ from water released downstream from the dam. If the water in the impoundment area does not circulate or turn over periodically, it could become anoxic. A change in temperature, dissolved oxygen, turbidity, or pH could change water quality.

DOWNSTREAM AQUATIC FAUNAL HABITAT

The impacts of the project on aquatic faunal habitat could be substantial. The project may affect the breeding and nursery habitat of many aquatic species. Impacts to fish spawning areas may be detrimental when turbidity, nutrient content, and depth of the water suddenly increase or decrease, by altering the conditions needed for a successful fish hatch. Plant populations may decrease as a result of fluctuating water depths, clarity, and quality. Invertebrate populations may decline, which could reduce the food supply for fish and other aquatic species.

Impacts to downstream aquatic faunal communities in the Rio Indio project area could be substantial, because the dam structure will prevent their migration throughout the riverine habitat. The dam structure would be designed for multi-level releases to maintain a water level downstream from the dam site. The dam should act as a large sediment trap; thus, the released water would have low turbidity, which would result in better visibility and increased predation on the fish species. Aquatic faunal habitats downstream would be deprived of the beneficial nutrients and silts that were transported in the sediment. Native riverine fish species may be negatively impacted as a result of the project; the extent of the impact is not known.

FUTURE LAKE AQUATIC PLANT COMMUNITY

The impacts of the project on future aquatic plant communities depend on water quality and stability of water levels. Plant species in the Lower Rio Trinidad portion of Gatun Lake could be impacted by fluctuating water levels. Aquatic plant communities could be impacted during project implementation; however, they could re-establish themselves after conditions stabilize.

The severity of impacts from the Rio Indio project will depend on water level fluctuations. Since water levels are anticipated to fluctuate widely, large portions of the shores would be covered with mud, where neither aquatic nor terrestrial plants could thrive.

AQUATIC FAUNA INHABITING AFFECTED AREAS

The proposed project impacts could have some unavoidable, adverse environmental impacts on aquatic fauna in the Lower Rio Trinidad and associated rivers and tributaries. These impacts should be identified and minimized with appropriate mitigation measures to be discussed in a feasibility level study. Gatun Lake has populations of peacock bass and tilapia, both introduced species that have adapted well. However, several native riverine species that formerly occupied the impoundment have disappeared.

The impacts of the Rio Indio project on aquatic fauna in the Rio Indio and its upstream tributaries could be substantial, since the habitat area would change from riverine to lacustrine. Some aquatic species would continue to inhabit the area; however, non-native fish species would become dominant in the impoundment area and native riverine species would be pushed upstream or extirpated. Other manmade lakes in the Republic of Panama have been stocked with peacock bass and tilapia, both of which have adapted well. The impoundment area would probably be stocked with these species to promote sport fishing and to provide the local communities with fish for food.

WETLANDS

The impacts to wetlands could be significant. Inundation of wetlands could cause them to become aquatic habitat. The changes in water depth caused by the project may lead to increased or decreased sedimentation and turbidity which could hamper the biological processes in the wetlands and decrease their productivity. Such impacts could be detrimental to the health and sustainability of the Lower Rio Trinidad area of Gatun Lake. Fish and other aquatic species use shallow water areas as spawning grounds as well as habitat for their juvenile aquatic species, that survive in the shallow waters of the wetlands until they are large enough to venture into deeper water. These wetlands are vital to the sustainability of this portion of Gatun Lake, including the Lower Rio Trinidad area.

The impacts to wetlands both upstream and downstream from the Rio Indio project area could be significant. Owing to the topography of the project area, a number of wetlands could be impacted. It is possible that although the reservoir level will fluctuate, new wetlands could develop in the littoral zones. Downstream from the dam site, wetlands along the minimal flow zone would survive; however, wetlands that depend on seasonal flooding for survival may be adversely affected.

AIR QUALITY

During project implementation, emissions from construction equipment, as well as from the slash and burn activities could cause deterioration of air quality. After project implementation, the air quality may be impacted by the operation of the power generation facility and the pumping stations.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

The potential impacts on cultural resources and historic properties from the Rio Indio project can be defined and mitigated, in particular, in the La Boca de Uracillo area, which is near previously identified archaeological sites. The project area is relatively large and is known to contain pre-Columbian sites; therefore, the presence of cultural resources and historic properties is highly probable. Prior to construction, surveys to locate cultural resources and historic properties would be conducted, and the important sites would be preserved or salvaged as appropriate.

SOCIO-ECONOMIC IMPACTS

The socio-economic impacts of the project could be substantial. The relocation of the towns and other small communities along the lakeshore would be an important issue. The average monthly income of families in the project area ranges from less than $100 to $200 per month. No indigenous groups are known to reside in the impact area. Land use would be greatly impacted by the inundation of pastures and agricultural lands to expand the impoundment. The relocation of agricultural and ranching activities would be an important issue, because approximately 10 percent of the land in the impoundment area is used for farming and ranching. After the water level is raised, additional agricultural land could be lost as a result of creation of islands that were once isthmuses. The incremental surface area of the proposed lake is 3,968 ha; another 1,044 ha from the Lower Trinidad project and 634 ha from the Rio Indio project will be occupied by the dam and construction areas, including permanent disposal areas.

During construction, the influx of workers could create a temporary demand for additional housing, which could result in an increase in housing values near the dam site. However, after completion of the project, the workers could leave, the housing demands could drop, and the housing values could return to pre-construction levels. Currently, all residents have access to public schools and health centers. During construction, these services should continue to be available, and additional public and community services may be offered. After construction, these services would return to the normal level.

To construct the dam, some existing roads would be improved and some new roads would be built. However, some paved and unpaved roads within the impoundment area would be eliminated, which would change traffic patterns and could cause some communities to lose overland transportation, communication, cohesion, and commerce with other communities. During construction, the traffic volumes over both new and existing roads systems would increase; however, following completion of construction, the traffic volumes could decline. Noise levels would temporarily increase during construction and could negatively impact noise-sensitive receptors, however, after construction noise levels may remain elevated as a result of the pump station.

The communities that receive people displaced by the project could be negatively impacted by overcrowding and by competition for jobs, land, and working areas. Construction of the dams would permanently displace people and disrupt community cohesion through the division of communities, separation of families, and loss of livelihood. Following completion of the impoundment, tourism trade in the affected region, including sport fishing and ecotourism, could increase.

Additional Environmental Information Required

This section identifies the subject areas for which additional data are required to evaluate in further detail, the scope and magnitude of the potential effects of the Lower Rio Trinidad and Rio Indio alternative. The subject areas are discussed by impact category.

SOCIO-ECONOMIC IMPACTS

- Conduct a SIA. The SIA would consist of three tasks: scoping, assessment, and mitigation and monitoring. The following information should be developed:
  - Business, Industrial, and Agricultural Activities;
  - Employment;
  - Land Use;
  - Property Values;
  - Public and Community Facilities and Services (including utilities and schools);
  - Transportation;
  - Housing;
  - Health (vector routes);
  - Population;
  - Community Cohesion; and,
  - Recreational Resources.

TERRESTRIAL AND AQUATIC HABITAT

- Prepare site-specific habitat maps to ensure that the major types of aquatic habitat are identified and quantified.
- Conduct field studies to locate rare and unique habitats, such as wetlands, primary forests, roosting sites, foraging areas, old growth, and migration flyways.
- Determine the present quality and ecosystem value of existing habitats within the Gatun Lake project area.
- Coordinate with local experts to identify and evaluate aquatic and terrestrial habitat areas.
- Prepare species inventory lists for each site area, identifying their status as native or exotic and whether they are threatened and/or endangered species.
- Conduct additional research into water currents and estimated turbidity levels to evaluate impacts to the shallow areas along Barro Colorado Island.
- Address cumulative effects caused by natural flow diversions.

ANIMALS ON THE ENDANGERED LIST

- Compile habitat maps to assess the availability and quality of suitable habitats for the animals on the endangered and/or threatened species list.
- Establish field methodology to assess wildlife habitat values.
- Conduct site surveys to determine the presence of selected species or their habitats.
- Develop candidate mitigation measures for the appropriate project alternatives to be considered in the Conceptual Phase.
- Coordinate with local experts on the presence of these species.

WATER QUALITY

- Since limited water quality data are available for the Gatun Lake area, compile information on total suspended solids, conductivity, total dissolved solids, dissolved oxygen, nutrients, pH, and coliform bacteria.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

- Information regarding cultural resources and historic properties in the project area is incomplete. Additional evaluation studies should be completed to identify any such resources and/or properties.

Evaluation Matrices

Table 38- 1 Developmental Effects

Evaluation Criteria	Function	Measure [1/]	Importance [2/]	Composite [3/]
Water Contribution (Water Yield)	Meets M&I Demands	8	10	80
	Supplements Existing System	0	10	0
	Satisfies Future Canal Needs/Expansion	0	10	0
	Additional Hydropower Potential	0	5	0
Technical Viability	Design Constraints	2	6	12
	Feasibility of Concept	2	6	12
Operational Issues	Compatibility	8	6	48
	Maintenance Requirements	4	2	8
	Operational Resources Required	4	2	8
Economic Feasibility	Net Benefits	0	9	0
	Total			168

[1/] Measure - A numerical from 0 to 10 value representing the degree or level the alternative satisfies the criteria. Value of 10 indicates the most significant beneficial impact and 0 the most significant adverse impact.
[2/] Importance - A weighting factor from 0 to 10 to balance the significance of a criteria to the others.
[3/] Composite - the product of the measure and importance.

Table 38 - 2 Environmental Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Terrestrial Habitat	3	8	24
Animals on Extinction List	2	10	20
Water Quantity Impacts – Lake	8	10	80
Water Quantity Impacts -- Downstream	4	7	28
Water Quality	5	10	50
Downstream Aquatic Fauna Habitat	3	8	24
Future Lake Aquatic Plant Community	6	8	48
Aquatic Faunal Inhabiting Affected Area and Upstream Tributaries	4	5	20
Potential for Fishing on Lake	6	6	36
Wetlands	4	4	16
Air Quality	5	3	15
Cultural Resources and Historic Properties	3	10	30
Total			391

[1/] Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
[2/] Importance - 1 to 10 increasing in importance.
[3/] Composite - the product of the measure and importance.

Table 16 - 3 Socio-Economic Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Land Use	1	7	7
Relocation of People	2	10	20
Relocation of Agricultural/Ranching Activities	2	6	12
Post-Construction Business	6	5	30
Post-Construction on Existing Employment	6	5	30
Property Values During Construction	7	4	28
Property Values Post-Construction	5	5	25
Public/Community Services During Construction	6	4	24
Public/Community Services Post-Construction	5	8	40
Traffic Volumes over Existing Roadway System During Construction	3	5	15
Traffic Volumes over New Roadway System Post-Construction	5	5	25
Noise-Sensitive Resources or Activities	4	4	16
Communities Receiving Displaced People	1	8	8
Community Cohesion	1	8	8
Tourism	6	5	30
Total			318

[1/] Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
[2/] Importance - 1 to 10 increasing in importance.
[3/] Composite - the product of the measure and importance.

Pertinent Data

Table 38 - 16 presents pertinent data for the proposed Lower Rio Trinidad project.

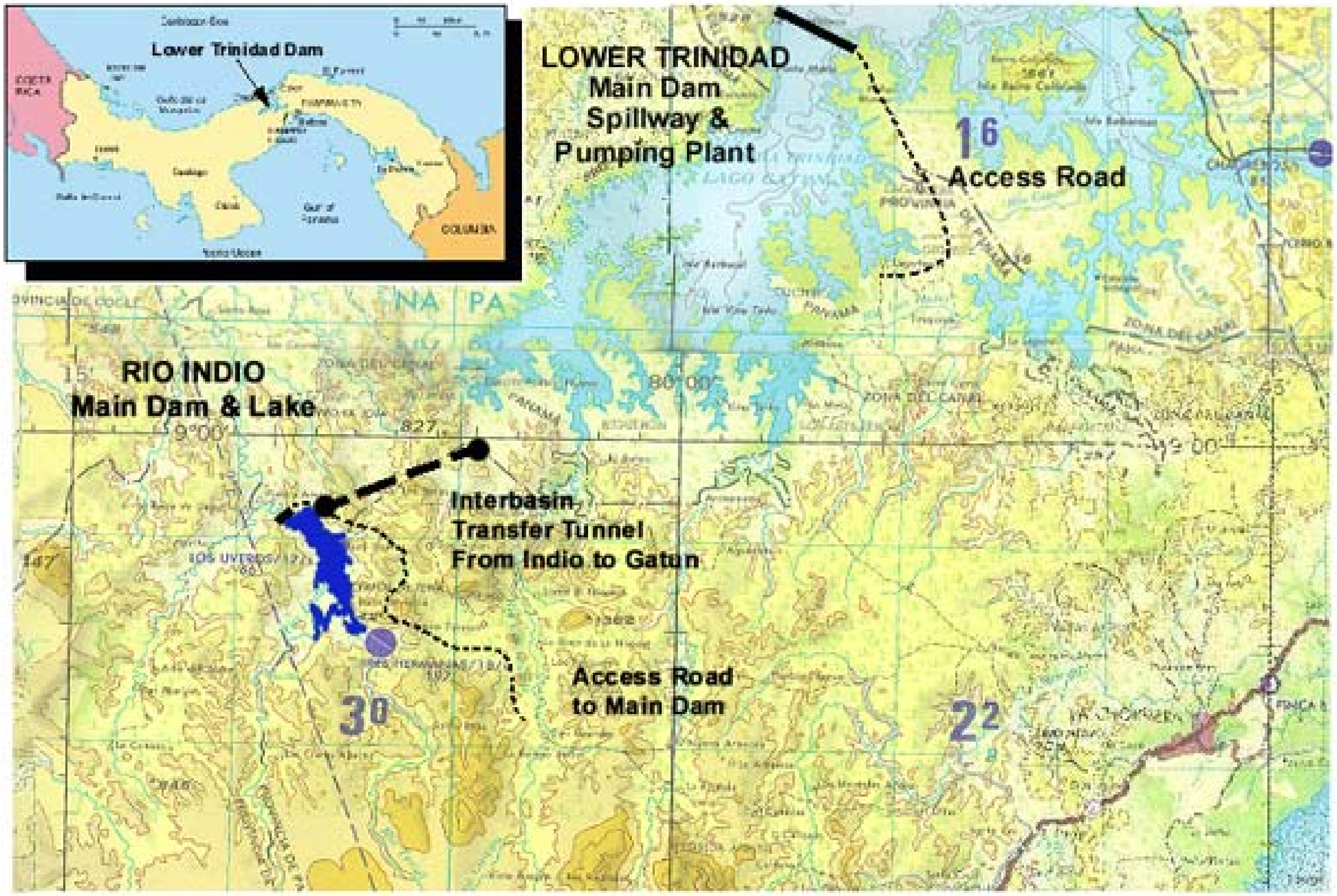
Table 38 - 16 Pertinent Data for Operating Scenario 3

GENERAL	**Gatun**	**Trinidad**	**Indio**
Drainage Area above Dam Site	2597.5 km^2	741 km^2	256 km^2
Average Annual Flow at Dam Site	60 CMS	30 CMS	16.8 CMS
LAKE			
Elevation of Maximum Operating Lake Level	26.67 m MSL	30.48 m MSL	50.0 m MSL
Elevation of Maximum Flood Storage Lake Level	26.74 m MSL	31.09 m MSL	53.0 m MSL
Elevation of Minimum Operating Lake Level	25.91 m MSL	22.86 m MSL	45.5 m MSL
Useable Storage between Max. and Min. levels	214.1 MCM	1139.5 MCM	35.6 MCM
Area at Maximum Operating Lake Level	29,410 ha	18,169 ha	863.8 ha
Area at Maximum Flood Storage Lake Level	29,775 ha	18,835 ha	897.6 ha
Area at Minimum Operating Lake Level	28,987 ha	9,019 ha	732 ha
Top Clearing Elevation	30.5 m MSL	30.48 m MSL	50 m MSL
Lower Clearing Elevation	22.9 m MSL	22.9 m MSL	45 m MSL
EMBANKMENTS			
Dam – Rock Fill Embankment			
Top Elevation of Dam	32 m MSL	31.5 m MSL	53m MSL
Fixed Crest Width	13m	13m	13m
Height above Lowest Foundation	?15 m	25 m	38m
Overall Length of Dam	varies m	4473 m	632m
SPILLWAY			
Type of Spillway	Gated Ogee	Gated Ogee	Uncontrolled Ogee
Number of Gates	14	11	-
Width of Gates	13.72 m	18.33 m	-
Net Length	192.02 m	201.17 m	-
Total Length	246.27 m	238 m	113 m
Elevation of Crest	21.03 m MSL	25.91 m MSL	50.0 m MSL
Maximum Discharge	5150 CMS	3794 CMS	618 CMS

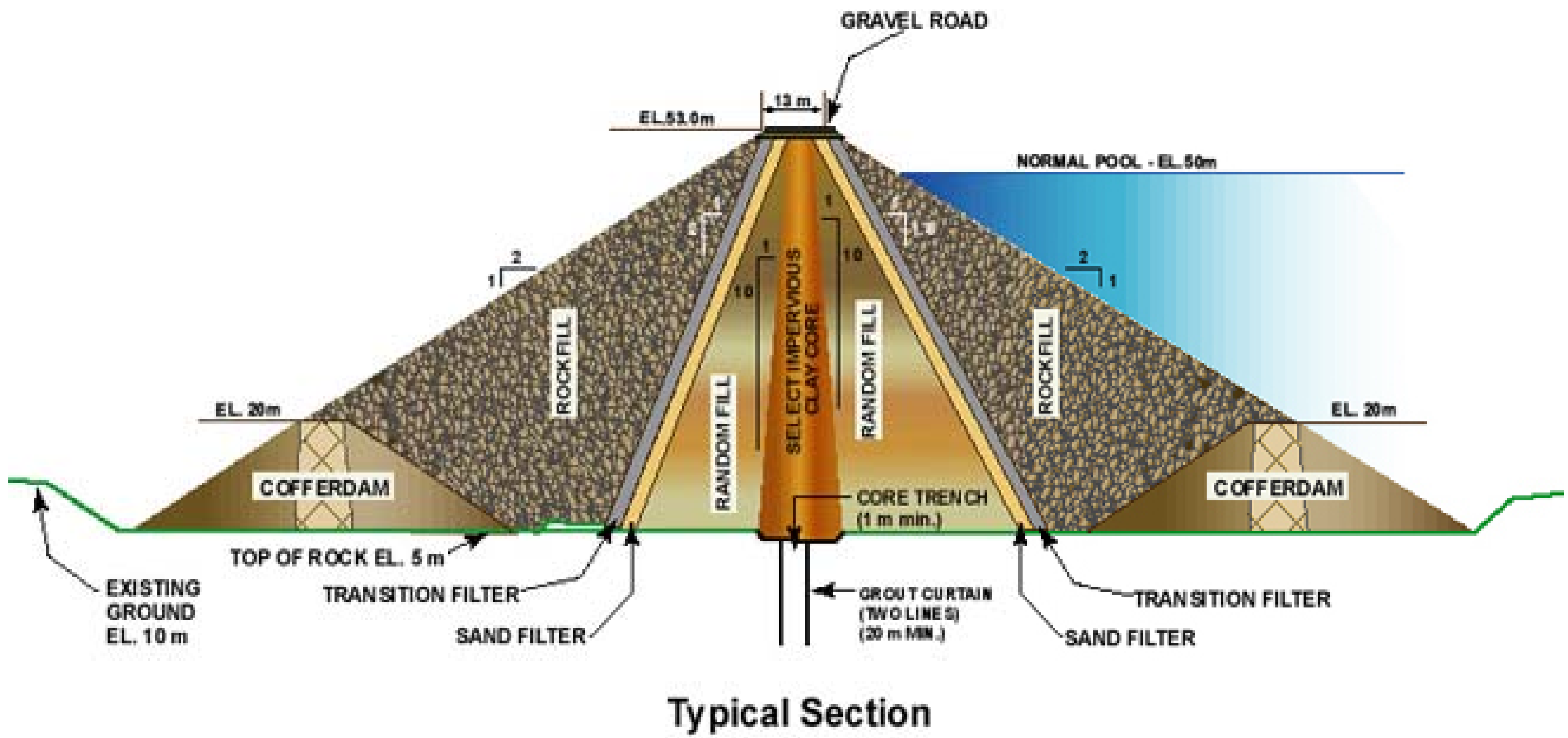
INDIO ONLY	
INTER-BASIN TRANSFER TUNNEL	
Tunnel diameter	4.5 m
Tunnel length	7651 m
Inlet invert	45.5 m MSL
Outlet invert	40 m MSL
Tunnel capacity	37.9 CMS
HYDROPOWER PLANTS	
Dam	
Type of hydropower plant construction	Reinforced concrete
Number of units	1
Capacity of each unit	5 MW
Inter-basin Transfer Tunnel	
Type of hydropower plant construction	Reinforced concrete
Number of units	1
Capacity of unit	2 MW
CONSTRUCTION / POWERHOUSE DIVERSION	
Diversion length	800 m
Tunnel diameter	7 m
Inlet invert	12 m
Outlet invert	10 m
Design discharge	462.4 CMS
MINIMUM FLOW CONDUIT	
Conduit diameter	600 mm
Conduit length	800 m
Inlet invert	12 m
Outlet invert	10 m
Conduit capacity	1.7 CMS
EMBANKMENTS N/A	

Plate 38 - 1 Project Location Map

LOWER TRINIDAD / UPPER RIO INDIO



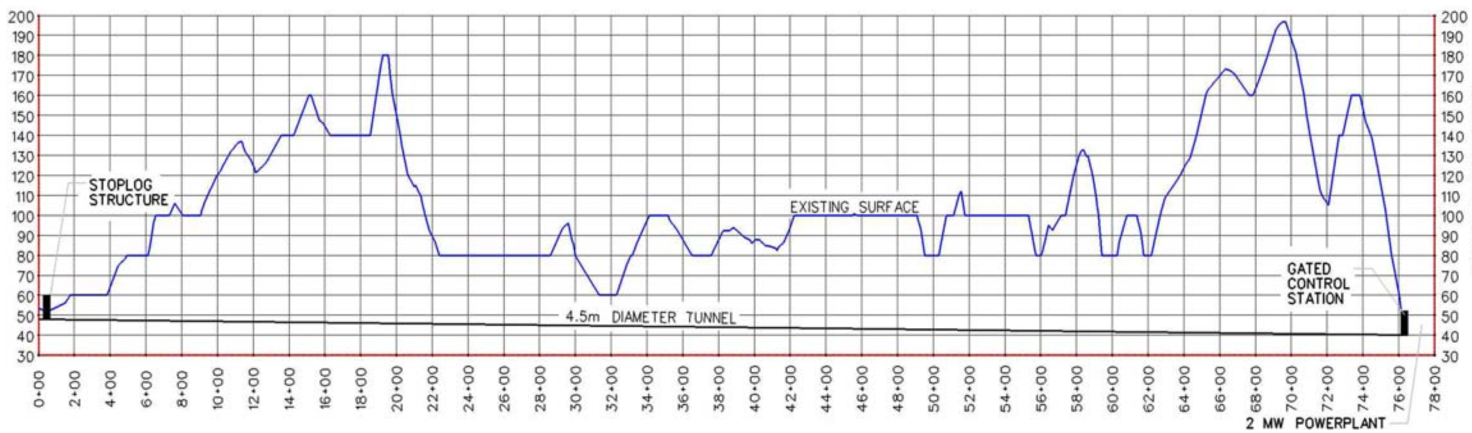
Project Location Map



Typical Section at Embankment

Plate 38 - 2 Typical Section at Embankment

UPPER RIO INDIO



TYPICAL SECTION

Inter-basin Transfer Tunnel Profile

Plate 38 - 3 Inter-basin Tunnel Profile

SECTION 39

Lower Rio Trinidad 22.9m to 30.5m
Rio Quebrado 22.9m to 30.5m
Rio Indio 50m to 80m

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

Synopsis

The development plan presented combines a dam and a lake in the Trinidad basin within, a dam and lake on the Rio Caño Quebrado of the Panama Canal watershed within, and a dam and lake on the Rio Indio to the west of Lake Gatun. Water impounded in the Lower Rio Trinidad and Rio Caño Quebrado Lakes should add storage to the Panama Canal system of lakes. This additional storage would be further enhanced by incorporation of a pumping plant into the Lower Rio Trinidad Dam. This facility allows storage of excess water from Gatun Lake and extended usage of the waters contained in the Lower Rio Trinidad and Rio Caño Quebrado Lakes. Water impounded at the Rio Indio site comprises new water for use in the Panama Canal System and would be transferred via a tunnel to the Lower Rio Trinidad Lake.

The Rio Trinidad watershed is located on the western side of the Panama Canal watershed. The proposed dam site is located within Gatun Lake across the Trinidad arm near the town of Escobal. The dam should extend from Punta Mala on the west shore of Gatun Lake to Guacha Island and then straight across to the eastern shore of the Trinidad arm just south of the South Range Point lighthouse. This alignment follows closely that proposed in the Study and Report on Increasing the Water Supply of the Panama Canal prepared by Tudor Engineering Company, San Francisco, CA, 1962, for the Panama Canal Company (hereinafter referred to as the Tudor Report). Plate 39 - 1 shows the location of the proposed Lower Rio Trinidad Dam project. The structures for the proposed Lower Rio Trinidad project consists of a rock fill dam constructed by underwater deposition of fill materials, a large pumping plant, and a gated spillway, both constructed in the dry on or near Guacha Island. This spillway should have 11 gate bays, each measuring 18.33 m wide. The pumping plant consists of the pumping station and intake and outflow facilities separated from the lakes above and below the Lower Rio Trinidad dam by large gate structures. The total project first costs of the proposed Lower Rio Trinidad project are estimated to be $811,400,000.

The Rio Caño Quebrado watershed comprises a portion of the western side of the Panama Canal watershed. The proposed dam site is located within Gatun Lake across the Rio Caño Quebrado arm near the city of La Laguna and should constructed in two parts. The first section of the dam extends from Punta Manguito, on the west shore of the Rio Caño Quebrado arm of Gatun Lake, in a northwest-southeast orientation to the eastern shore of the Rio Caño Quebrado arm. The second section extends in an east-west orientation across the Rio Caño Quebrado eastern arm, just north of the mouth of the Rio Paja. The lake formed by these dams may communicate directly with Lower Rio Trinidad Lake at all operational levels. Plate 39 - 1 shows the location of the Rio Caño Quebrado Dam project. The main features required for the Rio Caño Quebrado project are two sections of rock fill dam, and a dug channel connecting between Rio Caño Quebrado and Lower Rio Trinidad Lakes. The total project first costs of the proposed Rio Caño Quebrado project are estimated to be $19,330,000.

The Rio Indio watershed is located adjacent to the western side of the Panama Canal watershed. The proposed Rio Indio dam site is approximately 25 km inland from the Atlantic Ocean and is near the mountain named Cerro Tres Hermanas. Plate 39 - 1 shows the location of the proposed Rio Indio project. The structures for this proposed project consist of a rock fill dam, two saddle dams, an uncontrolled ogee spillway, inter-basin transfer facilities, two hydropower plants, and other outlet works. The tunnel transfers water from Indio Lake to the

Panama Canal watershed as needed for canal operations. The total project first cost of the proposed Rio Indio project is estimated at $245,868,000.

The Lower Rio Trinidad portion of this project should pose great construction difficulties because of the extremely large quantities of underwater fill required for construction of the dam. It should require extensive drilling and site investigation prior to construction and, because of the uncertainties inherent with this type of construction; extensive unforeseen costs can be encountered during construction. Also, the spillway would be constructed in an island setting where the structures practically engulf the entire island. This should pose extreme space limitations on the construction effort and would be very costly.

The proposed Lower Rio Trinidad and Rio Caño Quebrado Dam projects, taken in conjunction with the Rio Indio Dam project, can contribute greatly to the hydrologic reliability of the Panama Canal to serve its customers and should help to reduce the need for imposing draft restrictions and resulting light loading of vessels during traditional periods of low water availability. The existing hydrologic reliability of the Panama Canal, based on the period of record from January 1948 through July 1998 and current demands (38.68 lockages), is approximately 99.6 percent. The hydrologic reliability with the demand increasing to 120 percent of the current level (46.42 lockages) is 98.8 percent. With construction of the proposed Lower Rio Trinidad, Rio Caño Quebrado, and Rio Indio projects, the existing high hydrologic reliability can be continued as demand for lockages increases up to 50.3 percent above current demand levels (up to 19.47 lockages).

Site Selection

Project definition and description is developed with a view toward maximizing the water impounded, while minimizing the volume of material required for construction of the dam and minimizing the number of saddle dams required to contain the lake.

The site chosen for the proposed Lower Rio Trinidad Dam is approximately 10 km south of Gatun Locks and 14 km southwest of the navigation channel. The dam would be approximately 4 km northeast the town of Escobal. This site should accommodate construction of a dam with a maximum operating lake level at EL. 30.5 m MSL. Flood storage accommodations are between EL. 30.5 and 28.7 m MSL.

The Rio Caño Quebrado project definition and description is developed with a view toward maximizing the water impounded, while minimizing the volume of material required for construction of the dam and minimizing the number of saddle dams required to contain the lake.

The site chosen for the Rio Caño Quebrado Dam would be approximately 22 km southeast of Gatun Locks and 14 km northwest of the Pedro Miguel Locks. The dam site is approximately 7 km southwest of Barro Colorado Island and 4 km northeast of the town of La Laguna. This site can accommodate construction of a dam with a maximum operating lake level at EL. 30.5 m MSL. Flood storage would be accommodated above the normal operating levels between EL. 30.5 and 24.8 m MSL.

The proposed Upper Rio Indio dam site is chosen with a view toward maximizing the water impounded, while minimizing the volume of material required for construction of the dam, thus minimizing the number of saddle dams required to contain the lake, and minimizing the impact on the existing populated areas in the Lower Rio Indio Basin. It is desirable to locate the dam immediately above the confluence of the Rio Trinidad and the Rio Uracillo, as far downstream in the upper arm of the Rio Indio watershed as possible. In choosing a site for the dam, the ideal location is where the surrounding hillsides are relatively steep and high, and the valley relatively narrow, features afforded by the site chosen.

The site chosen for the proposed Rio Indio Dam would be approximately 25 km inland from the Atlantic Ocean and is near Cerro Tres Hermanas Mountain. This site should accommodate construction of a dam with a normal operating lake level at EL. 80 m MSL and a maximum flood lake level at EL. 82.5 m MSL.

Hydrologic Considerations

Rio Trinidad
The Rio Trinidad flows northward from the Continental Divide to the Gatun Lake. The headwater of the watershed begins at EL. 1,000 m MSL, approximately 75 km inland, and falls to 26 m MSL at Gatun Lake. The distribution of the average annual rainfall over the Rio Trinidad watershed varies from a high of 2,200 mm in the western part of the watershed to 2,000 mm on the eastern side of the watershed. The proposed Lower Rio Trinidad Lake receives runoff from approximately 750 km^2 of the upper portion of the watershed. Rainfall runoff produces an average annual flow of 32 CMS at the proposed dam site.

The discharge rate at the Lower Rio Trinidad and Rio Caño Quebrado dam sites are obtained from the drainage area ratio to the established record for Gatun. The Gatun Lake runoff is based on records developed by the U.S. Army Corps of Engineers Hydrologic Engineering Center and the ACP in a separate study.

Since the Lower Rio Trinidad and Rio Caño Quebrado Lakes are located within Gatun Lake, the monthly evaporation rates established for Gatun Lake are considered appropriate for the evaporation rates of Trinidad and Rio Caño Quebrado Lake.

Rio Caño Quebrado
Three major rivers flow into Rio Caño Quebrado Lake; Rio Caño Quebrado, Rio Paja and Rio Los Hules. All three rivers flow northward from the Continental Divide to Gatun Lake. The headwaters of the watershed begin at EL. 1,000 m MSL, approximately 75 km inland, and fall to 26 m MSL at Gatun Lake. The distribution of the average annual rainfall over the Rio Caño Quebrado watershed varies from 2,200 mm in the western part of the watershed to 2,000 mm on the eastern side. The proposed Rio Caño Quebrado Lake receives runoff from approximately 310 km^2 of the existing Panama Canal watershed. Rainfall runoff produces an average annual flow of 10.2 CMS at the proposed dam site.

Rio Indio
The Rio Indio flows northward from the Continental Divide to the Atlantic Ocean. The headwaters of the watershed begin at EL. 1,000 m MSL approximately 75 km inland and falls to mean sea level at its mouth. The distribution of the average annual rainfall over the Rio Indio watershed varies from a high of 4,000 mm at the coast to a low of 2,500 mm in the middle watershed area. It increases again to over 3,000 mm in the Continental Divide. The proposed

Indio Lake should receive runoff from approximately 381 km^2 of the upper portion of the watershed. Rainfall runoff produces an average annual flow of 25 CMS at the proposed dam site.

The calculated discharge at the Rio Indio dam site is extrapolated, recorded, and correlated stream flow data from the Boca de Uracillo hydrologic station. This station began operation in 1979 and is located on the Rio Indio, approximately 2.5 km upstream from the dam site. Data established from a statistical correlation, with the discharge data of the Rio Ciri Grande at Los Cañones using standard hydrologic techniques, completed missing data and increased the period of record. Utilization of the double mass curve method satisfactorily verified the consistency of the data measured and correlated.

Due to the proximity of Rio Indio to Gatun Lake, and because of the absence of site-specific information, the monthly evaporation rates established for Gatun Lake are considered appropriate for the evaporation rates of Indio Lake.

Geologic Considerations

Rio Trinidad

The proposed Lower Rio Trinidad dam site is investigated in 1962 by Geo-Recon, Inc. of Seattle, Washington, as part of the Tudor report. The investigation consisted of seismic velocity and electrical resistively profiles in conjunction with four test borings (all located in the lake and drilled by the Panama Canal Company). The results of the geophysical surveys reportedly compared well with the logs of the test borings in the deep-water areas (up to 23 m deep) of Gatun Lake. In June 1963, Tudor Engineering submitted another report including additional foundation investigations. The foundation investigations are made by the firm Shannon & Wilson, Inc. Soil Mechanics and Foundation Engineers, from Seattle, Washington, and consisted of 77 cone penetrometer borings, 24 classification borings, 11 undisturbed sample borings, and 6 field vane shear borings. The investigations submitted by Shannon & Wilson, Inc. where recently reanalyzed in Geology of the Proposed Dam Across Trinidad Arm of Gatun Lake, by Mr. Pastora Franceschi S., for the Geotechnical Section of the Panama Canal Authority.

In the lake areas the investigations disclosed that overburden material included recent lake deposits, the Atlantic Muck Formation, alluvial deposits, and residual deposits. Between the west shore and Guacha Island these deposits consist of soft to very soft clay, silt, sand and peat (Atlantic Muck Formation) overlying soft to hard deposits of clay, silt, sand and gravel derived both from alluvial deposition and the weathering of bedrock. The upper two phases of the Atlantic Muck Formation, judged to be the most compressible portion of the formation, is found to have an average thickness of about 18.3 m and a maximum thickness of 22.9 m. Recent, soft lake deposits ranging from 1.2 to 2.4 m thick are found overlying the Atlantic Muck Formation. In the length between Guacha Island and Tern Island, the Atlantic Muck Formation is either not found, or is very thin. In this area, Recent-aged soft sediments (averaging 2 m thick) are generally found to overlay residual soil and weathered rock. The Atlantic Muck Formation, where present, occurred between the Recent-aged material and the residual soil, and is a maximum 5 m thick. Between Tern Island and the east mainland, only recent lake sediments (1.5 m thick) overlying residual clay are found above the conglomerate of the Bohio Formation.

Guacha, Tern and Booby Islands are each found to have an overlying stratum of soft overburdened and weathered rock of variable thickness. In general, firm bedrock is found available below EL. 22.9 m MSL and the islands are judged to offer suitable foundation conditions for control structures.

Firm bedrock under both the land and the lake consists of low velocity sedimentary rock composed primarily of sandstone and the Bohio Formation. Two areas containing abrupt changes in bedrock velocities are located during the survey. One of the areas is a narrow zone located on Guacha Island that is a possible shear zone in rock of similar type. The second area has an abrupt change in bedrock velocity on Tern Island that is interpreted as a possible fault contact between two formations, or between different lithologic units of the same formation. The top of the bedrock on land is interpreted from the geophysical results to be weathered to below lake level. The core borings in the lake determined the weathered zone of bedrock to range from 1.2 to 3.1 m in thickness.

Satisfactory foundation conditions exist for construction of a pumping station, and a spillway at the Lower Rio Trinidad site. Serious consideration, however, must be given to problems that would be caused by the anticipated settlement and instability of the embankment materials.

Rio Caño Quebrado

The main dam portion of the proposed Rio Caño Quebrado project is located in an area where volcanic rocks of the Tucue Formation are encountered at the surface. The rocks of the Tucue Formation consist of lava flows, breccias, tuffs and plugs, and are andesitic or basaltic in nature. These rocks show a wide variation in quality, from high quality extrusive lava flows to weathered and lesser quality volcanic tuffs. It is anticipated most of the strata of the Tucue Formation would make satisfactory rock fill for a dam, but a significant amount may not be satisfactory for concrete aggregate. Volcanic rocks of the Tucue Formation may also contain constituents that are reactive with alkalies found in cement. Neither weathered rock nor rock with reactive materials would be satisfactory for concrete aggregate. It is recommended that cores be drilled early during the planning studies to determine general depths of weathering and to determine the suitability of the rock for use as concrete aggregate.

Oligocene-aged sedimentary rocks of the Caimito Formation underlie the inter-basin transfer basin canal and spillway portions of the project. Three members of the Caimito Formation are recognized; the lower, middle and upper. The deposits of each of these members are mainly marine, but they are lithologically heterogeneous. The lower member is composed of conglomerate and tuffaceous sandstone. The middle member consists chiefly of tuffaceous sandstone, some of which is calcareous, and lenticular limestone. The upper, principal member consists of tuff, agglomeratic tuff, tuffaceous siltstone, and discontinuous sandy tuffaceous limestone. In general, the rocks of all members are hard, thinly to thickly bedded, and closely to moderately jointed. It is not known which member of the Caimito Formation underlies the project area. It is considered that it would make an acceptable foundation for the canal and spillway. The Caimito Formation would be unacceptable for use as concrete aggregate and may be only marginally acceptable for use as fill in an earth and rock fill dam.

In the absence of detailed geologic mapping for the proposed Rio Caño Quebrado project, a degree of extrapolation is necessary. It is predicted that rock at the proposed construction locations outside the lake would be encountered at a shallow depth and would be of sufficient quality to serve as foundation for the appurtenant structures.

Upper Rio Indio

The proposed Rio Indio Dam project is located in an area of the Isthmus of Panama underlain by Oligocene-aged sedimentary rocks of the Caimito Formation. Three members of the Caimito Formation are recognized: the lower, the middle and the upper. The deposits of each of these members are mainly marine, but are lithologically heterogeneous. The lower member is composed of conglomerate and tuffaceous sandstone. The middle member consists chiefly of tuffaceous sandstone, some of which is calcareous, and lenticular limestone. The upper, principal member consists of tuff, agglomeratic tuff, tuffaceous siltstone, and discontinuous sandy tuffaceous limestone. In general, all members are hard, thinly to thickly bedded, and closely to moderately jointed. The lower member weathers to greater depths. A summary of test data developed in 1966, as part of the studies for a sea level canal, listed compressive strengths for samples of Caimito Formation material varying between 79,450 and 5,955,257 kg/m^2. The same 1966 studies assigned an allowable bearing capacity of 195,300 kg/m^2 for the material of the Caimito Formation.

The preparation of this report required an investigative visit to the proposed site for the Rio Indio dam. The investigation found moderately hard siltstone, fitting the description of strata of the principal member of the Caimito Formation, exposed along the riverbed at the proposed site. This siltstone should make an acceptable foundation for an earth and rock fill dam. It would be unacceptable for use as concrete aggregate and only marginally acceptable for use as fill in some of the less important zones. Due to dense vegetation, it is unknown whether sedimentary or volcanic material underlies the ridges that form the proposed abutments. Further development of this project requires drilling of cores in each abutment early during planning studies to identify the abutment material and to determine its general suitability for use as construction material. In addition, the cores should be of sufficient depth to check for the occurrence of any soluble limestone strata that could possibly underlie the dam foundation.

The proposed inter-basin transfer tunnel connecting the Rio Indio Lake to the Panama Canal watershed is probably located very near the contact of the Caimito Formation and the overlying Miocene-aged volcanic rocks. Many springs occur in the area of the proposed tunnel inlets and outlets, and groundwater flowing in volcanic rock above impervious strata of the Caimito Formation may be the cause. In addition, a 1921 drawing shows two coalmines in the general area of the tunnel inlets. Further development of this project would require drilling of cores near the proposed tunnel inlets and outlets early during planning studies to determine the general relationship between the tunnel alignments and the sedimentary/volcanic rock contact, coal or peat beds, and the water table.

In the absence of detailed geologic mapping for the proposed Rio Indio Dam site, a degree of extrapolation is necessary. Available general geologic mapping and general data are the basis of predictions that rock, encountered at a shallow depth and of sufficient quality can serve as foundation for the dam and appurtenant structures. Furthermore, assumptions for this report are: excavation should produce sufficient rock for fill; the immediate area contains adequate impervious materials; and concrete aggregate for use in the construction.

Lake Operation

The operating scenario considers periods when water would be transferred from Lower Rio Trinidad Lake to Gatun Lake for canal operations is detailed in Volume 1. Water impounded in the Rio Caño Quebrado Lake would be transmitted to Gatun Lake via the Lower Rio Trinidad facilities. Following is a reiteration of the tabulated pool levels contained in Volume One.

Table 39 - 1 Lake Operating Options

Lake Level (El. m MSL)	Lower Rio Trinidad & Rio Caño Quebrado	Gatun
Normal Operating Lake Level	30.48	26.67
Minimum Operating Lake Level	22.86	25.91
Maximum Flood Lake Level	31.09	27.13

The operating scenario for periods that require water transferal from Indio Lake to the Panama Canal watershed for canal operations allow the water surface of the lake to fluctuate from the normal operating lake level at EL. 80 m MSL down to a minimum operating lake level at EL. 50 m MSL and provide 993,000,000 M^3 of usable storage. The maximum flood lake level would be at EL. 82.5 m MSL. The volume between the maximum flood lake level and the normal operating lake level can store flood waters and reduce peak flood flows. Areas along the Rio Indio downstream of the dam should realize some reduction in flooding. Table 39- 2 shows the lake levels for this scenario.

Table 39 - 2 Lake Operating Options

Lake Level (El. m MSL)	Rio Indio
Normal Operating Lake Level	80
Minimum Operating Lake Level	50
Maximum Flood Lake Level	82.5

Project Features

GENERAL

The structures for the Lower Rio Trinidad project consist of a rock fill dam, a large pumping plant, and a gated spillway. Modification of one existing saddle dam and construction of two additional saddle dams is required. Plate 39 - 1 shows the dam site in downstream left bank perspective and indicates the location of the spillway and pumping facilities. Project details would be similar to those depicted in Volume Three, Section 36, Plates 36-3 and following.

The structures for the Rio Caño Quebrado project consist of a rock fill dam in two distinct sections, and a dug channel connecting Rio Caño Quebrado Lake to Lower Rio Trinidad Lake at lower pool levels. Plate 39 - 1 depicts the location of the dam.

The structures for the Rio Indio project consist of a rock fill dam, two saddle dams, an uncontrolled ogee spillway, inter-basin transfer facilities, two hydropower plants, and outlet works. The project details would be as depicted in Volume Three, Section 37, Plates 37 - 2 through following.

The following paragraph provides a description of the proposed structures and improvements for these projects.

Design is performed only to the extent necessary to establish, with reasonable accuracy, the principal dimensions, elevations, and costs of the proposed project. Separate documentation is provided to the ACP that contained assumptions and design calculations for the reconnaissance level investigations of these structures. If this project is carried into the planning studies, the project features and improvements must be optimized.

EMBANKMENTS

Lower Rio Trinidad Dam

The proposed dam consists of an embankment with the top at EL. 31.50 m MSL and with a crest width of 13 m with a final crest of 7 m upon completion of all settlement of the embankment and bridge work. The left abutment of the embankment will be located at Universal Transverse Mercator Grid, Zone 17, Clark 1866 Spheroid Coordinates 1015858 north and 614864 east. The right abutment will be 1013937 north and 618229 east coordinates. The normal lake El. 30.48 m MSL while the ground surface elevations along the axis of the dam vary from El. 2 m MSL in the lake bottom to El. 39 m MSL on Guacho Island and El. 38 m MSL on Tern Island. The Gatun Lake subgrade supporting the embankment occupies a broad flat valley having sides, which slope, upward from the valley at grades up to 40 percent. Water depths are 21.3 to 26.3 m over 80 percent of the site. The Atlantic Muck Formation, consisting of very soft organic clays, silts and peats varying in thickness from 7.6 m to 48.7 m, underlies approximately two thirds of the alignment subgrade. The Atlantic Muck Formation in the old river channel is further underlain by soft silts, sand and clay strata.

The critical challenge for design espoused by the Tudor Report and others is the depth of subgrade degradation during the initial fill placements. The materials will lose much of its natural strength when disturbed and will only regain strength after the effects of consolidation of a surcharge fill. However, complete restoration of strength can only be assumed to a depth of 5 to 7 m. If the effects of the subgrade disturbance extend appreciably deeper, then an extremely weak material will be under the more stable subgrade and surcharge creating a condition of lateral instability.

Due to the inability to accurately analyze this condition, a test fill was performed on the western end of the alignment. In early 1963, 1,000-cy bottom-dump barges deposited some 168,000 cy of blasted rock from the cut widening project, extending some 305 m. One hundred fifty-five meters of the fill was placed to a height of 11 m while the remaining 150 m was filled to 5 m. The differential heights were use to simulate initial and intermediate fill placement effects. Divers were then used to observe the performance of the fills placed along the alignment. The mechanisms of failure within the subgrade were caused by impact and static loadings. The impact of the initial placements caused severe destruction of the surface materials creating lateral displacements up to 5 meters. However, when a continuous blanket of fill had been established and subsequent fill was placed, then conventional failures such as slip circle shear failures and horizontal shears creating large mud waves outward from embankment were observed. Therefore, to predict the behavior of the embankment during construction and long term, it is imperative that a foundation mat be established to such a depth to prevent subgrade rupture with subsequent fill placement. It is recommended that a 5 m thick minimum crushed rock blanket with maximum sizes of 20 cm be placed initially to act as the supporting blanket. Special barge dumping methods were to be employed so loads would not fall as an integral mass, which would create destructive forces on the subgrade. These recommendations were offered by the Tudor Engineering Company in their final report.

The placement of a large hydraulic structure on a deep-seated weak foundation is the most challenging of geotechnical endeavors. It is virtually impossible to analyze with great deal of certainty and the owner must be prepared to accept possible additional costs during construction and long term maintenance due to the potential for lateral instabilities and high degrees of settlement. The Tudor Report has predicted some 2.5 to 3 m of predicted settlement below the crest elevation for a construction duration of 7-years and an additional 2.5 to 3 m of maximum settlement below the crest for the 50-year service life of the project. These settlements are predicted where the Atlantic Muck and underlying compressible materials are the thickest. These movements are reduced as the fill approaches the mainlands and the two islands. This implies that significant differential settlements are predicted within these approaches as well. The key to any successful construction and maintenance of this embankment will be to establish a blanket mat atop the subgrade where subsequent fill can be economically placed without fear of rupturing the foundation to greater depths. Any significant lateral failure of the embankment during construction or productive use will render that alignment unsuitable. Additional embankment sections must be established upstream or downstream to reestablish the embankment section to the proper elevation. This repair will take considerable time and prevent its use as a road. Based on these considerations, our recommendations were presented for ultimate costs considerations in comparison to alternatives with a greater degree of performance certainty.

The divers observed that the test fill had trouble placing the fill in the correct locations within the alignment and the lift thickness varied significantly over the fill cross section. It is imperative that the blanket fill be placed intact with the least subgrade disturbance in order for the embankment to act as monolithic mass. Therefore, the initial 5 m of fill will be barged to the site and placed by lowering a clamshell to the subgrade surface. The positioning of the barges must be strictly controlled by survey positioning systems established on land. The initial fill should have a maximum size of 20 cm and the percent fines should be controlled to remain fairly intact during placement. Materials with a significant size differential and a large fine content can create weak shear zones with the embankment. The subsequent fill materials above this zone can be placed by bottom dumped barges or clamshells from El. 8 to 21 m MSL. The material above El. 21 m MSL must be placed by clamshell due to the draft and door operations of the barges. These materials will be more random in gradation having a maximum size of 30 cm and a greater degree of fines. The materials placed below El. 27 m MSL will assume a side slope of 1 V:15 H. A 15 m berm will be constructed and the materials will continue to be placed by clam shell and spread with a dozer to El. 31.5 m MSL, assuming a side slope of 1 V:3 H and a crest width of 13 m. The flatter side slopes are needed to distribute bearing pressures and to reduce the lateral displacements. This configuration should also reduce the construction and total settlements predicted by the Tudor report and provide acceptable factors of safety for lateral stability during fill placement. The side slope berms and extra crest width will facilitate the future fill placements of up to 3 m over the life of the project. The road surface atop the dam embankment will remain gravel surfaced for the foreseeable future due to future fill placements. The dam will be approximately 30 m high, and the overall length 4,473 m. The top of the dam will be 5 m above the normal Gatun Lake level. The total volume of fill material required to construct and maintain the main dam to El. 31.5 m MSL is approximately 29,550,850 M^3. Water access from the main channel to Guacha and Tern Islands will be built during construction. After access roads have been constructed, fill placements from the east mainland to Tern and Gaucha Islands could be delivered by truck and placed by end-dumping from the east mainland. This technique could prove beneficial if a material source was found near the Gatun Lock area. The side slopes and overall embankment configuration was offered for ease of calculation, to reduce the foundation pressure on the soft subgrade and to account for the lateral displacement of embankment materials. The increased foundation base should help the structure survive a relatively minor seismic event.

The methods of subgrade stabilization and embankment strengthening offered in the powerpoint presentations from the ACP Engineering Division are examples of many ideas for enhancing the performance of the embankment during construction and post construction. The use of wick drains have been an effective tool for accelerating consolidations under a mass loading. It is felt that the Atlantic Muck materials will not readily transmit water to the drains, therefore the spacing of the drains must be much closer than that implied and the effectiveness of the drains will be restricted to the top 15 to 20 feet of the foundation subgrade. The drains must be effectively tied into the foundation blanket for continuity of the drainage path. We are very concerned by the use of vibro-flotation or stone columns techniques above the mat. The mat will not effectively dampen these compaction forces and some rupture of the mat could be possible. A safer reinforcing technique could be the use of reinforcing within the embankment section, such as high strength geogrids placed in layers. All reinforcing techniques are expensive but could be offset by the reduction in fill quantities ultimately required. Any reinforcing selected for use in production must be part of a comprehensive test fill program to demonstrate its effectiveness.

The Tudor Report identified considerable leakage to be expected from the completed embankment. Since loss of any water from storage is a significant reduction in benefits, the seepage must be prevented. Therefore a bentonite slurry trench should be installed within the centerline of the embankment. The trench will be a minimum of 3 feet wide and extend to several meters below the original lake bottom. The trench can be excavated using rockmill techniques. Since the embankment will undergo significant settlement, both total and differential, it is likely that the trench will be sheared and will require replacement within the deeper portions of the lake during the life of the project.

Rio Caño Quebrado Dam

The Rio Caño Quebrado dam consists of two sections, the west and east embankments, with the top at EL. 31.5 m MSL and a crest width of 13 m. The left abutment of the embankment would be located at Universal Transverse Mercator Grid, Zone 17, Clark 1866 Spheroid Coordinates 1004554 north and 632455 east. The right abutment would be 1004595 north and 632599 east coordinates. The embankments shall be constructed by depositing cohesive materials along the alignment of the proposed dam until the stacked material reached its natural angle of repose and the consolidation, within the subgrade, stabilize. The side slopes would be 10 H : 1 V within the submerged sections transitioning to 2 H : 1 V in the portions traversing the existing islands. The subgrade is extremely soft and considerable displacement is anticipated as evidenced by the original construction experience at Gatun Dam. The dam would be approximately 16 m high, and the overall length 404 m. The top of the dam would be 4.3 m above the maximum normal operating level in Gatun Lake. The total volume of fill material required to construct the embankments would be approximately 244,150 M^3 for the west embankment and 114,500 M^3 for the east embankment.

Rio Indio Dam

The Rio Indio dam would be an embankment with the top at EL. 83.5 m MSL and with a crest width of 13 m. The left abutment of the embankment would be located at Universal Transverse Mercator Grid, Zone 17, Clark 1866 Spheroid Coordinates 994408 north and 589644 east. The right abutment would be 994801 north and 590432 east coordinates. The embankment would be constructed with an impervious earth and rock fill core encased in rock fill, and the final side slopes would be 2 H : 1 V. The dam at its highest point would be approximately 73.5 m high, and the overall length 891 m. Further study must determine the actual side slopes and crest width and is contingent upon the need for vehicular access across the embankment, the size and quality of the rock fill, and the detailed design of the embankment. Plate 37 - 3 presents a typical section of the embankment at the dam, incorporating upstream and downstream cofferdams within the section.

Foundation grouting would be required across the entire base of the dam and on a portion of the valley walls. A blend of bentonite and native fill materials in a core trench can provide seepage cutoff in the embankment foundations. A concrete or bentonite cutoff wall can also provide seepage cutoff.

The crest width and side slopes are presented here for comparison purposes between projects. The actual crest width and side slopes shall be determined during further study and are contingent upon the need for vehicular access across the embankments, the size and quality of the fill materials available for use, and the detailed design for the embankments.

Saddle Dams

As noted in the Tudor Report, the existing Caño Saddle Dam No. 4, located along the western shoreline of the Trinidad Arm of Gatun Lake, needs to be raised and/or strengthened to accommodate the higher lake levels. Immediately to the north of this location, two additional smaller saddle dams are required. All saddle dams must be built to provide a minimum top El. 31.50 m MSL. The total volume of fill material required for these three dams is approximately 50,000 M^3, based on a crest width of 13 m. The Rio Caño Quebrado dam must be constructed as a saddle dam to contain the Lower Rio Trinidad Pool.

Two saddle dams are required to complete the lake impoundment at Rio Indio. For this study, both saddle dams are configured with an impervious earth and rock fill core encased in rock fill, and the final side slopes would be 2 H : 1 V. The top of the saddle dams would be set at EL. 83.5 m MSL, a crest width of 13 m. The length of the north saddle dam shall be 255 m, while the length of the south saddle dam would be 272 m.

The actual side slopes and crest widths would be determined during further study and are contingent upon the need for vehicular access across the embankment, the size and quality of the rock fill, and the detailed design of the embankment (see Volume One, Section 5).

SPILLWAYS

Spillways are required at two of the dam sites, Rio Indio and Lower Rio Trinidad under this scenario. The Lower Rio Trinidad spillway handles all flows into the Rio Caño Quebrado area.

Under normal flow conditions water should pass from Lower Rio Trinidad Lake to Gatun Lake through a gated spillway. This spillway should have 8 gate bays, each 18.33 m wide. The gate bays would be separated/flanked by 3 m wide reinforced concrete piers (9 piers in all), which should provide support for the gates and access to the gate operating machinery, as well as providing support for a roadway bridge over the top of the spillway. Each of the 8 spillway gates should have a nominal width of 18.33 m and a height of 5.48 m to provide 0.3 m freeboard above the maximum lake operating level. The overall length of the spillway, from out-to-out of the end piers would be 173.64 m. The spillway sills would be placed at the minimum lake operating level, EL. 25.91 m MSL.

A bridge across the tops of the spillway piers would be constructed as a part of the roadway across the top of the dam. It would be approximately 7 m wide, thus allowing for two-way traffic and providing access to the spillway gate operating machinery.

For this study, stop logs for servicing the gates, guides, etc. can be placed either from the roadway or from barges using floating cranes. With the spillway sill at the prescribed level, stoplogs would be required both upstream and downstream to allow work to be done on the gates and sills in the dry season.

The spillway would be situated along the axis of the dam in the western leg of Guacha Island. This allows the construction to be performed completely within a dry construction cut requiring a minimum of construction dewatering. Once the concrete structures are completed, the entrance and exit channels to the spillway can be opened.

At the Rio Indio dam an uncontrolled ogee spillway with a length of 120 m and a crest at EL. 80 m MSL would be required. The spillway crest would be 3.5 m below the elevation of the top of the dam. The maximum discharge from the spillway would be 920 CMS at a maximum flood lake level at EL. 82.5 m MSL. The spillway design discharge is equivalent to a 1 in 1,000 frequency unregulated flow at the dam site. The spillway would be located within the abutment adjacent to the left end of the dam and consists of a mass concrete sill section embedded in the natural rock. A sloped and/or stepped, natural rock cut tailrace channel should return flow to the existing stream. The tailrace channel should extend from the sill section to its confluence with the natural stream some distance downstream from the toe of the dam. The task of dissipating energy at the downstream end of the tailrace channel requires excavation of a stilling basin into the rock adjacent to the natural channel. See Plate 37 - 2 for the location of the spillway and Plate 37 - 4 for a typical section at the spillway.

PUMPING PLANT

A large pumping plant is included in this scenario at the Lower Rio Trinidad dam. This pumping facility should provide for pumping in two directions, allowing Lower Rio Trinidad Lake to be drawn down to a level below that of Gatun Lake during extremely dry months, and/or pumping excess water from Gatun Lake into Lower Rio Trinidad Lake during flood season. Water thus stored would be available for navigation during the dry season. The pumping plant is configured to provide pumping to EL. 33.53 m MSL in Lower Rio Trinidad Lake. For lake elevations below this level, the plant may be reduced somewhat in size, however it is considered that the higher-level configuration should provide an estimate of the overall construction cost. See Table 39-3 for the controlling head and flow data used for this study.

This plant consists of 6, 1407 HP pumps, each capable of pumping slightly more than 62 CMS for a total plant pumping capacity of 373 CMS at a total dynamic head of 4.6 m. The pumping units would be mounted in a reinforced concrete housing and arranged in a row perpendicular to the axis of the dam, with intake and outlet channels on either side. It is assumed that these channels would be excavated primarily in solid rock. The channels are to be separated from the Lower Rio Trinidad and Gatun Lakes by large concrete walls containing sluice gates for controlling flows into the pumping plant. These sluiceways are configured to provide average entry velocities of approximately 7.7 MPS. The channels are configured to provide this velocity or less and should therefore require no special armoring of walls or inverts for scour protection. The outlet channel invert would be at approximately EL. 20 m MSL, or 13.5 m. below the centerline of the pump outlets. This should provide sufficient water depth at maximum pumping to buffer the erosive effects of the very large outflows.

In conjunction with this facility, a roadway bridge would be required to connect the pumping station structure to the banks on either side of the intake and exit channels, thus continuing the roadway across the facility. This bridge should also provide both operational and maintenance access to the pumping plant. The bridge should have two 15 m long spans with steel girders, a concrete bridge deck on each side of the pumping station, a 7 m wide travel way, one bridge bent including a cap, two round columns and a spread footing (located within each channel section).

Table 39-3 Pumping Data

Pumping Cycle	**Head** (m.)	**Average Daily Flow** (M^3/sec)
Lower Rio Trinidad (Elev. 22.86) to Gatun Lake (Elev. 25.91)	3.05	127.43
Gatun Lake (Elev. 26.67) to Lower Rio Trinidad (Elev. 30.48)	3.81	56.64

IMPOUNDMENT

The lake formed by the Lower Rio Trinidad Dam under this scenario should have a normal operating lake El. 30.48 m MSL. The surface area at the normal operating lake level would be approximately 18,169 ha. At the maximum flood level, EL. 31.09 m MSL, the surface area would be approximately 18,835 ha. With the minimum operating level at EL. 22.86 m MSL, the surface area would be approximately 9,019 ha. It should be noted that the current operating levels of Gatun Lake vary up to EL. 26.67 m MSL; therefore areas below the maximum Gatun Lake level are already subject to inundation.

The lake formed by the proposed Rio Caño Quebrado Dam should have a normal operating lake level at EL. 30.48 m MSL. The surface area at the normal operating lake level would be approximately 2,609 ha. At the maximum flood lake level, EL. 31.09 m MSL, the surface area would be approximately 2762 ha. With the minimum operating lake level at EL. 22.86 m MSL the surface area would be approximately 1,151 ha.

The lake formed by the proposed Rio Indio Dam should have a normal operating lake level at EL. 80 m MSL. The surface area at the normal operating lake level would be approximately 4,280 ha. At the maximum flood lake level, EL. 82.5 m MSL, the surface area would be approximately 4,440 ha. With the minimum operating lake level at EL. 50 m MSL, the surface area would be approximately 2,360 ha.

CLEARING AND/OR GRUBBING

Clearing and grubbing would be required for all areas above the existing Gatun Lake that are required for construction of the dam (embankments and spillway), access roads, and disposal and staging areas. For the Trinidad Lake area, clearing would be required for the 3,700 ha in the lake area between the maximum operating lake level of Gatun Lake and EL. 30.5 m MSL.

Clearing only would be required for the 740 ha in the Rio Caño Quebrado Lake area between the maximum operating lake level of Gatun Lake and EL. 30 m MSL.

For the Rio Indio Lake, clearing would be required in all areas necessary for construction of the dam (embankments and spillway), inter-basin transfer facilities, outlet works, hydropower plants, access roads, and disposal and staging areas should require clearing and grubbing. Only the 650 ha in the lake area between the normal operating lake level at EL. 80 m MSL and the minimum operating lake level at EL. 50 m MSL should require clearing. The transmission lines should also require clearing

ACCESS ROUTE

Lower Rio Trinidad

The route from Colon is westward across the Panama Canal and then southwestward along existing roads that follow the westernmost boundary of Gatun Lake to Cape Mala, near the western abutment of the dam. A very short access road is required from the existing road to the dam site. This route requires crossing the Panama Canal near the Gatun Locks using the existing lock gate bridge. This bridge is narrow and operates only intermittently since canal operations take precedence over roadway traffic. It may be undersized and may lack the load carrying capacity needed for heavy construction materials and equipment loads anticipated.

Access to the spillway and pumping plant construction sites would be by water since these structures are to be placed on Guacha and Tern Islands, respectively. A water access route is considered for conveyance of much, if not all, of the construction equipment and materials. This requires the construction of offloading facilities near the west abutment of the dam, on Guacha Island, and near the eastern abutment site in the vicinity of South Range Point.

Since much of the construction for this project would be in the existing lake or on islands in the lake, it is concluded that both land and water access is required. Plate 36-1 shows the general location of the proposed features and the possible land and water access available or to be provided.

Access to Rio Caño Quebrado can best be gained from the Panama City area by way of existing roads extended to the village of Santa Clara, located to the south and east of the Rio Caño Quebrado dam site. From Santa Clara, a new roadway is required to the dam construction site, a distance of approximately 8 km. Roadway access should also be required to the spillway site, which would be located some distance to the south and west, and across the existing lake from the dam site. Existing roadway access in this area is now available to the village of La Laguna. From a point just south of La Laguna, a new access road would be required around the south side of the existing lake to the spillway site. This route should require approximately 5 km of new roadway.

Rio Indio

For access to the Rio Indio site it is concluded that the route from Panama City westward across the Bridge of the Americas, then generally southwestward along the Inter-American Highway, and then generally westward along existing roads to Ciri Grande, is best. This route requires that the road between Panama City and Ciri Grande be upgraded over much of its length and the route west of Ciri Grande should have to traverse the mountains. The proposed access road would be 26 km in length, and bridges and/or culverts would be required at 15 streams. Table 39-1 shows the portion of the proposed access road from Ciri Grande to the construction sites.

In addition to providing construction access, this new corridor into the interior of the country west of the Panama Canal would be nefit those living in the region, providing access to the centers of commerce in the southern part of the country. It should also provide continuous access along the new power transmission lines from the dam site to the connection with the power grid.

Sources of Construction Material

Lower Rio Trinidad

The bottom 5 m layer of the dam embankments shall be constructed with material less than 8 in. maximum size, and with no more than 5 percent passing the #200 screen. Such a material should require crushing and processing across a grizzly to remove oversize rock, and washing to remove fines. Material for this bottom layer must be reasonably well graded so as to prevent the removal of the finer fraction by piping. The overlying main portion of the embankment would be constructed with (-12 in.) sized material. This material should also require crushing and processing across a grizzly to remove oversize rock.

The majority of the materials used for the embankment construction would be obtained from upland sources adjacent to the Gaillard Cut, transported to the site by barge and clam shelled along the proposed embankment alignment. The initial materials would be obtained from the existing disposal sites for the Gaillard Cut widening above Pedro Miguel Locks. Based on the information received from the ACP, these sites contain approximately 5.5 million M^3 of suitable excavated rock. However, this rock is not stockpiled in an orderly manner, is randomly mixed with unsuitable material and is covered with unsuitable material. All the rock materials, from whatever source, should need to be crushed, graded and loaded on trucks for transport to a loading facility adjacent to the canal at the Cucaracha Reach on the east side, or the mouth of the Mandinga River on the west side. These loading facilities should require excavation into the bank area and bulkheaded for crane support and barge placement. Working stockpiles would be maintained next to the transfer points to facilitate the loading process. Additional materials within the immediate area should come from the Third Locks excavation adjacent to the Pedro Miguel Locks. These materials would be drilled and blasted in place, excavated, and then transported to one of the transfer facilities for processing. Additional materials should come from newly developed quarry sources in areas such as Hodges Hill, Escabor Hill, Contractor Hill, and others within 10 km of the transfer points. Each of these new sources should require extensive excavation to remove the overburden and soft rock materials. These materials would be stockpiled adjacent to the work area for restoration once the rock fill materials have been acquired. The suitable rock materials would be blasted, crushed and graded and trucked to the transfer points. All material would be loaded onto barges, transported to the dam site and clam shelled within the dam limits.

Cement is available within the country. Rock obtained from developed quarries may be used to produce concrete aggregates on-site, or they may be obtained from commercial quarries. Concrete additives and cement replacement materials (i.e., fly ash) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) need to be fabricated

outside the Republic of Panama and imported for final assembly and installation at the proposed dam site.

Rio Caño Quebrado
The sources of the embankment and other construction materials for Rio Caño Quebrado are the same as those for Lower Rio Trinidad.

Rio Indio
Rock removed from the spillway site can used as fill in the embankment portion of the dam. Impervious materials might be obtained from outside the project area; however, for this study it is assumed that these materials would be available locally in sufficient quantity to supply the project needs. If further study indicates that impervious materials are unavailable locally, then other materials, such as roller compacted concrete, would be considered for construction of the dam.

Cement is available within the Republic of Panama. Rock obtained from developed quarries may be used to produce concrete aggregates on-site, or they may be obtained from commercial quarries. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) need to be fabricated outside the country and imported for final assembly and installation at the proposed dam site.

Real Estate Requirements

The proposed Lower Rio Trinidad Lake site is located within the former Panama Canal Zone and is presently managed and controlled by the ACP. Construction of this project requires acquisition of approximately 800 ha. Table 39 - 4 shows the amount of land required for the various project features. Real estate for access roads is included in the estimated quantities for the other items listed in the table. The ACP provided the estimated cost of the land for the proposed project.

Table 39 - 4 Real Estate Requirements

Project Feature	Land Required (ha)
Lake	0
Dam Site	0
Staging Area	200
Housing and Facilities	200
Disposal Area	400
Total	800

The proposed Rio Caño Quebrado Lake site is located within the former Panama Canal Zone and is presently managed and controlled by the ACP. It is assumed that the future management of the Panama Canal should retain the same authority. The acquisition of lands for The proposed Rio Caño Quebrado Lake would be located within the former Panama Canal Zone the

lake area should not be required. Construction of this proposed project should require acquisition of approximately 800 ha. Table 39 - 5 shows the amount of land required for the various project features. Real estate for access roads is included in the estimated quantities for the other items listed in the table.

Table 39 - 5 Real Estate Requirements

Project Feature	Land Required (ha)
Lake	0
Dam Site	0
Staging Area	200
Housing and Facilities	200
Disposal Area	400
Total	800

The proposed Rio Indio project would be located in the Cocle, Colon, and Panama Provinces. Construction of this proposed project should require acquisition of approximately 5,600 ha. Table 39 - 6 shows the amount of land required for the various project features. Real estate for access roads is included in the estimated quantities for the other items listed in the table.

Table 39 - 6 Indio Real Estate Requirements

Project Feature	Land Required (ha)
Lake	4,600
Dam Site	200
Staging Area	200
Housing and Facilities	200
Disposal Area	400
Total	5,600

Relocations

The Lower Rio Trinidad Lake site is located within the existing Panama Canal Zone. Structures and facilities established along the water's edge in the Trinidad arm between the existing Gatun Lake levels and EL. 30 m MSL need to be relocated or modified. This includes a major portion of the town of Escobal. There are only a few small communities and isolated individual structures along the lakeshore with very limited access by land.

The Rio Caño Quebrado Lake site is located within the existing Panama Canal Zone. Structures and facilities established along the water's edge in the Rio Caño Quebrado arm between the existing Gatun Lake level and EL. 30 m MSL should need to be relocated or modified. This region has a few settlements along the lakeshores with limited access by land.

The Rio Indio Lake site is located in a sparsely settled region with few roads and utilities. This area is devoted primarily to subsistence farming and ranching. Structures and individuals located in the lake area below EL. 85 m MSL should require relocation because of the normal lake inundation and to secure the lake perimeter for flood considerations. The required relocations should include the five towns in the lake area (El Limon, Los Uveros, La Boca de Urcelillo, Aguila, and Tres Hermanas), 30 other small settlements, and numerous isolated structures. The five towns all have elementary schools, churches, electricity, and limited telephone coverage.

Development Sequence

Each of the two major component lake projects, Lower Rio Trinidad Lake and Rio Indio Lake, can be constructed as a stand-alone facility. The Rio Caño Quebrado Lake can function as an arm of the Lower Rio Trinidad Lake, having no water handling facilities of its own but dependent on the Lower Rio Trinidad spillway and pumping plant to regulate the lake water level.

If the Rio Indio facilities are constructed first and placed into service before the Lower Rio Trinidad facilities, the interbasin transfer tunnel may be used to navigational advantage while the Lower Rio Trinidad and Rio Caño Quebrado projects are being completed. During the interim the Rio Indio project should help control flooding on the Lower Rio Indio and can contribute to the electric power output of the country.

The development sequence for each individual project should follow roughly the same progression. This progression is summarized below with pertinent site-specific notations as appropriate.

Each project must be evaluated to assure that the plan presented includes all of the features required to function. Each project must be assessed as to its effectiveness in providing navigation water to the Panama Canal, with due recognition of any secondary benefits. Environmental assessments of the proposed projects need to be made to assure environmental acceptability of the project features. These environmental assessments begin during the planning studies phase and continue into the final design, advertising and award phases. Environmental coordination begins with planning studies and continues through the completion of construction. After completion of the final design, plans and specifications must be prepared for the advertising and award phase.

Project implementation begins with land acquisition and construction of the access facilities. Lands for the housing and facilities project feature, which includes the access roads, need to be acquired initially. Lands for the dam site, staging area, disposal area, and lake can then be acquired.

Socio-economic programs must begin shortly before construction of the dam. The relocation of the small settlements and isolated structures must be accomplished. Socio-economic programs to assist those individuals impacted by the construction of the proposed project should continue throughout the construction phase.

Construction of the Rio Indio Dam begins with the clearing and grubbing of the construction sites and clearing the perimeter of the lake area. Materials used for the embankment construction can obtained from upland sources then transported to the site.

Upstream and downstream cofferdams are required for construction of the Rio Indio Dam and appurtenant facilities. These shall be configured to form a portion of the finished dam.

Limited cofferdams would be required to accomplish construction of the spillway and pumping station. These efforts may be accomplished simultaneously. Following completion of the pumping plant and spillway, the channels connecting these structures to the lake areas upstream and downstream may be excavated. Where possible, materials removed from these sites would be placed directly into the dam.

Once the western leg of the dam, pumping station and spillway are completed, the eastern leg may be constructed, thus completing the dam. The pool may then be raised. Upon completion of this phase of construction, all facilities must undergo trial operations, before being commissioned for service.

Considering the construction methods and the nature of the work, it is estimated that development of the Lower Rio Trinidad, Rio Caño Quebrado, and Rio Indio projects can be completed in approximately the time spans indicated in Figures 39-1, 39-2, and 39-3, below, from initial planning to lake filling. The Lower Rio Trinidad and Rio Caño Quebrado projects can be constructed simultaneously. Assuming the development of the Rio Indio and Lower Rio Trinidad Projects are overlapped by 1 year, the total development time is 22 years.

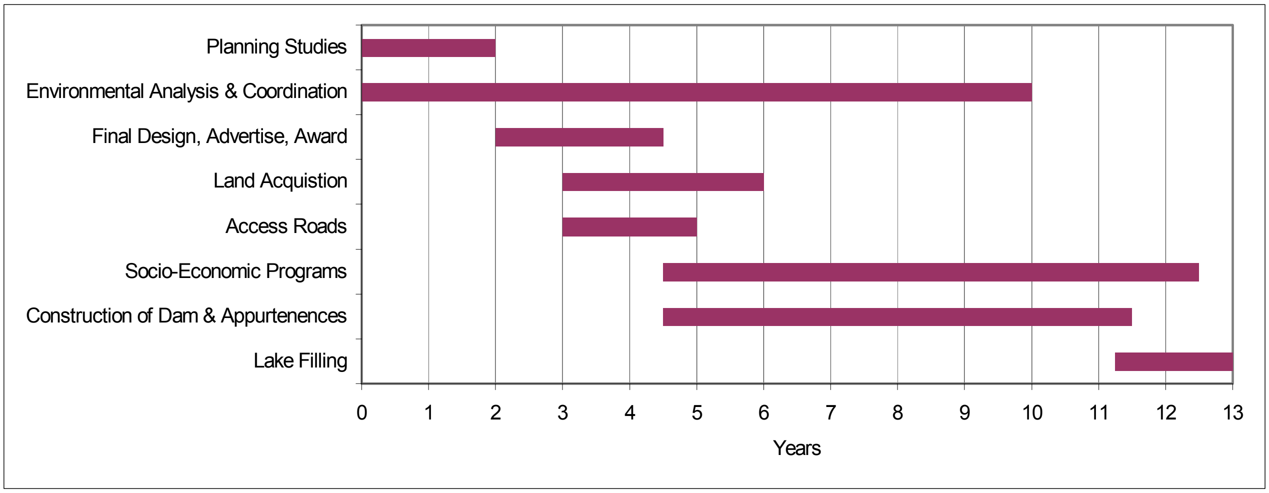


Figure 39 - 1 Development Sequence – Lower Rio Trinidad

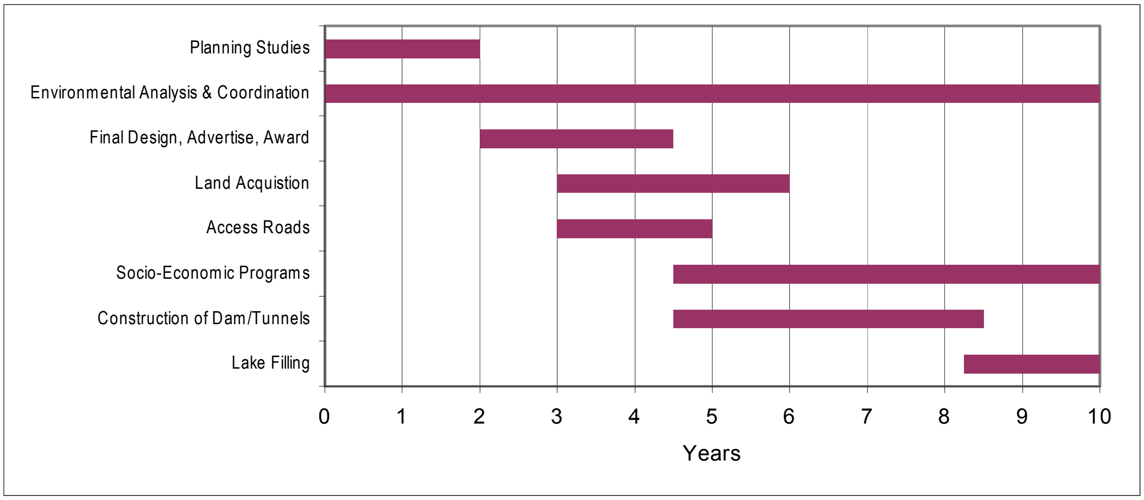


Figure 39 - 2 Development Sequence – Rio Indio

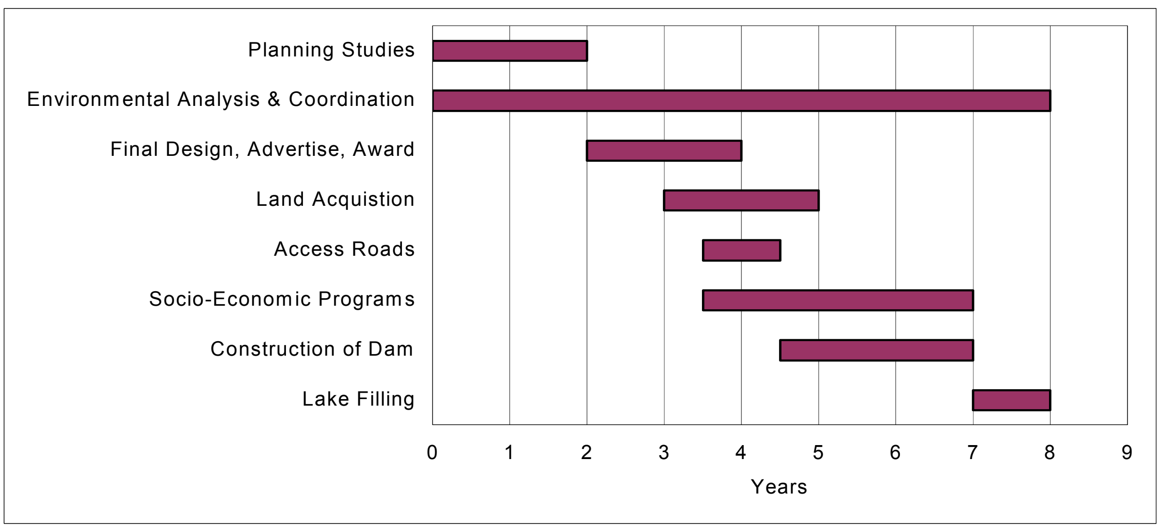


Figure 39 - 3 Development Sequence – Rio Caño Quebrado (Concurrent with Lower Rio Trinidad)

Hydrologic Reliability

In order to determine the effect of the proposed Lower Rio Trinidad, Rio Caño Quebrado and Indio Lakes on the hydrologic reliability of the Panama Canal, the existing HEC-5 model is modified to include the Lower Rio Trinidad Lake with pumpback operation and diversion from Rio Indio Lake. The existing Gatun Lake parameters (surface areas, storages, and local inflows) are reduced by the proportion that Lower Rio Trinidad and Rio Caño Quebrado Lakes should capture.

HEC-5 model simulations are conducted for both the existing canal system and the Scenario 2 operating system. The simulations considered proportionally increasing demands up to 180 percent of current demand levels. The period of simulation considered 52 years (January 1948 through December 1999) of hydrologic record. Figure 39 - 4 presents the resulting hydrologic reliability for two configurations with demands increasing up to 180 percent of current demands. These configurations are:

- Existing system,
- Scenario 4 – Rio Indio Lake fluctuating between the normal operation lake at EL. 80 m MSL and the minimum operation lake level at EL. 50 m MSL, with a 3 m diversion tunnel; Lower Rio Trinidad and Rio Caño Quebrado Lake fluctuating between the normal operating level at EL. 30.48 m MSL and the minimum operating lake level at EL. 22.86 m MSL with pumping capability to and from Gatun Lake; and Gatun Lake fluctuating between the normal operating lake level at EL. 26.67 m MSL and the minimum operation lake level at EL. 25.91 m

The horizontal axis along the bottom of Figure 39 - 4 reflects demand as a ratio of the five-year average from 1993 to 1997, and the axis along the top reflects demands in lockages (assuming 55 million gallons per lockage).

As shown in Figure 39 - 4, the existing hydrologic reliability of the Panama Canal, based on the period of record of 52 years, is 99.6 percent, while the hydrologic reliability, with a demand ratio of 1.8, is 86.3 percent. This period of record includes the worst drought on record for the area, which occurred in 1998. The hydrologic reliability, with a demand ratio of 1.0, is 100 percent for operating Scenario 4, and the hydrologic reliability with a demand ratio of 1.8 would be 97.75 percent. Table 39 - 6 displays the number of lockages associated with various levels of reliability.

Without additional water supplies, the hydrologic reliability of the canal system should decrease. With the construction of the Lower Rio Trinidad Pumpback, Rio Caño Quebrado Dam and Indio Dams projects, the existing high hydrologic reliability can be continued as demand for water increases to 50.3 percent (19.47 lockages) above current demand levels.

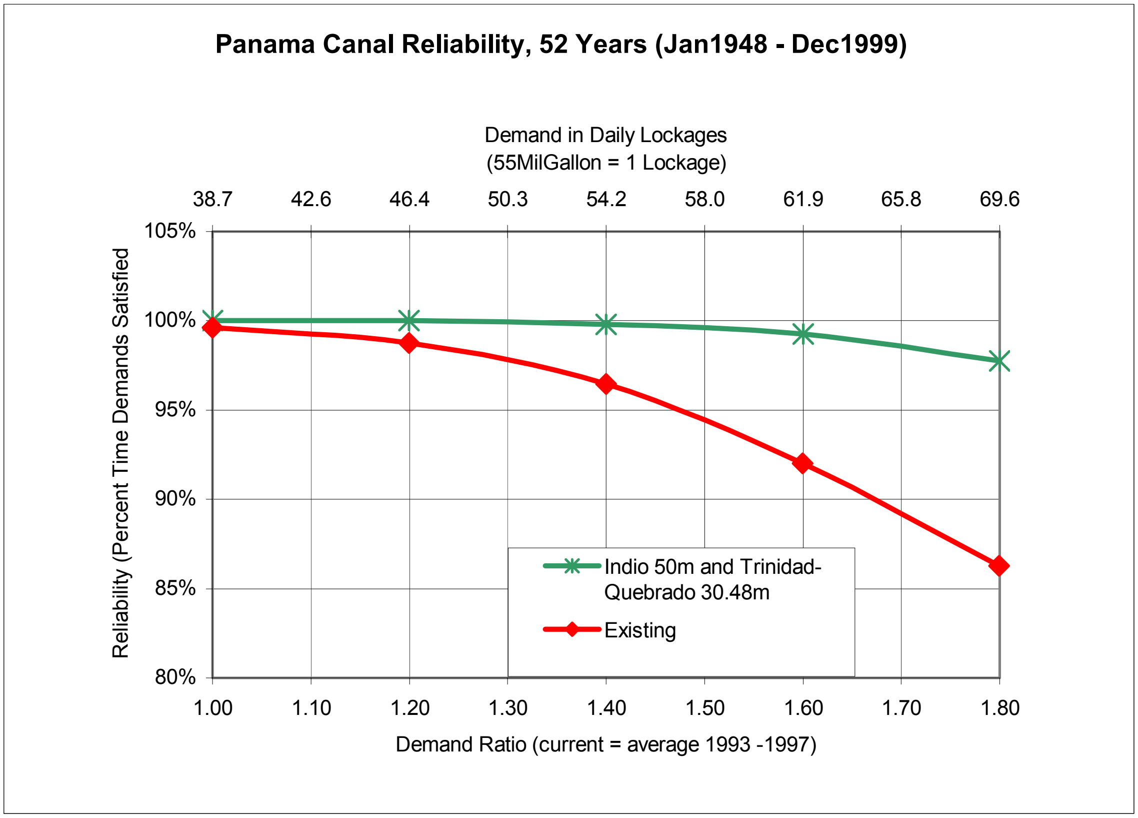


Figure 39 - 4 Panama Canal Hydrologic Reliability

Project Costs

GENERAL

The quantities estimated for the various items of work required for the construction of this project are derived from the layouts shown on Plates 36-2 through 36-8. The unit prices applied to these quantities are based on: historical information from previous estimates prepared for similar construction by the ACP; estimates for similar construction in the Mobile District; information gathered from Mobile District Construction Division personnel in Panama; and the book Feasibility Studies For Small Scale Hydropower Additions, A Guide Manual, written by The Hydrologic Engineering Center of the U.S. Army Corps of Engineers.

Engineering and design is estimated to be 12 percent and supervision while administration is estimated to be 6 percent of the construction cost items. An allowance of 2 percent of the construction cost items is allowed for field overhead (construction camp, contractor facilities, etc.). An allowance of 25 percent is included for contingencies. The ACP provided the estimated cost of the land for the proposed project.

FIRST COSTS

The total project first costs are estimated at $1,076,592,000. Table 39 - 7 provides a summary of the first costs for the principal features. Separate documentation provided to the ACP includes a detailed cost estimate containing the sub-features of the work.

Table 39 - 7 Summary of First Costs

	Rio Trinidad	Rio Indio	Rio Caño Quebrado
Item	Costs ($)	Costs ($)	Costs ($)
Lands and Relocations	2,000,000	14,000,000	2,000,000
Access Roads	9,574,000	8,030,000	4,440,000
Clearing and/or Grubbing	556,250	3,566,250	778,750
Cofferdam	850,000	4,850,665	N/A
Dam	491,824,842	22,723,329	2,386,390
Spillway	8,891,206	43,387,450	N/A
Intakes	N/A	7,701,295	N/A
Saddle Dikes	2,143,390	4,241,143	N/A
Transfer Ditch	N/A	N/A	3,281,400
Pumping Station	22,999,637	N/A	N/A
Diversion Tunnel	N/A	14,732,944	N/A
Interbasin Transfer Tunnel	N/A	11,595,800	N/A
Transfer Intake Indio-Gatun	N/A	365,258	N/A
Hydropower Plants	N/A	22,118,125	N/A
Transmission Lines	2,090,000	6,600,000	N/A
Subtotal	540,929,325	163,912,258	12,886,540
E&D, S&A, Field Overhead	108,185,865	32,782,450	2,577,308
Contingencies	162,278,798	49,173,675	3,865,962
Total Project First Cost	811,393,988 Approximately 811,400,000	245,868,375 Approximately 245,868,000	19,329,810 Approximately 19,330,000

OPERATION AND MAINTENANCE

Staff

A staff should operate and maintain the proposed Lower Rio Trinidad Dam project during the day and then run the facility remotely at night. The full-time staff should consist of a total force of 9, including a station manager, a multi-skilled supervisor, 2 leaders (Electronics/Instrumentation, Electrical/Mechanical), 4 craftsmen and a laborer. A part-time staff would be required for two to three months each year to perform general maintenance and overhaul of the project. The part-time staff may consist of three mechanics and three electricians. The annual staffing costs are estimated to be $350,000. The annual staffing costs estimated for the Lower Rio Trinidad project is sufficient to include for the Rio Caño Quebrado project as well. The annual staffing costs for the proposed Rio Indio project are estimated to be $500,000.

Ordinary Maintenance

Ordinary maintenance and care are required and include minor repair materials, lubricants and other supplies. It is estimated the costs of ordinary maintenance are $18,000 per year for the access road and $100,000 per year for the main project facilities. Fuel consumption for the pumps is estimated at $648,000. This estimate considers the growth in demand for water over time and the variability in flows to Gatun Lake, as well as the Lower Rio Trinidad Lake. An estimated $150,000 would be needed for rock placement to account for settling of the project. The total ordinary maintenance is $916,000. The ordinary maintenance costs estimated for the Lower Rio Trinidad project is sufficient to include for the Rio Caño Quebrado project as well. The ordinary maintenance costs for the proposed Rio Indio project are estimated to be $320,000.

Major Replacements

The average service life of gates, electrical equipment, pumps, trash racks and other features is less than the total useful life of the project (100 years). To estimate the major replacement costs during the 50-year planning period, it is assumed that specific items should not change in price. No allowance is made for salvageable fixed parts. Table 39-8 lists the service life, number of times each component may be replaced, the future costs of each item, and the present worth of the replacement costs for the major components. Based on these values, the present worth of the proposed replacements would be $2,214,200 and the average annual replacement costs would be $267,000. There would be no major replacements needed for the Caño Quebrado project. The average annual replacement costs for the proposed Rio Indio project are estimated to be $91,000.

Table 39 - 8 – Major Replacement Costs

Component	Service Life (years)	Number of Times Replaced During Planning Period	Future Costs ($)	Present Worth of Replacement Costs ($)
Roads	50	1	12,435,000	43,000
Bridges	50	1	1,800,000	6,200
Pump Station				
Pumps	25	2	21,006,000	654,200
Sluice Gates	50	1	1,275,525	4,400
Sluice Trash Racks	50	1	458,850	1,600
Electrical Controls	25	2	2,100,000	65,400
Fuel Tanks, etc.	50	1	450,000	1,600
Misc. Equip. & Comm	25	2	3,183,000	99,100
Slurry Trench	25	2	39,000,000	1,214,500
Spillway				
Bridge Girders	50	1	365,271	1,300
Tainter Gates	50	1	1,980,000	6,900
Tainter Gate Hoists	50	1	1,320,000	4,600
Tainter Gate Op Sys.	50	1	360,000	1,200
Stoplogs	50	1	475,950	1,600
Misc. Mech. Items	25	2	1,500,000	46,700
Electrical Controls	25	2	1,650,000	51,400
Transmission Lines	50	1	3,135,000	10,800
Total			92,494,596	2,214,500
Average Annual Replacement Costs				267,000

Annual Costs

The project first costs for the proposed Lower Rio Trinidad project are estimated at $811,400,000. The project first costs for the Rio Caño Quebrado project are estimated at $19,330,000. The total project first costs, including the $245,868,000 for the Rio Indio project, are estimated to be $1,076,592,000. These total project first costs are distributed across the development period using generalized curves for contractor earnings for large, heavy construction jobs. Interest on the proposed Rio Indio project first costs are computed from mid-year throughout the 22-year development period from initiation of planning and design until the Lower Rio Trinidad area is filled. Interest during construction for the Lower Rio Trinidad project is computed from mid-year throughout its 13-year development period until lake filling is complete. The interest during construction at 12 percent is $658,745,000 for Lower Rio Trinidad, $8,588,000 for the Rio Caño Quebrado project and $1,222,371,000 for Rio Indio for a total interest during construction of $1,889,704,000. These costs are added to the total project first costs for total project investment costs of $2,966,296,000. A capital recovery factor for the 50-year planning period is applied to get the annual average investment costs of $357,191,000. Annual operation and maintenance costs are added. Major replacement costs are estimated and are converted to an annual cost by discounting the future replacement costs of major components of the project back to completion of the project construction. Table 39 - 9 contains a summary of the $359,636,000 total annual costs.

Table 39 - 9 Summary of Annual Costs

Item	Costs ($)
Total Project First Costs - Lower Rio Trinidad	811,394,000
Total Project First Costs – Rio Indio	245,868,000
Total Project First Costs – Rio Caño Quebrado	19,330,000
Interest During Construction – Lower Rio Trinidad	658,745,000
Interest During Construction – Rio Indio	1,222,371,000
Interest During Construction – Rio Caño Quebrado	8,588,000
Total Project Investment Costs	2,966,296,000
Annual Average Investment Costs	357,191,000
Operation and Maintenance Costs	
Staff Costs – Lower Rio Trinidad	350,000
Staff Costs – Rio Indio	500,000
Ordinary Maintenance Costs – Lower Rio Trinidad	916,000
Ordinary Maintenance Costs – Rio Indio	320,000
Major Replacement Costs – Lower Rio Trinidad	267,000
Major Replacement Costs – Rio Indio	91,000
Total Average Annual Costs	359,636,000

Annual Benefits

NAVIGATION

The procedures and assumptions used in estimating the benefits are described in Volume 1. The following paragraphs present the results of the economic investigations for the proposed Lower Rio Trinidad, Rio Caño Quebrado and Rio Indio projects. The 50-year period for the economic analysis of this proposal is 2024 to 2073.

The Lower Rio Trinidad, Rio Caño Quebrado and Rio Indio projects should increase the reliability of providing water to accommodate the total daily number of lockages demanded. Table 39 - 10 provides the increase in the hydrologic reliability of providing the sum of the demands for both navigation and M&I water supply keyed to years. The hydrologic reliability percentages are obtained from the data used to develop Figure 39 - 4. The 99.6 percent level of reliability for this proposal is used to estimate the water supply benefits for navigation and the net change in reliability is used to estimate the reliability benefits for navigation and M&I water uses.

Table 39 - 10 Panama Canal Hydrologic Reliability
(Based on Period of Record from January 1948 to July 1998)

Current Demand Ratio	Year	Demand in Daily Average Number of Lockages (Navigation and M&I)	Hydrologic Reliability	
			Existing System (%)	With Lower Rio Trinidad, Rio Caño Quebrado & Rio Indio [1/] (%)
1	2000	38.68 [2/]	99.60	100.00
	2010	45.11	98.91	100.00
1.2		46.42	98.76	100.00
	2015	46.82	98.64	99.98
	2020	47.61	98.41	99.97
	2025	48.52	98.14	99.95
	2030	49.55	97.83	99.92
	2035	50.72	97.48	99.89
	2040	52.02	97.10	99.86
	2045	53.49	96.65	99.82
1.4		54.15	96.45	99.81
	2050	55.13	95.89	99.74
	2055	56.98	94.83	99.56
	2060	59.05	93.65	99.56
	2065	61.37	92.32	99.29
1.6		61.89	92.02	99.25
	2070	63.97	90.47	98.84
1.8		69.63	86.27	97.75

[1/] The lakes behind the Lower Rio Trinidad and Rio Caño Quebrado Dams should fluctuate from the normal operating lake level at EL. 30.48 m MSL down to the minimum operating lake level at EL. 22.86 m MSL and the lake behind the Rio Indio Dam should fluctuate from the normal operating lake level at EL. 80 m MSL down to the minimum operating lake level at EL. 50 m MSL.

[2/] 2000 Daily Demand is Average of 1993-1997.

With the proposed Lower Rio Trinidad, Rio Caño Quebrado and Rio Indio projects, water supply shortages for navigation should continue. The demand for the M&I purposes should always be met first. As these demands grow, the amount of water available to meet the demands for navigation should decrease. Thus, the benefits for the additional water supply are estimated at the value for navigation. With the addition of the proposed Lower Rio Trinidad, Rio Caño Quebrado and Rio Indio projects, these shortages should occur less frequently. With a hydrologic reliability of 99.6 percent, the proposed project increases the amount of water supplied by 19.47 equivalent lockages. The 99.6 percent hydrologic reliability should occur after the year 2058, with an equivalent daily average number of lockages of 58.15. Benefits of additional water are attributable to navigation since the amount of M&I water demanded would be provided first. Therefore, all shortages would be attributable to navigation. The benefits are estimated using the toll revenue per lockage and the increased daily average number of lockages. The annual average of benefits for water supply is $233,801,000. Table 39 - 11 provides the estimate of daily shortages under the existing system, the remaining daily shortages with the Lower Rio Trinidad, Rio Caño Quebrado and Rio Indio projects in operation, the annual benefits for meeting shortages and the average annual benefits.

Table 39 - 11 Benefits for Additional Water Supply for Navigation

Year	Daily Shortages In Lockages Under Existing System	Remaining Daily Shortages	Annual Benefits For Navigation ($)
2023	9.51	0.00	196,137,742
2030	10.87	0.00	224,201,428
2040	13.34	0.00	275,146,640
2050	16.45	0.00	339,265,866
2060	20.36	0.89	401,532,407
2070	25.29	5.82	401,532,407
Average Annual Benefits			233,801,000
With the Lower Rio Trinidad and Rio Caño Quebrado projects operating between 22.86 and 30.48 m and the Rio Indio project operating between 50 and 80 m, the system should provide a total of 58.15 lockages at the 99.6 percent level of reliability or 19.47 more lockages than the existing system.			

With the Lower Rio Trinidad, Rio Caño Quebrado and Rio Indio projects, the reliability of the system to provide all of the water demanded by navigation and M&I water can be improved. Using the increase in hydrologic reliability, the forecast number of vessels converted to a daily average number of lockages, the toll revenue for each average lockage, and a project discount rate of 12 percent, the average annual benefits for navigation reliability attributable to the proposed Lower Rio Trinidad, Rio Caño Quebrado and Rio Indio projects is $18,680,000.

Table 39 - 12 provides the forecast daily average number of lockages, the forecast value per daily lockage, the annual benefits for increased reliability, and the average annual benefits.

Table 39 - 12 Average Annual Reliability Benefits For Navigation

Year	Daily Average Number of Lockages	Value Per Lockage ($)	Annual Benefits For Navigation ($)
2023	40.0	2,260,000	14,197,000
2030	40.0	2,260,000	17,268,000
2040	40.0	2,260,000	22,845,000
2050	40.0	2,260,000	31,704,000
2060	40.0	2,260,000	41,827,000
2070	40.0	2,260,000	69,078,000
Average Annual Benefits			18,680,000

M&I WATER SUPPLY

The future demand for water supply for M&I purposes is based upon the growth in population. The ACP provided a forecast for the area surrounding the Panama Canal. The current usage is estimated at 4.0 equivalent lockages per day; an equivalent lockage is 55 million gallons of water. One equivalent lockage is added to the forecast to account for the burgeoning tourist industry, beginning in the year 2010. The increased reliability of the system to provide water supply for navigation similarly provides the same increase in reliability to provide water for M&I purposes. Using the increased hydrologic reliability of the system with the addition of the Lower Rio Trinidad, Rio Caño Quebrado and Rio Indio projects, the current costs to the ACP to process finished water ($0.69 per 1,000 gallons), the number of daily lockages demanded, and a project discount rate of 12 percent, the average annual benefits for M&I reliability are $3,412,000. Table 39 - 13 displays the population forecast, the resulting number of equivalent lockages per day, and the benefits for M&I water supply.

Table 39 - 13 Average Annual Reliability Benefits For M&I Water Supply

Year	Population	Equivalent Lockages per Day	Annual M&I Water Supply Benefits ($)
2023	2,294,000	8.15	1,954,000
2030	2,688,000	9.55	2,774,000
2040	3,384,000	12.02	4,609,000
2050	4,259,000	15.13	8,052,000
2060	5,360,000	19.05	13,381,000
2070	6,746,000	23.97	27,815,000
Average Annual Benefits			3,412,000

HYDROPOWER

The amount of hydropower energy that can be produced by the system of Gatun Lake and Madden Lake should decline over time as the demands for navigation and M&I water supply increase. With the inclusion of the Lower Rio Trinidad and the Rio Caño Quebrado projects, the system will loose hydropower generation at Gatun Lake and Madden Lake due to the change in the operation of the system. With the inclusion of the Rio Indio Dam project, however, the system can produce additional megawatt hours of hydropower for a net gain in hydropower generation. The value for hydropower energy used in this analysis is $0.070 / kWh. On an average annual basis, the project should have benefits of $3,002,000. Table 39 - 14 provides the net additional megawatt hours of hydropower generation and the resulting benefits.

Table 39 - 14 Average Annual Benefits For Hydropower Generation

Year	Net Generation [1] (MWh)	Annual Benefits For Hydropower ($)
2023	44,813	3,137,000
2030	43,419	3,039,000
2040	40,960	2,867,000
2050	37,515	2,626,000
2060	32,222	2,256,000
2070	25,138	1,760,000
Average Annual Benefits		3,002,000
[1] Net generation of Gatun, Madden, and Indio above generation of Gatun and Madden hydropower plants.		

SUMMARY OF ANNUAL BENEFITS

As shown in Table 39 - 15, total average annual benefits for the proposed Lower Rio Trinidad, Rio Caño Quebrado and Rio Indio projects would be $258,895,000.

Table 39 - 15 Summary of Annual Benefits

Benefit Category	Average Annual Benefits ($)
Navigation – Water Supply	233,801,000
Navigation – Reliability	18,680,000
M&I – Reliability	3,412,000
Hydropower	3,002,000
Total	258,895,000

To perform an analysis of benefits versus costs, a common point in time is selected. This common point is at the completion of filling the proposed Lower Rio Trinidad project (the end of the year 2022). In these analyses, it is important to note that the average annual benefits or average annual costs are the amortized value of the sum of the present worth of either the benefits or costs at the point of comparison. The development sequence for the proposed Lower Rio Trinidad and Rio Indio projects is to develop the Rio Indio project first (2001 – 2010) and then the Lower Rio Trinidad project (2009 – 2022).

The benefits attributable to the proposed Rio Indio project begin to accrue in 2010 when the reservoir is filled. Thus, the Rio Indio project benefits for the period 2011 to 2022 are escalated by the project discount rate, 12 percent, in order to estimate the total present worth ($4,446,416,000 in the year 2022). The average annual benefits for the Rio Indio project accruing during construction of the Lower Rio Trinidad project are estimated at $535,423,000.

To estimate the interest during construction, similar calculations are made for the costs of each proposed project. For the proposed Rio Indio project, interest during construction is calculated from year 2001 to year 2022 and the interest during construction for the proposed Lower Rio Trinidad project is taken from the year 2009 to the year 2022.

The sequence of development of the two projects is crucial to the estimate of average annual benefits and costs. If the Lower Rio Trinidad project is developed first, then the average annual costs double in size and the average annual benefits reduce to less than half. This occurs because the first costs for the Lower Rio Trinidad project are four times the cost for the Rio Indio project ($812 M vs. $245 M). The estimate of interest during construction changes from approximately $2 B to $4 B depending upon which project is developed first. Likewise, the Rio Indio project provides approximately 80 percent of the total average annual benefits of the combined projects ($212 M of $258 M). The estimate of benefits for the first project during the period of construction of the other project changes from $150 M to $600 M.

Total average annual benefits and average annual costs are then estimated, and the ratio of benefits to costs and the net benefits (net of costs) are computed. In the first instance, the analysis determines the feasibility of the proposal. The net benefits determine which proposal among several provides the greatest value for the investment dollars. Table 39 - 16 lists the benefit to cost ratio and the net benefits.

Table 39 - 16 Economic Evaluation

Item	Value ($)
Average Annual Benefits	
Lower Rio Trinidad and Caño Quebrado	258,895,000
Rio Indio	535,423,000
Total Average Annual Benefits	794,318,000
Average Annual Costs	
Lower Rio Trinidad	178,562,000
Rio Indio	177,712,000
Caño Quebrado	3,362,000
Total Average Annual Costs	359,636,000
Benefit to Cost Ratio	2.2
Net Benefits	434,683,000

Internal Rate of Return

An internal rate of return analysis for this proposed project is performed. The annual construction costs are used as the investment, and the undiscounted benefits are used as return cash flows. The internal rate of return is 24.4 percent.

Socio-Economic Impacts

The description of the environmental setting is based on field observations made while conducting field reconnaissance throughout Gatun Lake, specifically the Lower Rio Trinidad and Rio Indio areas with ACP personnel. Autoridad Nacional del Ambiente (ANAM), ACP, Asociacion Nacional para la Conservacion de la Naturaleza (ANCON), Electrical Transmission Agency, Smithsonian Tropical Research Institute (STRI), and Directorate of Mineral Resources personnel were interviewed to gain information on site characteristics and potential activities that could affect the project. In addition, extrapolations of the 2000 census data were used, and a review of the Informe de Cobertura Boscosa 1992 were used to determine the extent of forest cover.

Environmental Setting

This alternative combines three projects, the Lower Rio Trinidad (lake level 22.9 - 30.5 m) with Rio Caño Quebrado (lake level 22.9 - 30.5 m), and Rio Indio (lake level 50 - 80 m). This project will provide additional storage of water for Gatun Lake and 19.47 additional lockages per day on a continual basis. The project area consists of 22,400 hectares within Gatun Lake and 5,600 ha within the Rio Indio watershed. The area near Gatun Lake is sparsely populated and has a topography consisting of rolling hills, low regions near Gatun Lake. Near Rio Indio, the area is sparsely populated with terrains and a topography consisting of steep hills, as well as coastal regions. The Lower Rio Trinidad, Rio Caño Quebrado, and Rio Indio are west of the Panama Canal and flow northward from the Continental Divide into Gatun Lake. The watershed above the Lower Rio Trinidad with Rio Caño Quebrado and the Rio Indio dam project covers approximately 1,052 km^2 and 381 km^2 respectively. The incremental impoundment area, which covers approximately 6,577 ha, consists of approximately 50 percent of forested land, 30 percent of pasture land (used by ranchers), 10 percent of cropland, and 10 percent of newly slashed and burned land. Gatun Lake's normal pool level is 26.7 m. The lake level during field observations (August 2001) was approximately 25.4 m.

LAND USE

The Lower Rio Trinidad project area encompasses the southwestern portion of Gatun Lake and areas along its shores. The areas to be flooded or partially flooded include the town of Escobal (population – 1,653), Nuevo Provenir (population – 121), Cuipo (population – 249), Ciricito (population – 72), La Arenosa (population – 242), La Garterita (population – 138), La Gartera (population – 348), and a few small isolated establishments.

The Rio Caño Quebrado project proposes to maintain the impoundment at pool levels between 22.9 and 30.5 m. The normal pool level is 26.67 m. La Laguna (population 246) and Pueblo Nuevo (population 47) are the only towns on the Rio Caño Quebrado arm. The lake is also used for fishing, bathing, and transportation. Houses in La Laguna and Pueblo Nuevo are constructed of forest products and/or of concrete.

Some areas along the shores of the Lower Rio Trinidad and Rio Caño Quebrado have been deforested. Approximately 65 percent of the lakeshore areas are forested, mostly with secondary growth. Farms and ranches of various sizes, as well as plantations of teak and African mahogany, occupy the remaining land. Farm crops include maize, rice, beans, sugar, coffee, mangos, pineapples, and tobacco. Ranchers raise cows, horses, chickens, hogs, and tilapia. Some of the farmers and ranchers operate commercial enterprises, others rely on cash crops and subsistence farming. No significant ore deposits or mineral resources are located along the Rio Caño Quebrado arm of Gatun Lake.

The Rio Indio project area is inhabited by about 2,300 people, residing in the towns of Tres Hermanas (population – 200), Los Cedros (population – 80), El Coquillo (popoulation – 150), El Limon (population – 140), Los Uveros (population – 140), and La Boca de Uracillo (population – 110), and in approximately 30 smaller settlements. Downstream from the dam site, at El Limon, are 14 communities with a combined population of approximately 600. The largest of these is La Boca del Rio Indio with a population of more than 150.

Approximately 60 percent of the land in the project area is occupied by farms and ranches of various sizes as well as some teak plantations. Farm crops include maize, rice, beans, sugar, coffee, and tobacco. Ranches raise horses, cows, chickens, and hogs. Some of the farmers and ranchers run small commercial enterprises, or rely on cash crop and subsistence farming.

INFRASTRUCTURE

During site investigations in the Lower Rio Trinidad area, the town of Escobal was the largest settlement visited. Escobal has businesses, schools, churches, cemeteries, medical centers, residences, and paved roadways of good condition. A new and improved roadway (Highway 35) is adjacent to the project area near Escobal. Other establishments in the project area are - Nuevo Provenir; Cuipo; Ciricito; La Arenosa; La Garterita; La Gartera - and a few small isolated establishments, which all have elementary schools, small cemeteries, churches and meeting centers, medical clinics, and a few small businesses (i.e. general stores). The towns and villages depend on Gatun Lake or groundwater wells for their potable water supply. Each community also had docks, small ports, and other boat access facilities. Goods are transported from one town to another by boat. No treatment of community waste is provided. Wastewater from showers and washing is discharged into the environment; some of it may eventually reach the Lower Rio Trinidad portion of Gatun Lake. Disposal of domestic waste is the responsibility of individual homeowners: some homes have septic tanks, while others have an outdoor latrine (a hole in the ground). There are some health problems, such as hepatitis, dysentery, dermatitis, intestinal parasites, and respiratory illnesses, which are attributable to the present waste disposal methods. No major industries or meat processing plants are located in the project area. The project area is traversed by unpaved horseback riding trails that link the various communities and by unpaved roads used by the ACP for maintenance. Due to the relatively isolated location of the project area, these roads are extremely important to the residents for transportation, community cohesion, commerce, and communication with neighboring communities.

In the Caño Quebrado project area, La Laguna and Pueblo Nuevo have access to cemeteries, churches, and medical centers, and rely on Gatun Lake or groundwater wells for their drinking water supply. Most homes have electricity and limited telephone service. No treatment of community waste is provided. Wastewater from showers and washing is discharged into the environment; some of it likely reaches Gatun Lake. Disposal of domestic waste is the responsibility of individual homeowners: some have a septic system or an outdoor latrine. There are some health problems, such as hepatitis, diarrhea, dermatitis, intestinal parasites, and respiratory illnesses that are attributed to the present waste disposal methods. No known major industries or meat processing plants are located in the project area. La Laguna is accessible by a poorly maintained unpaved road that is usable only in the dry season (mid-December through March). The roads are rarely graded and receive little attention from either the Ministry of Public Works or the local government. Pueblo Nuevo is accessible only by an unpaved trail. Due to the relatively isolated location of the project area, these roads and trails are extremely important to the residents for transportation, community cohesion, commerce, and communication with neighboring communities.

In the Rio Indio project area, towns of El Limon, El Silencio, San Cristobal, and Piedra Amarilla have elementary schools. Several towns have cemeteries, churches, and medical centers. All these towns obtain water from rivers or groundwater wells. Some have electricity (from small generators) and limited telephone service. No treatment of community waste is provided. Wastewater from showers and washing is discharged into the environment; some of it may eventually reach Rio Indio and its tributaries. Disposal of domestic waste is the responsibility of individual homeowners; each home has an outdoor latrine. There are some known health problems, such as hepatitis, diarrhea, dermatitis, intestinal parasites, and respiratory illnesses that are attributed to the present waste disposal methods. No known major industries or poultry or beef processing plants are located in the project area. The only roads in the project area are unpaved and poorly maintained, and are usable only in the dry season (mid-December through March). The roads are rarely graded and receive little attention from either the Ministry of Public Works or the local government. Due to the relatively isolated location of the project area, these roads are extremely important to the residents for transportation, community cohesion, commerce, and communication with neighboring communities.

TERRESTRIAL HABITAT

The terrestrial habitat in the Lower Rio Trinidad and Rio Caño Quebrado project areas of Gatun Lake consists of tropical forest ecosystems, mostly secondary growth forests with patches of primary forest. About 65 percent of the land along the Lower Rio Trinidad and Rio Caño Quebrado areas of Gatun Lake is forested and probably supports diverse wildlife populations. The Lower Rio Trinidad and Rio Caño Quebrado areas of Gatun Lake also contain islands inhabited by wildlife. Some of the wildlife species do not interact with species on the mainland; others migrate between the island and the mainland. The species interrelationships are of great interest to scientists studying tropical ecosystems. Slash and burn activities have opened tracts of land for farming and cattle grazing; however, the majority of the lakeshore is forested to the edge of the water. Terrestrial areas are used by migratory species as wintering, breeding, and feeding grounds. The complex and diverse tropical ecosystems offer habitat to connect a variety of wildlife communities and may provide critical wildlife habitat to many native species.

In Rio Indio, forests along the river that could support diverse wildlife populations cover about 90 percent of the areas along the Rio Indio and its tributaries. The forests also extend to the mountainous areas above the Rio Indio impoundment. As a result of slash and burn activities, there are no large contiguous tracts of forests at lower elevations in the impoundment.

ANIMALS ON ENDANGERED LIST

ANAM, Resolution 002-80 enacted on June 7, 1995 declared 33 mammals, 39 birds, and 11 reptiles and amphibians as being in danger of becoming extinct in Panama. Although their presence has not been confirmed to date, some of the listed species of interest on the threatened list might be found in the project area. The manatee is an aquatic mammal known to inhabit Gatun Lake around the Barro Colorado Island; however, it has not been sighted in the project area.

AQUATIC HABITAT

Gatun Lake, one of the world's largest manmade lakes, was created during the construction of the Panama Canal. The lake's water depth and quality vary widely. Aquatic habitat ranges from inundated forests to clear water in areas distant from shipping lanes. The Lower Rio Trinidad and Rio Caño Quebrado areas of Gatun Lake provide habitat for a variety of wildlife species, both resident and migratory, as well as for both native and introduced fish and other aquatic species.

Rio Indio in the project area has characteristics typical of streams in mountainous regions. Its water is clean and cool, and its bottom ranges from sand to boulders, with numerous riffles, runs, and pools. Tributaries to Rio Indio include four major streams: Rio El Torno, Rio Uracillo, Rio Teria, and Rio Riacito, and 20 smaller streams. The river is approximately 16 km long, its width ranges from 3 m (in the dry season) to 10 m. The tributaries appear to support some fish communities; however, information about these is limited.

WETLANDS

Areas that contain hydric soils and hydrophytic plant communities, and that are subject to hydric conditions are termed wetlands. Wetlands occur in topographic area where water remains pooled long enough to produce hydric soil conditions and wetland plant communities. Wetlands in the Lower Rio Trinidad and Rio Caño Quebrado project areas consist of shallow water habitat and lands subject to frequent flooding. Shallow water areas along the banks of the Lower Rio Trinidad and Rio Caño Quebrado areas of Gatun Lake receive sunlight to approximately 1 m. Sunlight stimulates growth of submergent, emergent, or floating mats of aquatic vegetation. Wetlands in the project area are stressed as a result of sediments, municipal waste, agricultural runoff, and other debris carried in the runoff.

Wetlands in the Rio Indio project area consist of forested riparian habitat and are limited by their relatively steep topography. The width of the riparian habitat within the impoundment area varies from approximately 5 to 50 m. Approximately 90 percent of the streams both above and below the dam site along the Rio Indio and its tributaries are bordered by forested riparian habitat.

AIR QUALITY

Air quality in the project area is generally good, except during the slash and burn activities. At the end of the dry season in March or early April, areas of forest and secondary growth are burned and cleared for agricultural use. During this period, the air is filled with smoke and ash, which may be transported by winds to the Lower Rio Trinidad and Rio Caño Quebrado areas of Gatun Lake. Based on observations in the Rio Indio project area, approximately 10 percent (or 400 hectares) of forested land is burned annually. Air quality monitoring has not been implemented within the project area.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

Barro Colorado Island is an international center for tropical research and one of the first biological reserves established in the Neotropics. From 1923 through 1940, a scientific committee of the U.S. National Academy of Sciences administered the biological reserve/laboratory. In 1940, by an Act of the United States Congress, the facility was renamed the Panama Canal Zone Biological Area, and in 1946, the responsibility for its maintenance was assigned to the Smithsonian Institution. With the Panama Canal Treaty Implementation in 1977, the island was granted the category of National Monument and to date it continues to be managed by the Smithsonian Institute. It should also be noted that most of the Atlantic region of Panama is within the interest and objectives of the Mesoamerican Biological Corridor, an international project to conserve biodiversity.

In the pre-Columbian period, Rio Indio was a language frontier; that is, the inhabitants on each side of the river spoke a different native language. During the Spanish colonial period, the river served as a political boundary; thus, the project area has a high potential to be rich in archaeological and historical remains.

Environmental Impacts

TERRESTRIAL HABITAT

The impacts of the project on terrestrial habitat in the Lower Rio Trinidad and Rio Caño Quebrado areas of Gatun Lake could be substantial. The boundary between two types of habitats, in this case between a forest and a lake, is called an ecotone. Ecotones are inhabited by a variety of species from neighboring habitats, and are unique, with high species diversity. Considering the proposed operating levels for both impoundments, between 22.9 - 30.5 m, as the normal zone of operation, erosion of the shoreline may be substantial as pool levels rise and fall. Terrestrial habitat that would be inundated above the 26. 7 m (existing level) to the 30.5 m proposed normal pool level consists of 18,169 ha for the Lower Rio Trinidad project. The permanent raising of the water level in Rio Caño Quebrado Lake will impact wildlife habitat as approximately 2,609 ha of additional land will be inundated. The placement of a dam structure, access roads, and pump station would permanently impact terrestrial habitat. Wildlife species that are able to relocate to suitable areas will compete with similar species for resources. Wildlife species that are not able to relocate will not survive. As a result, competition for natural resources in surrounding habitat areas will increase. This is considered a secondary impact to terrestrial habitat outside the proposed zone of inundation and construction.

The terrestrial impacts of the Rio Indio project, which is located in an area of relatively high quality forest habitat, would be substantial. With the creation of the lake, the migratory routes of some species could be adversely affected. Forested areas along lower elevations would be lost as a result of the impoundment. The only forests that would remain near the Rio Indio reservoir and its drainage basin would be confined to the higher elevations, where the vegetation and species may be completely different from those found on lower elevations. Natural communities are linked together by complex interactions and relationships among various species, therefore impacts to upper forested areas may occur resulting from the inundation of the lower forests.

ANIMALS ON ENDANGERED LIST

The severity of impacts on endangered species cannot be determined at this time, because although it is expected that some of the listed species are found in the region, it is not known which of the listed species inhabit the proposed project area. Some endangered and/or threatened species may use the Lower Rio Trinidad and Rio Caño Quebrado areas of Gatun Lake during some or all parts of their life cycle.

WATER QUANTITY

The impacts of the Lower Rio Trinidad and Rio Caño Quebrado projects on water quantity would be substantial. The increase in the volume of water could have negative impacts to lakeshore communities as well as on existing ecosystems. The same is true if the lake level is lowered and maintained at 22.9 m.

The impacts of the Rio Indio project area on water quality would also be substantial. The volume of water will increase, making fresh water available in the surrounding areas during the dry season. The impacts downstream from the dam would be significant. Sediment loads would be deposited upstream from the dam as water velocity slows. Downstream from the dam the water will be released at an increased velocity, causing erosion of banks and river bottoms. Seasonal flooding could be significantly reduced. It would also be possible to periodically release water in appropriate amounts to avoid problems with water quality and temperature downstream. The cumulative impacts downstream from the dam site depend on the amount of water being released.

WATER QUALITY

Project impacts on water quality are not known. Damming the Lower Rio Trinidad and Rio Caño Quebrado could increase the amounts of nutrients and debris in this portion of Gatun Lake. A pilot plant tilapia farm is in the project area and may affect water quality. The rate at which nutrients and debris enter the lake will determine the severity of their impact on water quality. Project implementation could cause an increase in turbidity, which would interfere with photosynthesis and deprive plants and other aquatic species from sunlight. Aquatic plants and organisms serve to maintain water quality. The dam would interfere with the circulation of freshwater throughout the Gatun Lake environment. Species inhabiting specific depths could be impacted when lake depth increases to 30.5 m and/or decreases to 22.9 m.

The impacts of the Rio Indio project on water quality could be positive. The people living downstream from the dam and around the impoundment would have access to a water supply of higher quality. Water quality in the impoundment area would differ from water released downstream from the dam. If the water in the impoundment area does not circulate or turn over periodically, it could become anoxic. A change in temperature, dissolved oxygen, turbidity, or pH could change water quality.

DOWNSTREAM AQUATIC FAUNAL HABITAT

The impacts of the project on aquatic faunal habitat could be substantial. The project may affect the breeding and nursery habitat of many aquatic species. Impacts to fish spawning areas may be detrimental when turbidity, nutrient content, and depth of the water suddenly increase or decrease, by altering the conditions needed for successful fish hatching. Plant populations may decrease as a result of fluctuating water depths, clarity, and quality. Invertebrate populations may decline, which could reduce the food supply for fish and other aquatic species.

Impacts to downstream aquatic faunal communities in the Rio Indio project area could be substantial, because the dam structure will prevent their migration throughout the riverine habitat. The dam structure would be designed for multi-level releases to maintain a water level downstream from the dam site. The dam should act as a large sediment trap; thus, the released water would have low turbidity, which would result in better visibility and increased predation on the fish species. Aquatic faunal habitats downstream would be deprived of the beneficial nutrients and silts that were transported in the sediment. Native riverine fish species may be negatively impacted as a result of the project; the extent of the impact is not known.

FUTURE LAKE AQUATIC PLANT COMMUNITY

The impacts of the project on future aquatic plant communities depend on water quality and stability of water levels. Plant species in the Lower Rio Trinidad and Rio Caño Quebrado portions of Gatun Lake could be impacted by fluctuating water levels. Aquatic plant communities could be impacted during project implementation; however, they could re-establish themselves after conditions stabilize.

The severity of impacts from the Rio Indio project will depend on water level fluctuations. Since water levels are anticipated to fluctuate widely, large portions of the shores would be covered with mud, where neither aquatic nor terrestrial plants could thrive.

AQUATIC FAUNA INHABITING AFFECTED AREAS

The proposed project impacts could have some unavoidable, adverse environmental impacts on aquatic fauna in the Lower Rio Trinidad, Rio Caño Quebrado, and associated rivers and tributaries. These impacts should be identified and minimized with appropriate mitigation measures to be discussed in a feasibility level study. Gatun Lake has populations of peacock bass and tilapia, both introduced species that have adapted well. However, several native riverine species that formerly occupied the impoundment have disappeared.

The impacts of the Rio Indio project on aquatic fauna in the Rio Indio and its upstream tributaries could be substantial, since the habitat area would change from riverine to lacustrine. Some aquatic species would continue to inhabit the area; however, non-native fish species would become dominant in the impoundment area and native riverine species would be pushed upstream or extirpated. Other manmade lakes in the Republic of Panama have been stocked with peacock bass and tilapia, both of which have adapted well. The impoundment area would probably be stocked with these species to promote sport fishing and to provide the local communities with fish for food.

WETLANDS

The impacts on wetlands could be significant. Inundation of wetlands could cause them to become aquatic habitat. The changes in water depth caused by the project may lead to increased or decreased sedimentation and turbidity, which could hamper the biological processes in the wetlands and decrease their productivity. Such impacts could be detrimental to the health and sustainability of the Lower Rio Trinidad and Rio Caño Quebrado areas of Gatun Lake. Fish and other aquatic species use shallow water areas as spawning grounds, as well as habitat for their juvenile aquatic species that survive in the shallow waters of the wetlands until they are large enough to venture into deeper water. These wetlands are vital to the sustainability of this portion of Gatun Lake, including the Lower Rio Trinidad and Rio Caño Quebrado areas.

The impacts to wetlands both upstream and downstream from the Rio Indio project area could be significant. Owing to the topography of the project area, a number of wetlands could be impacted. It is possible that although the reservoir level will fluctuate, new wetlands could develop in the littoral zones. Downstream from the dam site, wetlands along the minimal flow zone would survive; however, wetlands that depend on seasonal flooding for survival may be adversely affected.

AIR QUALITY

During project implementation, emissions from construction equipment, as well as from the slash and burn activities could cause deterioration of air quality. After project implementation, the air quality may be impacted by the operation of the power generation facility and the pumping stations.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

The potential impacts on cultural resources and historic properties from the Rio Indio project can be defined and mitigated, in particular, in the La Boca de Uracillo area, which is near previously identified archaeological sites. The project area is relatively large and is known to contain pre-Columbian sites; therefore, the presence of cultural resources and historic properties is highly probable. Prior to construction, surveys to locate cultural resources and historic properties would be conducted, and the important sites would be preserved or salvaged as appropriate.

SOCIO-ECONOMIC IMPACTS

The socio-economic impacts of the project could be substantial. The relocation of the towns and other small communities along the lakeshore would be an important issue. The average monthly income of families in the project area ranges from less than $100 to $200 per month. No indigenous groups are known to reside in the impact area. Land use would be greatly impacted by the inundation of pastures and agricultural lands to expand the impoundment. The relocation of agricultural and ranching activities would be an important issue, because approximately 10 percent of the land in the impoundment area is used for farming and ranching. After the water level is raised, additional agricultural land could be lost as a result of creation of islands that were once isthmuses. The incremental surface area of the proposed lake is 6,577 ha; another 1,504 ha from the Lower Trinidad Rio Caño Quebrado project; and 760 ha from the Rio Indio project will be occupied by the dam and construction areas, including permanent disposal areas.

During construction, the influx of workers could create a temporary demand for additional housing, which could result in an increase in housing values near the dam site. However, after completion of the project, the workers could leave, the housing demands could drop, and the housing values could return to pre-construction levels. Currently, all residents have access to public schools and health centers. During construction, these services should continue to be available, and additional public and community services may be offered. After construction, these services would return to the normal level.

To construct the dam, some existing roads would be improved and some new roads should be built. However, some paved and unpaved roads within the impoundment area would be eliminated, changing traffic patterns and may cause some communities to lose overland transportation, communication, cohesion, and commerce with other communities. During construction, the traffic volumes over both new and existing roads systems would increase; however, following completion of construction, the traffic volumes could decline. Noise levels would temporarily increase during construction and could negatively impact noise-sensitive receptors; however, after construction noise levels may remain elevated as a result of the power generation facility and pump stations.

Overcrowding and competition for jobs, land, and working areas could negatively impact the communities receiving people displaced by the project. Construction of the dams would permanently displace some people and disrupt community cohesion through the division of communities, separation of families, and loss of livelihood. Following completion of the impoundment, tourism trade in the affected region, including sport fishing and ecotourism, could increase.

Additional Environmental Information Required

This section identifies the subject areas for which additional data are required to evaluate in further detail, the scope and magnitude of the potential effects of the Lower Rio Trinidad, Rio Caño Quebrado, and Rio Indio alternative. The subject areas are discussed by impact category.

SOCIO-ECONOMIC IMPACTS

Conduct a SIA. The SIA would consist of three tasks: scoping, assessment, and mitigation and monitoring. The following information should be developed:

- Business, Industrial, and Agricultural Activities;
- Employment;
- Land Use;

- Property Values;
- Public and Community Facilities and Services (including utilities and schools);
- Transportation;
- Housing;
- Health (vector routes);
- Population;
- Community Cohesion; and,
- Recreational Resources.

TERRESTRIAL AND AQUATIC HABITAT

- Prepare site-specific habitat maps to ensure that the major types of aquatic habitat are identified and quantified.
- Conduct field studies to locate rare and unique habitats such as wetlands, primary forests, roosting sites, foraging areas, old growth, and migration flyways.
- Determine the present quality and ecosystem value of existing habitats within the Gatun Lake project area.
- Coordinate with local experts to identify and evaluate aquatic and terrestrial habitat areas.
- Prepare species inventory lists for each site area, identifying their status as native or exotic and whether they are threatened and or endangered species.
- Conduct additional research into water currents and estimated turbidity levels to evaluate impacts to the shallow areas along Barro Colorado Island.
- Address cumulative effects caused by natural flow diversions.

ANIMALS ON THE ENDANGERED LIST

- Compile habitat maps to assess the availability and quality of suitable habitats for the animals on the endangered and/or threatened species list.
- Establish field methodology to assess wildlife habitat values.
- Conduct site surveys to determine the presence of selected species or their habitats.
- Develop candidate mitigation measures for the appropriate project alternatives to be considered in the Conceptual Phase.
- Coordinate with local experts to determine on the presence of endangered species.

WATER QUALITY

- Since limited water quality data are available for the Gatun Lake area, compile information on total suspended solids, conductivity, total dissolved solids, dissolved oxygen, nutrients, pH, and coliform bacteria.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

- Information regarding cultural resources and historic properties in the project area is incomplete. Additional evaluation studies should be completed to identify any such resources and/or properties.

Evaluation Matrices

Table 39 - 1 Developmental Effects

Evaluation Criteria	Function	Measure [1/]	Importance [2/]	Composite [3/]
Water Contribution (Water Yield)	Meets M&I Demands	10	10	100
	Supplements Existing System	10	10	100
	Satisfies Future Canal Needs/Expansion	1	10	10
	Additional Hydropower Potential	1	5	5
Technical Viability	Design Constraints	2	6	12
	Feasibility of Concept	2	6	12
Operational Issues	Compatibility	8	6	48
	Maintenance Requirements	4	2	8
	Operational Resources Required	4	2	8
Economic Feasibility	Net Benefits	10	9	90
	Total			393

[1/] Measure - A numerical from 0 to 10 value representing the degree or level the alternative satisfies the criteria. Value of 10 indicates the most significant beneficial impact and 0 the most significant adverse impact.
[2/] Importance - A weighting factor from 0 to 10 to balance the significance of a criteria to the others.
[3/] Composite - the product of the measure and importance.

Table 39 - 2 Environmental Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Terrestrial Habitat	2	8	16
Animals on Extinction List	2	10	20
Water Quantity Impacts – Lake	8	10	80
Water Quantity Impacts -- Downstream	4	7	28
Water Quality	5	10	50
Downstream Aquatic Fauna Habitat	3	8	24
Future Lake Aquatic Plant Community	6	8	48
Aquatic Faunal Inhabiting Affected Area and Upstream Tributaries	4	5	20
Potential for Fishing on Lake	6	6	36
Wetlands	2	4	8
Air Quality	5	3	15
Cultural Resources and Historic Properties	3	10	30
Total			375

[1/] Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
[2/] Importance - 1 to 10 increasing in importance.
[3/] Composite - the product of the measure and importance.

Table 39 - 3 Socio-Economic Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Land Use	2	7	14
Relocation of People	1	10	10
Relocation of Agricultural/Ranching Activities	1	6	6
Post-Construction Business	6	5	30
Post-Construction on Existing Employment	6	5	30
Property Values During Construction	7	4	28
Property Values Post-Construction	5	5	25
Public/Community Services During Construction	6	4	24
Public/Community Services Post-Construction	5	8	40
Traffic Volumes over Existing Roadway System During Construction	3	5	15
Traffic Volumes over New Roadway System Post-Construction	5	5	25
Noise-Sensitive Resources or Activities	4	4	16
Communities Receiving Displaced People	1	8	8
Community Cohesion	1	8	8
Tourism	6	5	30
Total			309

[1/] Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
[2/] Importance - 1 to 10 increasing in importance.
[3/] Composite - the product of the measure and importance.

Pertinent Data

Table 39 - 4 presents pertinent data for the proposed Lower Rio Trinidad project.

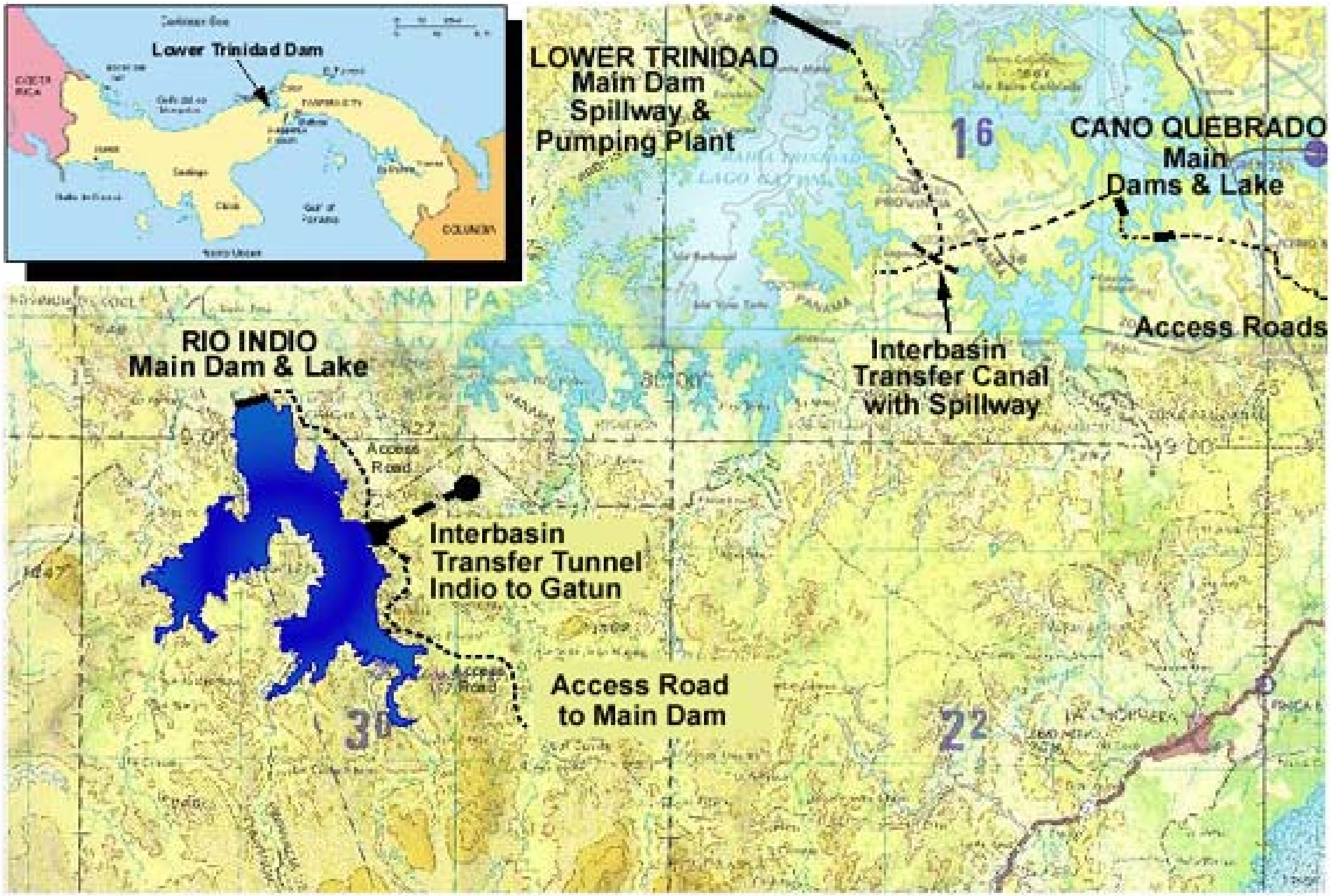
Table 39 - 4 Pertinent Data for Operating Scenario 4

GENERAL	**Gatun**	**Trinidad and Quebrado**	**Indio**
Dam Site, above Gatun Dam		10 km	
Drainage Area above Dam Site	1,261.5 km^2	1,051.5 km^2	381 km^2
Average Annual Flow at Dam Site	50.4 CMS	39.6 CMS	25 CMS
LAKE			
Elevation of Maximum Operating Lake Level	26.67 m MSL	30.48 m MSL	80 m MSL
Elevation of Maximum Flood Storage Lake Level	26.74 m MSL	31.09 m MSL	82.5 m MSL
Elevation of Minimum Operating Lake Level	25.91 m MSL	22.86 m MSL	50 m MSL
Useable Storage between Max. and Min. levels	200.4 MCM	1286.5 MCM	993 MCM
Area at Maximum Operating Lake Level	27,514 ha	20,778 ha	4,280 ha
Area at Maximum Flood Storage Lake Level	27,550 ha	21,597 ha	4,440 ha
Area at Minimum Operating Lake Level	27,321 ha	10,170 ha	2,360 ha
Top Clearing Elevation	30.5 m MSL	30.48 m MSL	80 m MSL
Lower Clearing Elevation	22.9 m MSL	22.86 m MSL	50 m MSL
EMBANKMENTS			
Dam – Rock Fill Embankment			
Top Elevation of Dam	32 m MSL	31.5 m MSL	83.5m MSL
Fixed Crest Width	13 m	13 m	13 m
Height above Lowest Foundation	15 m	25 m	73.5m
Overall Length of Dam	varies m	?4473/404 m	891m
SPILLWAY			
Type of Spillway	Gated Ogee	Gated Ogee	Uncontrolled Ogee
Number of Gates	14	8	-
Width of Gates	13.72 m	18.33 m	-
Net Length	192.02 m	149.35 m	-
Total Length	246.27 m	173.64 m	120 m
Elevation of Crest	21.03 m MSL	25.91 m MSL	80.0 m MSL
Maximum Discharge	5150 CMS	6038 CMS	920 CMS

INDIO ONLY	
INTER-BASIN TRANSFER TUNNEL	
Tunnel diameter	3 m
Tunnel length	5.2 km
Inlet invert	60 m MSL
Outlet invert	40 m MSL
Tunnel capacity	42.5 CMS
HYDROPOWER PLANTS	
Dam	
Type of hydropower plant construction	Reinforced concrete
Number of units	2
Capacity of each unit	12.5 MW
Inter-basin Transfer Tunnel	
Type of hydropower plant construction	Reinforced concrete
Number of units	1
Capacity of unit	5 MW
CONSTRUCTION / POWERHOUSE DIVERSION	
Diversion length	1,500 m
Horseshoe tunnel dimensions	8 m X 8 m
Inlet invert	10 m
Outlet invert	7 m
MINIMUM FLOW CONDUIT	
Conduit diameter	1.2 m
Conduit length	800 m
Inlet invert	10 m
Outlet invert	8 m
Conduit capacity	2.5 CMS
EMBANKMENTS	
Dam	
Type of dam	Rock fill embankment
Top elevation of dam	83.5 m
Fixed crest width	13 m
Height	73.5 m
Overall length of dam	891 m
Saddle dam (North)	
Type of saddle dam	Earth / rock fill embankment
Top elevation of saddle dam	83.5 m MSL
Fixed crest width	13 m
Overall length of saddle dam	255 m
Saddle dam (South)	
Type of saddle dam	Earth / rock fill embankment
Top elevation of saddle dam	83.5 m MSL
Fixed crest width	13 m
Overall length of saddle dam	272 m

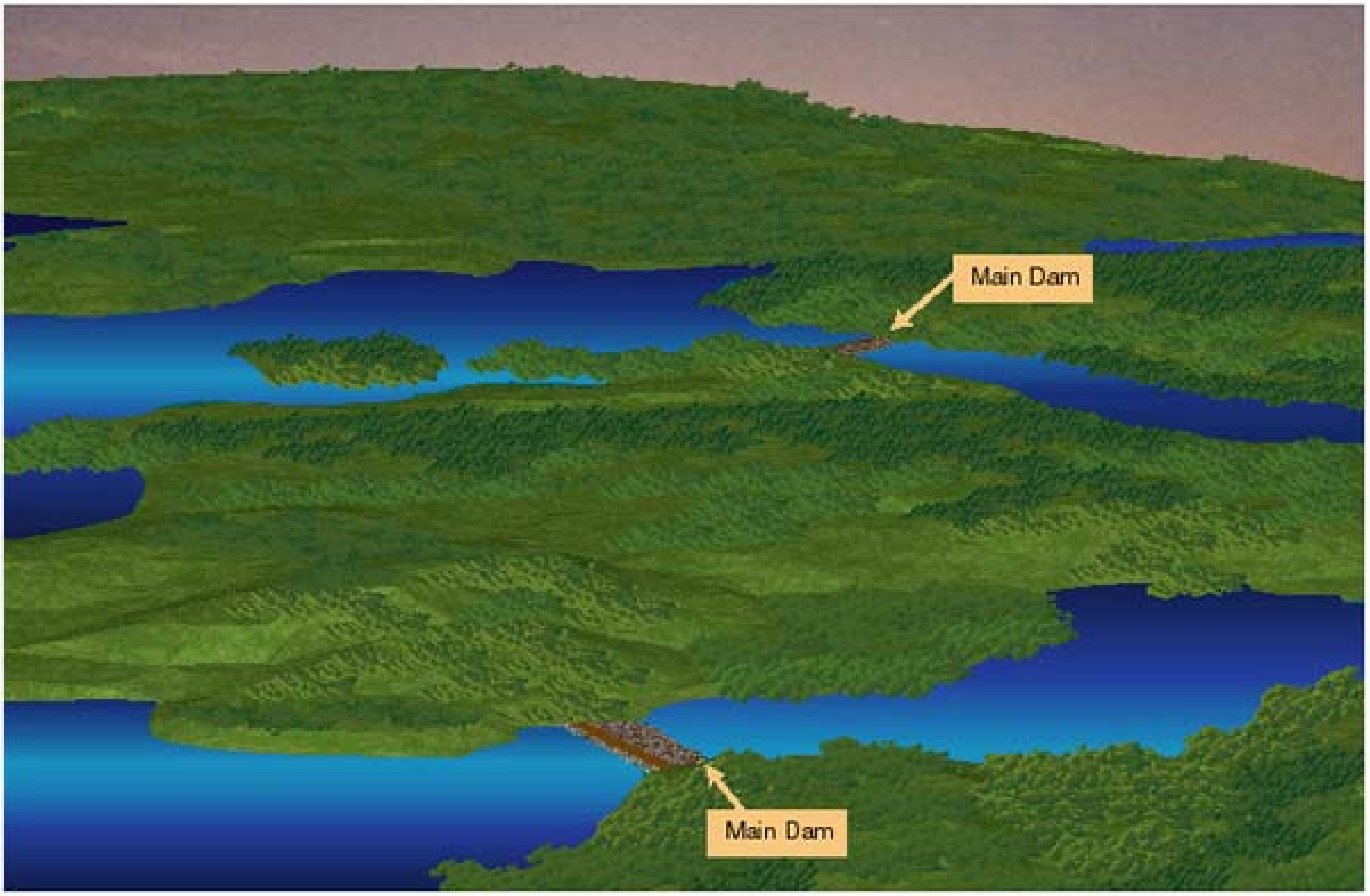
Plate 39 - 1 Project Location Map

LOWER TRINIDAD / CAÑO QUEBRADO / RIO INDIO



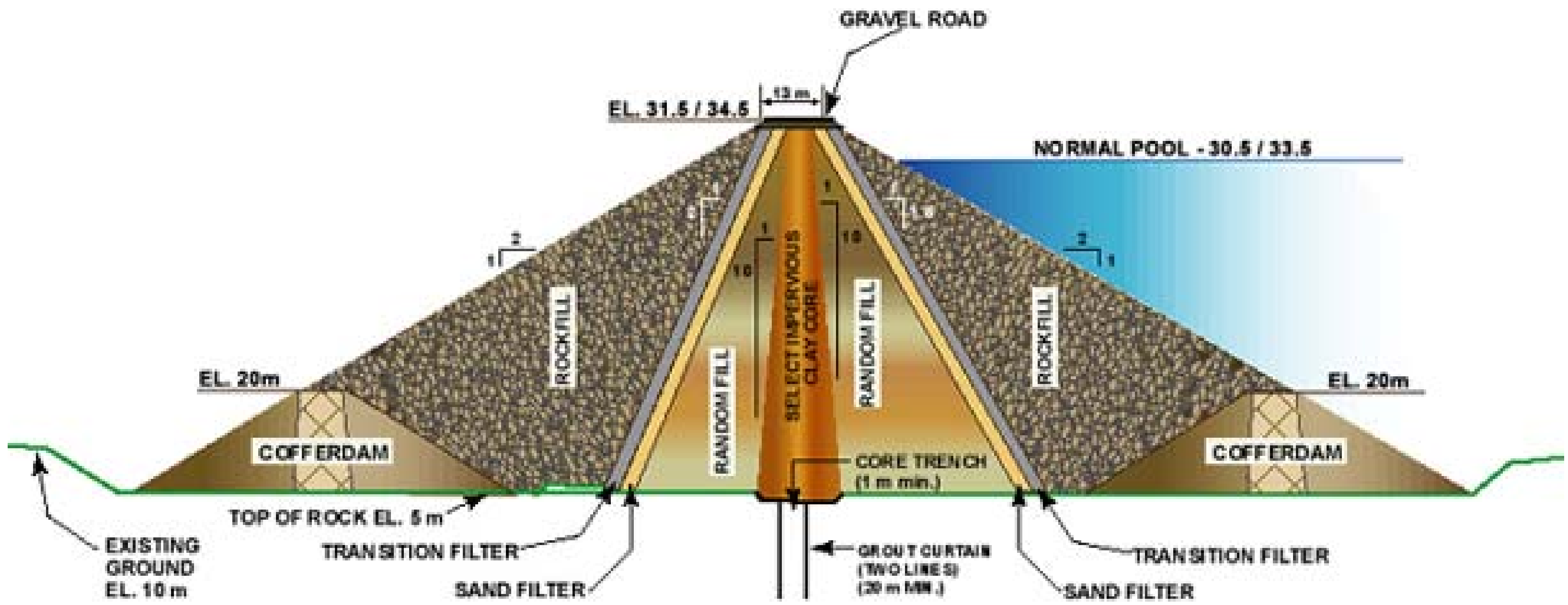
Project Location Map

CAÑO QUEBRADO



Site Plan

Plate 39 - 2 Site Map



Typical Section

Typical Section at Embankment

Plate 39 - 3 Typicial Section at Embankment

SECTION 40

Lower Rio Trinidad 22.9m to 30.5m
Rio Caño Quebrado 22.9m to 30.5m
Upper Rio Indio 50m

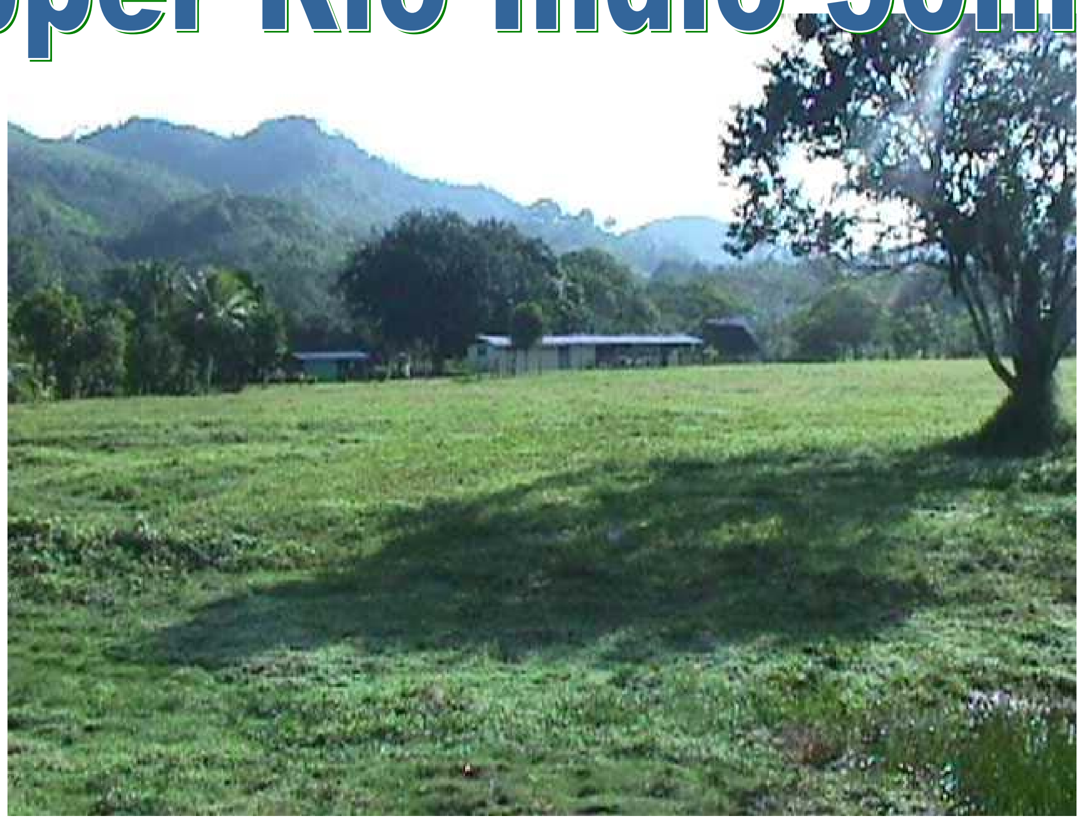


TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

Synopsis

The development plan presented herein combines: a dam and a lake in the Trinidad basin within the Panama Canal watershed at Gatun Lake southwest of Gatun Locks; a dam and lake on the Rio Caño Quebrado basin of the Panama Canal watershed, within Gatun Lake; and a dam and lake on the Rio Indio to the west of Lake Gatun. Water impounded in the Lower Rio Trinidad and Rio Caño Quebrado Lakes adds storage to the Panama Canal system of lakes. This additional storage would be further enhanced by incorporation of a pumping plant into the Lower Rio Trinidad Dam. This facility should allow storage of excess water from Gatun Lake and extended usage of the waters contained in the Lower Rio Trinidad and Rio Caño Quebrado Lakes. Water impounded at the Rio Indio site should supply new water for use in the Panama Canal System and would be transferred via a tunnel to the Lower Rio Trinidad Lake.

The Rio Trinidad watershed is located on the western side of the Panama Canal watershed. The proposed dam site is located within Gatun Lake across the Trinidad arm near the town of Escobal. The proposed dam extends from Punta Mala, on the west shore of Gatun Lake, to Guacha Island, then across to the eastern shore of the Trinidad arm, just south of the South Range Point lighthouse. This alignment follows closely the proposed path found in the Study and Report on Increasing the Water Supply of the Panama Canal (referred to as the Tudor Report), prepared by Tudor Engineering Company, San Francisco, California 1962, for the Panama Canal Company. Plate 40 - 1 shows the location of the proposed Lower Rio Trinidad Dam project. The structures for the proposed Lower Rio Trinidad project consist of a rock fill dam constructed by underwater deposition of fill materials, a large pumping plant, and a gated spillway. This spillway should have 11 gate bays, each measuring 18.33 m wide. The pumping plant consists of the pumping station; intake and outflow facilities are separated from the lakes above and below the Lower Rio Trinidad dam by large gate structures. The total project first costs of the proposed Lower Rio Trinidad project are estimated at $811,400,000.

The Rio Caño Quebrado watershed comprises a portion of the western side of the Panama Canal watershed. The proposed dam site is located within Gatun Lake across the Rio Caño Quebrado arm near the city of La Laguna and should constructed in two parts. The first section of the dam extends from Punta Manguito, on the west shore of the Rio Caño Quebrado arm of Gatun Lake, in a northwest-southeast orientation to the eastern shore of the Rio Caño Quebrado arm. The second section extends in an east-west orientation across the Rio Caño Quebrado eastern arm, just north of the mouth of the Rio Paja. The lake formed by these dams may communicate directly with Lower Rio Trinidad Lake at all operational levels. Plate 40 - 1 shows the location of the Rio Caño Quebrado Dam project. The main features required for the Rio Caño Quebrado project are two sections of rock fill dam, and a dug channel connecting between Rio Caño Quebrado and Lower Rio Trinidad Lakes. The total project first costs of the proposed Rio Caño Quebrado project are estimated at $19,330,000.

The Upper Rio Indio watershed is located adjacent to the western side of the Panama Canal watershed. The proposed Upper Rio Indio dam site is 29 km inland from the Atlantic Ocean and near the mountain Cerro Tres Hermanas. Plate 40- 1 shows the location of the proposed Upper Rio Indio project. The structures for this project consists of a rock fill dam, an uncontrolled ogee spillway, inter-basin transfer facilities, two hydropower plants, and other outlet works. The tunnel should transfer water from Rio Indio Lake to the Panama Canal watershed as needed for canal operations. The total project first cost of the proposed Rio Indio project is estimated at $199,177,000.

The Lower Rio Trinidad poses great construction difficulties because of the extremely large quantities of underwater fill required for construction of the dam. It requires extensive drilling and site investigation prior to construction and, because of the uncertainties inherent with this type of construction; extensive unforeseen costs may be encountered during construction. Also, the spillway and pumping plant must be constructed in island settings where the structures and appurtenances practically engulf the island areas. This poses extreme space limitations on the construction effort and is very costly.

The proposed Lower Rio Trinidad and Rio Caño Quebrado Dam projects, taken in conjunction with the Rio Indio Dam project, should contribute greatly to the hydrologic reliability of the Panama Canal. The project should also increase the ACP's ability to serve its customers by reducing draft restrictions and the light loading of vessels, especially during periods of low water availability. The existing hydrologic reliability of the Panama Canal, based on the period of record from January 1948 through July 1998 and current demands (38.68 lockages), is approximately 99.6 percent. The hydrologic reliability with the demand increasing to 120 percent of the current level (46.42 lockage) is 98.8 percent. With construction of the proposed Lower Rio Trinidad and Rio Indio Dam projects, the existing high hydrologic reliability may be continued as demand for lockages increases up to 21.5 percent above current demand levels (up to 8.32 lockages).

Site Selection

The Lower Rio Trinidad dam site project definition and description developed with a view toward maximizing the water impounded, while minimizing the volume of material required for construction of the dam and minimizing the number of saddle dams required to contain the lake. The site chosen for the Lower Rio Trinidad Dam is 10 km south of Gatun Locks and 14 km southwest of the navigation channel. The dam would be approximately 4 km northeast the town of Escobal. This site should accommodate construction of a dam with a maximum operating lake level at EL. 30.5 m MSL. Flood storage would be accommodated between EL. 30.5 and 28.7 m MSL.

The proposed Rio Caño Quebrado dam site project definition and description developed with a view toward maximizing the water impounded, while minimizing the volume of material required for construction of the dam and the number of saddle dams required to contain the lake. The site chosen is 22 km southeast of Gatun Locks and 14 km northwest of the Pedro Miguel Locks. The dam site is 7 km southwest of Barro Colorado Island and 4 km northeast of the town of La Laguna. This site can accommodate construction of a dam with a maximum operating lake level at EL. 30.5 m MSL. Flood storage accommodations are available above the normal operating levels between EL. 30.5 and 24.8 m MSL.

The proposed Upper Rio Indio dam site may maximize the water impounded, while minimizing the volume of material required for construction of the dam, the number of saddle dams required to contain the lake, and the impact on the existing populated areas in the Lower Rio Indio Basin. To accomplish these ends it is desirable to locate the dam immediately above the confluence of the Lower Rio Trinidad and the Rio Uracillo, as far downstream in the upper arm of the Rio Indio watershed as possible. The ideal location is where the surrounding hillsides are relatively steep and high, and the valley is relatively narrow, features that are afforded by the site chosen.

The proposed Upper Rio Indio dam site is 29 km inland from the Atlantic Ocean and 4 km upstream from the confluence of the Rio Indio and the Rio Uracillo. This site should accommodate construction of a dam with a normal operating lake level at EL. 50 m MSL and a maximum flood lake level at EL. 53 m MSL.

Hydrologic Considerations

Lower Rio Trinidad
The Rio Trinidad flows northward from the Continental Divide to the Gatun Lake. The headwater of the watershed begins at EL. 1,000 m MSL, approximately 75 km inland, and falls to El. 26 m MSL at Gatun Lake. The distribution of the average annual rainfall over the Rio Trinidad watershed varies from a high of 2,200 mm in the western part of the watershed to 2,000 mm on the eastern side of the watershed. The proposed Lower Rio Trinidad Lake site receives runoff from approximately 750 km^2 of the upper portion of the watershed. Rainfall runoff produces an average annual flow of 32 CMS at the proposed dam site.

The discharge at the Lower Rio Trinidad and Rio Caño Quebrado dam sites are obtained observing the drainage area ratio established for Gatun. The Gatun Lake runoff is based on records developed by the U.S. Army Corps of Engineers Hydrologic Engineering Center and the ACP in a separate study.

Since the Lower Rio Trinidad and Rio Caño Quebrado Lakes are located within Gatun Lake the monthly evaporation rates established for Gatun Lake are considered appropriate for the evaporation rates of Trinidad and Rio Caño Quebrado Lake.

Rio Caño Quebrado
Three major rivers flow into Rio Caño Quebrado Lake; Rio Caño Quebrado, Rio Paja and Rio Los Hules. All three rivers flow northward from the Continental Divide to Gatun Lake. The headwaters of the watershed begin at EL. 1,000 m MSL approximately 75 km inland and fall to 26 m MSL at Gatun Lake. The distribution of the average annual rainfall over the Rio Caño Quebrado watershed varies from 2,200 mm in the western part of the watershed to 2,000 mm on the eastern side. The proposed Rio Caño Quebrado Lake would receive runoff from approximately 310 km^2 of the existing Panama Canal watershed. Rainfall runoff would produce an average annual flow of 10.2 CMS at the proposed dam site.

Upper Rio Indio
The Upper Rio Indio flows northward from the Continental Divide to the Atlantic Ocean. The headwaters of the watershed begin at EL. 1,000 m MSL approximately 75 km inland and fall to mean sea level at its mouth. The distribution of the average annual rainfall over the Rio Indio watershed varies from a high of 4,000 mm at the coast to a low of 2,500 mm in the middle watershed area. It increases again to over 3,000 mm in the Continental Divide. The proposed Indio Lake should receive runoff from approximately 256 km^2 of the upper portion of the watershed. Rainfall runoff produces an average annual flow of 16.8 CMS at the proposed dam site.

The calculated discharge at the Rio Indio dam site is extrapolated, recorded, and correlated stream flow data from the Boca de Uracillo hydrologic station. This station began operation in

1979 and is located on the Rio Indio, approximately 6 km upstream from the dam site. Data established from a statistical correlation, with the discharge data of the Rio Indio at Limon, 3 km downstream from the dam site, using standard hydrologic techniques, completed missing data and increased the period of record. Utilization of the double mass curve method satisfactorily verified the consistency of the data measured and correlated.
Due to the proximity of Upper Rio Indio to Gatun Lake, and because of the absence of site-specific information, the monthly evaporation rates established for Gatun Lake are considered appropriate for the evaporation rates of Indio Lake.

Geologic Considerations

Lower Rio Trinidad
The proposed Lower Rio Trinidad dam site is investigated in 1962 by Geo-Recon, Inc. of Seattle, Washington, as part of the Tudor report. The investigation consisted of seismic velocity and electrical resistively profiles in conjunction with four test borings (all located in the lake and drilled by the Panama Canal Company). The results of the geophysical surveys reportedly compared well with the logs of the test borings in the deep-water areas (up to 23 m deep) of Gatun Lake. In June 1963, Tudor Engineering submitted another report including additional foundation investigations. The foundation investigations are made by the firm Shannon & Wilson, Inc., Soil Mechanics and Foundation Engineers, from Seattle, Washington, and consisted of 77 cone penetrometer borings, 24 classification borings, 11 undisturbed sample borings, and 6 field vane shear borings. The investigations submitted by Shannon & Wilson, Inc where recently reanalyzed in Geology of the Proposed Dam Across Trinidad Arm of Gatun Lake, by Mr. Pastora Franceschi S., for the Geotechnical Section of the Panama Canal Authority.

In the lake areas the investigations disclosed that overburden material included recent lake deposits, Atlantic Muck Formation, alluvial deposits, and residual deposits. Between the west shore and Guacha Island these deposits consist of soft to very soft clay, silt, sand and peat (Atlantic Muck Formation) overlying soft to hard deposits of clay, silt, sand and gravel derived both from alluvial deposition and the weathering of bedrock. The upper two phases of the Atlantic Muck Formation, judged to be the most compressible portion of the formation, is found to have an average thickness of about 18.3 m and a maximum thickness of 22.9 m. Recent, soft lake deposits ranging from 1.2 to 2.4 m thick are found overlying the Atlantic Muck Formation. In the length between Guacha Island and Tern Island, the Atlantic Muck Formation is either not found, or is very thin. In this area, Recent-aged soft sediments (averaging 2 m thick) are generally found to overlay residual soil and weathered rock. Atlantic Muck, where present, occurred between the Recent-aged material and the residual soil, and is a maximum 5 m thick. Between Tern Island and the east mainland, only recent lake sediments (1.5 m thick) overlying residual clay are found above the conglomerate of the Bohio Formation.

Guacha, Tern and Booby Islands are each found to have an overlying stratum of soft overburdened and weathered rock of variable thickness. In general, firm bedrock is found available below EL. 22.9 m MSL and the islands are judged to offer suitable foundation conditions for control structures.

Firm bedrock under both the land and the lake consists of low velocity sedimentary rock composed primarily of sandstone and the Bohio Formation. Two areas containing abrupt changes in bedrock velocities are located during the survey. One of the areas is a narrow zone located on Guacha Island that is a possible shear zone in rock of similar type. The second area has an abrupt change in bedrock velocity on Tern Island that is interpreted as a possible fault contact between two formations, or between different lithologic units of the same formation. The top of the bedrock on land is interpreted from the geophysical results to be weathered to below lake level. The core borings in the lake determined the weathered zone of bedrock to range from 1.2 to 3.1 m in thickness.

Satisfactory foundation conditions exist for construction of a pumping station, and a spillway at the Lower Rio Trinidad site. Serious consideration, however, must be given to problems that would be caused by the anticipated settlement and instability of the embankment materials.

Rio Caño Quebrado

The main dam portion of the proposed Rio Caño Quebrado project is located in an area where volcanic rocks of the Tucue Formation are encountered at the surface. The rocks of the Tucue Formation consist of lava flows, breccias, tuffs and plugs, and are andesitic or basaltic in nature. These rocks show a wide variation in quality, from high quality extrusive lava flows to weathered and lesser quality volcanic tuffs. It is anticipated most of the strata of the Tucue Formation should make satisfactory rock fill for a dam, but a significant amount may not be satisfactory for concrete aggregate. Volcanic rocks of the Tucue Formation may also contain constituents that are reactive with alkalies found in cement. Neither weathered rock nor rock with reactive materials would be satisfactory for concrete aggregate. It is recommended that cores be drilled during the planning studies to determine general depths of weathering and to determine the suitability of the rock for use as concrete aggregate.

Oligocene-aged sedimentary rocks of the Caimito Formation underlie the inter-basin transfer basin canal and spillway portions of the project. Three members of the Caimito Formation are recognized; the lower, middle and upper. The deposits of each of these members are mainly marine, but they are lithologically heterogeneous. The lower member is composed of conglomerate and tuffaceous sandstone. The middle member consists chiefly of tuffaceous sandstone, some of which is calcareous, and lenticular limestone. The upper, principal member consists of tuff, agglomeratic tuff, tuffaceous siltstone, and discontinuous sandy tuffaceous limestone. In general, the rocks of all members are hard, thinly to thickly bedded, and closely to moderately jointed. It is not known which member of the Caimito Formation underlies the project area. It should make an acceptable foundation for the canal and spillway. The Caimito Formation would be unacceptable for use as concrete aggregate and may be only marginally acceptable for use as fill in an earth and rock fill dam.

In the absence of detailed geologic mapping for the proposed Rio Caño Quebrado project, a degree of extrapolation is necessary. It is predicted that rock at the proposed construction locations outside the lake would be encountered at a shallow depth and would be of sufficient quality to serve as foundation for the appurtenant structures.

Upper Rio Indio

The proposed Upper Rio Indio project is located in an area of the Isthmus of Panama underlain by Oligocene-aged sedimentary rocks of the Caimito Formation. Three members of the Caimito Formation are recognized: the lower, the middle and the upper. The deposits of each of these members are mainly marine, but are lithologically heterogeneous. The lower member is composed of conglomerate and tuffaceous sandstone. The middle member consists chiefly of tuffaceous sandstone, some of which is calcareous, and lenticular limestone. The upper, principal member consists of tuff, agglomeratic tuff, tuffaceous siltstone, and discontinuous sandy tuffaceous limestone. In general, all members are hard, thinly to thickly bedded, and closely to moderately jointed. The lower member weathers to greater depths. A summary of test data developed in 1966, as part of the studies for a sea level canal, listed compressive strengths for samples of Caimito Formation material varying between 79,450 and 5,955,257 kg/m^2. The same 1966 studies assigned an allowable bearing capacity of 195,300 kg/m^2 for the material of the Caimito Formation. The abutments at the project site may consist of Miocene volcanic rocks, possibly of the Tucue Formation.

It is believed that the Caimito Formation material should make an acceptable foundation for an earth and rock fill dam, however, it is be unacceptable for use as concrete aggregate and only marginally acceptable for use as fill. Further development of this project should require drilling of cores early during the planning studies to identify the foundation and abutment materials and to determine their general suitability for use as construction material. In addition, the cores should be of sufficient depth to check for the occurrence of any soluble limestone strata that may underlie the dam foundation.

The proposed inter-basin transfer tunnel connecting the Rio Indio Lake to the Panama Canal watershed is also located very near the contact of the Caimito Formation and the overlying Miocene-aged volcanic rocks. Groundwater flowing in volcanic rock above impervious strata of the Caimito Formation may cause problems. Further development of this project should require drilling of cores near the proposed tunnel inlets and outlets early during planning studies to determine the general relationship between the tunnel alignments, the sedimentary/volcanic rock, and the water table.

In the absence of detailed geologic mapping for the proposed Upper Rio Indio dam site, a degree of extrapolation is necessary. Available general geologic mapping and general data are the basis of predictions that rock, encountered at a shallow depth and of sufficient quality, could serve as foundation for the dam and appurtenant structures. Furthermore, assumptions for this report are: the required excavation should make available sufficient rock for fill, and the immediate area contains available impervious materials and concrete aggregate for use in the construction of the proposed project.

Lake Operation

The operating scenario considered in this study for periods when water would be transferred from Lower Rio Trinidad Lake to Gatun Lake for canal operations is detailed in Volume Three, Section 36. Water impounded in the Rio Caño Quebrado Lake would be transmitted to Gatun Lake via the Lower Rio Trinidad facilities. Following is a reiteration of the tabulated pool levels contained in that narrative

Table 40 - 1 Lake Operating Options

Lake Level (m MSL)	Lower Rio Trinidad & Rio Caño Quebrado	Gatun
Normal Operating Lake Level	30.48	26.67
Minimum Operating Lake Level	22.86	25.91
Maximum Flood Lake Level	31.09	27.13

Under this scenario the Upper Rio Indio Lake would be operate in a "run-of-the–river" mode, transferring all flows above the invert of the interbasin transfer tunnel, EL. 45.5 m MSL, to the Lower Trinidad Lake for storage and subsequent use for navigation. This transfer of water between Upper Rio Indio and Lower Trinidad Lakes would be made via a tunnel constructed beneath the divide separating the two basins. The tunnel shall be sized to carry all but the greatest flood flows from the Upper Rio Indio basin. The maximum flood flows would be passed over the fixed crest spillway to the lower Rio Indio. Table 40-2 shows the lake levels affecting the Upper Rio Indio design for this scenario.

Table 40 - 2 Lake Operating Levels

Lake Level (m MSL)	Upper Rio Indio
Normal Operating Lake Level	50
Minimum Operating Lake Level	45.5
Maximum Flood Lake Level	52.0

Project Features

GENERAL

The structures for the proposed Lower Rio Trinidad project should consist of a rock fill dam, a pumping plant, and a gated spillway. Modification of one existing saddle dam and construction of two additional saddle dams is required. The following paragraphs provide a description of the proposed structures and improvements for the Lower Rio Trinidad Lake project. Plate 36 - 2 shows the dam site in downstream left bank perspective and indicates the location of the pumping plant.

The structures for the proposed Rio Caño Quebrado project consist of a rock fill dam in two distinct sections, and a gated spillway. The following paragraphs provide a description of the proposed structures and improvements for the Rio Caño Quebrado Lake project. Plate 36 - 2 depicts the location of the dam and the gated spillway.

The structures for the proposed Upper Rio Indio project consist of a rock fill dam, an uncontrolled ogee spillway, inter-basin transfer facilities, two hydropower plants, and outlet works. Plate 40 - 1 depicts the site plan.

Design was performed only to the extent necessary to establish, with reasonable accuracy, the principal dimensions, elevations., and costs of the proposed project. Separate documentation was provided to the ACP that contained assumptions and design calculations for the reconnaissance level investigations of these structures. If this project is carried into the planning studies, optimization of the project features and improvements must be accomplished.

EMBANKMENTS

Dams

Lower Rio Trinidad Dam
The proposed dam consists of an embankment with the top at EL. 31.50 m MSL and with a crest width of 13 m with a final crest of 7 m upon completion of all settlement of the embankment and bridgework. The left abutment of the embankment will be located at Universal Transverse Mercator Grid, Zone 17, Clark 1866 Spheroid Coordinates 1015858 north and 614864 east. The right abutment will be 1013937 north and 618229 east coordinates. The normal lake elevation is 30.48 m while the ground surface elevations along the axis of the dam vary from El. 2 m MSL in the lake bottom to El. 39 m MSL on Guacho Island and El. 38 m MSL on Tern Island. The Gatun Lake subgrade supporting the embankment occupies a broad flat valley having sides, which slope, upward from the valley at grades up to 40 percent. Water depths are 21.3 to 26.3 m over 80 percent of the site. The Atlantic Muck Formation, consisting of very soft organic clays, silts and peats varying in thickness from 7.6 m to 48.7 m, underlies approximately two thirds of the alignment subgrade. The Atlantic Muck Formation in the old river channel is further underlain by soft silts, sand and clay strata.

The critical challenge for design espoused by the Tudor Report and others is the depth of subgrade degradation during the initial fill placements. The materials will lose much of its natural strength when disturbed and will only regain strength after the effects of consolidation of a surcharge fill. However, complete restoration of strength can only be assumed to a depth of 5 to 7 m. If the effects of the subgrade disturbance extend appreciably deeper, then an extremely weak material will be under the more stable subgrade and surcharge creating a condition of lateral instability.

Due to the inability to accurately analyze this condition, a test fill was performed on the western end of the alignment. In early 1963, 1,000-cy bottom-dump barges deposited some 168,000 cy of blasted rock from the cut widening project, extending some 305 m. 155 m of the fill was placed to a height of 11 m while the remaining 150 m was filled to 5 m. The differential heights were use to simulate initial and intermediate fill placement effects. Divers were then used to observe the performance of the fills placed along the alignment. The mechanisms of failure within the subgrade were caused by impact and static loadings. The impact of the initial placements caused severe destruction of the surface materials creating lateral displacements up to 5 meters. However, when a continuous blanket of fill had been established and subsequent fill was placed, then conventional failures such as slip circle shear failures and horizontal shears creating large mud waves outward from embankment were observed. Therefore, to predict the behavior of the embankment during construction and for the long term, it is imperative that a foundation mat be established to such a depth to prevent subgrade rupture with subsequent fill placement. It is recommended that a 5 m thick minimum crushed rock blanket with maximum sizes of 20 cm be placed initially to act as the supporting blanket. Special barge dumping methods were to be employed so loads would not fall as an integral mass, which would create destructive forces on the subgrade. These recommendations were offered to the Tudor Engineering Company for use in their final study report.

The placement of a large hydraulic structure on a deep-seated weak foundation is the most challenging of geotechnical endeavors. It is virtually impossible to analyze with great deal of certainty and the owner must be prepared to accept possible additional costs during construction and long term maintenance due to the potential for lateral instabilities and high degrees of settlement. The Tudor Report has predicted some 2.5 to 3 m of predicted settlement below the crest elevation for a construction duration of 7-years and an additional 2.5 to 3 m of maximum settlement below the crest for the 50-year service life of the project. These settlements are predicted where the Atlantic Muck and underlying compressible materials are the thickest. These movements are reduced as the fill approaches the mainlands and the two islands. This implies that significant differential settlements are predicted within these approaches as well. The key to any successful construction and maintenance of this embankment will be to establish a blanket mat atop the subgrade where subsequent fill can be economically placed without fear of rupturing the foundation to greater depths. Any significant lateral failure of the embankment during construction or productive use will render that alignment unsuitable. Additional embankment sections must be established upstream or downstream to reestablish the embankment section to the proper elevation. This repair will take considerable time and prevent its use as a road. Based on these considerations, our recommendations were presented for ultimate costs considerations in comparison to alternatives with a greater degree of performance certainty.

The divers observed that the test fill had trouble placing the fill in the correct locations within the alignment and the lift thickness varied significantly over the fill cross section. It is imperative that the blanket fill be placed intact with the least subgrade disturbance in order for the embankment to act as monolithic mass. Therefore, the initial 5 m of fill will be barged to the site and placed by lowering a clamshell to the subgrade surface. The positioning of the barges must be strictly controlled by survey positioning systems established on land. The initial fill should have a maximum size of 20 cm and the percent fines should be controlled to remain fairly intact during placement. Materials with a significant size differential and a large fine content can create weak shear zones with the embankment. The subsequent fill materials above this zone can be placed by bottom dumped barges or clamshells from El. 8 to 21 m MSL. The material above El. 21 m MSL must be placed by clamshell due to the draft and door operations of the barges. These materials will be more random in gradation having a maximum size of 30 cm and a greater degree of fines. The materials placed below El. 27 m MSL will assume a side slope of 1 V:15 H. A 15 m berm will be constructed and the materials will continue to be placed by clam shell and spread with a dozer to El. 31.5 m MSL, assuming a side slope of 1 V : 3 H and a crest width of 13 m. The flatter side slopes are needed to distribute bearing pressures and to reduce the lateral displacements. This configuration should also reduce the construction and total settlements predicted by the Tudor report and provide acceptable factors of safety for lateral stability during fill placement. The side slope berms and extra crest width will facilitate the future fill placements of up to 3 m over the life of the project. The road surface atop the dam embankment will remain gravel surfaced for the foreseeable future due to future fill placements. The dam will be approximately 30 m high, and the overall length 4,473 m. The top of the dam will be 5 m above the normal Gatun Lake level. The total volume of fill material required to construct and maintain the main dam to El. 31.5 m MSL is approximately 29,550,850 M^3. Water access from the main channel to Guacha and Tern Islands will be built during construction. After access roads have been constructed, fill placements from the east mainland to Tern and Gaucha Islands could be delivered by truck and placed by end dumping from the east mainland. This technique could prove beneficial if a material source was found near the Gatun Lock area. The side slopes and overall embankment configuration was offered for ease of calculation, to reduce the foundation pressure on the soft subgrade and to account for the lateral displacement of embankment materials. The increased foundation base should help the structure survive a relatively minor seismic event.

The methods of subgrade stabilization and embankment strengthening offered in the powerpoint presentations from the ACP Engineering Division are examples of many ideas for enhancing the performance of the embankment during construction and post construction. The use of wick drains has been an effective tool for accelerating consolidations under a mass loading. However, we feel that the Atlantic Muck materials will not readily transmit water to the drains, therefore the spacing of the drains must be much closer than that implied and the effectiveness of the drains will be restricted to the top 15 to 20 feet of the foundation subgrade. The drains must be effectively tied into the foundation blanket for continuity of the drainage path. There are concerns over the use of vibro-flotation or stone columns techniques above the mat. The mat will not effectively dampen these compaction forces and some rupture of the mat could be possible. A safer reinforcing technique could be the use of reinforcing within the embankment section, such as high strength geogrids placed in layers. All reinforcing techniques are expensive but could be offset by the reduction in fill quantities ultimately required. Any reinforcing selected for use in production must be part of a comprehensive test fill program to demonstrate its effectiveness.

The Tudor Report identified considerable leakage to be expected from the completed embankment. Since loss of any water from storage is a significant reduction in benefits, the seepage must be prevented. Therefore a bentonite slurry trench should be installed within the centerline of the embankment. The trench will be a minimum of 3 feet wide and extend to several meters below the original lake bottom. The trench can be excavated using rockmill techniques. Since the embankment will undergo significant settlement, both total and differential, it is likely that the trench will be sheared and will require replacement within the deeper portions of the lake during the life of the project.

Rio Caño Quebrado Dam

The Rio Caño Quebrado dam consists of two sections, the west and east embankments, with the top at EL. 31.5 m MSL and with a crest width of 13 m. The left abutment of the embankment would be located at Universal Transverse Mercator Grid, Zone 17, Clark 1866 Spheroid Coordinates 1004554 north and 632455 east. The right abutment would be 1004595 north and 632599 east coordinates. The embankments would be constructed by depositing cohesive materials along the alignment of the proposed dam until the stacked material reached its natural angle of repose and the consolidation, within the subgrade, has stabilized. The assumed side slopes are 10 H : 1 V within the submerged sections transitioning to 2 H : 1 V in the portions traversing the existing islands. The subgrade is extremely soft and considerable displacement is anticipated as evidenced by the original construction experience at Gatun Dam. The dam would be 16 m high, and the overall length would be 404 m. The top of the dam would be 4.3 m above the maximum normal operating level in Gatun Lake. The total volume of fill material required to construct the embankments is 244,150 M^3 for the west embankment and 114,500 M^3 for the east embankment.

Upper Rio Indio Dam

The Upper Rio Indio dam would be an embankment with the top at EL. 53.0 m MSL and with a crest width of 13 m. The left abutment of the embankment would be located at Universal Transverse Mercator Grid, Zone 17, Clark 1866 Spheroid Coordinates 990717 north and 591922 east. The right abutment would be 991200 north and 592330 east coordinates. The embankment shall be constructed with an impervious earth and rock fill core encased in rock fill, and the final side slopes would be 2 H : 1 V. The dam at its highest point would be 43.5 m high, and the overall length 632 m. Further study is needed to determine the actual side slopes and crest width and is contingent on the need for vehicular access across the embankment, the size and quality of the rock fill, and the detailed design of the embankment. Plate 38 - 3 presents a typical section of the embankment at the dam, incorporating upstream and downstream cofferdams within the section. The estimated quantity of fill to complete this embankment is 1,534,905 cm.

Foundation grouting is required across the entire base of the dam and on a portion of the valley walls. A blend of bentonite and native fill materials in a core trench provide seepage cutoff in the embankment foundations. A concrete or bentonite cutoff wall can also provide seepage cutoff. The crest widths and side slopes presented here are for comparison purposes between projects. The actual crest widths and side slopes shall be determined during further study and are contingent on the need for vehicular access across the embankments, the size and quality of the fill materials available for use, and the detailed design for the embankments.

The crest width and side slopes are presented here for comparison purposes between projects. The actual crest width and side slopes would be determined during further study and are contingent upon the need for vehicular access across the embankments, the size and quality of the fill materials available for use, and the detailed design for the embankments.

Saddle Dams

As noted in the Tudor Report, the existing Caño Saddle Dam No. 4, located along the western shoreline of the Trinidad Arm of Gatun Lake, needs to be raised and/or strengthened to accommodate the higher lake levels. Immediately to the north of this location, two additional smaller saddle dams are required. All saddle dams must be built to provide a minimum top El. 31.50 m MSL. The total volume of fill material required for these three dams is approximately 50,000 M^3, based on a crest width of 13 m.

The actual side slopes and crest widths would be determined during further study and are contingent upon the need for vehicular access across the embankment, the size and quality of the rock fill, and the detailed design of the embankment. A typical section of the embankment at the saddle dams and main dam would be similar to that shown for the embankments for the Upper Rio Indio project, Volume One of the parent document to this report.

SPILLWAY

Lower Rio Trinidad
Under normal flow conditions water should pass from Lower Rio Trinidad Lake to Gatun Lake through a gated spillway. This spillway should have 11 gate bays, separated/flanked by 3 m wide reinforced concrete piers (12 piers in all). These provide support for the gates, and access to the gate operating machinery, as well as for a roadway bridge over the top of the spillway. Each of the 11 spillway gates should have a nominal width of 18.33 m and a height of 5.48 m to provide 0.3 m freeboard above the maximum lake operating level. The overall length of the spillway, from out-to-out of the end piers is 237.67 m. The spillway sills shall be placed at the minimum lake operating level for Gatun Lake, EL. 25.91 m MSL.

A bridge across the tops of the spillway piers would be constructed as a part of the roadway across the top of the dam. The roadway must be approximately 7 m wide thus allowing for two-way traffic and providing ready access to the spillway gate operating machinery.

For this study, stop logs for servicing the gates, guides, etc. may be placed either from the roadway or from barges using floating cranes. Also, it should be noted that, with the spillway sill at the prescribed level, stoplogs are required both upstream and downstream to allow work to be done on the gates and sills in the dry.

The spillway would be situated along the axis of the dam centered in the western leg of Guacha Island. This allows the construction to be performed completely within a dry construction cut requiring a minimum of construction dewatering. Once the concrete structures are completed, the entrance and exit channels to the spillway can be opened

Upper Rio Indio
At Upper Rio Indio, an uncontrolled ogee spillway, with a length of 113.11 m and a crest at EL. 50 m MSL, is required. The spillway crest would be 3 m below the elevation of the top of the dam. The maximum discharge from the spillway would be 618 CMS at a maximum flood lake level at EL. 52 m MSL. The spillway design discharge is equivalent to a 1 in 1,000 frequency unregulated flow at the dam site. The spillway site is located within the abutment adjacent to the left end of the dam and should consist of a mass concrete sill section embedded in the natural rock. A sloped and/or stepped, natural rock cut tailrace channel would transfer flow to the adjacent Rio Uracillo tributary. The tailrace channel extends from the sill section to its confluence with the Rio Uracillo. The task of dissipating energy at the downstream end of the tailrace channel requires excavation of a stilling basin into the rock adjacent to the natural channel. See Plate 38 - 2 for the location of the spillway and Plate 38 - 4 for a typical section at the spillway.

PUMPING PLANT

A large pumping plant is included in this scenario at the Lower Rio Trinidad dam. This pumping facility provides for pumping in two directions, allowing Lower Rio Trinidad Lake to be drawn down to a level below that of Gatun Lake during extremely dry months, and providing the capability of pumping excess water from Gatun Lake into Lower Rio Trinidad Lake during the flood season. Water thus stored would be available for navigation during the dry season. The pumping plant is configured to provide pumping to EL. 33.53 m MSL in Lower Rio Trinidad Lake. For the purpose of this study the pumping plant is located in the northwest segment of Tern Island. See Table 40-3 for the controlling head and flow data used for this study.

This plant should consist of six 1407 HP pumps, each capable of pumping slightly more than 62 CMS for a total plant pumping capacity of 373 CMS at a total dynamic head of 4.6 m. The pumping units would be mounted in a reinforced concrete housing and arranged in a row perpendicular to the axis of the dam, with intake and outlet channels on either side. The channels would be separated from the Lower Rio Trinidad and Gatun Lakes by large concrete walls containing low-level sluiceways and gates for controlling flows into and away from the pumping plant. These sluiceways are configured to provide average entry velocities of approximately 7.7 MPS. The channels are configured to provide this velocity or less and require no special armoring of walls or inverts for scour protection. The channel invert would be at EL. 20 m. MSL, or 13.5 m. below the centerline of the pump outlets. This may provide sufficient water depth at maximum pumping to buffer the erosive effects of the very large outflows required.

In conjunction with this facility a roadway bridge would be required to connect the pumping station structure to the banks on either side of the intake and exit channels thus continuing the roadway across the facility. This bridge should also provide both operational and maintenance access to the pumping plant. As configured for this study, the bridge must have two 15 m long spans with steel girders and a concrete bridge deck on each side of the pumping station. It shall have a 7 m wide travel way and include one bridge bent including a cap, two round columns and a spread footing, located within each channel section.

Table 40-3 Pumping Data

Pumping Cycle	Head (m.)	Average Daily Flow (M^3/sec)
Lower Rio Trinidad (Elev. 22.86) to Gatun Lake (Elev. 25.91)	3.05	127.43
Gatun Lake (Elev. 26.67) to Lower Rio Trinidad (Elev. 30.48)	3.81	56.64

IMPOUNDMENT

The lake formed by the proposed Lower Rio Trinidad Dam should have a normal operating lake elevation. of 30.48 m MSL. The surface area at the normal operating lake level would be approximately 18,169 ha. At the maximum flood level, EL. 31.09 m MSL, the surface area would be approximately 18,835 ha. With the minimum operating level at EL. 22.86 m MSL, the surface area would be approximately 9,019 ha. It should be noted that the current operating levels of Gatun Lake vary up to EL. 26.67 m MSL; therefore areas below the maximum Gatun Lake level are already subject to inundation.

The lake formed by the proposed Rio Caño Quebrado Dam should have a normal operating lake level at EL. 30.48 m MSL. The surface area at the normal operating lake level would be 2,609 ha. At the maximum flood lake level, EL. 31.09 m MSL, the surface area would be 2762 ha. With the minimum operating lake level, EL. 22.86 m MSL, the surface area is 1,151 ha.

The lake formed by the proposed Upper Rio Indio Dam should have a normal operating lake level at EL. 50 m MSL. The surface area is 863.8 ha. At the maximum flood lake level, EL. 52 m MSL, the surface area is 897.6 ha. With the minimum operating lake level at EL. 45.5 m MSL, the surface area is 732 ha.

CLEARING AND/OR GRUBBING

Clearing and grubbing would be required for all areas above the existing Gatun Lake that are required for construction of the dam (embankments and spillway), access roads, and disposal and staging areas. For the Lower Rio Trinidad Lake area, clearing would be required for the 3,700 ha in the lake area between the maximum operating lake level of Gatun Lake and EL. 30.5 m MSL. Clearing only would be required for the 740 ha in the Rio Caño Quebrado Lake area between the maximum operating lake level of Gatun Lake and EL. 30 m MSL.

For the Upper Rio Indio Lake, clearing is required in all areas necessary for construction of the dam (embankments and spillway), inter-basin transfer facilities, outlet works, hydropower plants, access roads. Disposal and staging areas require clearing and grubbing. Only the 900 ha in the lake area between the normal operating lake level, EL. 50 m MSL, and the minimum operating lake level, EL. 45.5 m MSL, require clearing. The transmission lines also require clearing.

ACCESS ROUTE

Lower Rio Trinidad
Access to the lake site and the various construction sites was evaluated from the main population centers, Colon on the Atlantic coast and Panama City on the Pacific coasts.

The route from Colon is westward across the Panama Canal and then southwestward along existing roads that follow the westernmost boundary of Gatun Lake to Cape Mala, near the western abutment of the dam. A very short access road is required from the existing road to the dam site. This route requires crossing the Panama Canal near the Gatun Locks using the existing lock gate bridge. This bridge is narrow and operates only intermittently since canal operations take precedence over roadway traffic. It may be undersized and may lack the load carrying capacity needed for heavy construction materials and equipment loads anticipated.

Access to the spillway and pumping plant construction sites would be by water since these structures are to be placed on Guacha and Tern Islands, respectively. A water access route was considered for conveyance of much, if not all, of the construction equipment and materials. This requires the construction of offloading facilities near the west abutment of the dam, on Guacha Island, and near the eastern abutment site in the vicinity of South Range Point.

Since much of the construction for this project would be in the existing lake or on islands in the lake, it is concluded that both land and water access is required. Plate 40-1 shows the general location of the proposed features and the possible land and water access available or to be provided.

Rio Caño Quebrado
Access for Rio Caño Quebrado can best be gained from the Panama City area by way of existing roads as far as the village of Santa Clara, located to the south and east of the Rio Caño Quebrado dam site. From Santa Clara, a new roadway would be required to the dam construction site, a distance of approximately 8 km. Roadway access should also be required to the spillway site, which would be located some distance to the south and west, and across the existing lake from the dam site. Existing roadway access in this area is now available to the village of La Laguna. From a point just south of La Laguna, a new access road would be required around the south side of the existing lake to the spillway site. This route requires approximately 5 km of additional new roadway.

In addition to providing construction access, this new corridor into the remote areas surrounding Gatun Lake would be nefit to those living in the region. It should provide ready access to the main centers of commerce in the southern part of the country, as well as access to the lake for recreation interests.

Upper Rio Indio
For access to the Rio Indio site it is concluded that the route from Panama City westward across the Bridge of the Americas, then southwestward along the Inter-American Highway, and then westward along existing roads to Ciri Grande, may be best. This route requires that the road between Panama City and Ciri Grande be upgraded over much of its length and the route west of Ciri Grande must traverse the mountains. The proposed access road would be 26 km in length, and bridges and / or culverts would be required at 15 streams. Plate 40-1 shows the portion of the proposed access road from Ciri Grande to the construction sites.

In addition to providing dam construction access, this new corridor into the country west of the Panama Canal benefit those living in the region, providing access to the main centers of commerce in the southern part of the country. It should also provide continuous access along the new power transmission lines from the dam site to the connection with the power grid.

Sources of Construction Material

Lower Rio Trinidad
The bottom 5 m layer of the dam embankments shall be constructed with material less than 8 in. maximum size, and with no more than 5 percent passing the #200 screen. Such a material would require crushing and processing across a grizzly to remove oversize rock, and washing to remove fines. Material for this bottom layer must be reasonably well graded so as to prevent the removal of the finer fraction by piping. The overlying main portion of the embankment would be constructed with (-12 in.) sized material. This material should also require crushing and processing across a grizzly to remove oversize rock.

The majority of the materials used for the embankment construction would be obtained from upland sources adjacent to the Gaillard Cut, transported to the site by barge and clam shelled along the proposed embankment alignment. The initial materials would be obtained from the existing disposal sites for the Gaillard Cut widening above Pedro Miguel Locks. Based on the information received from the ACP, these sites contain approximately 5.5 million M^3 of suitable excavated rock. However, this rock is not stockpiled in an orderly manner, is randomly mixed with unsuitable material and is covered with unsuitable material. All the rock materials, from whatever source, would need to be crushed, graded and loaded on trucks for transport to a loading facility adjacent to the canal at the Cucaracha Reach on the east side, or the mouth of the Mandinga River on the west side. These loading facilities should require excavation into the bank area and bulkheaded for crane support and barge placement. Working stockpiles would be maintained next to the transfer points to facilitate the loading process. Additional materials within the immediate area should come from the Third Locks excavation adjacent to the Pedro Miguel Locks. These materials would be drilled and blasted in place, excavated, and then transported to one of the transfer facilities for processing. Additional materials should come from newly developed quarry sources in areas such as Hodges Hill, Escabor Hill, Contractor Hill, and others within 10 km of the transfer points. Each of these new sources should require extensive excavation to remove the overburden and soft rock materials. These materials would be stockpiled adjacent to the work area for restoration once the rock fill materials have been acquired. The suitable rock materials would be blasted, crushed and graded and trucked to the transfer points. All material would be loaded onto barges, transported to the dam site and clam shelled within the dam limits.

Cement is available within the country. Rock obtained from developed quarries may be used to produce concrete aggregates on-site, or they may be obtained from commercial quarries. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) need to be fabricated outside the Republic of Panama and imported for final assembly and installation at the proposed dam site.

Rio Caño Quebrado
The source of the embankment and other construction materials for Rio Caño Quebrado are expected to be the same as those for Lower Rio Trinidad.

Upper Rio Indio
Rock removed from the spillway site can used as fill in the embankment portion of the dam. Impervious materials might be obtained from outside the project area; however, for this study it is assumed that these materials would be available locally in sufficient quantity to supply the project needs. If further study indicates that impervious materials are unavailable locally, then other materials, such as roller compacted concrete, would be considered for construction of the dam.

Cement is available within the Republic of Panama. Rock obtained from developed quarries may be used to produce concrete aggregates on-site, or they may be obtained from commercial quarries. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) need to be fabricated outside the country and imported for final assembly and installation at the proposed dam site.

Real Estate Requirements

The proposed Lower Rio Trinidad Lake site is located within the former Panama Canal Zone and is presently managed and controlled by the ACP. Construction of this project requires acquisition of approximately 800 ha. Table 40 - 4 shows the amount of land required for the various project features. Real estate for access roads is included in the estimated quantities for the other items listed in the table. The ACP provided the estimated cost of the land for the proposed project.

Table 40 - 4 Real Estate Requirements – Lower Rio Trinidad

Project Feature	Land Required (ha)
Lake	0
Dam Site	0
Staging Area	200
Housing and Facilities	200
Disposal Area	400
Total	800

The proposed Rio Caño Quebrado Lake site is located within the former Panama Canal Zone and is presently managed and controlled by the ACP. Construction of this proposed project requires acquisition of approximately 800 ha. Table 40 - 5 shows the amount of land required for the various project features. Real estate for access roads is included in the estimated quantities for the other items listed in the table.

Table 40 - 5 Real Estate Requirements – Rio Caño Quebrado

Project Feature	Land Required (ha)
Lake	0
Dam Site	0
Staging Area	200
Housing and Facilities	200
Disposal Area	400
Total	800

The proposed Upper Rio Indio project site is located in the Cocle, Colon, and Panama Provinces. Construction of this proposed project requires acquisition of approximately 1900 ha. Table 40 - 6 shows the amount of land required for the various project features. Real estate for access roads is included in the estimated quantities for the other items listed in the table.

Table 40 - 6 Real Estate Requirements

Project Feature	Land Required (ha)
Lake	900
Dam Site	200
Staging Area	200
Housing and Facilities	200
Disposal Area	400
Total	1,900

Relocations

The Lower Trinidad Lake would be located within the existing former Panama Canal Zone. Structures and facilities established along the waters edge in the Trinidad arm between the existing Gatun Lake levels and EL. 30 m MSL would need to be relocated or modified. This would include a major portion of the town of Escobal. Additionally, there are only a few small communities and isolated individual structures along the lakeshore with very limited access by land.

The Rio Caño Quebrado Lake would be located within the existing former Panama Canal Zone. Structures and facilities established along the waters edge in the Rio Caño Quebrado arm between the existing Gatun Lake level and EL. 30 m MSL need to be relocated or modified. This region appears to have a few settlements along the lakeshores with very limited access by land.

The Upper Rio Indio Lake would be located in a sparsely settled region with few roads and utilities. This area is devoted primarily to subsistence farming and ranching. Structures and individuals located in the lake area below EL. 55 m MSL would require relocation because of the normal lake inundation and the need to secure the lake perimeter for flood considerations. The required relocations would include the towns in the lake area Los Uveros, and Tres Hermanas, approximately 12 other small settlements (just a few structures), and numerous isolated structures. The two towns all have elementary schools, churches, electricity, and limited telephone coverage.

Development Sequence

Each of the component lake projects is designed and constructed as a stand-alone facility. The Rio Caño Quebrado Lake should function as an arm of the Lower Rio Trinidad, and should not have any water handling facilities, but should depend on the Lower Trinidad spillway and pumping plant to regulate the lake water level. If the Upper Rio Indio facilities are constructed first and placed into service before the Lower Rio Trinidad facilities, the interbasin transfer tunnel can used to navigational advantage while the Lower Rio Trinidad Dam project is being completed. During the interim, the Upper Rio Indio Dam project can also help control flooding on the Lower Rio Indio and can contribute to the electric power output of the country.

The development sequence for each individual project follows roughly the same progression. This progression is summarized below with pertinent site-specific notations as appropriate.

Each project must be evaluated to assure that the plan presented includes all of the features required to function. Each project must be assessed as to its effectiveness in providing navigation water to the Panama Canal, with due recognition of any secondary benefits. Environmental assessments of the proposed projects need to be made to assure environmental acceptability of the project features. These environmental assessments begin during the planning studies phase and continue into the final design, advertising and award phases. Environmental coordination begins with planning studies and continues through the completion of construction. After completion of the final design, plans and specifications must be prepared for the advertising and award phase.

Project implementation begins with land acquisition and construction of the access facilities. Lands for the housing and facilities project feature, which includes the access roads, need to be acquired initially. Lands for the dam site, staging area, disposal area, and lake can then be acquired.

Socio-economic programs must begin shortly before construction of the dam. The relocation of the small settlements and isolated structures must be accomplished. Socio-economic programs to assist those individuals impacted by the construction of the proposed project should continue throughout the construction phase.

Construction of the Upper Rio Indio Dam begins with the clearing and grubbing of the construction sites and clearing the perimeter of the lake area. Materials used for the embankment construction can obtained from upland sources then transported to the site.

Upstream and downstream cofferdams would be required for construction of the Upper Rio Indio Dam and appurtenant facilities. These would be configured so as to form a portion of the finished dam.

Upstream and downstream cofferdams are required for construction of the Rio Indio Dam and appurtenant facilities. These shall be configured to form a portion of the finished dam.

Limited cofferdams would be required to accomplish construction of the spillway and pumping station. These efforts may be accomplished simultaneously. Following completion of the pumping plant and spillway, the channels connecting these structures to the lake areas upstream and downstream may be excavated. Where possible, materials removed from these sites would be placed directly into the dam.

Once the western leg of the dam, pumping station and spillway are completed, the eastern leg may be constructed, thus completing the dam. The pool may then be raised. Upon completion of this phase of construction, all facilities must undergo trial operations, before being commissioned for service.

Considering the construction methods required and the nature of the work, it is estimated that development of the Lower Rio Trinidad and Upper Rio Indio Dam projects may be completed in approximately the time spans indicated in Figures 40-2 and 40-3, below, from initial planning to lake filling. Assuming that the development of the two projects is overlapped by 1 year the total development time is approximately 22 years.

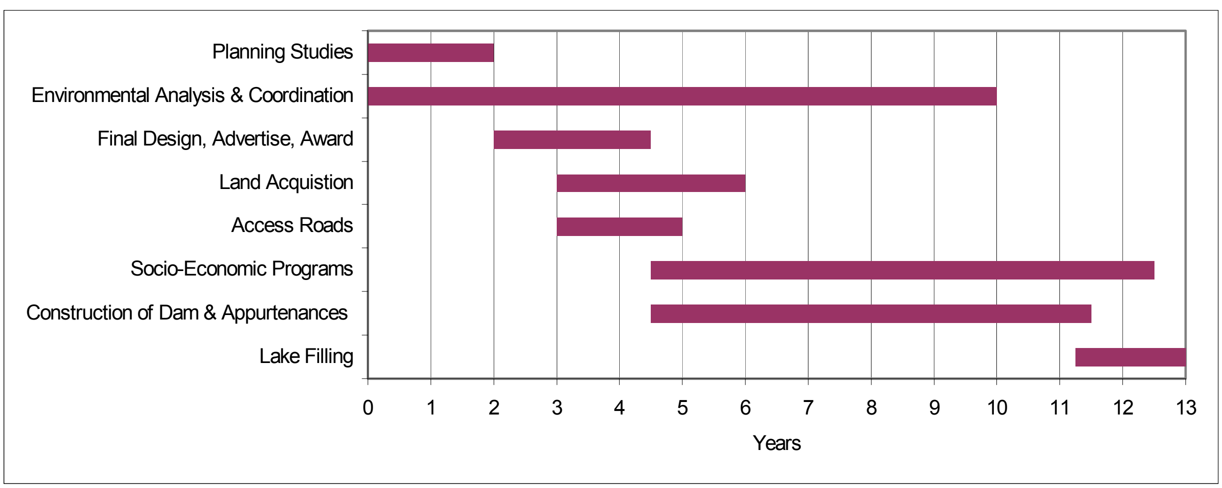


Figure 40 - 1 Development Sequence – Lower Rio Trinidad

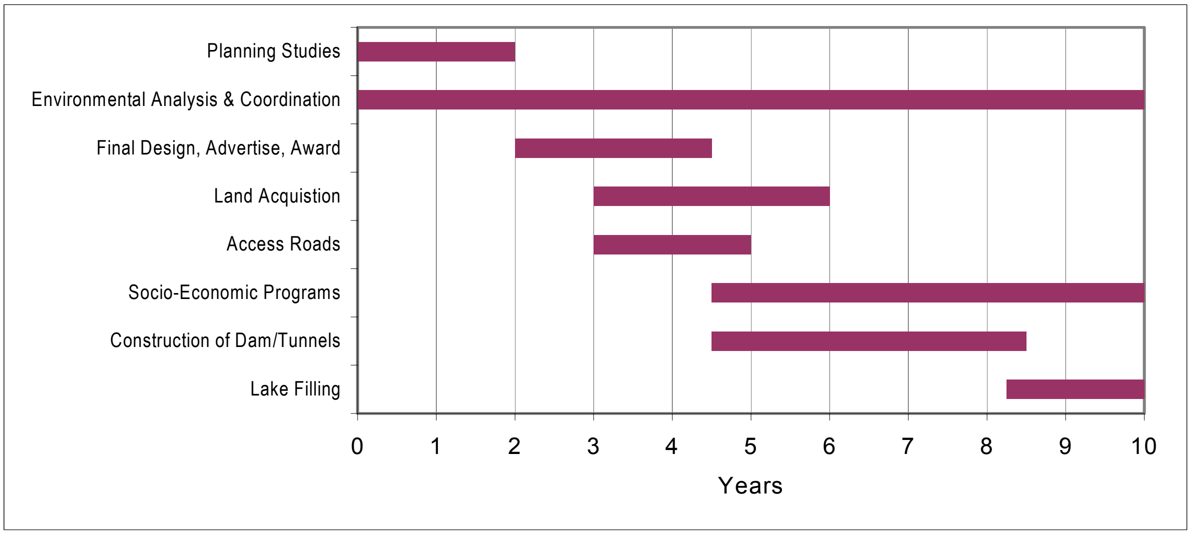


Figure 40 - 2 Development Sequence – Upper Rio Indio

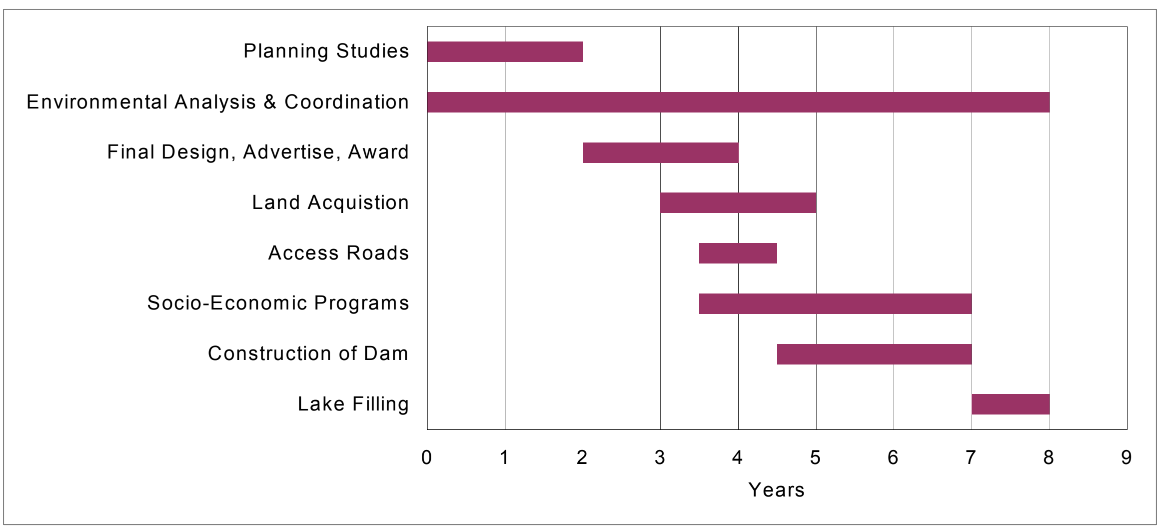


Figure 40 - 3 Development Sequence – Rio Caño Quebrado (Concurrent with Lower Rio Trinidad)

Hydrologic Reliability

In order to determine the effect of the proposed Lower Rio Trinidad, Rio Caño Quebrado and Indio Lakes on the hydrologic reliability of the Panama Canal, the existing HEC-5 model is modified to include the Lower Rio Trinidad Lake with pumpback operation and diversion from Upper Rio Indio Lake. The existing Gatun Lake parameters (surface areas, storages, and local inflows) are reduced by the proportion that Lower Rio Trinidad and Rio Caño Quebrado Lakes should capture.

HEC-5 model simulations were conducted for both the existing canal system and the Scenario 5 operating system. The simulations considered proportionally increasing demands up to 180 percent of current demand levels, see Figure 40-4. The period of simulation considered 52 years (January 1948 through December 1999) of hydrologic record. Figure 40 - 4 presents the resulting hydrologic reliability for two configurations with demands increasing up to 180 percent of current demands. These configurations were:

- Existing system,
- Scenario 5 – Upper Rio Indio Lake has a normal operating level of 50 m MSL and should operate as a “run-of-river” dam., transferring flows to Lower Rio Trinidad via 4.5 m interbasin transfer tunnel, EL.; Lower Rio Trinidad and Rio Caño Quebrado Lake fluctuating between the normal operating lake level at EL. 30.48 m MSL and the minimum operating lake level at EL. 22.86 m MSL with pumping capability to and from Gatun Lake; and Gatun Lake fluctuating between the normal operating lake level at EL. 26.67m MSL and the minimum operation lake level at EL. 25.91m MSL.

The horizontal axis along the bottom of Figure 40 - 4 reflects demands as a ratio of the 5-year average from 1993 to 1997, and the axis along the top reflects demands in lockages (assuming 55 million gallons per lockage).

As shown in Figure 40 - 4, the existing hydrologic reliability of the Panama Canal, based on the period of record of 52 years, is approximately 99.6 percent, while the hydrologic reliability with a demand ratio of 1.8 is 86.3 percent. This period of record includes the worst drought on record for the area which occurred in 1998. The hydrologic reliability with a demand ratio of 1.0 is 100 percent for operating Scenario 5, and the hydrologic reliability with a demand ratio of 1.8 is 93.18 percent. Figure 40 - 4 displays the number of lockages associated with various levels of reliability.

Without additional water supplies, the hydrologic reliability of the canal system should decrease. With the construction of the proposed Lower Rio Trinidad Pumpback, Rio Caño Quebrado Dam and Upper Rio Indio Dams projects using Scenario 5 operation, the existing high hydrologic reliability can be continued as demand for water increases up to 21.5 percent (8.32 lockages) above current demand levels.

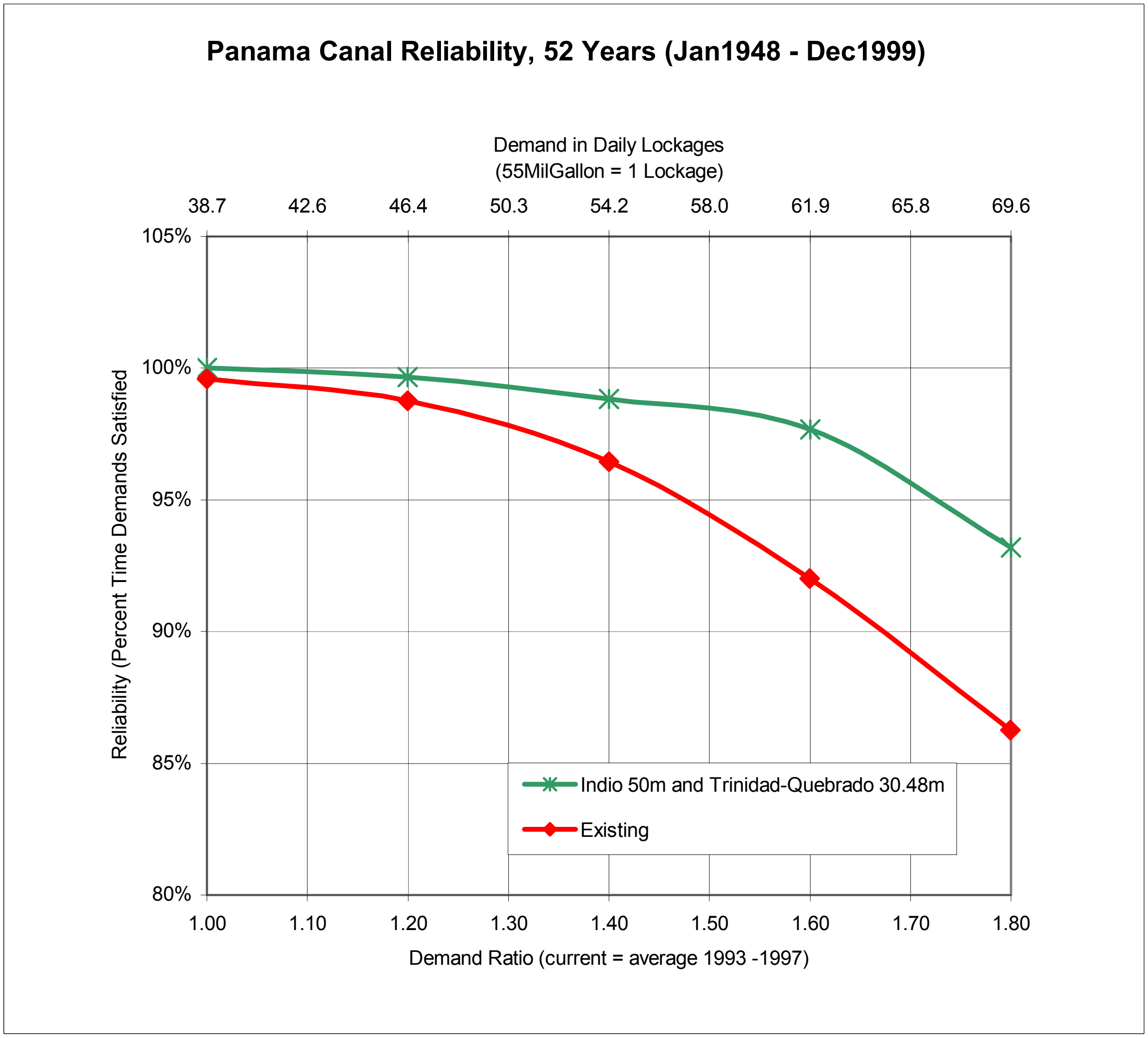


Figure 40 - 4 Panama Canal Hydrologic Reliability

Project Costs

GENERAL

The quantities estimated for the principal features required in the construction of this project are derived from the layouts shown on Plates 40 - 1 and 40 - 2 and on data derived from the Tudor report. The unit prices applied to these quantities are based on historical information from previous estimates prepared for similar construction in the Republic of Panama, previous estimates for similar construction in the Southeastern United States, and from information gathered from U.S. Army Corps of Engineers, Mobile District, Construction Division personnel in the Republic of Panama.

Engineering and design is estimated to be 12 percent while supervision and administration is estimated to be 6 percent of the construction cost items. An allowance of 2 percent of the construction cost items is allowed for field overhead (construction camp, contractor facilities, etc.). An allowance of 25 percent is included for contingencies.

FIRST COSTS

The total project first costs are estimated to be $1,029,900,000. Table 40-7 provides a summary of the first costs for the principal features. Separate documentation provided to the ACP includes a detailed cost estimate containing the sub-features of the work.

Table 40 - 7 Summary of First Costs

	Lower Rio Trinidad	Rio Indio	Rio Caño Quebrado
Item	Costs ($)	Costs ($)	Costs ($)
Lands and Relocations	2,000,000	4,750,000	2,000,000
Access Roads	9,574,000	7,810,000	4,440,000
Clearing and / or Grubbing	556,250	2,957,500	778,750
Cofferdam	850,000	4,850,665	N/A
Dam	491,824,842	15,226,374	2,386,390
Spillway	8,891,206	42,070,303	N/A
Intakes	N/A	7,701,295	N/A
Saddle Dams	2,143,000	N/A	N/A
Transfer Ditch	N/A	N/A	3,281,400
Pumping Station	22,999,637	N/A	N/A
Diversion Tunnel	N/A	4,714,622	N/A
Interbasin Transfer Tunnel	N/A	27,806,250	N/A
Transfer Intake Indio-Gatun	N/A	371,194	N/A
Hydropower Plants	N/A	7,926,380	N/A
Transmission Lines	2,090,000	6,600,000	N/A
Subtotal	540,929,325	132,784,583	12,886,540
E&D, S&A, Field Overhead	108,185,865	26,556,917	2,577,308
Contingencies	162,278,798	39,835,375	3,865,962
Total Project First Cost	811,393,988 Approximately 811,4000,000	199,176,875 Approximately 199,177,000	19,329,810 Approximately 19,330,000

OPERATION AND MAINTENANCE

Staff

A staff would operate and maintain the proposed Lower Trinidad project during the day and then run the facility remotely. The full-time staff would ultimately consist of 9 people, including a station manager, a multi-skilled supervisor, 2 leaders (Electronics / Instrumentation, Electrical and Mechanical), 4 craftsmen and a laborer. A part-time staff would be required for two to three months each year to perform general maintenance and overhaul of the proposed project. The part-time staff would consist of three mechanics and three electricians. The annual costs of the staff are estimated to be $350,000. The staff for the Lower Rio Trinidad project would be sufficient to operate and maintain the Rio Caño Quebrado project. The annual costs of the staff for the proposed Upper Rio Indio project are estimated to be $500,000.

Ordinary Maintenance

Ordinary maintenance and care is required and includes minor repair materials, lubricants and other supplies needed by project staff. It is estimated that the costs of ordinary maintenance is $18,000 per year for the access road and $100,000 per year for the main project facilities. Fuel consumption for the pumps is estimated at $648,000. This estimate considers the growth in demand for water over time and the variability in inflows to Gatun Lake, as well as the proposed Lower Rio Trinidad project. An estimated $150,000 would be needed for rock placement to account for settling of the project. The total ordinary maintenance is $916,000. The ordinary maintenance estimate for the Lower Rio Trinidad project would be sufficient to include the Rio Caño Quebrado project. The ordinary maintenance costs for the proposed Rio Indio project are estimate to be $320,000.

Major Replacements

The average service life of gates, electrical equipment, pumps, trash racks and other features would be less than the total useful life of the project (100 years). To estimate the major replacement costs necessary during the 50-year planning period for this proposed project, it is assumed that specific items should cost the same as at present. No allowance is made for salvageable fixed parts. Table 40 - 8 presents the service life, number of times each component should be replaced during the 50-year planning period, the future costs of each item, and the present worth of the replacement costs for the major components. Based on these values, the present worth of the proposed replacements would be $2,214,500 and the average annual replacement costs would be $267,000. There are no major replacements needed for the Rio Caño Quebrado project. The average annual replacement costs for the Upper Rio Indio project would be $33,000.

Table 40 - 8 Major Replacement Costs

Component	Service Life (years)	Number of Times Replaced During Planning Period	Future Costs ($)	Present Worth of Replacement Costs ($)
Roads	50	1	12,435,000	43,000
Bridges	50	1	1,800,000	6,200
Pump Station				
Pumps	25	2	21,006,000	654,200
Sluice Gates	50	1	1,275,525	4,400
Sluice Trash Racks	50	1	458,850	1,600
Electrical Controls	25	2	2,100,000	65,400
Fuel Tanks, etc.	50	1	450,000	1,600
Misc. Equip. & Comm	25	2	3,183,000	99,100
Slurry Trench	25	2	39,000,000	1,214,500
Spillway				
Bridge Girders	50	1	365,271	1,300
Tainter Gates	50	1	1,980,000	6,900
Tainter Gate Hoists	50	1	1,320,000	4,600
Tainter Gate Op Sys.	50	1	360,000	1,200
Stoplogs	50	1	475,950	1,600
Misc. Mech. Items	25	2	1,500,000	46,700
Electrical Controls	25	2	1,650,000	51,400
Transmission Lines	50	1	3,135,000	10,800
Total			92,494,596	2,214,500
Average Annual Replacement Costs				267,000

Annual Costs

The project first costs for the proposed Lower Rio Trinidad project are estimated to be $811,400,000. The project first costs for the proposed Rio Caño Quebrado project are estimated to be $19,330,000. The total project first costs that include the $199,177,000 costs for the Rio Indio project are estimated to be $1,029,901,000. These total project first costs are distributed across the development period using generalized curves for contractor earnings for large, heavy construction jobs. Interest on the proposed Upper Rio Indio project first costs is computed from mid-year throughout the 22-year development period. Interest during construction for the Lower Rio Trinidad project is computed from mid-year throughout its 13-year development. The interest during construction, at 12 percent, is $658,745,000 for Lower Rio Trinidad, $8,588,000 for the Rio Caño Quebrado project and $1,001,634,000 for Upper Rio Indio - for a total interest during construction of $1,668,967,000. These costs are added to the total project first costs for total project investment costs of $2,698,868,000. A capital recovery factor for the 50-year planning period is applied to get the annual average investment costs of $324,989,000. Annual operation and maintenance costs are added. Major replacement costs are estimated and converted to an annual cost by discounting the future replacement costs of major components of the project back to completion of the project construction. Table 40 - 9 contains a summary of the $327,375,000 total annual costs.

Table 40 - 9 Summary of Annual Costs

Item	Costs ($)
Total Project First Costs - Lower Rio Trinidad	811,394,000
Total Project First Costs – Rio Indio	199,177,000
Total Project First Costs – Caño Quebrado	19,330,000
Interest During Construction – Lower Rio Trinidad	658,745,000
Interest During Construction – Rio Indio	1,001,634,000
Interest During Construction – Caño Quebrado	8,588,000
Total Project Investment Costs	2,698,967,000
Annual Average Investment Costs	324,989,000
Operation and Maintenance Costs	
Staff Costs – Lower Rio Trinidad	350,000
Staff Costs – Rio Indio	500,000
Ordinary Maintenance Costs – Lower Rio Trinidad	916,000
Ordinary Maintenance Costs – Rio Indio	320,000
Major Replacement Costs – Lower Rio Trinidad	267,000
Major Replacement Costs – Rio Indio	33,000
Total Average Annual Costs	327,375,000

Annual Benefits

NAVIGATION

The procedures and assumptions used in estimating the benefits are described in Section 4. The following paragraphs present the results of the economic investigations for the proposed Lower Rio Trinidad, Rio Caño Quebrado and Upper Rio Indio projects. The 50-year period for the economic analysis of this proposal is 2024 to 2073.

The proposed Lower Rio Trinidad, Caño Quebrado and Rio Indio projects should increase the reliability of providing water to accommodate the total daily number of lockages demanded. Table 40 - 10 provides the increase in the hydrologic reliability of providing the sum of the demands for both navigation and M&I water supply keyed to years. The hydrologic reliability percentages are obtained from the data used to develop Figure 40 – 10. The 99.6 percent level of reliability for this proposal is used to estimate the water supply benefits for navigation and the net change in reliability is used to estimate the reliability benefits for navigation and M&I water uses.

Table 40 - 10 Panama Canal Hydrologic Reliability
(Based on Period of Record from January 1948 to July 1998)

Current Demand Ratio	Year	Demand in Daily Average Number of Lockages (Navigation and M&I)	Hydrologic Reliability	
			Existing System (%)	With Lower Rio Trinidad, Caño Quebrado & Rio Indio [1/] (%)
1	2000	38.68 [2/]	99.60	100.0
	2010	45.11	98.91	99.72
1.2		46.42	98.76	99.66
	2015	46.82	98.64	99.62
	2020	47.61	98.41	99.54
	2025	48.52	98.14	99.44
	2030	49.55	97.83	99.33
	2035	50.72	97.48	99.21
	2040	52.02	97.10	99.07
	2045	53.49	96.65	98.91
1.4		54.15	96.45	98.84
	2050	55.13	95.89	98.69
	2055	56.98	94.83	98.32
	2060	59.05	93.65	98.32
	2065	61.37	92.32	97.75
1.6		61.89	92.02	97.67
	2070	63.97	90.47	96.47
1.8		69.63	86.27	93.18

[1/] The lakes behind the Lower Rio Trinidad and Rio Caño Quebrado Dams would fluctuate from the normal operating lake level at EL. 30.48 m MSL down to the minimum operating lake level at EL. 22.86 m MSL and the lake behind the Rio Indio Dam would operate at EL. 50 m MSL.

[2/] 2000 Daily Demand is Average of 1993-1997.

With the proposed Lower Rio Trinidad, Rio Caño Quebrado and Upper Rio Indio projects, water supply shortages for navigation should continue. The demand for the M&I purposes should always be met first. As these demands grow, the amount of water available to meet the demands for navigation should decrease. Thus, the benefits for the additional water supply are estimated at the value for navigation. With the addition of the proposed Lower Rio Trinidad, Rio Caño Quebrado and Upper Rio Indio projects, these shortages would be less frequent. With a hydrologic reliability of 99.6 percent, the proposed project should increase the amount of water supplied by 8.32 equivalent lockages. The 99.6 percent hydrologic reliability should occur after the year 2018, with an equivalent daily average number of lockages of 47.0. Additional benefits of the additional water are attributable to navigation since the amount of M&I water demanded would be provided first. Therefore, all shortages are attributable to navigation. The benefits are estimated using the toll revenue per lockage and the increased daily average number of lockages. The average annual benefits for water supply are $171,498,000. Table 40 - 11 provides the estimate of daily shortages under the existing system, the remaining daily shortages with the proposed Lower Rio Trinidad, Rio Caño Quebrado and Upper Rio Indio projects in operation, the annual benefits for meeting shortages and the average annual benefits.

Table 40 - 11 Benefits for Additional Water Supply for Navigation

Year	Daily Shortages In Lockages Under Existing System	Remaining Daily Shortages	Annual Benefits For Navigation ($)
2023	9.51	1.19	171,498,000
2030	10.87	2.56	171,498,000
2040	13.34	5.03	171,498,000
2050	16.45	8.14	171,498,000
2060	20.36	12.05	171,498,000
2070	25.29	16.97	171,498,000
Average Annual Benefits			171,498,000
With the Lower Rio Trinidad and Rio Caño Quebrado projects operating between 22.86 and 30.48 m and the Rio Indio project operating at 50 m, the system should provide a total of 47.00 lockages at the 99.6 percent level of reliability or 8.32 more lockages than the existing system.			

With the proposed Lower Rio Trinidad, Rio Caño Quebrado and Upper Rio Indio projects, the reliability of the system to provide the water demanded by navigation and M&I water would be improved. Using the increase in hydrologic reliability, the forecast number of vessels converted to a daily average number of lockages, the toll revenue for each average lockage, and a project discount rate of 12 percent, the average annual benefits for navigation reliability attributable to the proposed Lower Rio Trinidad, Rio Caño Quebrado and Upper Rio Indio projects is $13,443,000. Table 40 - 12 provides the forecast daily average number of lockages, the forecast value per daily lockage, the annual benefits for increased reliability, and the average annual benefits.

Table 40 - 12 Average Annual Reliability Benefits For Navigation

Year	Daily Average Number of Lockages	Value Per Lockage ($)	Annual Benefits For Navigation ($)
2023	40.0	2,260,000	10,218,000
2030	40.0	2,260,000	12,380,000
2040	40.0	2,260,000	16,305,000
2050	40.0	2,260,000	23,103,000
2060	40.0	2,260,000	31,638,000
2070	40.0	2,260,000	49,453,000
Average Annual Benefits			13,443,000

M&I WATER SUPPLY

The future demand for water supply for M&I purposes is based upon the growth in population. The ACP provided a forecast for the area surrounding the Panama Canal. The current usage is estimated at 4.0 equivalent lockages per day; an equivalent lockage is 55 million gallons of water. One equivalent lockage is added to the forecast to account for the burgeoning tourist industry, beginning in the year 2010. The increased reliability of the system to provide water supply for navigation similarly provides the same increase in reliability to provide water for M&I purposes. Using the increased hydrologic reliability of the system with the addition of the proposed Lower Rio Trinidad, Rio Caño Quebrado and Upper Rio Indio projects, the current costs to the ACP to process finished water ($0.69 per 1,000 gallons), the number of daily lockages demanded, and a project discount rate of 12 percent, the average annual benefits for M&I reliability are $2,460,000. Table 40 - 13 displays the population forecast, the resulting number of equivalent lockages per day, and the benefits for M&I water supply.

Table 40 - 13 Average Annual Reliability Benefits For M&I Water Supply

Year	Population	Equivalent Lockages per Day	Annual M&I Water Supply Benefits ($)
2023	2,294,000	8.15	1,406,000
2030	2,688,000	9.55	1,988,000
2040	3,384,000	12.02	3,290,000
2050	4,259,000	15.13	5,868,000
2060	5,360,000	19.05	10,121,000
2070	6,746,000	23.97	19,913,000
Average Annual Benefits			2,460,000

HYDROPOWER

The amount of hydropower energy that can be produced by the system of Gatun Lake and Madden Lake should decline over time as the demands for navigation and M&I water supply increase. With the inclusion of the Lower Rio Trinidad and Rio Caño Quebrado projects, the system will loose hydropower generation at Gatun Lake and Madden Lake due to the change in the operation of the system. The inclusion of the Upper Rio Indio Dam project, however, will not produce enough additional megawatt hours of hydropower to offset those losses in hydropower generation. Thus, the system will have a net decrease in hydropower production. The value for hydropower energy used in this analysis is $0.070 / kWh. On an average annual basis, the proposed project should lose ($1,206,000). Table 40 - 14 provides the net additional megawatt hours of hydropower generation and the resulting benefits.

Table 40 - 14 Average Annual Benefits For Hydropower Generation

Year	Net Generation [1] (MWh)	Annual Benefits For Hydropower ($)
2023	(17,269)	(1,209,000)
2030	(17,148)	(1,200,000)
2040	(16,936)	(1,186,000)
2050	(17,392)	(1,217,000)
2060	(19,942)	(1,396,000)
2070	(21,921)	(1,534,000)
Average Annual Benefits		(1,206,000)

[1] Net generation of Gatun, Madden, and Indio above generation of Gatun and Madden hydropower plants.

SUMMARY OF ANNUAL BENEFITS

As shown in Table 40 - 15, total average annual benefits for the proposed Lower Rio Trinidad, Rio Caño Quebrado and Upper Rio Indio projects is $186,195,000.

Table 40 - 15 Summary of Annual Benefits

Benefit Category	Average Annual Benefits ($)
Navigation – Water Supply	171,498,000
Navigation – Reliability	13,443,000
M&I - Reliability	2,460,000
Hydropower	(1,206,000)
Total	186,195,000

To perform an analysis of benefits versus costs, a common point in time is selected. This common point is at the completion of filling of the project, the end of the year 2022. In these analyses, it is important to note that the average annual benefits or average annual costs are the amortized value of the sum of the present worth of either the benefits or costs at the point of comparison. The development sequence for the proposed Lower Rio Trinidad and Upper Rio Indio Dam projects would be to develop the Rio Indio Dam project first (2001 – 2010) and then the Lower Rio Trinidad Dam project (2009 – 2022).

The benefits attributable to the proposed Upper Rio Indio project begin to accrue in 2010 when the reservoir is filled. Thus, the Upper Rio Indio project benefits for the period 2011 to 2022 are escalated by the project discount rate, 12 percent, in order to estimate the total present worth of $1,270,111,000, in the year 2022. The average annual benefits for the proposed Upper Rio Indio project would be accrued during the construction of the proposed Lower Rio Trinidad project are estimated at $152,943,000.

To estimate the interest during construction, similar calculations were made for the costs of each proposed project. For the proposed Upper Rio Indio project, interest during construction is taken from year 2001 to year 2022 and the interest during construction for the proposed Lower Rio Trinidad project is taken from the year 2009 to the year 2022.

The sequence of development of the two projects is crucial to the estimate of average annual benefits and costs. If the Lower Rio Trinidad Dam project is developed first, then the average annual costs double in size and the average annual benefits reduce to less than half of the values that are estimated for the development sequence of Upper Rio Indio and then Lower Rio Trinidad. This occurs because the first costs for the Lower Rio Trinidad Dam project are four times the cost for the Upper Rio Indio Dam project ($812M vs. $245M). The estimate of interest during construction changes from approximately $4B to $2B. Likewise, the Upper Rio Indio Dam project provides approximately 80 percent of the total average annual benefits of the combined projects ($212M of $258M). The estimate of benefits for the first project during the period of construction of the other project changes from $150M to $600M.

Total average annual benefits and average annual costs are estimated, and the ratio of benefits to costs and the net benefits (net of costs) computed. In the first instance, the analysis determines the feasibility of the proposal. The net benefits determine which proposal provides the greatest value for the investment dollars. Table 40 - 16 provides the benefit to cost ratio and the net benefits.

Table 40 - 16 Economic Evaluation

Item	Value ($)
Average Annual Benefits	
Lower Rio Trinidad and Caño Quebrado	186,195,000
Rio Indio	152,943,000
Total Average Annual Benefits	339,138000
Average Annual Costs	
Lower Rio Trinidad	178,562,000
Rio Indio	145,451,000
Caño Quebrado	3,362,000
Total Average Annual Costs	327,375,000
Benefit to Cost Ratio	1.04
Net Benefits	11,763,000

Internal Rate of Return

An internal rate of return analysis for this proposed project was performed. To accomplish this analysis, the annual construction costs are used as the investment, and the undiscounted benefits are used as return cash flows. The internal rate of return is 12.5 percent.

Socio-Economic Impacts

The description of the environmental setting is based on field observations made while conducting field reconnaissance throughout Gatun Lake, specifically the Lower Rio Trinidad and Rio Indio areas with ACP personnel. Autoridad Nacional del Ambiente (ANAM), ACP, Asociacion Nacional para la Conservacion de la Naturaleza (ANCON), Electrical Transmission Agency, Smithsonian Tropical Research Institute (STRI), and Directorate of Mineral Resources personnel were interviewed to gain information on site characteristics and potential activities that could affect the project. In addition, extrapolations of the 2000 census data were used, and a review of the Informe de Cobertura Boscosa 1992 were used to determine the extent of forest cover.

Environmental Setting

This alternative combines three projects, the Lower Rio Trinidad (lake level (22.9 - 30.5 meters) with Rio Caño Quebrado (lake level 22.9 - 30.5 meters), and Upper Rio Indio (lake level 50 meters). This Lower Trinidad Dam project will provide additional storage of water for Gatun Lake and 8.32 additional lockages per day on a continual basis. The structures for the proposed project would consist of a rock fill dam, a pumping station, a gated spillway, and access/maintenance roads. The project area consists of 22,397 ha within Gatun Lake and 1,898 hectares within the Rio Indio watershed. The area near Gatun Lake is sparsely populated and has a topography consisting of rolling hills, low regions near Gatun Lake. Near Upper Rio Indio, the area is sparsely populated with a terrain and a topography of steep hills, as well as coastal regions. The Lower Rio Trinidad, Rio Caño Quebrado, and Upper Rio Indio are west of the Panama Canal and flow northward from the Continental Divide. The watershed above the Lower Rio Trinidad with Rio Caño Quebrado and the Upper Rio Indio the dam project covers approximately 1,052 km^2 and 256 km^2 respectively The incremental impoundment area, which covers approximately 6,577 ha, is approximately 50 percent forested land, 30 percent pasture land (used by ranchers), 10 percent cropland, and 10 percent newly slashed and burned land. Gatun Lake's normal pool level is 26.7 meters MSL. The lake level during field observations (August 2001) was approximately 25.4 meters MSL.

LAND USE

The Lower Rio Trinidad project area encompasses the southwestern portion of Gatun Lake and areas along its shores. The areas to be flooded or partially flooded include the town of Escobal (population – 1,653), Nuevo Provenir (population – 121), Cuipo (population – 249), Ciricito (population – 72), La Arenosa (population – 242), La Garterita (population – 138), La Gartera (population – 348), and a few small isolated establishments.

The Rio Caño Quebrado project proposes to maintain the impoundment at pool levels between 22.9 and 30.5 m. The normal pool level is 26.67 m. La Laguna (population 246) and Pueblo Nuevo (population 47) are the only towns on the Rio Caño Quebrado arm. The lake is also used for fishing, bathing, and transportation. Houses in La Laguna and Pueblo Nuevo are constructed of forest products and/or of concrete.

Some areas along the shores of the Lower Rio Trinidad and Rio Caño Quebrado have been deforested. Approximately 65 percent of the lakeshore areas are forested, mostly with secondary growth. Farms and ranches of various sizes, as well as plantations of teak and African mahogany, occupy the remaining land. Farm crops include maize, rice, beans, sugar, coffee, mangos, pineapples, and tobacco. Ranchers raise cows, horses, chickens, hogs, and tilapia. Some of the farmers and ranchers operate commercial enterprises, others rely on cash crops and subsistence farming. No significant ore deposits or mineral resources are located along the Caño Quebrado arm of Gatun Lake.

Approximately 2,300 people inhabits the Upper Rio Indio project area; they live in the towns of Tres Hermanas (population – 200), Los Cedros (population – 80), El Coquillo (popoulation – 150), El Limon (population – 140), Los Uveros (population – 140), and La Boca de Uracillo (population – 110), and in nearly 30 smaller settlements. Downstream from the dam site at El Limon there are 14 communities with a combined population of approximately 600. The largest of these is La Boca del Rio Indio with a population of more than 150.

Farms and ranches of various sizes, including some teak plantations, occupy approximately 60 percent of the land in the Upper Rio Indio area. Farm crops include maize, rice, beans, sugar, coffee, and tobacco. Ranches raise horses, cows, chickens, and hogs. Some of the farmers and ranchers run small commercial enterprises, or rely on cash crop and subsistence farming.

INFRASTRUCTURE

During site investigations in the Lower Rio Trinidad area, the town of Escobal was the largest settlement visited. Escobal has businesses, schools, churches, cemeteries, medical centers, residences, and paved roadways of good condition. A new and improved roadway (Highway 35) is adjacent to the project area near Escobal. Other establishments in the project area Nuevo Provenir; Cuipo; Ciricito; La Arenosa; La Garterita; La Gartera; and a few small isolated establishments have elementary schools, small cemeteries, churches and meeting centers, medical clinics, and a few small businesses (i.e. general stores). The towns and villages depend on Gatun Lake or groundwater wells for their potable water supply. Each community also had docks, small ports, and other boat access facilities. Goods are transported from one town to another by boat. No treatment of community waste is provided. Wastewater from showers and washing is discharged into the environment; some of it may eventually reach the Lower Rio Trinidad portion of Gatun Lake. Disposal of domestic waste is the responsibility of individual homeowners: some homes have septic tanks, while others have an outdoor latrine (a hole in the ground). There are some health problems, such as hepatitis, dysentery, dermatitis, intestinal parasites, and respiratory illnesses that are attributable to the present waste disposal methods. No major industries or meat processing plants are located in the project area. The project area is traversed by unpaved horseback riding trails that link the various communities and by unpaved roads used by the ACP for maintenance. Due to the relatively isolated location of the project area, these roads are extremely important to the residents for transportation, community cohesion, commerce, and communication with neighboring communities.

In the Rio Caño Quebrado project area, La Laguna and Pueblo Nuevo have access to cemeteries, churches, and medical centers, and rely on Gatun Lake or groundwater wells for their drinking water supply. Most homes have electricity and limited telephone service. No treatment of community waste is provided. Wastewater from showers and washing is discharged into the environment; some of it most likely reaches Gatun Lake. Disposal of domestic waste is the responsibility of individual homeowners: some have a septic system or an outdoor latrine. There are some health problems, such as hepatitis, diarrhea, dermatitis, intestinal parasites, and respiratory illnesses that are attributed to the present waste disposal methods. No known major industries or meat processing plants are located in the project area. La Laguna is accessible by a poorly maintained unpaved road that is usable only in the dry season (mid-December through March). The roads are rarely graded and receive little attention from either the Ministry of Public Works or the local government. Pueblo Nuevo is accessible only by an unpaved trail. Due to the relatively isolated location of the project area, these roads and trails are extremely important to the residents for transportation, community cohesion, commerce, and communication with neighboring communities.

In the Upper Rio Indio project area, towns of El Limon, El Silencio, San Cristobal, and Piedra Amarilla have elementary schools. Several towns have cemeteries, churches, and medical centers. All these towns obtain water from rivers or groundwater wells. Some have electricity (from small generators) and limited telephone service. No treatment of community waste is provided. Wastewater from showers and washing is discharged into the environment; some of it might eventually reach Rio Indio and its tributaries. Disposal of domestic waste is the responsibility of individual homeowners; each home has an outdoor latrine. There are some known health problems, such as hepatitis, diarrhea, dermatitis, intestinal parasites, and respiratory illnesses that are attributed to the present waste disposal methods. No known major industries or meat processing plants are located in the project area. The only roads in the project area are unpaved and poorly maintained, and are usable only in the dry season (mid-December through March). The roads are rarely graded and receive little attention from either the Ministry of Public Works or the local government. Due to the relatively isolated location of the project area, these roads are extremely important to the residents for transportation, community cohesion, commerce, and communication with neighboring communities.

TERRESTRIAL HABITAT

The terrestrial habitat in the Lower Rio Trinidad and Rio Caño Quebrado project areas of Gatun Lake consists of tropical forest ecosystems, mostly secondary growth forests with patches of primary forest. About 65 percent of the land along the Lower Rio Trinidad and Rio Caño Quebrado areas of Gatun Lake is forested and probably supports diverse wildlife populations. The Lower Rio Trinidad and Rio Caño Quebrado areas of Gatun Lake also contain islands inhabited by wildlife. Some of the wildlife species do not interact with species on the mainland; others migrate between the island and the mainland. The species interrelationships are of great interest to scientists studying tropical ecosystems. Slash and burn activities have opened tracts of land for farming and cattle grazing; however, the majority of the lakeshore is forested to the edge of the water. Terrestrial areas are used by migratory species as wintering, breeding, and feeding grounds. The complex and diverse tropical ecosystems offer habitat to connect a variety of wildlife communities and may provide critical wildlife habitat to many native species.

In Upper Rio Indio, forests along the river that could support diverse wildlife populations cover about 90 percent of the areas along the Rio Indio and its tributaries. The forests also extend to the mountainous areas above the Rio Indio impoundment. As a result of slash and burn activities, there are no large contiguous tracts of forests at lower elevations in the impoundment.

ANIMALS ON ENDANGERED LIST

ANAM, Resolution 002-80 enacted on June 7, 1995, declared 33 mammals, 39 birds, and 11 reptiles and amphibians are in danger of becoming extinct in Panama. Although their presence has not been confirmed to date, some of the listed species of interest on the threatened list might be found in the project area. The manatee is an aquatic mammal known to inhabit Gatun Lake around the Barro Colorado Island; however, it has not been sighted in the project area.

AQUATIC HABITAT

Gatun Lake, one of the world's largest manmade lakes, was created during the construction of the Panama Canal. The lake's water depth and quality vary widely. Aquatic habitat ranges from inundated forests to clear water in areas distant from shipping lanes. The Lower Rio Trinidad and Rio Caño Quebrado areas of Gatun Lake provide habitat for a variety of wildlife species, both resident and migratory, as well as for both native and introduced fish and other aquatic species.

Rio Indio in the project area has characteristics typical of streams in mountainous regions. Its water is clean and cool, and its bottom ranges from sand to boulders, with numerous riffles, runs, and pools. Tributaries to Rio Indio include four major streams: Rio El Torno, Rio Uracillo, Rio Teria, and Rio Riacito, and 20 smaller streams. The river is approximately 16 km long, its width ranges from 3 m (in the dry season) to 10 m. The tributaries appear to support some fish communities; however, information about these is limited.

WETLANDS

Areas that contain hydric soils and hydrophytic plant communities, and that are subject to hydric conditions are termed wetlands. Wetlands occur in topographic area where water remains pooled long enough to produce hydric soil conditions and wetland plant communities. Wetlands in the Lower Rio Trinidad and Rio Caño Quebrado project areas consist of shallow water habitat and lands subject to frequent flooding. Shallow water areas along the banks of the Lower Rio Trinidad and Rio Caño Quebrado areas of Gatun Lake receive sunlight to approximately 1 m. Sunlight stimulates growth of submergent, emergent, or floating mats of aquatic vegetation. Wetlands in the project area are stressed as a result of sediments, municipal waste, agricultural runoff, and other debris carried in the runoff.

Wetlands in the Rio Indio project area consist of forested riparian habitat and are limited by their relatively steep topography. The width of the riparian habitat within the impoundment area varies from approximately 5 to 50 m. Approximately 90 percent of the streams both above and below the dam site along the Rio Indio and its tributaries are bordered by forested riparian habitat.

AIR QUALITY

Air quality in the project area is generally good, except during the slash and burn activities. At the end of the dry season in March or early April, areas of forest and secondary growth are burned and cleared for agricultural use. During this period, the air is filled with smoke and ash, which may be transported by winds to the Lower Rio Trinidad and Rio Caño Quebrado areas of

Gatun Lake. Based on observations in the Upper Rio Indio project area, approximately 10 percent (or 400 ha) of forested land is burned annually. Air quality monitoring has not been implemented within the project area.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

Barro Colorado Island is an international center for tropical research and one of the first biological reserves established in the Neotropics. From 1923 through 1940, a scientific committee of the U.S. National Academy of Sciences administered the biological reserve/laboratory. In 1940, by an Act of the United States Congress, the facility was renamed the Panama Canal Zone Biological Area, and in 1946, the responsibility for its maintenance was assigned to the Smithsonian Institution. With the Panama Canal Treaty Implementation in 1977, the island was granted the category of National Monument and to date it continues to be managed by the Smithsonian Institute. It should also be noted that most of the Atlantic region of Panama is within the interest and objectives of the Mesoamerican Biological Corridor, an international project to conserve biodiversity.

In the pre-Columbian period, Upper Rio Indio was a language frontier; the inhabitants on each side of the river spoke a different native language. During the Spanish colonial period, the river served as a political boundary; thus, the project area has a high potential to be rich in archaeological and historical remains.

Environmental Impacts

TERRESTRIAL HABITAT

The impacts of the project on terrestrial habitat in the Lower Rio Trinidad and Rio Caño Quebrado areas of Gatun Lake could be substantial. The boundary between two types of habitats, in this case between a forest and a lake, is called an ecotone. Ecotones are inhabited by a variety of species from neighboring habitats, and are unique, with high species diversity. Considering the proposed operating levels for both impoundments, between 22.9 - 30.5 m, as the normal zone of operation, erosion of the shoreline may be substantial as pool levels rise and fall. Terrestrial habitat that would be inundated above the 26.67 m (existing level) to the 30.5 m proposed normal pool level consists of 18,169 ha for the Lower Rio Trinidad project. The permanent raising of the water level in Rio Caño Quebrado Lake will impact wildlife habitat as approximately 2.609 ha of additional land will be inundated. The placement of a dam structure, access roads and pump stations would permanently impact terrestrial habitat. Wildlife species that are able to relocate to suitable areas will compete with similar species for resources. Wildlife species that are not able to relocate will not survive. As a result, competition for natural resources in surrounding habitat areas will increase. This is considered a secondary impact to terrestrial habitat outside the proposed zone of inundation and construction.

The terrestrial impacts of the Upper Rio Indio project, which is located in area of relatively high quality forest habitat, would be substantial. With the creation of the lake, the migratory routes of some species could be adversely affected. Forested areas along lower elevations would be lost as a result of the impoundment. The only forests that would remain near the Rio Indio reservoir and its drainage basin would be confined to the higher elevations, where the vegetation and species may be completely different from those found on lower elevations. Natural communities are linked together by complex interactions and relationships among various species, therefore impacts to upper forested areas may occur resulting from the inundation of the lower forests.

ANIMALS ON ENDANGERED LIST

The severity of impacts on endangered species cannot be determined at this time, because although it is expected that some of the listed species are found in the region, it is not known which of the listed species inhabit the proposed project area. Some endangered and/or threatened species may use the Lower Rio Trinidad and Rio Caño Quebrado areas of Gatun Lake during some or all parts of their life cycle.

WATER QUANTITY

The impacts of the Lower Rio Trinidad and Rio Caño Quebrado projects on water quantity would be substantial. The increase in the volume of water could have negative impacts to lakeshore communities as well as on existing ecosystems. The same is true if the lake level is lowered and maintained at 22.9 m.

The impacts of the Upper Rio Indio project area on water quality would also be substantial. The volume of water will increase, making fresh water available in the surrounding areas during the dry season. The impacts downstream from the dam would be significant. Sediment loads would be deposited upstream from the dam as water velocity slows. Downstream from the dam the water will be released at an increased velocity, causing erosion of banks and river bottoms. Seasonal flooding could be significantly reduced. It would also be possible to periodically release water in appropriate amounts to avoid problems with water quality and temperature downstream. The cumulative impacts downstream from the dam site depend on the amount of water being released.

WATER QUALITY

Project impacts on water quality are not known. Damming the Lower Rio Trinidad and Rio Caño Quebrado could increase the amounts of nutrients and debris in this portion of Gatun Lake. A pilot plant tilapia farm is in the project area and may affect water quality. The rate at which nutrients and debris enter the lake will determine the severity of their impact on water quality. Project implementation could cause an increase in turbidity, which would interfere with photosynthesis and deprive plants and other aquatic species from sunlight. Aquatic plants and organisms serve to maintain water quality. The dam would interfere with the circulation of freshwater throughout the Gatun Lake environment. Species inhabiting specific depths could be impacted when lake depth increases to 30.5 m and/or decreases to 22.9 m.

The impacts of the Upper Rio Indio project on water quality could be positive. The people living downstream from the dam and around the impoundment would have access to a water supply of higher quality. Water quality in the impoundment area would differ from water released downstream from the dam. If the water in the impoundment area does not circulate or turn over periodically, it could become anoxic. A change in temperature, dissolved oxygen, turbidity, or pH could change water quality.

DOWNSTREAM AQUATIC FAUNAL HABITAT

The impacts of the project on aquatic faunal habitat could be substantial. The project may affect the breeding and nursery habitat of many aquatic species. Impacts on fish spawning areas may be detrimental when turbidity, nutrient content, and depth of the water suddenly increase or decrease, by altering the conditions needed for successful fish hatching. Plant populations may decrease as a result of fluctuating water depths, clarity, and quality. Invertebrate populations may decline, which could reduce the food supply for fish and other aquatic species.

Impacts to downstream aquatic faunal communities in the Upper Rio Indio project area could be substantial, because the dam structure will prevent their migration throughout the riverine habitat. The dam structure would be designed for multi-level releases to maintain a water level downstream from the dam site. The dam should act as a large sediment trap; thus, the released water would have low turbidity, which would result in better visibility and increased predation on the fish species. Aquatic faunal habitats downstream would be deprived of the beneficial nutrients and silts that were transported in the sediment. Native riverine fish species may be negatively impacted as a result of the project; the extent of the impact is not known.

FUTURE LAKE AQUATIC PLANT COMMUNITY

The impacts of the project on future aquatic plant communities depend on water quality and stability of water levels. Plant species in the Lower Rio Trinidad and Rio Caño Quebrado portions of Gatun Lake could be impacted by fluctuating water levels. Aquatic plant communities could be impacted during project implementation; however, they could re-establish themselves after conditions stabilize.

The severity of impacts from the Upper Rio Indio project will depend on water level fluctuations. Since water levels are anticipated to fluctuate widely, large portions of the shores would be covered with mud, where neither aquatic nor terrestrial plants could thrive.

AQUATIC FAUNA INHABITING AFFECTED AREAS

The proposed project impacts could have some unavoidable, adverse environmental impacts on aquatic fauna in the Lower Rio Trinidad, Rio Caño Quebrado, and associated rivers and tributaries. These impacts should be identified and minimized with appropriate mitigation measures to be discussed in a feasibility level study. Gatun Lake has populations of peacock bass and tilapia, both introduced species that have adapted well. However, several native riverine species that formerly occupied the impoundment have disappeared.

The impacts of the Upper Rio Indio project on aquatic fauna in the Rio Indio and its upstream tributaries could be substantial, since the habitat area would change from riverine to lacustrine. Some aquatic species would continue to inhabit the area; however, non-native fish species could become dominant in the impoundment area and native riverine species could be pushed upstream or extirpated. Other manmade lakes in the Republic of Panama have been stocked with peacock bass and tilapia, both of which have adapted well. The impoundment area would probably be stocked with these species to promote sport fishing and to provide the local communities with fish for food.

WETLANDS

The impacts to wetlands could be significant. Inundation of wetlands could cause them to become aquatic habitats. The changes in water depth caused by the project may lead to increased or decreased sedimentation and turbidity, which could hamper the biological processes in the wetlands and decrease their productivity. Such impacts could be detrimental to the health and sustainability of the Lower Rio Trinidad and Rio Caño Quebrado areas of Gatun Lake. Fish and other aquatic species use shallow water areas as spawning grounds, as well as habitat for their juvenile aquatic species that survive in the shallow waters of the wetlands until they are large enough to venture into deeper water. These wetlands are vital to the sustainability of this portion of Gatun Lake, including the Lower Rio Trinidad and Rio Caño Quebrado areas.

The impacts to wetlands both upstream and downstream from the Upper Rio Indio project area could be significant. Owing to the topography of the project area, a number of wetlands could be impacted. It is possible that although the reservoir level will fluctuate, new wetlands could develop in the littoral zones. Downstream from the dam site, wetlands along the minimal flow zone would survive; however, wetlands that depend on seasonal flooding for survival may be adversely affected.

AIR QUALITY

During project implementation, emissions from construction equipment, as well as from the slash and burn activities, could cause deterioration of air quality. After project implementation, the air quality may be impacted by the operation of the pumping stations.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

The potential impacts on cultural resources and historic properties from the Upper Rio Indio project can be defined and mitigated, in particular, in the La Boca de Uracillo area, which is near previously identified archaeological sites. The project area is relatively large and is known to contain pre-Columbian sites; therefore, the presence of cultural resources and historic properties is highly probable. Prior to construction, surveys to locate cultural resources and historic properties would be conducted, and the important sites would be preserved or salvaged as appropriate.

SOCIO-ECONOMIC IMPACTS

The socio-economic impacts of the project could be substantial. The relocation of the towns and other small communities along the lakeshore would be an important issue. The average monthly income of families in the project area ranges from less than \$100 to \$200 per month. No indigenous groups are known to reside in the impact area. Land use would be greatly altered by the inundation of pastures and agricultural lands to expand the impoundment. The relocation of agricultural and ranching activities would be an important issue, because approximately 10 percent of the land in the impoundment area is used for farming and ranching. After the water level is raised, additional agricultural land could be lost as a result of creation of islands that were once isthmuses. The incremental surface area of the proposed lake is 6,577 ha; another 1,219 ha from the Lower Trinidad and Rio Caño Quebrado projects, and

634 ha from the Upper Rio Indio project will be occupied by the dam and construction areas, including permanent disposal areas.

During construction, the influx of workers could create a temporary demand for additional housing, which could result in an increase in housing values near the dam site. However, after completion of the project, the workers could leave, the housing demands could drop, and the housing values could return to pre-construction levels. Currently, all residents have access to public schools and health centers. During construction, these services should continue to be available, and additional public and community services may be offered. After construction, these services would return to the normal level.

Constructing the dam would require some existing roads to be improved and some new roads to be built. However, some paved and unpaved roads within the impoundment area would be eliminated, which would change traffic patterns and could cause some communities to lose overland transportation, communication, cohesion, and commerce with other communities. During construction, the traffic volumes over both new and existing roads systems would increase; however, following completion of construction, the traffic volumes could decline. Noise levels would temporarily increase during construction and could negatively impact noise-sensitive receptors, however, after construction noise levels may remain elevated as a result of the power generation facility and pump stations.

The communities that receive people displaced by the project could be negatively impacted by overcrowding and by competition for jobs, land, and working areas. Construction of the dams would permanently displace people and disrupt community cohesion through the division of communities, separation of families, and loss of livelihood. Following completion of the impoundment, tourism trade in the affected region, including sport fishing and ecotourism, could increase.

Additional Environmental Information Required

This section identifies the subject areas for which additional data are required to evaluate in further detail, the scope and magnitude of the potential effects of the Lower Rio Trinidad, Rio Caño Quebrado, and Upper Rio Indio alternative. The subject areas are discussed by impact category.

SOCIO-ECONOMIC IMPACTS

Conduct a SIA. The SIA would consist of three tasks; scoping, assessment, mitigation and monitoring. The following information should be developed:

- Business, Industrial, and Agricultural Activities;
- Employment;
- Land Use;
- Property Values;
- Public and Community Facilities and Services (including utilities and schools);
- Transportation;
- Housing;
- Health (vector routes);
- Population;

- Community Cohesion; and,
- Recreational Resources.

TERRESTRIAL AND AQUATIC HABITAT

- Prepare site-specific habitat maps to ensure the major types of aquatic habitat are identified and quantified.
- Conduct field studies to locate rare and unique habitats, such as wetlands, primary forests, roosting sites, foraging areas, old growth, and migration flyways.
- Determine the present quality and ecosystem value of existing habitats within the Gatun Lake project area.
- Coordinate with local experts to identify and evaluate aquatic and terrestrial habitat areas.
- Prepare species inventory lists for each site area, identifying their status as native or exotic species, and whether they are threatened and or endangered species.
- Conduct additional research into water currents and estimated turbidity levels to evaluate impacts to the shallow areas along Barro Colorado Island.
- Address cumulative effects caused by natural flow diversions.

ANIMALS ON THE ENDANGERED LIST

- Compile habitat maps to assess the availability and quality of suitable habitats for the animals on the endangered and/or threatened species list.
- Establish field methodology to assess wildlife habitat values.
- Conduct site surveys to determine the presence of selected species or their habitats.
- Develop candidate mitigation measures for the appropriate project alternatives to be considered in the Conceptual Phase.
- Coordinate with local experts on the presence of endangered species.

WATER QUALITY

- Since limited water quality data are available for the Gatun Lake area, compile information on total suspended solids, conductivity, total dissolved solids, dissolved oxygen, nutrients, pH, and coliform bacteria.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

- Information regarding cultural resources and historic properties in the project area is incomplete. Additional evaluation studies should be completed to identify any such resources and/or properties.

Evaluation Matrices

In accordance with evaluation procedures described in Volume One, the following tables reflect the conclusions derived for this alternative. A summary table with ranking is provided in Volume

One. Tables 40 - 17 through 40 – 19 present the evaluation of the proposed Lower Rio Trinidad project as related to developmental effects, environmental effects, and socio-economic effects.

Table 40 - 17 Developmental Effects

Evaluation Criteria	Function	Measure [1/]	Importance [2/]	Composite [3/]
Water Contribution (Water Yield)	Meets M&I Demands	8	10	80
	Supplements Existing System	0	10	0
	Satisfies Future Canal Needs/Expansion	0	10	0
	Additional Hydropower Potential	0	5	0
Technical Viability	Design Constraints	2	6	12
	Feasibility of Concept	2	6	12
Operational Issues	Compatibility	8	6	48
	Maintenance Requirements	4	2	8
	Operational Resources Required	4	2	8
Economic Feasibility	Net Benefits	1	9	9
	Total			177

[1/] Measure - A numerical from 0 to 10 value representing the degree or level the alternative satisfies the criteria. Value of 10 indicates the most significant beneficial impact and 0 the most significant adverse impact.
[2/] Importance - A weighting factor from 0 to 10 to balance the significance of a criteria to the others.
[3/] Composite - the product of the measure and importance.

Table 40 - 18 Environmental Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Terrestrial Habitat	2	8	16
Animals on Extinction List	2	10	20
Water Quantity Impacts – Lake	8	10	80
Water Quantity Impacts -- Downstream	4	7	28
Water Quality	5	10	50
Downstream Aquatic Fauna Habitat	3	8	24
Future Lake Aquatic Plant Community	6	8	48
Aquatic Faunal Inhabiting Affected Area and Upstream Tributaries	4	5	20
Potential for Fishing on Lake	6	6	36
Wetlands	3	4	12
Air Quality	5	3	15
Cultural Resources and Historic Properties	3	10	30
Total			379

[1/] Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
[2/] Importance - 1 to 10 increasing in importance.
[3/] Composite - the product of the measure and importance.

Table 40 - 19 Socio-Economic Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Land Use	2	7	14
Relocation of People	1	10	10
Relocation of Agricultural/Ranching Activities	1	6	6
Post-Construction Business	6	5	30
Post-Construction on Existing Employment	6	5	30
Property Values During Construction	7	4	28
Property Values Post-Construction	5	5	25
Public/Community Services During Construction	6	4	24
Public/Community Services Post-Construction	5	8	40
Traffic Volumes over Existing Roadway System During Construction	3	5	15
Traffic Volumes over New Roadway System Post-Construction	5	5	25
Noise-Sensitive Resources or Activities	4	4	16
Communities Receiving Displaced People	1	8	8
Community Cohesion	1	8	8
Tourism	6	5	30
Total			309

[1/] Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
[2/] Importance - 1 to 10 increasing in importance.
[3/] Composite - the product of the measure and importance.

Pertinent Data

Table 40 - 20 presents pertinent data for the proposed Lower Rio Trinidad project.

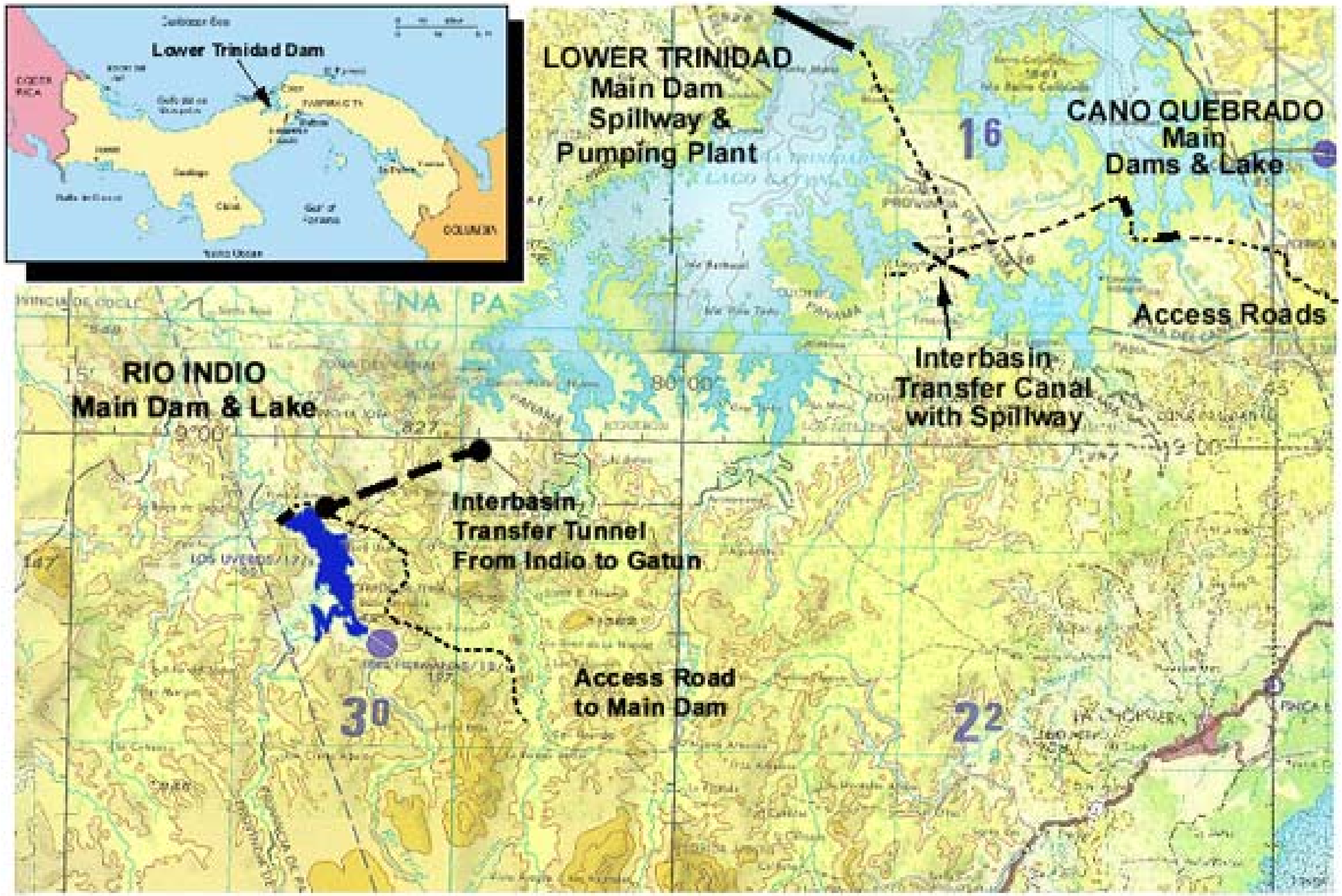
Table 40 - 20 Pertinent Data for Operating Scenario 5

GENERAL	**Gatun**	**Trinidad and Quebrado**	**Indio**
Dam Site, above Gatun Dam		10 km	
Drainage Area above Dam Site	1,261.5 km^2	1,051.5 km^2	256 km^2
Average Annual Flow at Dam Site	50.4 CMS	39.6 CMS	16.8 CMS
LAKE			
EL. of Maximum Operating Lake Level	26.67 m MSL	30.48 m MSL	50.0 m MSL
EL. of Maximum Flood Storage Lake Level	26.74 m MSL	31.09 m MSL	53.0 m MSL
EL. of Minimum Operating Lake Level	25.91 m MSL	22.86 m MSL	45.5 m MSL
Useable Storage between Max. and Min. levels	200.4 MCM	1286.5 MCM	35.6 MCM
Area at Maximum Operating Lake Level	27,514 ha	20,778 ha	2,134 ha
Area at Maximum Flood Storage Lake Level	27,550 ha	21,597 ha	2,218 ha
Area at Minimum Operating Lake Level	27,321 ha	10,170 ha	732 ha
Top Clearing EL.	30.5 m MSL	30.48 m MSL	50 m MSL
Lower Clearing EL.	22.9 m MSL	22.86 m MSL	45 m MSL
EMBANKMENTS			
Dam – Rock Fill Embankment			
Top EL. of Dam	32 m MSL	31.5 m MSL	53m MSL
Fixed Crest Width	13m	13m	13m
Height above Lowest Foundation	15m	25 m	38.5m
Overall Length of Dam	varies m	4473 m/404 m	632m
SPILLWAY			
Type of Spillway	Gated Ogee	Gated Ogee	Uncontrolled Ogee
Number of Gates	14	11	-
Width of Gates	13.72 m	18.33 m	-
Net Length	192.02 m	201.2 m	-
Total Length	246.27 m	238 m	113 m
EL. of Crest	21.03 m MSL	25.91 m MSL	50.0 m MSL
Maximum Discharge	5150 CMS	6038 CMS	618 CMS

INDIO ONLY	
INTER-BASIN TRANSFER TUNNEL	
Tunnel diameter	4.5 m
Tunnel length	7651 m
Inlet invert	45.5 m MSL
Outlet invert	40 m MSL
Tunnel capacity	37.9 CMS
HYDROPOWER PLANTS	
Dam	
Type of hydropower plant construction	Reinforced concrete
Number of units	1
Capacity of each unit	5 MW
Inter-basin Transfer Tunnel	
Type of hydropower plant construction	Reinforced concrete
Number of units	1
Capacity of unit	2 MW
CONSTRUCTION / POWERHOUSE DIVERSION	
Diversion length	800 m
Tunnel diameter	7 m
Inlet invert	12 m
Outlet invert	10 m
MINIMUM FLOW CONDUIT	
Conduit diameter	600 mm
Conduit length	800 m
Inlet invert	12 m
Outlet invert	10 m
Conduit capacity	1.7 CMS
EMBANKMENTS	
Dam	
Type of dam	Rock fill embankment
Top EL. of dam	53 m
Fixed crest width	13 m
Height	38.5 m
Overall length of dam	632m

Plate 40 - 1 Project Location Map

LOWER TRINIDAD / CAÑO QUEBRADO / UPPER RIO INDIO



Project Location Map

SECTION 41

Lower Rio Trinidad 22.9m to 33.5m
Rio Caño Quebrado 22.9m to 33.5m

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

Synopsis

The development plan presented herein combines a dam and a lake in the Trinidad basin, within the Panama Canal watershed at Gatun Lake, southwest of Gatun Locks, and a dam and lake on the Rio Caño Quebrado basin of the Panama Canal watershed, within Gatun Lake. Water impounded in the Lower Rio Trinidad and Rio Caño Quebrado Lakes should add storage up to EL. 30.48 m MSL. This additional storage is further enhanced by incorporation of a pumping plant into the Lower Rio Trinidad Dam. This facility allows storage of excess water from Gatun Lake and extends the usage of waters contained in the Lower Rio Trinidad and Cano Quebrado Lakes.

The Rio Trinidad watershed is located on the western side of the Panama Canal watershed. The proposed dam site is located within Gatun Lake across the Trinidad arm near the town of Escobal. The proposed dam extends from Punta Mala, on the west shore of Gatun Lake, to Guacha Island, then across to the eastern shore of the Trinidad arm, just south of the South Range Point lighthouse. This alignment follows closely the proposed path found in the Study and Report on Increasing the Water Supply of the Panama Canal (referred to as the Tudor Report), prepared by Tudor Engineering Company, San Francisco, California 1962, for the Panama Canal Company. Plate 41 - 1 shows the location of the proposed Lower Rio Trinidad Dam project. The structures for the proposed Lower Rio Trinidad project consist of a rock fill dam constructed by underwater deposition of fill materials, a large pumping plant, and a gated spillway. This spillway should have 11 gate bays, each measuring 18.33 m wide. The pumping plant consists of the pumping station; intake and outflow facilities are separated from the lakes above and below the Lower Rio Trinidad dam by large gate structures. The total project first costs of the proposed Lower Rio Trinidad project are estimated at $1,038,765,000.

The Rio Caño Quebrado watershed comprises a portion of the western side of the Panama Canal watershed. The proposed dam site is located within Gatun Lake across the Rio Caño Quebrado arm near the city of La Laguna and would be constructed in two parts. The first section of the dam extends from Punta Manguito on the west shore of the Rio Caño Quebrado arm of Gatun Lake to the eastern shore of the Rio Caño Quebrado arm. The second section extends across the Rio Caño Quebrado eastern arm just north of the mouth of the Rio Paja. The lake formed by these dams can be communicate directly with Lower Rio Trinidad Lake at all operational levels. Plate 41 - 1 shows the location of the Rio Caño Quebrado Dam project. The features required for the Rio Caño Quebrado project are the two sections of rock fill dam and a dug channel connecting Rio Caño Quebrado and Lower Rio Trinidad Lakes. The total project first costs of the proposed Rio Caño Quebrado project are estimated at $23,596,000.

The Lower Rio Trinidad poses great construction difficulties because of the extremely large quantities of underwater fill required for construction of the dam. It requires extensive drilling and site investigation prior to construction and, because of the uncertainties inherent with this type of construction; extensive unforeseen costs may be encountered during construction. Also, the spillway and pumping plant must be constructed in island settings where the structures and appurtenances practically engulf the island areas. This poses extreme space limitations on the construction effort and is very costly.

The proposed Lower Rio Trinidad and Rio Caño Quebrado Dam projects, can contribute greatly to the hydrologic reliability of the Panama Canal to serve its customers and should help to reduce the need for imposing draft restrictions and resulting light loading of vessels during traditional periods of low water availability. The existing hydrologic reliability of the Panama Canal, based on the period of record from January 1948 through July 1998 and current demands (38.68 lockages), is approximately 99.6 percent. The hydrologic reliability with the demand increasing to 120 percent of the current level (46.42 lockage) would be 98.8 percent. With construction of the proposed Lower Rio Trinidad and Rio Caño Quebrado, the existing high hydrologic reliability could be continued as demand for lockages increases up to 31.4 percent above current demand levels (up to 12.16 lockages).

Site Selection

Project definition and description developed with a view toward maximizing the water impounded, while minimizing the volume of material required for construction of the dam and minimizing the number of saddle dams required to contain the lake.

The site chosen for the proposed Lower Rio Trinidad Dam is 10 km south of Gatun Locks and 14 km southwest of the navigation channel. The dam would be 4 km northeast the town of Escobal. This site can accommodate construction of a dam with a maximum operating lake level at EL. 30.5 m MSL. Flood storage accommodations are between EL. 30.5 and 28.7 m MSL.

The proposed Rio Caño Quebrado dam project definition and description developed with a view toward maximizing the water impounded, while minimizing the volume of material required for construction of the dam and minimizing the number of saddle dams required to contain the lake.

The site chosen for the proposed Rio Caño Quebrado Dam is approximately 22 km southeast of Gatun Locks and 14 km northwest of the Pedro Miguel Locks. The dam would be approximately 7 km southwest of Barro Colorado Island and 4 km northeast of the town of La Laguna. This site can accommodate construction of a dam with a maximum operating lake level at EL. 30.5 m MSL. Flood storage accommodations are available above the normal operating levels, between EL. 30.5 and 24.8 m MSL.

Hydrologic Considerations

Lower Rio Trinidad

The Rio Trinidad flows northward from the Continental Divide to the Gatun Lake. The headwater of the watershed begins at EL. 1,000 m MSL, approximately 75 km inland and falls to 26 m MSL at Gatun Lake. The distribution of the average annual rainfall over the Rio Trinidad watershed varies from a high of 2,200 mm in the western part of the watershed to 2,000 mm on the eastern side of the watershed. The proposed Lower Rio Trinidad Lake receives runoff from approximately 750 km^2 of the upper portion of the watershed. Rainfall runoff produces an average annual flow of 32 CMS at the proposed dam site.

The discharge rate at the Lower Rio Trinidad and Rio Caño Quebrado dam sites are obtained by observing the drainage area ratio established for Gatun. The Gatun Lake runoff is based on records developed by the U.S. Army Corps of Engineers Hydrologic Engineering Center and the ACP in a separate study.

Since the Lower Rio Trinidad and Rio Caño Quebrado Lakes are located within Gatun Lake the monthly evaporation rates established for Gatun Lake are considered appropriate for the evaporation rates of Trinidad and Rio Caño Quebrado Lakes.

Rio Caño Quebrado

Three major rivers flow into Rio Caño Quebrado Lake; Rio Caño , Rio Paja and Rio Los Hules. All three rivers flow northward from the Continental Divide to Gatun Lake. The headwaters of the watershed begin at EL. 1,000 m MSL, approximately 75 km inland, and fall to EL. 26 m MSL at Gatun Lake. The distribution of the average annual rainfall over the Rio Caño Quebrado watershed varies from 2,200 mm in the western part of the watershed to 2,000 mm on the eastern side. The proposed Rio Caño Quebrado Lake receives runoff from approximately 310 km^2 of the existing Panama Canal watershed. Rainfall runoff produces an average annual flow of 10.2 CMS at the proposed dam site.

Geologic Considerations

Rio Trinidad

The proposed Lower Rio Trinidad Dam site was investigated in 1962 by Geo-Recon, Inc. of Seattle, Washington, as part of the Tudor report. The investigation consisted of seismic velocity and electrical resistivity profiles in conjunction with four test borings (all located in the lake and drilled by the Panama Canal Company). The results of the geophysical surveys reportedly compared well with the logs of the test borings in the deep-water areas (up to 23 m deep) of Gatun Lake. In June 1963, Tudor Engineering submitted a report including additional foundation investigations. The foundation investigations were made by the firm Shannon & Wilson, Inc., Soil Mechanics and Foundation Engineers, from Seattle, Washington, and consisted of 77 cone penetrometer borings, 24 classification borings, 11 undisturbed sample borings, and 6 field vane shear borings. The investigations submitted by Shannon & Wilson, Inc were recently reanalyzed in Geology of the Proposed Dam Across Trinidad Arm of Gatun Lake, by Mr. Pastora Franceschi S., for the Geotechnical Section of the Panama Canal Authority.

In the lake areas, the investigations disclosed that overburden material included recent lake deposits, Atlantic Muck Formation, alluvial deposits, and residual deposits. Between the west shore and Guacha Island these deposits consist of soft to very soft clay, silt, sand and peat (Atlantic Muck Formation) overlying soft to hard deposits of clay, silt, sand and gravel derived both from alluvial deposition and the weathering of bedrock. The upper two phases of the Atlantic Muck Formation, judged to be the most compressible portion of the formation, was found to have an average thickness of about 18.3 m and a maximum thickness of 22.9 m. Recent, soft lake deposits ranging from 1.2 to 2.4 m thick were found overlying the Atlantic Muck Formation. In the length between Guacha Island and Tern Island, the Atlantic Muck Formation was either not found, or was very thin. In this area, Recent-aged soft sediments (averaging 2 m thick) were found to overlay residual soil and weathered rock. Atlantic Muck Formation, where present, occurred between the Recent-aged material and the residual soil, and was a maximum 5 m thick. Between Tern Island and the east mainland, only recent lake sediments (1.5 m thick) overlying residual clay were found above the conglomerate of the Bohio Formation.

Guacha, Tern and Booby Islands, all located within Gatun Lake, were each found to have an overlying stratum of soft overburdened and weathered rock of variable thickness. In general, firm bedrock was found available below EL. 22.9 m MSL and the islands were judged to offer suitable foundation conditions for control structures.

Firm bedrock under both the land and the lake was found to consist of low velocity sedimentary rock composed primarily of sandstone and the Bohio Formation. Two areas containing abrupt changes in bedrock velocities were located during the survey. One of the areas was a narrow zone located on Guacha Island that was interpreted as a possible shear zone in rock of similar type. The second area was an abrupt change in bedrock velocity on Tern Island that was interpreted as a possible fault contact between two formations, or between different lithologic units of the same formation. The top of the bedrock on land was interpreted from the geophysical results to be weathered to below lake level. The core borings in the lake determined the weathered zone of bedrock to range from 1.2 to 3.1 m in thickness.

Satisfactory foundation conditions exist for construction of a pumping station, and a spillway at the Lower Rio Trinidad Dam site. Serious consideration, however, must be given to problems that would be caused by the anticipated settlement and instability of the embankment materials. Additionally, it is assumed that all concrete aggregates may be obtained from commercial sources.

Rio Caño Quebrado
The main dam portion of the proposed Rio Caño Quebrado project is located in an area where volcanic rocks of the Tucue Formation are encountered at the surface. The rocks of the Tucue Formation consist of lava flows, breccias, tuffs and plugs, and are andesitic or basaltic in nature. These rocks show a wide variation in quality, from high quality extrusive lava flows, to weathered and lesser quality volcanic tuffs. It is anticipated most of the strata of the Tucue Formation should make satisfactory rock fill for a dam, but a significant amount may not be satisfactory for concrete aggregate. Volcanic rocks of the Tucue Formation may also contain constituents that are reactive with alkalies found in cement. Neither weathered rock nor rock with reactive materials would be satisfactory for concrete aggregate. It is recommended that cores be drilled early during the planning studies to determine general depths of weathering and to determine the suitability of the rock for use as concrete aggregate.

Oligocene-aged sedimentary rocks of the Caimito Formation underlie the inter-basin transfer basin canal and spillway portions of the project. Three members of the Caimito Formation are recognized; the lower, middle and upper. The deposits of each of these members are mainly marine, but they are lithologically heterogeneous. The lower member is composed of conglomerate and tuffaceous sandstone. The middle member consists chiefly of tuffaceous sandstone, some of which is calcareous, and lenticular limestone. The upper, principal member consists of tuff, agglomeratic tuff, tuffaceous siltstone, and discontinuous sandy tuffaceous limestone. In general, the rocks of all members are hard, thinly to thickly bedded, and closely to moderately jointed. It is not known which member of the Caimito Formation underlies the project area. It is considered that it should make an acceptable foundation for the canal and spillway. The Caimito Formation would be unacceptable for use as concrete aggregate and may be only marginally acceptable for use as fill in an earth and rock fill dam.

In the absence of detailed geologic mapping for the proposed Rio Caño Quebrado project, a degree of extrapolation is necessary. It is predicted that rock at the proposed construction locations outside the lake would be encountered at a shallow depth and would be of sufficient quality to serve as foundation for the appurtenant structures.

Lake Operation

Two operating mechanisms are included in this study for periods when water would be transferred from Lower Rio Trinidad Lake to Gatun Lake for canal operations. Water impounded in the Rio Caño Quebrado Lake would be transmitted to Gatun Lake via the Lower Rio Trinidad facilities. The first consists of allowing the water surface of the Lower Rio Trinidad and Rio Caño Quebrado lakes to fluctuate from the normal operating lake level at EL. 33.53 m MSL down to the minimum operating lake level at Gatun Lake, EL. 26.43 m MSL providing 1,728 MCM of useable storage. Thereafter, the Lower Rio Trinidad Lake can be drawn down by pumping, allowing further fluctuation from the normal minimum Gatun operating lake level at EL. 25.91 m MSL, the minimum Lower Rio Trinidad Lake level, EL. 22.86 m MSL. This provides an additional 496 MCM of usable storage. The maximum flood level at Lower Rio Trinidad Lake is at EL. 34.14 m MSL. Flood storage accommodation are between EL. 22.86 and 34.14 m MSL. Trinidad Lake rule curve was designed to function similar to the rule curve for Madden Lake. Table 41-1 shows the lake levels for the two affected pools.

Table 41 - 1 Lake Operating Levels

Lake Level (m MSL)	Lower Rio Trinidad And Rio Caño Quebrado	Gatun
Normal Operating Lake Level	33.53	26.67
Minimum Operating Lake Level	22.86	25.91
Maximum Flood Lake Level	34.14	27.13

Project Features

GENERAL

The structures for the proposed Lower Rio Trinidad project would consist of a rock fill dam, a large pumping plant, and a gated spillway. Modification of one existing saddle dam and construction of two additional saddle dams is also required. The following paragraphs provide a description of the proposed structures and improvements for the Lower Rio Trinidad Lake project. Plate 41-1 shows the dam site in downstream left bank perspective and indicates the location of the spillway.The structures for the proposed Rio Caño Quebrado project consists of a rock fill dam in two distinct sections, and a dug channel connecting Rio Caño Quebrado Lake to Lower Rio Trinidad Lake at lower pool levels. The following paragraphs provide a description of the proposed structures and improvements for the Rio Caño Quebrado Lake project. Plate 41-1 depicts the location of the dam and the gated spillway.

Design is performed only to the extent necessary to establish, with reasonable accuracy, the principal dimensions, elevations, and costs of the proposed project. Separate documentation was provided to the ACP containing assumptions and design calculations for the reconnaissance level investigations of these structures. If this project is carried into the planning studies, optimization of the project features and improvements must be accomplished.

EMBANKMENTS

Lower Rio Trinidad Dam

The proposed dam consists of an embankment with the top at EL. 31.50 m MSL and with a crest width of 13 m with a final crest of 7 m upon completion of all settlement of the embankment and bridge work. The left abutment of the embankment will be located at Universal Transverse Mercator Grid, Zone 17, Clark 1866 Spheroid Coordinates 1015858 north and 614864 east. The right abutment will be 1013937 north and 618229 east coordinates. The normal lake El. 30.48 m MSL while the ground surface elevations along the axis of the dam vary from El. 2 m MSL in the lake bottom to El. 39 m MSL on Guacho Island and El. 38 m MSL on Tern Island. The Gatun Lake subgrade supporting the embankment occupies a broad flat valley having sides, which slope, upward from the valley at grades up to 40 percent. Water depths are 21.3 to 26.3 m over 80 percent of the site. The Atlantic Muck Formation, consisting of very soft organic clays, silts and peats varying in thickness from 7.6 m to 48.7 m, underlies approximately two thirds of the alignment subgrade. The Atlantic Muck Formation in the old river channel is further underlain by soft silts, sand and clay strata.

The critical challenge for design espoused by the Tudor Report and others is the depth of subgrade degradation during the initial fill placements. The materials will lose much of its natural strength when disturbed and will only regain strength after the effects of consolidation of a surcharge fill. However, complete restoration of strength can only be assumed to a depth of 5 to 7 m. If the effects of the subgrade disturbance extend appreciably deeper, then an extremely weak material will be under the more stable subgrade and surcharge creating a condition of lateral instability.

Because of the inability to accurately analyze this condition, a test fill was performed on the western end of the alignment. In early 1963, 1,000-cy bottom-dump barges deposited some 168,000 cy of blasted rock from the cut widening project, extending some 305 m. 155 m of the fill was placed to a height of 11 m while the remaining 150 m was filled to 5 m. The differential heights were use to simulate initial and intermediate fill placement effects. Divers were then used to observe the performance of the fills placed along the alignment. The mechanisms of failure within the subgrade were caused by impact and static loadings. The impact of the initial placements caused severe destruction of the surface materials creating lateral displacements up to 5 m. However, when a continuous blanket of fill had been established and subsequent fill was placed, then conventional failures such as slip circle shear failures and horizontal shears creating large mud waves outward from embankment were observed. Therefore, to predict the behavior of the embankment during construction and for the long term, it is imperative that a foundation mat be established to such a depth to prevent subgrade rupture with subsequent fill placement. The Tudor report recommended that a 5 m thick minimum crushed rock blanket with maximum sizes of 20 cm be placed initially to act as the supporting blanket. Special barge dumping methods were to be employed so loads would not fall as an integral mass, which would create destructive forces on the subgrade.

The placement of a large hydraulic structure on a deep-seated weak foundation is the most challenging of geotechnical endeavors. It is virtually impossible to analyze with great deal of certainty and the owner must be prepared to accept possible additional costs during construction and long term maintenance due to the potential for lateral instabilities and high degrees of settlement. The Tudor Report has predicted some 2.5 to 3 m of predicted settlement below the crest elevation for a construction duration of 7-years and an additional 2.5 to 3 m of maximum settlement below the crest for the 50-year service life of the project. These settlements are predicted where the Atlantic Muck and underlying compressible materials are the thickest. These movements are reduced as the fill approaches the mainlands and the two islands. This implies that significant differential settlements are predicted within these approaches as well. The key to any successful construction and maintenance of this embankment will be to establish a blanket mat atop the subgrade where subsequent fill can be economically placed without fear of rupturing the foundation to greater depths. Any significant lateral failure of the embankment during construction or productive use will render that alignment unsuitable. Additional embankment sections must be established upstream or downstream to reestablish the embankment section to the proper elevation. This repair will take considerable time and prevent its use as a road. Based on these considerations, our recommendations were presented for ultimate costs considerations in comparison to alternatives with a greater degree of performance certainty.

The divers observed that the test fill had trouble placing the fill in the correct locations within the alignment and the lift thickness varied significantly over the fill cross section. It is imperative that the blanket fill be placed intact with the least subgrade disturbance in order for the embankment to act as monolithic mass. Therefore, the initial 5 m of fill will be barged to the site and placed by lowering a clamshell to the subgrade surface. The positioning of the barges must be strictly controlled by survey positioning systems established on land. The initial fill should have a maximum size of 20 cm and the percent fines should be controlled to remain fairly intact during placement. Materials with a significant size differential and a large fine content can create weak shear zones with the embankment. The subsequent fill materials above this zone can be placed by bottom dumped barges or clamshells from El. 8 to 21 m MSL. The material above El. 21 m MSL must be placed by clamshell due to the draft and door operations of the barges. These materials will be more random in gradation having a maximum size of 30 cm and a greater degree of fines. The materials placed below El. 27 m MSL will assume a side slope of 1 V:15 H. A 15 m berm will be constructed and the materials will continue to be placed by clam shell and spread with a dozer to El. 34.5 m MSL, assuming a side slope of 1 V : 3 H and a crest width of 13 m. The flatter side slopes are needed to distribute bearing pressures and to reduce the lateral displacements. This configuration should also reduce the construction and total settlements predicted by the Tudor report and provide acceptable factors of safety for lateral stability during fill placement. The side slope berms and extra crest width will facilitate the future fill placements of up to 3 m over the life of the project. The road surface atop the dam embankment will remain gravel surfaced for the foreseeable future due to future fill placements. The dam will be approximately 30 m high, and the overall length 4,473 m. The top of the dam will be 5 m above the normal Gatun Lake level. The total volume of fill material required to construct and maintain the main dam to El. 34.5 m MSL is approximately 39,883,250 M^3. Water access from the main channel to Guacha and Tern Islands will be built during construction. After access roads have been constructed, fill placements from the east mainland to Tern and Gaucha Islands could be delivered by truck and placed by end-dumping from the east mainland. This technique could prove beneficial if a material source was found near the Gatun Lock area. The side slopes and overall embankment configuration was offered for ease of calculation, to reduce the foundation pressure on the soft subgrade and to account for the lateral displacement of embankment materials. The increased foundation base should help the structure survive a relatively minor seismic event.

The methods of subgrade stabilization and embankment strengthening offered in the powerpoint presentations from the ACP Engineering Division are examples of many ideas for enhancing the performance of the embankment during construction and post construction. The use of wick drains have been an effective tool for accelerating consolidations under a mass loading. However, we feel that the Atlantic Muck materials will not readily transmit water to the drains, therefore the spacing of the drains must be much closer than that implied and the effectiveness of the drains will be restricted to the top 15 to 20 feet of the foundation subgrade. The drains must be effectively tied into the foundation blanket for continuity of the drainage path. There are concerns over the use of vibro-flotation or stone columns techniques above the mat. The mat will not effectively dampen these compaction forces and some rupture of the mat could be possible. A safer reinforcing technique could be the use of reinforcing within the embankment section, such as high strength geogrids placed in layers. All reinforcing techniques are expensive but could be offset by the reduction in fill quantities ultimately required. Any reinforcing selected for use in production must be part of a comprehensive test fill program to demonstrate its effectiveness.

The Tudor Report identified considerable leakage to be expected from the completed embankment. Since loss of any water from storage is a significant reduction in benefits, the seepage must be prevented. Therefore a bentonite slurry trench should be installed within the centerline of the embankment. The trench will be a minimum of 3 feet wide and extend to several meters below the original lake bottom. The trench can be excavated using rockmill techniques. Since the embankment will undergo significant settlement, both total and differential, it is likely that the trench will be sheared and will require replacement within the deeper portions of the lake during the life of the project.

Rio Caño Quebrado Dam

The Rio Caño Quebrado dam consists of two sections, the west and east embankments, with the top at EL. 34.5 m MSL, and a crest width of 13 m. The left abutment of the embankment would be located at Universal Transverse Mercator Grid, Zone 17, Clark 1866 Spheroid Coordinates 1004554 north and 632455 east. The right abutment would be 1004595 north and 632599 east coordinates. The embankments would be constructed by depositing cohesive materials along the alignment of the proposed dam until the stacked material reached its natural angle of repose and the consolidation, within the subgrade, are stabilized. The assumed side slopes are 10 H : 1 V within the submerged sections, transitioning to 2 H : 1 V in the portions traversing the islands. The subgrade is extremely soft and considerable displacement is anticipated as evidenced by the original construction experience at Gatun Dam. The dam would be approximately 16 m high, and the overall length is 404 m. The top of the dam would be 4.3 m above the maximum normal operating level in Gatun Lake. The total volume of fill material required to construct the embankments is 244,150 M^3 for the west embankment and 114,500 M^3 for the east embankment. The crest width and side slopes are presented here for comparison purposes between projects. The actual crest width and side slopes would be determined during further study and are contingent upon the need for vehicular access across the embankments, the size and quality of the fill materials available for use, and the detailed design for the embankments.

The crest width and side slopes are presented for comparison purposes between the various projects. The actual crest width and side slopes would be determined during further study and contingent upon the need for vehicular access across the embankments, the size and quality of the fill materials available for use, and the detailed design for the embankments.

Saddle Dams

As noted in the Tudor Report, the existing Caño Saddle Dam No. 4 located along the western shoreline of the Trinidad Arm of Gatun Lake needs to be raised and/or strengthened to accommodate the higher lake levels. Immediately to the north of this location, two additional smaller saddle dams are required. All would be built to provide a minimum top EL. of 31 m MSL. The total volume of fill material required for these three dams is 50,000 M^3

The crest width and side slopes are presented for comparison purposes between the various projects. The actual crest width and side slopes would be determined during further study and contingent upon the need for vehicular access across the embankments, the size and quality of the fill materials available for use, and the detailed design for the embankments.

SPILLWAYS

Under normal flow conditions water passes from Lower Rio Trinidad Lake to Gatun Lake through a gated spillway. This spillway should have 8 gate bays, each 18.33 m wide. The gate bays would be separated/flanked by 3 m wide reinforced concrete piers (9 piers in all) which provide support for the gates and access to the gate operating machinery, as well as providing support for a roadway bridge over the top of the spillway. Each of the 8 spillway gates have a nominal width of 18.33 m and a height of 8.53 m, is providing 0.3 m freeboard above the maximum lake operating level. The overall length of the spillway, from out-to-out of the end piers is 173.65 m. The spillway sills would be placed at the minimum lake operating level, EL. 25.91 m MSL for this scenario.

A bridge across the tops of the spillway piers shall be constructed as a part of the roadway across the top of the dam. It would be 7 m wide, thus allowing for two-way traffic and should provide ready access to the spillway gate operating machinery.

For this study, stop logs for servicing the gates, guides, etc. may be placed either from the roadway or from barges using floating cranes. Also, it should be noted that, with the spillway sill at the prescribed level, stoplogs are required both upstream and downstream to allow work to be done on the gates and sills in the dry.

The spillway would be situated along the axis of the dam approximately centered in Guacha Island. This allows the construction to be performed completely within a dry construction cut requiring a minimum of construction dewatering. Once the concrete structures are completed, the entrance and exit channels to the spillway can be opened.

All flows from both Lower Rio Trinidad and Rio Caño Quebrado Lakes can be handled by the Lower Rio Trinidad spillway under this scenario.

PUMPING PLANT

A large pumping plant is included in this scenario at the Lower Rio Trinidad dam. This pumping facility provides pumping in two directions, allowing Lower Rio Trinidad Lake to be drawn down to a level below that of Gatun Lake during extremely dry months, and providing the capability of pumping excess water from Gatun Lake into Lower Rio Trinidad Lake during flood season.

Water thus stored would be available for navigation during the dry season. The pumping plant is configured to provide pumping to EL. 33.53 m MSL, in Lower Rio Trinidad Lake. For lake elevations below this level the plant might be reduced somewhat in size, however it is that the higher level configuration should provide a better estimate of the overall construction cost. See Table 41-2 for the controlling head and flow data used for this study.

This plant should consist of six 1407 HP pumps, each capable of pumping slightly more than 62 CMS for a total plant pumping capacity of 373 CMS at a total dynamic head of 4.6 m. The pumping units would be mounted in a reinforced concrete housing and arranged in a row perpendicular to the axis of the dam, with intake and outlet channels on either side. The channels would be separated from the Lower Rio Trinidad and Gatun Lakes by large concrete walls containing low-level sluiceways and gates for controlling flows into and away from the pumping plant. These sluiceways are configured to provide average entry velocities of approximately 7.7 MPS. The channels are configured to provide this velocity or less and require no special armoring of walls or inverts for scour protection. The channel invert would be at EL. 20 m. MSL, or 13.5 m. below the centerline of the pump outlets. This may provide sufficient water depth at maximum pumping to buffer the erosive effects of the very large outflows required.

In conjunction with this facility a roadway bridge would be required to connect the pumping station structure to the banks on either side of the intake and exit channels thus continuing the roadway across the facility. This bridge should also provide both operational and maintenance access to the pumping plant. As configured for this study, the bridge must have two 15 m long spans with steel girders and a concrete bridge deck on each side of the pumping station. It shall have a 7 m wide travel way and include one bridge bent including a cap, two round columns and a spread footing, located within each channel section.

Table 41 - 2 Pumping Data

Pumping Cycle	**Head** (m.)	**Average Daily Flow** (M^3/sec)
Lower Rio Trinidad (Elev. 22.86) to Gatun Lake (Elev. 25.91)	3.05	127.43
Gatun Lake (Elev. 26.67) to Lower Rio Trinidad (Elev. 33.53)	6.86	56.64

IMPOUNDMENT

The lake formed by the proposed Lower Rio Trinidad Dam should have a normal operating lake EL. 33.53 m MSL. The surface area at the normal operating lake level is 21,912 ha. At the maximum floodlevel, EL. 34.14 m MSL, the surface area is 22,830 ha. With the minimum operating level at EL. 22.86 m MSL, the surface area is 9,019ha. It should be noted that the current operating levels of Gatun Lake vary to EL. 26.67 m MSL; therefore areas below the maximum Gatun Lake level are already subject to inundation. The lake formed by the proposed Rio Caño Quebrado Dam should have a normal operating lake level at EL. 33.53 m MSL. The surface area in the Rio Caño Quebrado impoundment at the normal operating lake level is

3,443 ha. At the maximum flood lake level, EL. 34.14 m MSL, the surface area is 3,629 ha. With the minimum operating lake level at EL. 22.86 m MSL the surface area is 1,151 ha.

CLEARING AND/OR GRUBBING

Clearing and grubbing is required for all areas above the existing Gatun Lake that are required for construction of the dam (embankments and spillway), access roads, and disposal and staging areas. For the Trinidad Lake area, clearing is required for the 3,700 ha in the lake area between the maximum operating lake level of Gatun Lake and EL. 30.5 m MSL. Only clearing is required for the 740 ha in the Rio Caño Quebrado Lake area, between the maximum operating lake level of Gatun Lake and EL. 30 m MSL.

ACCESS ROUTE

Access to the lake site and the various construction sites was evaluated from the main population centers, Colon on the Atlantic coast and Panama City on the Pacific coasts.

The route from Colon is westward across the Panama Canal and then southwestward along existing roads that follow the westernmost boundary of Gatun Lake to Cape Mala, near the western abutment of the dam. A very short access road is required from the existing road to the dam site. This route requires crossing the Panama Canal near the Gatun Locks using the existing lock gate bridge. This bridge is narrow and operates only intermittently since canal operations take precedence over roadway traffic. It may be undersized and may lack the load carrying capacity needed for heavy construction materials and equipment loads anticipated.

Access to the spillway and pumping station construction sites would be by water since these structures are to be placed on Guacha Island. A water access route is a possible means of conveyance for much, if not all, of the construction equipment and materials. This requires offloading facilities be constructed near the west abutment of the dam on Guacha Island, and near the eastern abutment site in the vicinity of South Range Point.

Access to Rio Caño Quebrado can best be gained from the Panama City area by way of existing roads extended to the village of Santa Clara, located to the south and east of the Rio Caño Quebrado dam site. From Santa Clara, a new roadway is required to the dam construction site, a distance of approximately 8 km. Roadway access should also be required to the spillway site, which would be located some distance to the south and west, and across the existing lake from the dam site. Existing roadway access in this area is now available to the village of La Laguna. From a point just south of La Laguna, a new access road would be required around the south side of the existing lake to the spillway site. This route should require approximately 5 km of new roadway.

Since much of the construction for this project is in the existing lake or on an island in the lake, it is concluded that both land and water access is required. Plate 41 - 1 shows the general location of the proposed features and the possible land and water access available or to be provided.

Sources of Construction Material

Lower Rio Trinidad
The bottom 5 m layer of the dam embankments shall be constructed with material less than 8 in. maximum size, and with no more than 5 percent passing the #200 screen. Such a material would require crushing and processing across a grizzly to remove oversize rock, and washing to remove fines. Material for this bottom layer must be reasonably well graded so as to prevent the removal of the finer fraction by piping. The overlying main portion of the embankment would be constructed with (-12 in.) sized material. This material should also require crushing and processing across a grizzly to remove oversize rock.

The majority of the materials used for the embankment construction would be obtained from upland sources adjacent to the Gaillard Cut, transported to the site by barge and clam shelled along the proposed embankment alignment. The initial materials would be obtained from the existing disposal sites for the Gaillard Cut widening above Pedro Miguel Locks. Based on the information received from the ACP, these sites contain approximately 5.5 million M^3 of suitable excavated rock. However, this rock is not stockpiled in an orderly manner, is randomly mixed with unsuitable material and is covered with unsuitable material. All the rock materials, from whatever source, would need to be crushed, graded and loaded on trucks for transport to a loading facility adjacent to the canal at the Cucaracha Reach on the east side, or the mouth of the Mandinga River on the west side. These loading facilities should require excavation into the bank area and bulkheaded for crane support and barge placement. Working stockpiles would be maintained next to the transfer points to facilitate the loading process. Additional materials within the immediate area should come from the Third Locks excavation adjacent to the Pedro Miguel Locks. These materials would be drilled and blasted in place, excavated, and then transported to one of the transfer facilities for processing. Additional materials should come from newly developed quarry sources in areas such as Hodges Hill, Escabor Hill, Contractor Hill, and others within 10 km of the transfer points. Each of these new sources should require extensive excavation to remove the overburden and soft rock materials. These materials would be stockpiled adjacent to the work area for restoration once the rock fill materials have been acquired. The suitable rock materials would be blasted, crushed and graded and trucked to the transfer points. All material would be loaded onto barges, transported to the dam site and clam shelled within the dam limits.

Cement is available within the country. Rock obtained from developed quarries may be used to produce concrete aggregates on-site, or may be obtained from commercial quarries. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) need to be fabricated outside the Republic of Panama and imported for final assembly and installation at the proposed dam site.

Rio Caño Quebrado
The source of the embankment and other construction materials for Rio Quebrado are expected to be the same as those for Rio Trinidad.

Real Estate Requirements

The Lower Rio Trinidad Lake site is located within the former Panama Canal Zone and is presently managed and controlled by the ACP. Acquisition of lands for the new lake area would be required. Construction of this project requires acquisition of approximately 800 ha.
Table 41 - 3 shows the amount of land required for the various project features. Real estate for access roads is included in the estimated quantities for the other items listed in the table.

Table 41 - 3 Real Estate Requirements

Project Feature	Land Required (ha)
Lake	0
Dam Site	0
Staging Area	200
Housing and Facilities	200
Disposal Area	400
Total	800

The Rio Caño Quebrado Lake site is located within the former Panama Canal Zone and is presently managed and controlled by the ACP. Construction of this proposed project requires acquisition of approximately 800 ha. Table 41 - 4 details the amount of land required for the various project features. Real estate for access roads is included in the estimated quantities for the other items listed in the table.

Table 41 - 4 Real Estate Requirements

Project Feature	Land Required (ha)
Lake	0
Dam Site	0
Staging Area	200
Housing and Facilities	200
Disposal Area	400
Total	800

Relocations

The Lower Rio Trinidad Lake should located within the existing former Panama Canal Zone. Structures and facilities established along the waters edge in the Trinidad arm between the existing Gatun Lake levels and EL. 30 m MSL should need to be relocated or modified. This includes a major portion of the town of Escobal. Additionally, there are a few small communities and isolated individual structures along the lakeshore with very limited access by land.

The Rio Caño Quebrado Lake site is located within the existing former Panama Canal Zone. Structures and facilities established along the waters edge in the Rio Caño Quebrado arm between the existing Gatun Lake level and EL. 30 m MSL should need to be relocated or modified. This region appears to have a few settlements along the lakeshores and very limited access by land

Development Sequence

Each potentially viable project should evaluated to assure that the plan presented provides all of the necessary features required to make it function. Each should also be assessed for effectiveness in providing navigation water to the Panama Canal, with due recognition of any secondary benefits. Environmental assessments of the proposed projects should also be made to assure environmental acceptability of the project features. These environmental assessments begin during the planning studies phase and continue during the final design, advertising and award phase. Environmental coordination begins with planning studies and continues through completion of construction. The final design would be accomplished for the recommended project. After completion of the final design, plans and specifications are prepared for the advertising and award phase, and through construction.

Project implementation begins with land acquisition and construction of the access facilities. Lands for the housing and facilities project feature, which includes the access roads, would be acquired initially. Lands for the dam site, staging area, disposal area, and lake can then be acquired.

Access roads, equipment, and materials offloading docks, etc. would be constructed for the dam site and structure sites. A small boat channel would be dredged to route boat traffic around to the east side of Guacha Island during construction of the western leg of the dam. Boat traffic would be routed through this channel until completion of the western leg of the dam and the pumping plant. Navigation through this area would be discontinued. Socio-economic programs would be gin shortly before construction of the dam. The relocation of the small settlements and isolated structures would be accomplished. Socio-economic programs to assist those individuals impacted by the construction of the proposed project should continue throughout the construction phase.

Construction of the dam would be gin with the clearing and grubbing of the construction sites at Guacha Island and the clearing of the perimeter of the Lower Rio Trinidad Lake area. Some construction should need to be accomplished with floating plants within Gatun Lake. Materials used for the embankment construction could be obtained from upland sources, transported to the site and end-dumped along the proposed embankment alignment from the abutments. The material could also be obtained from dredged sources within Gatun Lake, deposited on the land for drainage, and then deposited along the proposed embankment alignment. It is assumed that rock fill required for armoring the slopes is available within the immediate lake area.

Limited cofferdams would be required to accomplish construction of the spillway and pumping station. These efforts may be accomplished simultaneously. Following completion of the pumping plant and spillway, the channels connecting these structures to the lake areas upstream and downstream may be excavated. Where possible, materials removed from these sites would be placed directly into the dam.

Once the western leg of the dam, pumping station and spillway are completed, the eastern leg may be constructed, thus completing the dam. The pool may then be raised. Upon completion of this phase of construction, all facilities must undergo trial operations, before being commissioned for service.

Considering the construction methods and the nature of the work, it is estimated that development of this project can be completed in approximately 13 years, from initial planning to lake filling.

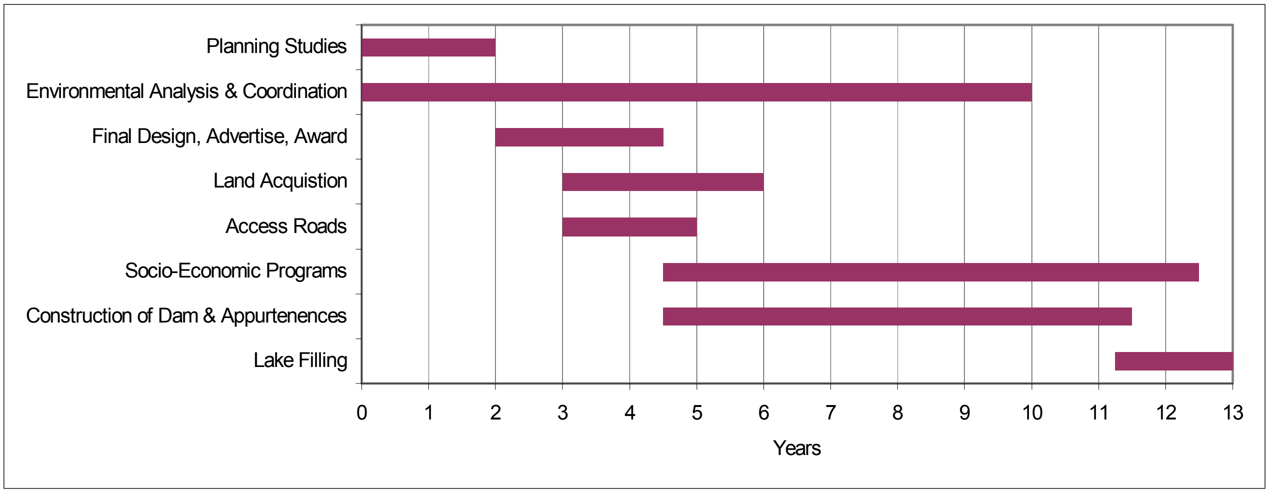


Figure 41 - 1 Development Sequence

Hydrologic Reliability

In order to determine the effect of the proposed Lower Rio Trinidad and Cano Quebrado Lakes on the hydrologic reliability of the Panama Canal, the existing HEC-5 model is modified to include the Lower Rio Trinidad Lake with pumpback. The existing Gatun Lake parameters (surface areas, storages, and local inflows) are reduced by the proportion that Lower Rio Trinidad and Rio Caño Quebrado Lakes should capture.

HEC-5 model simulations are conducted for both the existing canal system, and the Scenario 6 operating system. The simulations considered proportionally increasing demands to 180 percent of current demand levels. The period of simulation considered 52-years (January 1948 through December 1999) of hydrologic record. See Figure 41 - 2 presents the resulting hydrologic reliability for two configurations with demands increasing up to 180 percent of current demands. These configurations are:

- Existing system,
- Scenario 6 – Lower Rio Trinidad and Rio Caño Quebrado Lake fluctuating between the normal operating lake levels at EL. 33.5 m MSL and the minimum operating lake levels at EL. 22.86 m MSL, with pumping capability to and from Gatun Lake; and Gatun Lake fluctuating between the normal operating lake level at EL. 26.67 m MSL and the minimum operation lake level at EL. 25.91 m MSL.

The horizontal axis along the bottom of Figure 41 - 2 reflects demands as a ratio of the 5-year average from 1993 to 1997, and the axis along the top reflects demands in lockages (assuming 55 million gallons per lockage).

Figure 41 - 2, illustrates the existing hydrologic reliability of the Panama Canal, based on the period of record of 52 years, is approximately 99.6 percent, while the hydrologic reliability with a demand ratio of 1.8, is 86.3 percent. This period of record includes the worst droughton record for the area, which occurred in 1998. The hydrologic reliability, with a demand ratio of 1.0, is 100 percent for operating Scenario 6, and the hydrologic reliability, with a demand ratio of 1.8, is 91.46 percent. Table 41 - 6 displays the number of lockages associated with various levels of reliability.

Without additional water supplies, the hydrologic reliability of the canal system should decrease. With the construction of the proposed Lower Rio Trinidad Pumpback and Rio Caño Quebrado Dam projects using Scenario 6 operation, the existing high hydrologic reliability can be continued as demand for water increases up to 31.4 percent (12.16 lockages) above current demand levels.

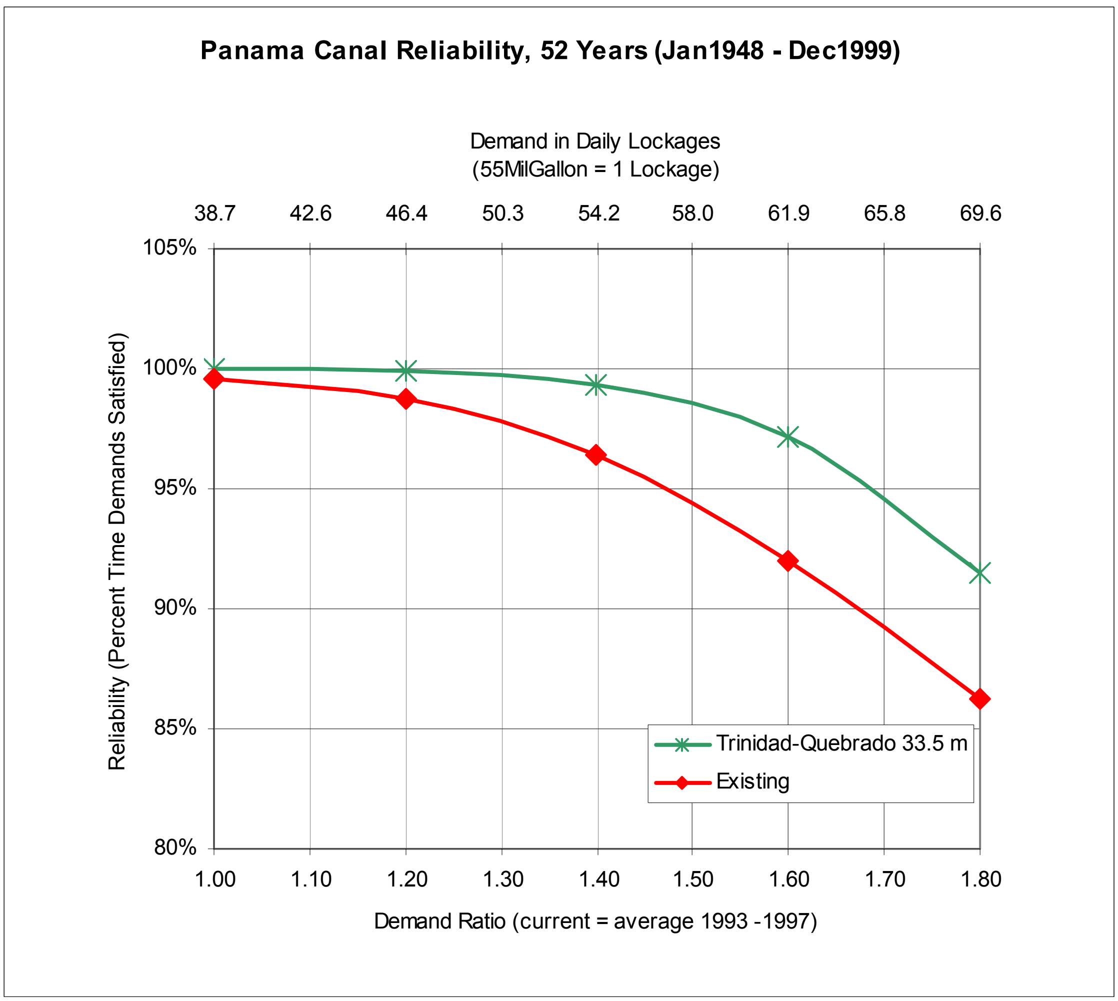


Figure 41 - 2 Panama Canal Hydrologic Reliability

Project Costs

GENERAL

The quantities estimated for the various items of work required for the construction of this project are derived from the layouts shown on Plate 41-1. The unit prices applied to these quantities are based on: historical information from previous estimates prepared for similar construction by the ACP; estimates for similar construction in the Mobile District; information gathered from Mobile District Construction Division personnel in Panama; and the book Feasibility Studies For Small Scale Hydropower Additions, A Guide Manual, written by The Hydrologic Engineering Center of the U.S. Army Corps of Engineers.

Engineering and design is estimated to be 12 percent while supervision and administration is estimated to be 6 percent of the construction cost items. An allowance of 2 percent of the construction cost items is allowed for field overhead (construction camp, contractor facilities, etc.). An allowance of 25 percent is included for contingencies.

FIRST COSTS

The total project first costs are estimated at $1,062,361,000. Table 41 - 5 provides a summary of the first costs for the principal features. Separate documentation provided to the ACP including a detailed cost estimate containing the sub-features of the work.

Table 41 - 5 Summary of First Costs

Item	Trinidad Costs ($)	Caño Quebrado Costs ($)
Lands and Relocations	2,000,000	2,000,000
Access Roads	9,574,000	6,690,000
Clearing and / or Grubbing	559,375	792,500
Cofferdam	850,000	N/A
Dam	643,786,212	2,966,970
Spillway	8,057,504	N/A
Transfer Ditch	N/A	3,281,400
Saddle Dams	2,593,390	N/A
Pumping Station	22,999,637	N/A
Transmission Lines	2,090,000	N/A
Subtotal	692,510,118	15,730,870
E&D, S&A, Field Overhead	138,502,024	3,146,174
Contingencies	207,753,035	4,719,261
Total Project First Cost	1,038,765,177 Approximately 1,038,765,000	23,596,305 Approximately 23,596,000

OPERATION AND MAINTENANCE

Staff

A staff should operate and maintain the proposed Lower Rio Trinidad Dam project during the day and then run the facility remotely at night. The full-time staff should consist of 9 people, including a station manager, a multi-skilled supervisor, 2 leaders (Electronics/Instrumentation, Electrical/Mechanical), 4 craftsmen and a laborer. A part-time staff would be required for two to three months each year to perform general maintenance and overhaul of the project. The part-time staff may consist of three mechanics and three electricians. The annual staffing costs are estimated to be $350,000. The staff for the Lower Rio Trinidad project would be sufficient to operate and maintain the Rio Caño Quebrado project.

Ordinary Maintenance

Ordinary maintenance and care is required and includes minor repair materials, lubricants and other supplies. It is estimated that the costs of ordinary maintenance is $18,000 per year for the access road and $100,000 per year for the main project facilities. Fuel consumption for the pumps is estimated to be $648,000. This estimate considers the growth in demand for water over time and the variability in inflows to Gatun Lake as well as the proposed Lower Rio Trinidad project. An estimated $288,000 would be needed for rock placement to account for settling of the project. The total ordinary maintenance is $1,054,000. The ordinary maintenance estimate for the Lower Rio Trinidad project is sufficient to include the Rio Caño Quebrado project.

Major Replacements

The average service life of gates, electrical equipment, pumps, trash racks and other features is less than the total useful life of 100-years. To estimate the major replacement costs necessary during the 50-year planning period for this proposed project, it was assumed that specific items should cost the same as at present. No allowance was made for salvageable fixed parts.

Table 41 - 6 presents the service life, number of times each component should be replaced during the 50-year planning period, the future costs of each item, and the present worth of the replacement costs for the major components. Based on these values, the present worth of the proposed replacements is $2,260,400 and the average annual replacement costs is $272,000. There are no major replacements needed for the Caño Quebrado project.

Table 41 - 6 Major Replacement Costs

Component	Service Life (years)	Number of Times Replaced During Planning Period	Future Costs ($)	Present Worth of Replacement Costs ($)
Roads	50	1	12,435,000	43,000
Bridges	50	1	1,800,000	6,200
Pump Station				
Pumps	25	2	21,006,000	654,200
Sluice Gates	50	1	1,275,525	4,400
Sluice Trash Racks	50	1	458,850	1,600
Electrical Controls	25	2	2,100,000	65,400
Fuel Tanks, etc.	50	1	450,000	1,600
Misc Equip & Comm.	25	2	3,183,000	99,100
Slurry Trench	25	2	40,462,500	1,260,100
Spillway				
Bridge Girders	50	1	280,676	1,000
Tainter Gates	50	1	2,280,000	7,900
Tainter Gate Hoists	50	1	1,200,000	4,200
Tainter Gate Op Sys.	50	1	360,000	1,200
Stoplogs	50	1	475,950	1,600
Misc. Mech. Items	25	2	1,500,000	46,700
Electrical Controls	25	2	1,650,000	51,400
Transmission Lines	50	1	3,135,000	10,800
Total			94,052,500	2,260,400
Average Annual Replacement Costs				272,000

Annual Costs

The project first costs for the proposed Lower Rio Trinidad project are estimated at $1,038,765,000. The project first costs for the proposed Rio Caño Quebrado project are estimated at $23,596,000. The total project first costs are estimated to be $1,062,361,000. These total project first costs are distributed across the development period using generalized curves for contractor earnings for large, heavy construction jobs. Interest during construction for the Lower Rio Trinidad project is computed from mid-year throughout its 13-year development. The interest during construction at 12 percent is $838,455,000 for Lower Rio Trinidad and $10,811,000 for the Rio Caño Quebrado project for a total interest during construction of $849,266,000. These costs are added to the total project first costs for total project investment costs of $1,911,627,000. A capital recovery factor for the 50-year planning period is applied to get the annual average investment costs of $230,192,000. Annual operation and maintenance costs are added. Major replacement costs are estimated and converted to an annual cost by discounting the future replacement costs of major components of the project back to completion of the project construction. Table 41 - 7 contains a summary of the $231,868,000 total annual costs.

Table 41 - 7 Summary of Annual Costs

Item	Costs ($)
Total Project First Costs - Lower Rio Trinidad	1,038,765,000
Total Project First Costs – Caño Quebrado	23,596,000
Interest During Construction – Lower Rio Trinidad	838,455,000
Interest During Construction – Caño Quebrado	10,811,000
Total Project Investment Costs	1,911,627,000
Annual Average Investment Costs	230,192,000
Operation and Maintenance Costs	
Staff Costs – Lower Rio Trinidad	350,000
Ordinary Maintenance Costs – Lower Rio Trinidad	1,054,000
Major Replacement Costs – Lower Rio Trinidad	272,000
Total Average Annual Costs	231,868,000

Annual Benefits

NAVIGATION

The procedures and assumptions used in estimating the benefits are described in Volume One. The following paragraphs present the results of the economic investigations for the proposed Lower Rio Trinidad project. The 50-year period for the economic analyses of this proposal is 2014 to 2063.

The proposed Lower Rio Trinidad and Rio Caño Quebrado projects should increase the reliability of providing water to accommodate the total daily number of lockages demanded.

Table 41 – 8 provides the increase in the hydrologic reliability of providing the sum of the demands for both navigation and M&I water supply keyed to years. The hydrologic reliability percentages are obtained from the data used to develop Figure 41 - 2. The 99.6 percent level of reliability for this proposal is used to estimate the water supply benefits for navigation and the net change in reliability is used to estimate the reliability benefits for navigation and M&I water uses.

Table 41 - 8 Panama Canal Hydrologic Reliability
(Based on Period of Record from January 1948 to July 1998)

Current Demand Ratio	Year	Demand in Daily Average Number of Lockages (Navigation and M&I)	Hydrologic Reliability	
			Existing System (%)	With Lower Rio Trinidad & Caño Quebrado [1/] (%)
1	2000	38.68 [2/]	99.60	100.0
	2010	45.11	98.91	99.95
1.2		46.42	98.76	99.94
	2015	46.82	98.64	99.89
	2020	47.61	98.41	99.84
	2025	48.52	98.14	99.77
	2030	49.55	97.83	99.69
	2035	50.72	97.48	99.59
	2040	52.02	97.10	99.49
	2045	53.49	96.65	99.37
1.4		54.15	96.45	99.32
	2050	55.13	95.89	99.03
	2055	56.98	94.83	98.30
	2060	59.05	93.65	98.30
	2065	61.37	92.32	97.18
1.6		61.89	92.02	97.03
	2070	63.97	90.47	95.48
1.8		69.63	86.27	91.29

[1/] The lakes behind the Lower Rio Trinidad and Caño Quebrado Dams should fluctuate from the normal operating lake level at EL. 33.53 m MSL down to the minimum operating lake level at EL. 22.86 m MSL.

[2/] 2000 Daily Demand is Average of 1993-1997

With the proposed Lower Rio Trinidad and Caño Quebrado projects, water supply shortages for navigation should continue. The demand for the M&I purposes should always be met first. As these demands grow, the amount of water available to meet the demands for navigation should decrease. Thus, the benefits for the additional water supply are estimated at the value for navigation. With the addition of the proposed Lower Rio Trinidad and Rio Caño Quebrado projects, these shortages would be less frequent. With a hydrologic reliability of 99.6 percent, the proposed project should increase the amount of water supplied by approximately 12.16 equivalent lockages. The 99.6 percent hydrologic reliability should occur after the year 2035 with an equivalent daily average number of lockages of 50.84. Benefits for these amounts of additional water are attributable to navigation since the amount of M&I water demanded are provided first. Therefore, all shortages are attributable to navigation. The benefits are estimated using the toll revenue per lockage and the increased daily average number of lockages. The average annual benefits for water supply are $184,877,000. Table 41 - 9 provides the estimate of daily shortages under the existing system, the remaining daily shortages with the proposed Lower Rio Trinidad and Rio Caño Quebrado projects in operation, the annual benefits for meeting shortages and the average annual benefits.

Table 41 - 9 Benefits for Additional Water Supply for Navigation

Year	Daily Shortages In Lockages Under Existing System	Remaining Daily Shortages	Annual Benefits For Navigation ($)
2014	8.00	0.00	163,238,000
2020	8.93	0.00	184,110,000
2030	10.87	0.00	224,201,000
2040	13.34	1.18	250,824,000
2050	16.45	4.29	250,824,000
2060	20.36	8.20	250,824,000
Average Annual Benefits			184,877,000
With the Lower Rio Trinidad and Caño Quebrado alternative operating between EL. 22.86 and 33.53 m MSL, the system should provide a total of 50.84 lockages at the 99.6 percent level of reliability or 12.16 more lockages than the existing system.			

With the proposed Lower Rio Trinidad and Rio Caño Quebrado projects, the reliability of the system to provide all of the water demanded by navigation and M&I water can be improved. Using the increase in hydrologic reliability, the forecast number of vessels converted to a daily average number of lockages, the toll revenue for each average lockage, and a project discount rate of 12 percent, the average annual benefits for navigation reliability attributable to the proposed Lower Rio Trinidad and Caño Quebrado projects is $12,791,000. Table 41 - 10 provides the forecast daily average number of lockages, the forecast value per daily lockage, the annual benefits for increased reliability, and the average annual benefits.

Table 41 - 10 Average Annual Reliability Benefits For Navigation

Year	Daily Average Number of Lockages	Value Per Lockage ($)	Annual Benefits For Navigation ($)
2014	40.0	2,236,000	7,945,000
2020	40.0	2,260,000	11,836,000
2030	40.0	2,260,000	15,337,000
2040	40.0	2,260,000	19,787,000
2050	40.0	2,260,000	25,865,000
2063	40.0	2,260,000	31,467,000
Average Annual Benefits			12,791,000

M&I WATER SUPPLY

The future demand for water supply for M&I purposes is based upon the growth in population. The ACP provided a forecast for the area surrounding the Panama Canal. The current usage is estimated at 4.0 equivalent lockages per day; an equivalent lockage is 55 million gallons of water. One equivalent lockage is added to the forecast to account for the burgeoning tourist industry, beginning in the year 2010. The increased reliability of the system to provide water supply for navigation similarly provides the same increase in reliability to provide water for M&I purposes. Using the increased hydrologic reliability of the system with the addition of the proposed Lower Rio Trinidad and Rio Caño Quebrado projects, the current costs to the ACP to process finished water ($0.69 per 1,000 gallons), the number of daily lockages demanded, and a project discount rate of 12 percent, the average annual benefits for M&I reliability is $1,784,000. Table 41 - 11 displays the population forecast, the resulting number of equivalent lockages per day, and the benefits for M&I water supply.

Table 41 - 11 Average Annual Reliability Benefits For M&I Water Supply

Year	Population	Equivalent Lockages per Day	Annual M&I Water Supply Benefits ($)
2014	1,880,000	6.00	887,000
2020	2,141,000	7.61	1,514,000
2030	2,688,000	9.55	2,463,000
2040	3,384,000	12.02	3,992,000
2050	4,259,000	15.13	6,569,000
2063	5,751,800	20.44	10,067,000
Average Annual Benefits			1,784,000

HYDROPOWER

The amount of hydropower energy that can be produced by the system of Gatun Lake and Madden Lake should decline over time as the demands for navigation and M&I water supply increase. With the inclusion of the Lower Rio Trinidad and Rio Caño Quebrado projects, the system will loose hydropower generation at Gatun Lake and Madden Lake due to the change in the operation of the system. Thus, the system will have a net decrease in hydropower production. The value for hydropower energy used in this analysis is $0.070 / kWh. On an average annual basis, the proposed project should have loses of ($3,168,000). Table 41 - 12 provides the net additional megawatt hours of hydropower generation and the resulting benefits.

Table 41 - 12 Average Annual Benefits For Hydropower Generation

Year	Net Generation [1] (MWh)	Annual Benefits For Hydropower ($)
2014	(44,892)	(3,142,471)
2020	(45,097)	(3,156,803)
2030	(45,602)	(3,192,117)
2040	(46,243)	(3,236,993)
2050	(47,123)	(3,298,619)
2063	(48,899)	(3,422,898)
Average Annual Benefits		(3,168,000)
[1/] Lose of net generation of Gatun and Madden hydropower plants with the operation of the Lower Rio Trinidad project.		

SUMMARY OF ANNUAL BENEFITS

As shown in Table 41 - 13, total average annual benefits for the proposed Lower Rio Trinidad and Rio Caño Quebrado projects would be $196,284,000.

Table 41 - 13 Summary of Annual Benefits

Benefit Category	Average Annual Benefits ($)
Navigation – Water Supply	184,877,000
Navigation – Reliability	12,791,000
M&I - Reliability	1,784,000
Hydropower	(3,168,000)
Total	196,284,000

To perform an analysis of benefits versus costs, a common point in time is selected. This common point is at the completion of the filling of the proposed Lower Rio Trinidad and Rio Caño Quebrado projects, the end of the year 2013. Thus, the 50-year period for the economic analyses of the proposed project is 2014 through 2063. Once average annual benefits and costs are estimated, the ratio of benefits to costs and the net benefits (net of costs) are computed. In the first instance, the analysis determines the feasibility of the proposal. The net benefits determine which proposal provides the greatest value for the investment dollars. Table 41 - 14 provides the benefit to cost ratio and the net benefits.

Table 41 - 14 Economic Evaluation

Item	Value ($)
Average Annual Benefits	196,284,000
Average Annual Costs	231,868,000
Benefit to Cost Ratio	0.8
Net Benefits	(35,584,000)

Internal Rate of Return

An internal rate of return analysis for this proposed project was performed. To accomplish this analysis, the annual construction costs are used as the investment, and the undiscounted benefits are used as return cash flows. The internal rate of return would be 12.0 percent.

Socio-Economic Impacts

The description of the environmental setting is based on field observations made while conducting field reconnaissance throughout Gatun Lake, specifically the Lower Rio Trinidad and

Rio Indio areas with ACP personnel. Autoridad Nacional del Ambiente (ANAM), ACP, Asociacion Nacional para la Conservacion de la Naturaleza (ANCON), Electrical Transmission Agency, Smithsonian Tropical Research Institute (STRI), and Directorate of Mineral Resources personnel were interviewed to gain information on site characteristics and potential activities that could affect the project. In addition, extrapolations of the 2000 census data were used, and a review of the Informe de Cobertura Boscosa 1992 were used to determine the extent of forest cover.

Environmental Setting

This alternative combines two projects, the Lower Rio Trinidad (lake level 22.9 - 33.5 m) and the Rio Caño Quebrado (lake level 22.9 - 33.5 m). The Lower Rio Trinidad project will provide additional water storage for Gatun Lake and 12.16 additional lockages per day on a continual basis. The Rio Trinidad project area covers 23,630 ha within Gatun Lake. This area is sparsely populated and includes rolling hills, as well as low regions near Gatun Lake. The Lower Rio Trinidad is located west of the Panama Canal, and flows northward from the Continental Divide into Gatun Lake. The Lower Rio Trinidad with Rio Caño Quebrado watershed above the dam covers approximately 1,051.5 km^2. The incremental impoundment area covers approximately 7,712 ha and consists of approximately 50 percent of forested land, 30 percent of pasture land (used by ranchers), 10 percent of cropland, and 10 percent of newly slashed and burned land. Gatun Lake's normal pool level is 26.7 m. During field observations (August 2001) the pool level was approximately 25.4 m.

The Rio Caño Quebrado project consists of a rockfill dam in two distinct sections and a gated spillway. The project area covers 3,629 ha within Gatun Lake. This area is sparsely populated, with terrain similar to that in the Lower Rio Trinidad project area. The Rio Caño Quebrado project area is located within the Panama Canal area, and flows northward from the Continental Divide into Gatun Lake. The Rio Caño Quebrado watershed above the dam covers approximately 1,052 km^2. The impoundment area, which would cover an additional 3,443 ha, consists of approximately 50 percent of forested land, 30 percent of pastureland (used by ranchers), 15 percent of cropland, and 5 percent newly slashed and burned land. The lake water elevation will fluctuate from 22.9 - 33.5 m. The project may impact unpaved roadways and paths in the area. Any impacts will be evaluated and minimized where possible.

LAND USE

The Lower Rio Trinidad project area encompasses the southwestern portion of Gatun Lake and the adjacent shores. The area to be fully or partially flooded encompasses the villages of Escobal (population – 1,653), Nuevo Provenir (population – 121), Cuipo (population – 249), Ciricito (population – 72), La Arenosa (population – 242), La Garterita (population – 138), La Gartera (population – 348), and a few small isolated establishments.

The Rio Caño Quebrado project proposes to maintain the impoundment at pool levels between 22.9 - 33.5 m. The normal pool level is 26.7 m. La Laguna (population 246) and Pueblo Nuevo (population 47) are the only towns on the Rio Caño Quebrado arm. The lake is also used for fishing, bathing, and transportation. Houses in La Laguna and Pueblo Nuevo are constructed of forest products and/or of concrete.

Some areas along the shores of the Lower Rio Trinidad and Rio Can Quebrado have been deforested. Approximately 65 percent of the lakeshore areas are forested, mostly with secondary growth. Farms and ranches of various sizes, as well as teak and African mahogany plantations, occupy the remaining land. Farm crops include maize, rice, beans, sugar, coffee, mangos, pineapples, and tobacco. Ranchers raise cows, horses, chickens, hogs, and tilapia. Some farmers and ranchers operate commercial enterprises, others rely on cash crops and subsistence farming. No significant ore deposits or mineral resources are located along the Caño Quebrado arm of Gatun Lake.

INFRASTRUCTURE

The town of Escobal was the largest community visited during site investigations. Escobal has businesses, schools, churches, cemeteries, medical centers, several houses, and paved roadways in good condition. A new and improved roadway (Highway 35) is in the project area near Escobal. Other settlements in the project area - Nuevo Provenir; Cuipo; Ciricito; La Arenosa; La Garterita; La Gartera - and a few small isolated establishments have elementary schools, small cemeteries, churches and meeting centers, medical clinics, and a few small businesses (general stores). The towns and villages depend on Gatun Lake or groundwater wells for their potable water supply. Each community also has docks, small ports, and other boat access facilities. Goods are transported from one town to the next by boat. No wastewater treatment is provided. Wastewater from showers and washing is discharged into the environment; some of it may reach the Lower Rio Trinidad portion of Gatun Lake. Disposal of domestic waste is the responsibility of individual homeowners: some homes have septic tanks, others have an outdoor latrine (a hole in the ground). Health problems, such as hepatitis, dysentery, dermatitis, intestinal parasites, and respiratory illnesses are attributable to the present waste disposal methods. No major industries or meat processing plants are located in the project area. The project area is traversed by unpaved horseback riding paths that link the various communities by unpaved maintenance roads used by the ACP. Due to the relatively isolated location of the project area, these roads are extremely important to the residents for transportation, community cohesion, commerce, and communication with neighboring communities.

La Laguna and Pueblo Nuevo have access to cemeteries, churches, and medical centers, and rely on Gatun Lake or groundwater wells for their drinking water supply. Most homes have electricity and limited telephone service. No treatment of community waste is provided. Wastewater from showers and washing is discharged into the environment; some of it is likely to reach Gatun Lake. Disposal of domestic waste is the responsibility of individual homeowners; some have a septic system, or an outdoor latrine (a hole in the ground). There are some health problems, such as hepatitis, diarrhea, dermatitis, intestinal parasites, and respiratory illnesses attributed to the present waste disposal methods. No known major industries or meat processing plants are located in the project area. La Laguna is accessible by a poorly maintained dirt road that is usable only in the dry season (mid-December through March). The roads are rarely graded and receive little attention from either the Ministry of Public Works or the local government. Pueblo Nuevo is accessible only by a dirt trail. These roads and trails are extremely important to the residents for transportation, community cohesion, commerce, and communication with neighboring communities because of the relatively isolated location of the project area.

TERRESTRIAL HABITAT

The terrestrial habitat observed along the Lower Rio Trinidad and Rio Caño Quebrado project areas of Gatun Lake consists of tropical forest ecosystems, mostly secondary growth forests with patches of primary forest. About 65 percent of the land along the Lower Rio Trinidad and Rio Caño Quebrado areas of Gatun Lake is forested and probably supports diverse wildlife populations. These also contain islands inhabited by wildlife. Some of the wildlife species do not interact with species on the mainland; others migrate between the island and the mainland. The species interrelationships are of great interest to the scientists studying tropical ecosystems. The slash and burn deforestation has opened tracts of land for farming and cattle grazing; however, the majority of the lakeshore is forested to the edge of the water. Terrestrial areas are used by migratory species as wintering, breeding, and feeding grounds. The complex and diverse tropical ecosystems offer habitat to connect a variety of wildlife communities and may provide habitat to many native species.

ANIMALS ON ENDANGERED LIST

ANAM, Resolution 002-80 enacted on June 7, 1995, declared 33 mammals, 39 birds, and 11 reptiles and amphibians to be in danger of becoming extinct in Panama. Although none have been identified to date, some of the species of interest on the threatened list might be found in the project area. The manatee is an aquatic mammal known to inhabit Gatun Lake around the Barro Colorado Island; however the probability of its presence in the project area has not been determined.

AQUATIC HABITAT

Gatun Lake, one of the world's largest manmade lakes, was created during the construction of the Panama Canal. The lake's water depth and quality vary widely. Aquatic habitat ranges from inundated forests to clear water in areas distant from shipping lanes. The Lower Rio Trinidad areas of Gatun Lake provide habitat for a variety of wildlife species, both resident and migratory, as well as for both native and introduced fish and other aquatic species.

WETLANDS

Areas that contain hydric soils and hydrophytic plant communities, and that are subject to hydrologic conditions are termed wetlands. Wetlands in the Lower Rio Trinidad and Rio Caño Quebrado project areas consist of shallow water habitat and lands subject to frequent flooding. In the shallow water zones along the banks of the Lower Rio Trinidad and Rio Caño Quebrado areas of Gatun Lake, sunlight penetrates to a depth of approximately 1 m. Sunlight stimulates growth of submergent, emergent, or floating mats of aquatic vegetation. Wetlands occur in terrain where water remains pooled long enough to allow development of hydric soil conditions and wetland plant communities. The wetlands in the project area are stressed by runoff that carries sediments, municipal waste, agricultural runoff, and debris from slash and burn sites.

AIR QUALITY

Air quality in the project area is generally good, except during slash and burn activities near the end of the dry season, in March or early April, when portions of forest are burned and cleared for agricultural use. During this period, the air is filled with smoke and ash, which may be carried by winds to the Lower Rio Trinidad and Rio Caño Quebrado areas of Gatun Lake. Air quality monitoring has not been implemented within the project area.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

Barro Colorado Island is an international center for tropical research and one of the first biological reserves established in the Neotropics. From 1923 through 1940, a scientific committee of the U.S. National Academy of Sciences administered the biological reserve/laboratory. In 1940, by an Act of the United States Congress, the facility was renamed the Panama Canal Zone Biological Area, and in 1946, the responsibility for its maintenance was assigned to the Smithsonian Institution. With the Panama Canal Treaty Implementation in 1977, the island was granted the category of National Monument and to date it continues to be managed by the Smithsonian Institute. It should also be noted that most of the Atlantic region of Panama is within the interest and objectives of the Mesoamerican Biological Corridor, an international project to conserve biodiversity.

Environmental Impacts

TERRESTRIAL HABITAT

The impacts of the project on terrestrial habitat in the Lower Rio Trinidad and Rio Caño Quebrado areas of Gatun Lake could be substantial. The boundary between two types of habitats, in this case between a forest and a lake, is called an ecotone. Ecotones are inhabited by species from neighboring habitats, and are unique, with high species diversity. Considering the proposed normal operating levels for both impoundments, between 22.9 and 33.5 m, erosion of the shoreline may be substantial as pool levels rise and fall. Terrestrial habitat areas that would be inundated above the 26.7 m (existing level) to the proposed normal pool level of 33.5 m consist of 20,778 ha for the Lower Rio Trinidad project. The permanent raising of the water level in Rio Caño Quebrado Lake will inundate approximately 4,577 ha of additional wildlife habitat surrounding the lake. The construction of a dam structure, access roads and pump stations would permanently impact terrestrial habitat. Wildlife species that are able to relocate to other suitable areas will compete with similar species for resources. Wildlife species that are not able to relocate will not survive. As a result, competition for natural resources in the surrounding areas will increase. This is considered a secondary impact to terrestrial habitat outside the proposed zone of inundation and construction.

ANIMALS ON ENDANGERED LIST

The severity of the impacts to endangered species cannot be determined at this time, because it is not known which of the listed species live within the proposed project area. It is expected that at least some of the species on the endangered list will be found in the region. Some endangered and/or threatened species may use the Lower Rio Trinidad and Rio Caño Quebrado areas of Gatun Lake during some or all parts of their life cycle.

WATER QUANTITY

The impacts of the project on water quantity would be substantial. The increase in the volume of water could have negative impacts to lakeshore communities as well as on existing ecosystems. The same is true if the lake level is lowered and maintained at 22.9 m.

WATER QUALITY

Project impacts on water quality are unknown. Damming the Lower Rio Trinidad and Rio Caño Quebrado could increase the amounts of nutrients and debris in this portion of Gatun Lake. A pilot tilapia farm is in the project area and may be affecting water quality. The rate nutrients and debris enter the lake will determine the severity of the impact on water quality. Project implementation could cause an increase in turbidity and interfere with photosynthesis. The increase in turbidity could deprive plants and other aquatic species from necessary sunlight. Aquatic plants and other organisms serve to maintain water quality. The dam would interfere with the circulation of freshwater throughout the Gatun Lake environment. Species inhabiting specific depths could be impacted when lake depth increases to 33.5 m and/or decreases to 22.9 m.

DOWNSTREAM AQUATIC FAUNAL HABITAT

The impacts of the project on aquatic faunal habitat could be substantial, especially on the breeding and nursery habitat of the many juvenile aquatic species. Fish spawning areas may be adversely affected by sudden changes in turbidity, nutrient content, and depth of the water, which alter the conditions needed for successful hatching. Plant populations may decrease as a result of fluctuations in water depth, clarity, and quality. Invertebrate populations may decline, which could reduce the food supply for fish and other aquatic species.

FUTURE LAKE AQUATIC PLANT COMMUNITY

The impacts of the project on future aquatic plant communities depend on water quality and stability of water levels. Plant species in the Lower Rio Trinidad portion of Gatun Lake could be impacted by fluctuating water levels. Aquatic plant communities could be impacted during project implementation; however, they could eventually re-establish after conditions stabilize.

AQUATIC FAUNA INHABITING AFFECTED AREAS

Impacts of the proposed project on aquatic fauna inhabiting the Lower Rio Trinidad, Rio Caño Quebrado and associated rivers and tributaries could be substantial. The unavoidable, adverse environmental impacts should be identified and minimized using appropriate mitigation measures (to be addressed in a feasibility level study). Gatun Lake has populations of peacock bass and tilapia, both of which are introduced species that have adapted well. However, several native riverine species that formerly occupied the impoundment have disappeared.

WETLANDS

The impacts to wetlands could be significant. As wetlands are inundated, they could become aquatic habitat. Project activities may lead to increased and/or decreased water depth, sedimentation, and turbidity which could hamper the biological processes of the wetlands and decrease their productivity. Such impacts could be detrimental to the health and sustainability of the Lower Rio Trinidad and Rio Caño Quebrado areas of Gatun Lake. Fish and other aquatic species use the shallow waters as spawning grounds. The juveniles survive in shallow water wetland areas until they are large enough to venture into deeper water. Each area is vital to the sustainability of this portion of Gatun Lake, including the Lower Rio Trinidad and Rio Caño Quebrado areas.

AIR QUALITY

During project implementation, emissions from construction equipment, along with slash and burn activities, could cause deterioration of air quality in the project area. After project implementation, the air quality may be impacted by the normal operation of the power generation facility and pumping stations.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

The potential impacts on cultural resources and historic properties cannot be identified. Before project implementation, surveys should be conducted to locate cultural resources and historic properties, and the important sites should be preserved or salvaged as appropriate.

SOCIO-ECONOMIC IMPACTS

The socio-economic impacts of the project could be substantial. The relocation of the town of Escobal and other small communities along the lakeshore would be an important issue. The average monthly income of families in the project area ranges from less than $100 to $200 per month. No indigenous groups are known to reside in the impact area. Land use would be greatly impacted by the inundation of pastures and agricultural lands to expand the impoundment. The relocation of agricultural and ranching activities would be an important issue, because approximately 10 percent of the land in the impoundment area is used for farming and ranching. After the water level is raised, additional agricultural land could be lost as islands are created from isthmuses. The incremental surface area of the proposed lake is 11,155 ha; another 1,504 ha will be used for the dam and construction sites, including permanent disposal areas.

During construction, the influx of workers could create a temporary demand for additional housing, which could result in an increase of housing values near the dam site. However, after completion of the project, the workers could leave, the housing demands could drop, and the housing values could return to pre-construction levels. Currently, all residents have access to public schools and health centers. During construction, these services should continue to be available, and additional public and community services may be offered. After construction, these services would return to the previous levels.

To construct the dam, some existing roads would be improved and some new roads would be built. However, some paved and unpaved roads within the impoundment area would be eliminated, which would change traffic patterns and could cause some communities to lose overland transportation, communication, cohesion, and commerce with other communities. During construction, the traffic volumes over both new and existing roads systems would increase; however following completion of construction, the traffic volumes could decline. Noise levels would temporarily increase during construction and could negatively impact noise-sensitive receptors; however, after construction noise levels may remain elevated as a result of the power generation facility and pump stations.

The communities that receive people displaced by the project could be negatively impacted by overcrowding and by competition for jobs, land, and working areas. Construction of the dams would permanently displace people and disrupt community cohesion through the division of communities, separation of families, and loss of livelihood. Following completion of the impoundment, tourism trade in the affected region, including sport fishing and ecotourism, could increase.

Additional Environmental Information Required

This section identifies the areas for which additional data are required to evaluate the scope and magnitude of the potential effects in further detail of the Lower Rio Trinidad and Rio Caño Quebrado alternative. The subject areas are discussed by impact category.

SOCIO-ECONOMIC IMPACTS

Conduct a SIA. The SIA would consist of three tasks scoping, assessment, and mitigation and monitoring. The following information should be developed:

- Business, Industrial, and Agricultural Activities;
- Employment;
- Land Use;
- Property Values;
- Public and Community Facilities and Services (including utilities and schools);
- Transportation;
- Housing;
- Health (vector routes);
- Population;
- Community Cohesion; and,
- Recreational Resources.

TERRESTRIAL AND AQUATIC HABITAT

- Prepare site-specific habitat maps to ensure that the major types of aquatic habitat are identified and quantified.
- Conduct field studies to locate rare and unique habitat features, such as wetlands, primary forests, roosting sites, foraging areas, old growth, and migration flyways.
- Determine the present quality and ecosystem value of existing habitats within the Gatun Lake project area.
- Coordinate with local experts to identify and evaluate aquatic and terrestrial habitat areas.

- Prepare species inventories lists for each site area, identifying their status as native or exotic, and whether they are threatened or endangered or both.
- Conduct additional research into water currents and estimated turbidity levels to evaluate impacts to the shallow areas along Barro Colorado Island.
- Address cumulative effects caused by natural flow diversions.

ANIMALS ON THE ENDANGERED LIST

- Compile habitat maps to assess the availability and quality of suitable habitats for the animals on the endangered and/or threatened species list.
- Establish field procedures for assessing wildlife habitat values.
- Conduct site surveys to determine the presence of selected species or their habitats.
- Coordinate with local experts on the presence of endangered species.
- Develop candidate mitigation measures for the appropriate project alternatives to be considered in the Conceptual Phase.

WATER QUALITY

- Since limited water quality data are available for the Gatun Lake area, compile information on total suspended solids, conductivity, total dissolved solids, dissolved oxygen, nutrients, pH, and coliform bacteria.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

- Information regarding cultural resources and historic properties in the project area is incomplete. Additional evaluation studies should be completed to identify any such resources and/or properties.

Evaluation Matrices

In accordance with evaluation procedures described in Volume One, the following tables reflect the conclusions derived for this alternative. A summary table with ranking is provided in Volume One. Tables 41 - 15 through 41 - 17 present the evaluation of the proposed Lower Rio Trinidad project as related to developmental effects, environmental effects, and socio-economic effects.

Table 41 - 15 Developmental Effects

Evaluation Criteria	Function	Measure [1/]	Importance [2/]	Composite [3/]
Water Contribution (Water Yield)	Meets M&I Demands	10	10	100
	Supplements Existing System	2	10	20
	Satisfies Future Canal Needs/Expansion	0	10	0
	Additional Hydropower Potential	0	5	0
Technical Viability	Design Constraints	2	6	12
	Feasibility of Concept	2	6	12
Operational Issues	Compatibility	8	6	48
	Maintenance Requirements	4	2	8
	Operational Resources Required	4	2	8
Economic Feasibility	Net Benefits	0	9	0
	Total			208

[1/] Measure - A numerical from 0 to 10 value representing the degree or level the alternative satisfies the criteria. Value of 10 indicates the most significant beneficial impact and 0 the most significant adverse impact.
[2/] Importance - A weighting factor from 0 to 10 to balance the significance of a criteria to the others.
[3/] Composite - the product of the measure and importance.

Table 41 - 16 Environmental Effects

Item	Measure 1/	Importance 2/	Composite 3/
Terrestrial Habitat	4	8	32
Animals on Extinction List	5	10	50
Water Quantity Impacts – Lake	9	10	90
Water Quantity Impacts -- Downstream	5	7	35
Water Quality	5	10	50
Downstream Aquatic Fauna Habitat	5	8	40
Future Lake Aquatic Plant Community	7	8	56
Aquatic Faunal Inhabiting Affected Area and Upstream Tributaries	5	5	25
Potential for Fishing on Lake	5	6	30
Wetlands	4	4	16
Air Quality	5	3	15
Cultural Resources and Historic Properties	5	10	50
Total			489

1/ Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
2/ Importance - 1 to 10 increasing in importance.
3/ Composite - the product of the measure and importance.

Table 41 - 17 Socio-Economic Effects

Item	Measure 1/	Importance 2/	Composite 3/
Land Use	4	7	28
Relocation of People	4	10	40
Relocation of Agricultural/Ranching Activities	4	6	24
Post-Construction Business	6	5	30
Post-Construction on Existing Employment	5	5	25
Property Values During Construction	5	4	20
Property Values Post-Construction	5	5	25
Public/Community Services During Construction	6	4	24
Public/Community Services Post-Construction	5	8	40
Traffic Volumes over Existing Roadway System During Construction	4	5	20
Traffic Volumes over New Roadway System Post-Construction	5	5	25
Noise-Sensitive Resources or Activities	5	4	20
Communities Receiving Displaced People	5	8	40
Community Cohesion	5	8	40
Tourism	7	5	35
Total			436

1/ Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
2/ Importance - 1 to 10 increasing in importance.
3/ Composite - the product of the measure and importance.

Pertinent Data

Table 41 - 18 presents pertinent data for the proposed Scenario 6 projects.

Table 41 - 18 Pertinent Data for Operating Option 1

GENERAL	Gatun	Trinidad and Quebrado
Dam Site, above Gatun Dam	km	10 km
Drainage Area above Dam Site	1,261.5 km^2	1,051.5 km^2
Average Annual Flow at Dam Site	50.4 CMS	39.6 CMS
LAKE		
EL. of Maximum Operating Lake Level	26.67 m MSL	33.53 m MSL
EL. of Maximum Flood Storage Lake Level	26.74 m MSL	34.14 m MSL
EL. of Minimum Operating Lake Level	25.91 m MSL	22.86 m MSL
Useable Storage between Max. and Min. levels	222 MCM	2,225 MCM
Area at Maximum Operating Lake Level	27,514 ha	25,355 ha
Area at Maximum Flood Storage Lake Level	27,550 ha	26,459 ha
Area at Minimum Operating Lake Level	27,321 ha	10,170 ha
Top Clearing EL.	33.5 m MSL	33.53 m MSL
Lower Clearing EL.	22.9 m MSL	22.9 m MSL
EMBANKMENTS		
Dam - Rock Fill Embankment		
Top EL. of Dam	34.5 m MSL	34.5 m MSL
Fixed Crest Width	13 m	13 m
Height above Lowest Foundation	18 m	28 m
Overall Length of Dam	varies m	4480 m/422 m
SPILLWAY		
Type of Spillway	Gated Ogee	Gated Ogee
Number of Gates	14	8
Width of Gates	13.72 m	18.33 m
Net Length	192.02 m	149.35 m
Total Length	246.27 m	173.65 m
EL. of Crest	21.03 m MSL	25.91 m MSL
Maximum Discharge	5150 CMS	6038 CMS

Plate 41 - 1 Project Location Map

LOWER TRINIDAD / CAÑO QUEBRADO

Project Location Map

SECTION 42

Lower Rio Trinidad 22.9m to 33.5m
Rio Indio 50m to 80m

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

Synopsis

The development plan presented herein combines a dam and a lake in the Trinidad basin within the Panama Canal watershed at Gatun Lake, southwest of Gatun Locks and a dam and lake on the Rio Indio, west of Lake Gatun. Water impounded in the Lower Rio Trinidad Lake adds storage to the Panama Canal system of lakes. This additional storage would be enhanced with the incorporation of a pumping plant into the Lower Rio Trinidad project. This facility allows storage of excess water from Gatun Lake and extends usage of the waters contained in the Lower Rio Trinidad Lake. Water impounded at the Rio Indio site should supply new water for use in the Panama Canal System and can be transferred via a tunnel to the Lower Rio Trinidad Lake.

The Rio Trinidad watershed is located on the western side of the Panama Canal watershed. The proposed dam site is located within Gatun Lake across the Trinidad arm near the town of Escobal. The proposed dam extends from Punta Mala, on the west shore of Gatun Lake, to Guacha Island, then across to the eastern shore of the Trinidad arm, just south of the South Range Point lighthouse. This alignment follows closely the proposed path found in the Study and Report on Increasing the Water Supply of the Panama Canal (referred to as the Tudor Report), prepared by Tudor Engineering Company, San Francisco, California 1962, for the Panama Canal Company. Plate 42 - 1 shows the location of the proposed Lower Rio Trinidad Dam project. The structures for the proposed Lower Rio Trinidad project consist of a rock fill dam constructed by underwater deposition of fill materials, a large pumping plant, and a gated spillway. This spillway should have 11 gate bays, each measuring 18.33 m wide. The pumping plant consists of the pumping station; intake and outflow facilities are separated from the lakes above and below the Lower Rio Trinidad dam by large gate structures. The total project first costs of the proposed Lower Rio Trinidad project are estimated at $1,038,765,000.

The Rio Indio watershed is located adjacent to the western side of the Panama Canal watershed. The proposed Rio Indio dam site is 25 km inland from the Atlantic Ocean and near the mountain Cerro Tres Hermanas. Plate 42- 1 shows the location of the proposed Rio Indio project. The structures for this project consists of a rock fill dam, two saddle dams, an uncontrolled ogee spillway, inter-basin transfer facilities, two hydropower plants, and other outlet works. The tunnel should transfer water from Rio Indio Lake to the Panama Canal watershed as needed for canal operations. The total project first cost of the proposed Rio Indio project is estimated at $245,868,000.

The Lower Rio Trinidad poses great construction difficulties because of the extremely large quantities of underwater fill required for construction of the dam. It requires extensive drilling and site investigation prior to construction and, because of the uncertainties inherent with this type of construction; extensive unforeseen costs may be encountered during construction. Also, the spillway and pumping plant must be constructed in island settings where the structures and appurtenances practically engulf the island areas. This poses extreme space limitations on the construction effort and is very costly.

The proposed Lower Rio Trinidad Dam project, in conjunction with the Rio Indio Dam project, should contribute greatly to the hydrologic reliability of the Panama Canal. The project should also increase the ACP's ability to serve its customers by reducing draft restrictions and the light loading of vessels, especially during periods of low water availability. The existing hydrologic reliability of the Panama Canal, based on the period of record from January 1948 through July 1998 and current demands (38.68 lockages), is approximately 99.6 percent. The hydrologic reliability with the demand increasing to 120 percent of the current level (46.42 lockage) is 98.8 percent. With construction of the proposed Lower Rio Trinidad and Rio Indio Dam projects, the existing high hydrologic reliability may be continued as demand for lockages increases up to 60.2 percent above current demand levels (up to 23.27 lockages).

Site Selection

The Lower Rio Trinidad dam project definition and description was developed with a view toward maximizing the water impounded, while minimizing the volume of material required for construction of the dam and minimizing the number of saddle dams required to contain the lake. The site chosen for the dam is 10 km south of Gatun Locks and 14 km southwest of the navigation channel. The dam would be approximately 4 km northeast the town of Escobal. This site can accommodate construction of a dam with a maximum operating lake level of EL. 30.5 m MSL. Flood storage accommodations are between EL. 30.5 and 28.7 m MSL.

The Rio Indio dam site was chosen to maximize the water impounded, while minimizing the volume of material required for construction of the dam and the number of saddle dams required to contain the lake. To maximize the water impounded, it is desirable to locate the dam as far downstream in the Rio Indio watershed as possible. The ideal location is where the surrounding hillsides are relatively steep and high, and the valley is relatively narrow. However, the downstream portion of the Rio Indio watershed does not contain any sites that meet these criteria, as it is comprised of rolling hills and valleys.

The site chosen for the proposed Rio Indio Dam is 25 km inland from the Atlantic Ocean and near the mountain, Cerro Tres Hermanas. This site can accommodate construction of a dam with a normal operating lake level of EL. 80 m MSL and a maximum flood lake level of EL. 82.5 m MSL.

Hydrologic Considerations

Lower Rio Trinidad

The Rio Trinidad flows northward from the Continental Divide to the Gatun Lake. The headwater of the watershed begins at EL. 1,000 m MSL, approximately 75 km inland, and falls to El. 26 m MSL at Gatun Lake. The distribution of the average annual rainfall over the Rio Trinidad watershed varies from a high of 2,200 mm in the western part of the watershed to 2,000 mm on the eastern side of the watershed. The proposed Lower Rio Trinidad Lake site receives runoff from approximately 750 km^2 of the upper portion of the watershed. Rainfall runoff produces an average annual flow of 32 CMS at the proposed dam site.

The discharge at the Lower Rio Trinidad Dam site was obtained by drainage area ratio to the established record for Gatun. The Gatun Lake runoff is based on records developed by the U.S. Army Corps of Engineers Hydrologic Engineering Center and the ACP in a separate study.

Since the Lower Rio Trinidad Lake is located within Gatun Lake the monthly evaporation rates established for Gatun Lake are considered appropriate for the evaporation rates of Trinidad Lake.

Rio Indio
The Rio Indio flows northward from the Continental Divide to the Atlantic Ocean. The headwaters of the watershed begin at EL. 1,000 m MSL, approximately 75 km inland, and falls to mean sea level at its mouth. The distribution of the average annual rainfall over the Rio Indio watershed varies from a high of 4,000 mm at the coast to a low of 2,500 mm in the middle watershed area. It increases again to over 3,000 mm in the Continental Divide. The proposed Rio Indio Lake receives runoff from approximately 381 km^2 of the upper portion of the watershed. Rainfall runoff produces an average annual flow of 25 CMS at the proposed dam site.

The calculated discharge at the Rio Indio Dam site is extrapolated, recorded, and correlated stream flow data of the Boca de Uracillo hydrologic station. This station began operation in 1979 and is located on the Rio Indio, approximately 2.5 km upstream from the dam site. Data established from a statistical correlation with the discharge data of the Rio Ciri Grande at Los Canones, using standard hydrologic techniques, completed missing data and increased the period of record. Utilization of the double mass curve method satisfactorily verified the consistency of the data measured and correlated.

Due to the proximity of Rio Indio to Gatun Lake, and because of the absence of site-specific information, the monthly evaporation rates established for Gatun Lake are considered appropriate for the evaporation rates of Rio Indio Lake.

Geologic Considerations

Lower Rio Trinidad
The proposed Lower Rio Trinidad Dam site was investigated in 1962 by Geo-Recon, Inc. of Seattle, Washington, as part of the Tudor report. The investigation consisted of seismic velocity and electrical resistivity profiles in conjunction with four test borings (all located in the lake and drilled by the Panama Canal Company). The results of the geophysical surveys reportedly compared well with the logs of the test borings in the deep-water areas (up to 23 m deep) of Gatun Lake. In June 1963, Tudor Engineering submitted a report including additional foundation investigations. The foundation investigations were made by the firm Shannon & Wilson, Inc., Soil Mechanics and Foundation Engineers, from Seattle, Washington, and consisted of 77 cone penetrometer borings, 24 classification borings, 11 undisturbed sample borings, and 6 field vane shear borings. The investigations submitted by Shannon & Wilson, Inc were recently reanalyzed in Geology of the Proposed Dam Across Trinidad Arm of Gatun Lake, by Mr. Pastora Franceschi S., for the Geotechnical Section of the Panama Canal Authority.

In the lake areas, the investigations disclosed that overburden material included recent lake deposits, Atlantic Muck Formation, alluvial deposits, and residual deposits. Between the west shore and Guacha Island these deposits consist of soft to very soft clay, silt, sand and peat (Atlantic Muck Formation) overlying soft to hard deposits of clay, silt, sand and gravel derived both from alluvial deposition and the weathering of bedrock. The upper two phases of the

Atlantic Muck Formation, judged to be the most compressible portion of the formation, was found to have an average thickness of about 18.3 m and a maximum thickness of 22.9 m. Recent, soft lake deposits ranging from 1.2 to 2.4 m thick were found overlying the Atlantic Muck Formation. In the length between Guacha Island and Tern Island, the Atlantic Muck Formation was either not found, or was very thin. In this area, Recent-aged soft sediments (averaging 2 m thick) were found to overlay residual soil and weathered rock. Atlantic Muck Formation, where present, occurred between the Recent-aged material and the residual soil, and was a maximum 5 m thick. Between Tern Island and the east mainland, only recent lake sediments (1.5 m thick) overlying residual clay were found above the conglomerate of the Bohio Formation.

Guacha, Tern and Booby Islands, all located within Gatun Lake, were each found to have an overlying stratum of soft overburdened and weathered rock of variable thickness. In general, firm bedrock was found available below EL. 22.9 m MSL and the islands were judged to offer suitable foundation conditions for control structures.

Firm bedrock under both the land and the lake was found to consist of low velocity sedimentary rock composed primarily of sandstone and the Bohio Formation. Two areas containing abrupt changes in bedrock velocities were located during the survey. One of the areas was a narrow zone located on Guacha Island that was interpreted as a possible shear zone in rock of similar type. The second area was an abrupt change in bedrock velocity on Tern Island that was interpreted as a possible fault contact between two formations, or between different lithologic units of the same formation. The top of the bedrock on land was interpreted from the geophysical results to be weathered to below lake level. The core borings in the lake determined the weathered zone of bedrock to range from 1.2 to 3.1 m in thickness.

Satisfactory foundation conditions exist for construction of a pumping station, and a spillway at the Lower Rio Trinidad Dam site. Serious consideration, however, must be given to problems that would be caused by the anticipated settlement and instability of the embankment materials. Additionally, it is assumed that all concrete aggregates may be obtained from commercial sources.

Rio Indio

The proposed Rio Indio Dam project is located in an area of the Isthmus of Panama underlain by Oligocene-aged sedimentary rocks of the Caimito Formation. Three members of the Caimito Formation are recognized: the lower, the middle and the upper. The deposits of each of these members are mainly marine, but are lithologically heterogeneous. The lower member is composed of conglomerate and tuffaceous sandstone. The middle member consists chiefly of tuffaceous sandstone, some of which is calcareous, and lenticular limestone. The upper, principal member consists of tuff, agglomeratic tuff, tuffaceous siltstone, and discontinuous sandy tuffaceous limestone. In general, all members are hard, thinly to thickly bedded, and closely to moderately jointed. The lower member weathers to greater depths. A summary of test data developed in 1966, as part of the studies for a sea level canal, listed compressive strengths for samples of Caimito Formation material varying between 79,450 and 5,955,257 kg/m^2. The same 1966 studies assigned an allowable bearing capacity of 195,300 kg/m^2 for the material of the Caimito Formation.

The report required an investigative visit to the proposed site for the Rio Indio Dam. The investigation found moderately hard siltstone, fitting the description of strata of the principal member of the Caimito Formation, exposed along the riverbed at the proposed site. This siltstone makes an acceptable foundation for an earth and rock fill dam. It would be unacceptable for use as concrete aggregate and only marginally acceptable for use as fill in some of the less important zones of an earth and rock fill dam. Due to dense vegetation, it is unknown whether sedimentary or volcanic material underlies the ridges that form the proposed abutments. Further development of this project requires drilling cores in each abutment early during planning studies to identify the abutment material and to determine its general suitability for use as construction material. In addition, the cores must be of sufficient depth to check for the occurrence of any soluble limestone strata that may underlie the dam foundation.

The proposed inter-basin transfer tunnel connecting the Rio Indio Lake to the Panama Canal watershed is probably located very near the contact of the Caimito Formation and the overlying Miocene volcanic rocks. Many springs occur in the area of the proposed tunnel inlets and outlets, and groundwater flowing in volcanic rock above impervious strata of the Caimito Formation may be the cause. In addition, a 1921 drawing shows two coal mines in the general area of the tunnel inlets. Further development of this project would require drilling of cores near the proposed tunnel inlets and outlets early during planning studies to determine the general relationship between the tunnel alignments and the sedimentary / volcanic rock contact, coal or peat beds, and the water table.

In the absence of detailed geologic mapping for the proposed Rio Indio Dam site, a degree of extrapolation is necessary. Available general geologic mapping and general data were the basis of predictions that rock, encountered at a shallow depth and of sufficient quality, could serve as foundation for the dam and appurtenant structures. Furthermore, assumptions for this report are: required excavation should make available sufficient rock for fill, and the immediate area contains enough impervious materials and concrete aggregate for use in the construction of the proposed project.

Lake Operation

Two operating mechanisms are included in this study for periods when water would be transferred from Lower Rio Trinidad Lake to Gatun Lake for canal operations. The first consists of allowing the water surface of the lake to fluctuate from the normal operating lake level, EL. 33.53 m MSL, to the minimum operating lake level at Gatun Lake, EL. 26.7 m MSL, which should provide 1,366.8 MCM of useable storage. Thereafter, the Lower Rio Trinidad Lake can be drawn down by pumping, allowing further fluctuation from the normal minimum Gatun operating lake level, EL. 25.91 m MSL, to the minimum Lower Rio Trinidad Lake level, EL. 22.86 m MSL. This should provide an additional 442.4 MCM of usable storage. The maximum flood level at Lower Rio Trinidad Lake is at EL. 34.14 m MSL. Flood storage accommodations are available between EL. 22.86 and 34.14 m MSL. Trinidad Lake rule curve is designed to function similar to the rule curve for Madden Lake. Table 42-1 shows the lake levels for the two affected pools.

Table 42 - 1 Lake Operating Levels – Lower Rio Trinidad & Gatun

Lake Level (m MSL)	Lower Rio Trinidad	Gatun
Normal Operating Lake Level	33.53	26.67
Minimum Operating Lake Level	22.86	25.91
Maximum Flood Lake Level	34.14	27.13

The operating scenario for periods that require water transferal from Rio Indio Lake to the Panama Canal watershed for canal operations allow the water surface of the lake to fluctuate from the normal operating lake level, EL. 80 m MSL, to the minimum operating lake level, EL. 50 m MSL and provides 993,000,000 M^3 of usable storage. The maximum flood lake level is at EL. 82.5 m MSL. The volume between the maximum flood lake level and the normal operating lake level can store floodwaters and reduce peak flood flows. Areas along the Rio Indio downstream of the dam should realize some reduction in flooding. Table 42 - 2 shows the lake levels for the lake at Rio Indio.

Table 42 - 2 Lake Operating Levels- Rio Indio

	Lake Level (m MSL)
Normal Operating Lake Level	80
Minimum Operating Lake Level	50
Maximum Flood Lake Level	82.5

Project Features

GENERAL

The structures for the proposed Lower Rio Trinidad project should consist of a rock fill dam, a large pumping plant, and a gated spillway. Modification of one existing saddle dam and construction of two additional saddle dams would also be required. Plate 42 - 2 shows the dam site in downstream left bank perspective and indicates the location of the spillway and pumping facilities.

The structures for the proposed Rio Indio project consists of a rock fill dam, two saddle dams, an uncontrolled ogee spillway, inter-basin transfer facilities, two hydropower plants, and outlet works. Plate 42 - 1 depicts the site plan for the Rio Indio Dam.

The following paragraphs provide a description of the proposed structures and improvements for these projects

Design is performed only to the extent necessary to establish, with reasonable accuracy, the principal dimensions, elevations, and costs of the proposed project. Separate documentation was provided to the ACP that contained assumptions and design calculations for the reconnaissance level investigations of these structures. If this project is carried into the planning studies, optimization of the project features and improvements must be accomplished.

EMBANKMENTS

Dams

Lower Rio Trinidad Dam
The proposed dam consists of an embankment with the top at EL. 31.50 m MSL and with a crest width of 13 m with a final crest of 7 m upon completion of all settlement of the embankment and bridgework. The left abutment of the embankment will be located at Universal Transverse Mercator Grid, Zone 17, Clark 1866 Spheroid Coordinates 1015858 north and 614864 east. The right abutment will be at 1013937 north and 618229 east coordinates. The normal lake El. 30.48 m MSL while the ground surface elevations along the axis of the dam vary from El. 2 m MSL in the lake bottom to El. 39 m MSL on Guacho Island and El. 38 m MSL on Tern Island. The Gatun Lake subgrade supporting the embankment occupies a broad flat valley having sides, which slope, upward from the valley at grades up to 40 percent. Water depths are 21.3 to 26.3 m over 80 percent of the site. The Atlantic Muck Formation, consisting of very soft organic clays, silts and peats varying in thickness from 7.6 m to 48.7 m, underlies approximately two thirds of the alignment subgrade. The Atlantic Muck Formation in the old river channel is further underlain by soft silts, sand and clay strata.

The critical challenge for design espoused by the Tudor Report and others is the depth of subgrade degradation during the initial fill placements. The materials will lose much of its natural strength when disturbed and will only regain strength after the effects of consolidation of a surcharge fill. However, complete restoration of strength can only be assumed to a depth of 5 to 7 m. If the effects of the subgrade disturbance extend appreciably deeper, then an extremely weak material will be under the more stable subgrade and surcharge creating a condition of lateral instability.

Due to the inability to accurately analyze this condition, a test fill was performed on the western end of the alignment. In early 1963, 1,000-cy bottom-dump barges deposited some 168,000 cy of blasted rock from the cut widening project, extending some 305 m. 155 m of the fill was placed to a height of 11 m while the remaining 150 m was filled to 5 m. The differential heights were use to simulate initial and intermediate fill placement effects. Divers were then used to observe the performance of the fills placed along the alignment. The mechanisms of failure within the subgrade were caused by impact and static loadings. The impact of the initial placements caused severe destruction of the surface materials creating lateral displacements up to 5 m. However, when a continuous blanket of fill had been established and subsequent fill was placed, then conventional failures such as slip circle shear failures and horizontal shears creating large mud waves outward from embankment were observed. Therefore, to predict the behavior of the embankment during construction and for the long term, it is imperative that a foundation mat be established to such a depth to prevent subgrade rupture with subsequent fill placement. The Tudor report recommended that a 5 m thick minimum crushed rock blanket with maximum sizes of 20 cm be placed initially to act as the supporting blanket. Special barge dumping methods were to be employed so loads would not fall as an integral mass, which would create destructive forces on the subgrade.

The placement of a large hydraulic structure on a deep-seated weak foundation is the most challenging of geotechnical endeavors. It is virtually impossible to analyze with great deal of certainty and the owner must be prepared to accept possible additional costs during construction and long term maintenance due to the potential for lateral instabilities and high degrees of settlement. The Tudor Report has predicted some 2.5 to 3 m of predicted settlement below the crest elevation for a construction duration of 7-years and an additional 2.5 to 3 m of maximum settlement below the crest for the 50-year service life of the project. These settlements are predicted where the Atlantic Muck and underlying compressible materials are the thickest. These movements are reduced as the fill approaches the mainlands and the two islands. This implies that significant differential settlements are predicted within these approaches as well. The key to any successful construction and maintenance of this embankment will be to establish a blanket mat atop the subgrade where subsequent fill can be economically placed without fear of rupturing the foundation to greater depths. Any significant lateral failure of the embankment during construction or productive use will render that alignment unsuitable. Additional embankment sections must be established upstream or downstream to reestablish the embankment section to the proper elevation. This repair will take considerable time and prevent its use as a road. Based on these considerations, our recommendations were presented for ultimate costs considerations in comparison to alternatives with a greater degree of performance certainty.

The divers observed that the test fill had trouble placing the fill in the correct locations within the alignment and the lift thickness varied significantly over the fill cross section. It is imperative that the blanket fill be placed intact with the least subgrade disturbance in order for the embankment to act as monolithic mass. Therefore, the initial 5 m of fill will be barged to the site and placed by lowering a clamshell to the subgrade surface. The positioning of the barges must be strictly controlled by survey positioning systems established on land. The initial fill should have a maximum size of 20 cm and the percent fines should be controlled to remain fairly intact during placement. Materials with a significant size differential and a large fine content can create weak shear zones with the embankment. The subsequent fill materials above this zone can be placed by bottom dumped barges or clamshells from El. 8 to 21 m MSL. The material above El. 21 m MSL must be placed by clamshell due to the draft and door operations of the barges. These materials will be more random in gradation having a maximum size of 30 cm and a greater degree of fines. The materials placed below El. 27 m MSL will assume a side slope of 1 V:15 H. A 15 m berm will be constructed and the materials will continue to be placed by clam shell and spread with a dozer to El. 34.5 m MSL, assuming a side slope of 1 V : 3 H and a crest width of 13 m. The flatter side slopes are needed to distribute bearing pressures and to reduce the lateral displacements. This configuration should also reduce the construction and total settlements predicted by the Tudor report and provide acceptable factors of safety for lateral stability during fill placement. The side slope berms and extra crest width will facilitate the future fill placements of up to 3 m over the life of the project. The road surface atop the dam embankment will remain gravel surfaced for the foreseeable future due to future fill placements. The dam will be approximately 30 m high, and the overall length 4,473 m. The top of the dam will be 5 m above the normal Gatun Lake level. The total volume of fill material required to construct and maintain the main dam to El. 34.5 m MSL is approximately 39,883,250 M^3. Water access from the main channel to Guacha and Tern Islands will be built during construction. After access roads have been constructed, fill placements from the east mainland to Tern and Gaucha Islands could be delivered by truck and placed by end-dumping from the east mainland. This technique could prove beneficial if a material source was found near the Gatun Lock area. The side slopes and overall embankment configuration was offered for ease of calculation, to reduce the foundation pressure on the soft subgrade and to account for the lateral displacement of embankment materials. The increased foundation base should help the structure survive a relatively minor seismic event.

The methods of subgrade stabilization and embankment strengthening offered in the powerpoint presentations from the ACP Engineering Division are examples of many ideas for enhancing the performance of the embankment during construction and post construction. The use of wick drains have been an effective tool for accelerating consolidations under a mass loading. However, we feel that the Atlantic Muck materials will not readily transmit water to the drains, therefore the spacing of the drains must be much closer than that implied and the effectiveness of the drains will be restricted to the top 15 to 20 feet of the foundation subgrade. The drains must be effectively tied into the foundation blanket for continuity of the drainage path. There are concerns over the use of vibro-flotation or stone columns techniques above the mat. The mat will not effectively dampen these compaction forces and some rupture of the mat could be possible. A safer reinforcing technique could be the use of reinforcing within the embankment section, such as high strength geogrids placed in layers. All reinforcing techniques are expensive but could be offset by the reduction in fill quantities ultimately required. Any reinforcing selected for use in production must be part of a comprehensive test fill program to demonstrate its effectiveness.

The Tudor Report identified considerable leakage to be expected from the completed embankment. Since loss of any water from storage is a significant reduction in benefits, the seepage must be prevented. Therefore a bentonite slurry trench should be installed within the centerline of the embankment. The trench will be a minimum of 3 feet wide and extend to several meters below the original lake bottom. The trench can be excavated using rockmill techniques. Since the embankment will undergo significant settlement, both total and differential, it is likely that the trench will be sheared and will require replacement within the deeper portions of the lake during the life of the project.

Rio Indio Dam

The Rio Indio Dam would be constructed as an embankment, with the top at EL. 83.5 m MSL and with a crest width of 13 m. The left abutment of the embankment would be located at Universal Transverse Mercator Grid, Zone 17, Clark 1866 Spheroid Coordinates 994408 north and 589644 east. The right abutment would be 994801 north and 590432 east coordinates. The embankment would be constructed with an impervious earth and rock fill core encased in rock fill, and the final side slopes would be 2 H : 1 V. The dam at its highest point shall be approximately 73.5 m high - the overall length 891 m. Further study should determine the actual side slopes and crest width and contingent upon the need for vehicular access across the embankment, the size and quality of the rock fill, and the detailed design of the embankment. Plate 42 - 3 presents a typical section of the embankment at the dam, incorporating upstream and downstream cofferdams within the section.

Foundation grouting would be required across the entire base of the dam and up a portion of the valley walls. A blend of bentonite and native fill materials in a core trench may provide seepage cutoff in the embankment foundations. A concrete or bentonite cutoff wall can also provide seepage cutoff.

The crest width and side slopes are presented for comparison purposes between the various projects. The actual crest width and side slopes would be determined during further study and contingent upon the need for vehicular access across the embankments, the size and quality of the fill materials available for use, and the detailed design for the embankments.

Saddle Dams

As noted in the Tudor Report, the existing Caño Saddle Dam No. 4, located along the western shoreline of the Trinidad Arm of Gatun Lake, needs to be raised and/or strengthened to accommodate the higher lake levels. Immediately to the north of this location, two additional smaller saddle dams are required. All saddle dams must be built to provide a minimum top El. 31 m MSL. The total volume of fill material required for these three dams is 50,000 M^3

The actual side slopes and crest widths would be determined during further study and are contingent upon the need for vehicular access across the embankment, the size and quality of the rock fill, and the detailed design of the embankment. A typical section of the embankment at the saddle dams and main dam is similar to that shown for the embankments for the Rio Indio project, Volume One of this report.

SPILLWAYS

Spillways are required at two of the dam sites, Rio Indio and Lower Rio Trinidad under this scenario.

Lower Rio Trinidad
Under normal flow conditions water passes from Lower Rio Trinidad Lake to Gatun Lake through a gated spillway. This spillway should have 8 gate bays, each 18.33 m wide. The gate bays would be separated/flanked by 3 m wide reinforced concrete piers (9 piers in all), which should provide support for the gates and operating machinery, as well as providing support for a roadway bridge over the top of the spillway. Each of the 8 spillway gates should have a nominal width of 18.33 m and a height of 8.53 m, providing 0.3 m freeboard above the maximum lake operating level. The overall length of the spillway, from out-to-out of piers is 173.64 m. The spillway sills would be placed at the minimum lake operating level, EL. 25.91 m MSL.

A bridge across the tops of the spillway piers would be constructed as a part of the roadway across the top of the dam. The roadway must be approximately 7 m wide thus allowing for two-way traffic and providing ready access to the spillway gate operating machinery.

For this study, stop logs for servicing the gates, guides, etc. may be placed either from the roadway or from barges using floating cranes. Also, it should be noted that, with the spillway sill at the prescribed level, stoplogs are required both upstream and downstream to allow work to be done on the gates and sills in the dry.

The spillway would be situated along the axis of the dam approximately centered in Guacha Island. This allows the construction to be performed completely within a dry construction cut requiring a minimum of construction dewatering. Once the concrete structures are completed, the entrance and exit channels to the spillway can be opened.

Rio Indio Dam
At the Rio Indio dam an uncontrolled ogee spillway with a length of 120 m and a crest at EL. 80 m MSL would be required. The spillway crest would be 3.5 m below the EL. of the top of the dam. The maximum discharge from the spillway would be 920 CMS at a maximum flood lake level at EL. 82.5 m MSL. The spillway design discharge was equivalent to a 1 in 1,000

frequency unregulated flow at the dam site. The spillway would be located within the abutment adjacent to the left end of the dam and would consist of a mass concrete sill section embedded in the natural rock. A sloped and / or stepped, natural rock cut tailrace channel would return flow to the existing stream. The tailrace channel would extend from the sill section to its confluence with the natural stream some distance downstream from the toe of the dam. The task of dissipating energy at the downstream end of the tailrace channel requires excavation of a stilling basin into the rock adjacent to the natural channel. See Plate 37 - 2 for the location of the spillway and Plate 37- 4 for a typical section at the spillway.

Foundation grouting would be required across the entire base of the dam and up a portion of the valley walls. A blend of bentonite and native fill materials in a core trench may provide seepage cutoff in the embankment foundations. A concrete or bentonite cutoff wall can also provide seepage cutoff.

PUMPING PLANT

A large pumping plant is included in this scenario at the Lower Rio Trinidad dam. This pumping facility provides for pumping in two directions, allowing Lower Rio Trinidad Lake to be drawn down to a level below that of Gatun Lake during extremely dry months, and providing the capability of pumping excess water from Gatun Lake into Lower Rio Trinidad Lake during the flood season. Water thus stored would be available for navigation during the dry season. The pumping plant is configured to provide pumping to EL. 33.53 m MSL in Lower Rio Trinidad Lake. For the purpose of this study the pumping plant is located in the northwest segment of Tern Island. See Table 42-3 for the controlling head and flow data used for this study.

This plant should consist of six 1407 HP pumps, each capable of pumping slightly more than 62 CMS for a total plant pumping capacity of 373 CMS at a total dynamic head of 4.6 m. The pumping units would be mounted in a reinforced concrete housing and arranged in a row perpendicular to the axis of the dam, with intake and outlet channels on either side. The channels would be separated from the Lower Rio Trinidad and Gatun Lakes by large concrete walls containing low-level sluiceways and gates for controlling flows into and away from the pumping plant. These sluiceways are configured to provide average entry velocities of approximately 7.7 MPS. The channels are configured to provide this velocity or less and require no special armoring of walls or inverts for scour protection. The channel invert would be at EL. 20 m. MSL, or 13.5 m. below the centerline of the pump outlets. This may provide sufficient water depth at maximum pumping to buffer the erosive effects of the very large outflows required.

In conjunction with this facility a roadway bridge would be required to connect the pumping station structure to the banks on either side of the intake and exit channels thus continuing the roadway across the facility. This bridge should also provide both operational and maintenance access to the pumping plant. As configured for this study, the bridge must have two 15 m long spans with steel girders and a concrete bridge deck on each side of the pumping station. It shall have a 7 m wide travel way and include one bridge bent including a cap, two round columns and a spread footing, located within each channel section.

Table 42 - 3 Pumping Data

Pumping Cycle	Head (m.)	Average Daily Flow (M^3/sec)
Lower Rio Trinidad (Elev. 22.86) to Gatun Lake (Elev. 25.91)	3.05	127.43
Gatun Lake (Elev. 26.67) to Lower Rio Trinidad (Elev. 33.53)	6.86	56.64

IMPOUNDMENT

The lake formed by the proposed Lower Rio Trinidad Dam under this scenario should have a normal operating lake, EL. 33.53 m MSL. The surface area at the normal operating lake level is 21,912 ha. At the maximum flood level, EL. 34.44 m MSL, the surface area is 22,830 ha. With the minimum operating level, EL. 22.86 m MSL, the surface area is 9,019 ha. It should be noted that the current operating levels of Gatun Lake vary to EL. 26.67 m MSL; therefore areas below the maximum Gatun Lake level are already subject to inundation.

The lake formed by the proposed Rio Indio Dam should have a normal operating lake level at EL. 80 m MSL. The surface area at the normal operating lake level is 4,280 ha. At the maximum flood lake level, EL. 82.5 m MSL, the surface area is 4,440 ha. With the minimum operating lake level, EL. 50 m MSL, the surface area is 2,360 ha.

CLEARING AND/OR GRUBBING

Clearing and grubbing is required for all areas above the existing Gatun Lake that are required for construction of the dam (embankments and spillway), access roads, and disposal and staging areas. For the Trinidad Lake area, clearing is required for the 3,700 ha in the lake area between the maximum operating lake level of Gatun Lake and EL. 30.5 m MSL.

For the Rio Indio Lake, clearing is required in all areas necessary for construction of the dam (embankments and spillway), inter-basin transfer facilities, outlet works, hydropower plants, access roads, and disposal and staging areas would require clearing and grubbing. Only the 650 ha in the lake area between the normal operating lake level, EL. 80 m MSL ,and the minimum operating lake level, EL. 50 m MSL, require clearing. The transmission lines also require clearing.

ACCESS ROUTE

Access to the lake site and the various construction sites was evaluated from the main population centers, Colon on the Atlantic coast and Panama City on the Pacific coasts.

Lower Rio Trinidad
The route from Colon is westward across the Panama Canal and then southwestward along existing roads that follow the westernmost boundary of Gatun Lake to Cape Mala, near the western abutment of the dam. A very short access road is required from the existing road to the

dam site. This route requires crossing the Panama Canal near the Gatun Locks using the existing lock gate bridge. This bridge is narrow and operates only intermittently since canal operations take precedence over roadway traffic. It may be undersized and may lack the load carrying capacity needed for heavy construction materials and equipment loads anticipated.

Access to the spillway and pumping station construction sites would be by water since these structures are to be placed on Guacha Island. A water access route is a possible means of conveyance for much, if not all, of the construction equipment and materials. This requires offloading facilities be constructed near the west abutment of the dam on Guacha Island, and near the eastern abutment site in the vicinity of South Range Point.

Since much of the construction for this project would be in the existing lake or on an island, it is concluded land and water are both required. Plate 42 - 1 shows the general location of the proposed features and the possible land and water access available or to be provided.

Rio Indio

For access to the Rio Indio site it is concluded that the route from Panama City westward across the Bridge of the Americas, then southwestward along the Inter-American Highway, and then westward along existing roads to Ciri Grande, may be best. This route requires that the road between Panama City and Ciri Grande be upgraded over much of its length and the route west of Ciri Grande must traverse the mountains. The proposed access road would be 26 km in length, and bridges and / or culverts would be required at 15 streams. Plate 42-1 shows the portion of the proposed access road from Ciri Grande to the construction sites.

In addition to providing dam construction access, this new corridor into the country west of the Panama Canal benefit those living in the region, providing access to the main centers of commerce in the southern part of the country. It should also provide continuous access along the new power transmission lines from the dam site to the connection with the power grid.

Sources of Construction Material

Lower Rio Trinidad

The bottom 5 m layer of the dam embankments shall be constructed with material less than 8 in. maximum size, and with no more than 5 percent passing the #200 screen. Such a material should require crushing and processing across a grizzly to remove oversize rock, and washing to remove fines. Material for this bottom layer must be reasonably well graded so as to prevent the removal of the finer fraction by piping. The overlying main portion of the embankment would be constructed with (-12 in.) sized material. This material should also require crushing and processing across a grizzly to remove oversize rock.

The majority of the materials used for the embankment construction would be obtained from upland sources adjacent to the Gaillard Cut, transported to the site by barge and clam shelled along the proposed embankment alignment. The initial materials would be obtained from the existing disposal sites for the Gaillard Cut widening above Pedro Miguel Locks. Based on the information received from the ACP, these sites contain approximately 5.5 million M^3 of suitable excavated rock. However, this rock is not stockpiled in an orderly manner, is randomly mixed with unsuitable material and is covered with unsuitable material. All the rock materials, from whatever source, should need to be crushed, graded and loaded on trucks for transport to a loading facility adjacent to the canal at the Cucaracha Reach on the east side, or the mouth of the Mandinga River on the west side. These loading facilities should require excavation into the bank area and bulkheaded for crane support and barge placement. Working stockpiles would be maintained next to the transfer points to facilitate the loading process. Additional materials within the immediate area should come from the Third Locks excavation adjacent to the Pedro Miguel Locks. These materials would be drilled and blasted in place, excavated, and then transported to one of the transfer facilities for processing. Additional materials should come from newly developed quarry sources in areas such as Hodges Hill, Escabor Hill, Contractor Hill, and others within 10 km of the transfer points. Each of these new sources should require extensive excavation to remove the overburden and soft rock materials. These materials would be stockpiled adjacent to the work area for restoration once the rock fill materials have been acquired. The suitable rock materials would be blasted, crushed and graded and trucked to the transfer points All material would be loaded onto barges, transported to the dam site and clam shelled within the dam limits.

Cement is available within the country. Rock obtained from developed quarries may be used to produce concrete aggregates on-site, or they may be obtained from commercial quarries. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) need to be fabricated outside the Republic of Panama and imported for final assembly and installation at the proposed dam site.

Rio Indio
Rock removed from the spillway site can used as fill in the embankment portion of the dam. Impervious materials might be obtained from outside the project area; however, for this study it is assumed that these materials would be available locally in sufficient quantity to supply the project needs. If further study indicates that impervious materials are unavailable locally, then other materials, such as roller compacted concrete, would be considered for construction of the dam.

Cement is available within the Republic of Panama. Rock obtained from developed quarries may be used to produce concrete aggregates on-site, or may be obtained from commercial quarries. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) need to be fabricated outside the country and imported for final assembly and installation at the proposed dam site.

Real Estate Requirements

The Lower Rio Trinidad Lake site is located within the former Panama Canal Zone and is presently managed and controlled by the ACP. Construction of this project requires the acquisition of 800 ha. Table 42 - 4 shows the amount of land required for the various project features. Real estate for access roads is included in the estimated quantities for the other items listed in the table.

Table 42 - 4 Real Estate Requirements

Project Feature	Land Required (ha)
Lake	0
Dam Site	0
Staging Area	200
Housing and Facilities	200
Disposal Area	400
Total	800

The Rio Indio project site is located in the Cocle, Colon, and Panama Provinces. Construction of this proposed project requires the acquisition of 5,600 ha. Table 42 - 5 shows the amount of land required for the various project features. Real estate for access roads is included in the estimated quantities for the other items listed in the table.

Table 42 - 5 Rio Indio Real Estate Requirements

Project Feature	Land Required (ha)
Lake	4,600
Dam Site	200
Staging Area	200
Housing and Facilities	200
Disposal Area	400
Total	5,600

Relocations

The proposed Lower Rio Trinidad Lake site is located within the existing former Panama Canal Zone. Structures and facilities established along the waters edge in the Rio Trinidad arm, between the existing Gatun Lake levels and EL. 30 m MSL, need to be relocated or modified. This includes a major portion of the town of Escobal. Additionally, there are a few small communities and isolated individual structures along the lakeshore with very limited access by land.

The proposed Rio Indio Lake site is located in a sparsely settled region with few roads and utilities. This area is devoted primarily to subsistence farming and ranching. Structures and individuals located in the lake area below EL. 85 m MSL require relocation because of the normal lake inundation, and to secure land on the lake perimeter for flood considerations. The required relocations include the five towns (El Limon, Los Uveros, La Boca de Urcelillo, Aguila, and Tres Hermanas), approximately 30 other small settlements, and numerous isolated structures. The five towns all have elementary schools, churches, electricity, and limited telephone coverage.

Development Sequence

Each component of the lake projects is designed and can be constructed as a stand-alone facility. If the Rio Indio facilities are constructed first and placed into service before the Lower Rio Trinidad facilities, the interbasin transfer tunnel can be used to navigational advantage while the Lower Rio Trinidad project is being completed. During the interim the Rio Indio project should help control flooding on the Lower Rio Indio and can contribute to the electric power output of the country.

The development sequence for each individual project follows roughly the same progression. This progression is summarized below with pertinent site-specific notations as appropriate.

Each project must be evaluated to assure that the plan presented includes all of the features required to function. Each project must be assessed as to its effectiveness in providing navigation water to the Panama Canal, with due recognition of any secondary benefits. Environmental assessments of the proposed projects need to be made to assure environmental acceptability of the project features. These environmental assessments begin during the planning studies phase and continue into the final design, advertising and award phases. Environmental coordination begins with planning studies and continues through the completion of construction. After completion of the final design, plans and specifications must be prepared for the advertising and award phase.

Project implementation begins with land acquisition and construction of the access facilities. Lands for the housing and facilities project feature, which includes the access roads, need to be acquired initially. Lands for the dam site, staging area, disposal area, and lake can then be acquired.

Socio-economic programs must begin shortly before construction of the dam. The relocation of the small settlements and isolated structures must be accomplished. Socio-economic programs to assist those individuals impacted by the construction of the proposed project should continue throughout the construction phase.

Construction of the Rio Indio Dam begins with the clearing and grubbing of the construction sites and clearing the perimeter of the lake area. Materials used for the embankment construction can obtained from upland sources then transported to the site.

Upstream and downstream cofferdams are required for construction of the Rio Indio Dam and appurtenant facilities. These shall be configured to form a portion of the finished dam.

Limited cofferdams would be required to accomplish construction of the spillway and pumping station. These efforts may be accomplished simultaneously. Following completion of the pumping plant and spillway, the channels connecting these structures to the lake areas upstream and downstream may be excavated. Where possible, materials removed from these sites would be placed directly into the dam.

Once the western leg of the dam, pumping station and spillway are completed, the eastern leg may be constructed, thus completing the dam. The pool may then be raised. Upon completion of this phase of construction, all facilities must undergo trial operations, before being commissioned for service.

Considering the construction methods required and the nature of the work, it is estimated that development of the Lower Rio Trinidad and Rio Indio Dam projects may be completed in approximately the time spans indicated in Figures 42-1 and 42-2, below, from initial planning to lake filling. Assuming that the development of the two projects is overlapped by 1-year the total development time is approximately 22-years.

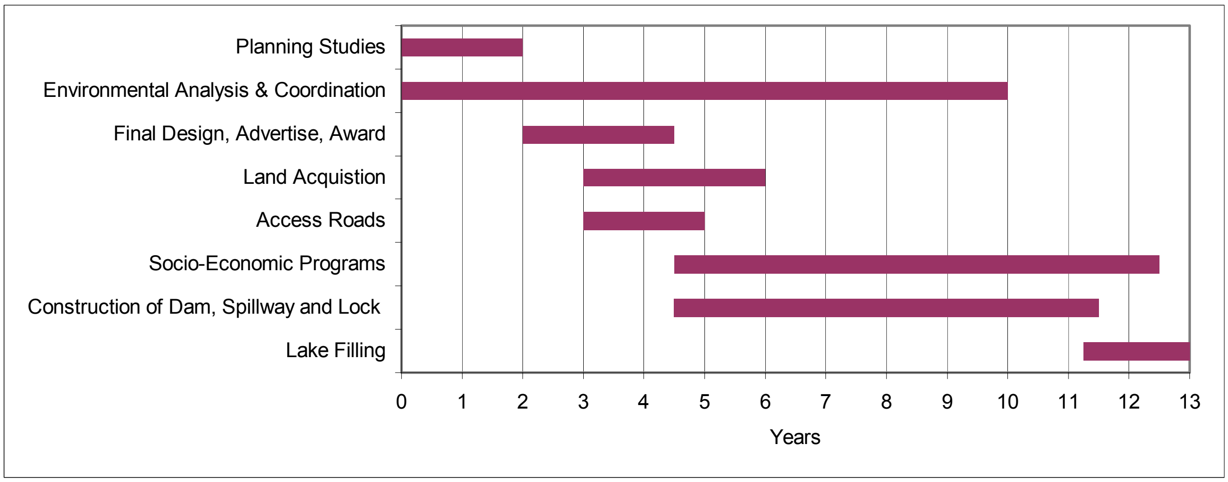


Figure 42 - 1 Development Sequence – Lower Rio Trinidad

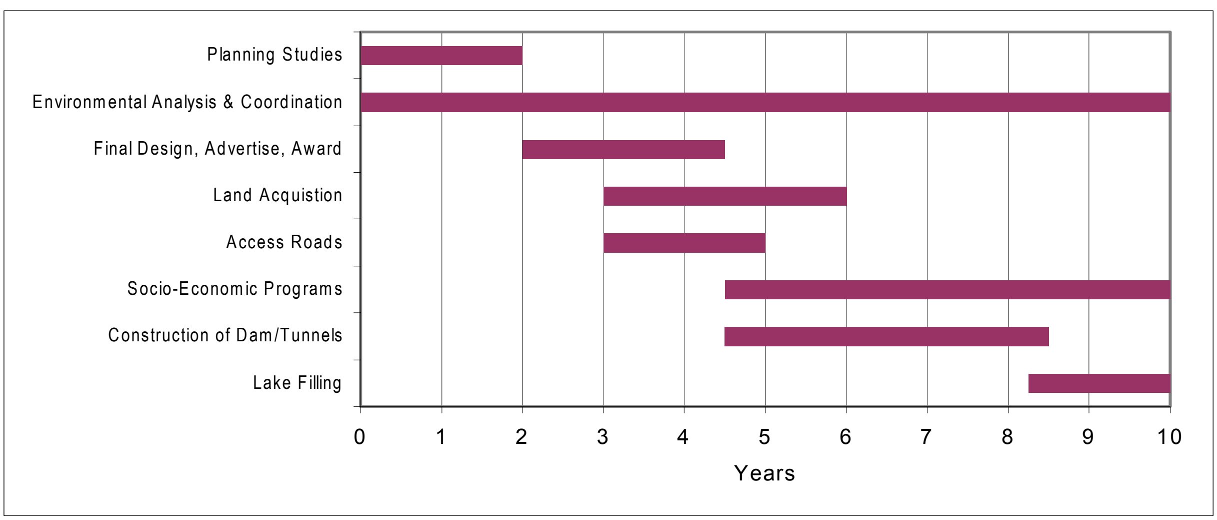


Figure 42 - 2 Development Sequence – Rio Indio

Hydrologic Reliability

In order to determine the effect of the proposed lakes on the hydrologic reliability of the Panama Canal, the existing HEC-5 model is modified to include the Lower Rio Trinidad Lake with pumpback operation and diversion from Rio Indio Lake. The existing Gatun Lake parameters (surface areas, storages, and local inflows) are reduced by the proportion that Lower Rio Trinidad would capture.

HEC-5 model simulations are conducted for both the existing canal system and the Scenario 7 operating system providing water to the Panama Canal watershed. The simulations considered proportionally increasing demands to 180 percent of current demand levels. The period of simulation considered 52 years (January 1948 through December 1999) of hydrologic record, see Figure 42 - 3. These configurations are:

- Existing system,
- Scenario 7 – Rio Indio Lake fluctuating between the normal operation lake, EL. 80 m MSL, and the minimum operation lake level, EL. 50 m MSL, with a 3 m diversion tunnel; Lower Rio Trinidad Lake fluctuating between the normal operating lake level, EL. 33.5 m MSL, and the minimum operating lake level, EL. 22.86 m MSL, with pumping capability to and from Gatun Lake; and Gatun Lake fluctuating between the normal operating lake level, EL. 26.67m MSL, and the minimum operation lake level, EL. 25.91m

The horizontal axis along the bottom of Figure 42 - 3 reflects demands as a ratio of the 5-year average from 1993 to 1997, and the axis along the top reflects demands in lockages (assuming 55 million gallons per lockage).

The existing hydrologic reliability of the Panama Canal, based on 52-years, is 99.6 percent, while the hydrologic reliability, with a demand ratio of 1.8, is 86.3 percent. This period of record includes the worst drought on record for the area, which occurred 1998. The hydrologic reliability, with a demand ratio of 1.0, is 100 percent for operating Scenario 7, and the hydrologic reliability, with a demand ratio of 1.8, is 98.19 percent. Table 42 - 6 displays the number of lockages associated with various levels of reliability.

Without additional water supplies, the hydrologic reliability of the canal system should decrease. With the construction of the proposed Lower Rio Trinidad Pumpback and Rio Indio Dams projects, the existing high hydrologic reliability can continued as demand for water increases by 60.2 percent (23.27 lockages) above current demand levels.

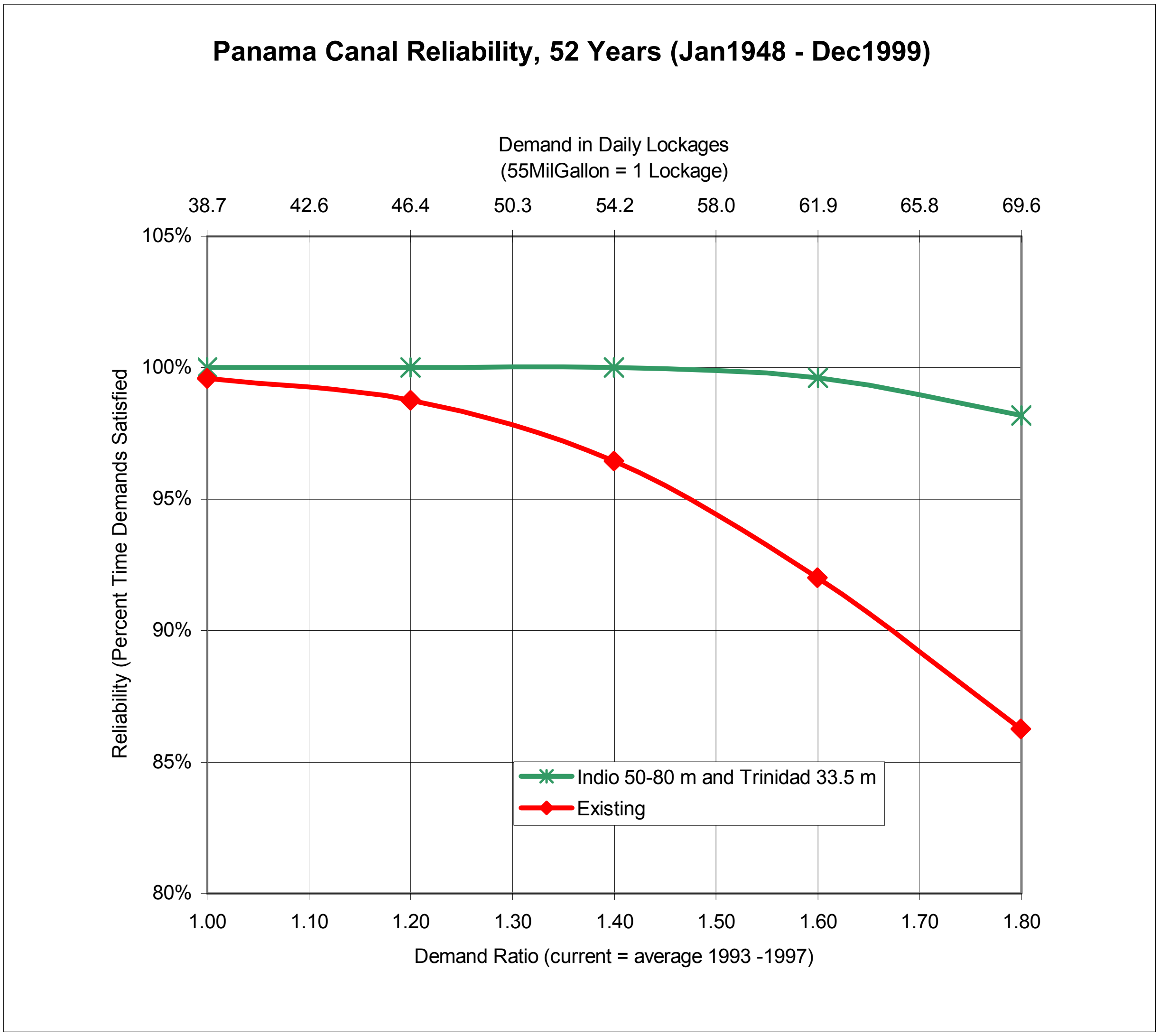


Figure 42 - 3 Panama Canal Hydrologic Reliability

Project Costs

GENERAL

The quantities estimated for the various items of work required for the construction of this project are derived from the layouts shown on Plates 37-2 through 37-8. The unit prices applied to these quantities are based on: historical information from previous estimates prepared for similar construction by the ACP; estimates for similar construction in the Mobile District; information gathered from Mobile District Construction Division personnel in Panama; and the book Feasibility Studies For Small Scale Hydropower Additions, A Guide Manual, written by The Hydrologic Engineering Center of the U.S. Army Corps of Engineers.

Engineering and design is estimated to be 12 percent while supervision and administration is estimated to be 6 percent of the construction cost items. An allowance of 2 percent of the construction cost items is allowed for field overhead (construction camp, contractor facilities, etc.). An allowance of 25 percent is included for contingencies.

FIRST COSTS

The total project first costs are estimated at $1,284,633,000. Table 42 - 6 provides a summary of the first costs for the principal features. Separate documentation provided to the ACP including a detailed cost estimate containing the sub-features of the work.

Table 42 - 6 Summary of First Costs

Item	Trinidad Costs ($)	Rio Indio Costs ($)
Lands and Relocations	2,000,000	14,000,000
Access Roads	9,574,000	8,030,000
Clearing and / or Grubbing	559,375	3,566,250
Cofferdam	850,000	4,850,665
Dam	643,786,212	22,723,329
Spillway	8,057,504	43,387,450
Intakes	N/A	7,701,295
Saddle Dams	2,593,390	4,241,143
Pumping Station	22,999,637	N/A
Diversion Tunnel	N/A	14,732,944
Inter-basin Transfer Tunnels	N/A	11,595,800
Transfer Intake Rio Indio-Gatun	N/A	365,258
Hydropower Plants	N/A	22,118,125
Transmission Lines	2,090,000	6,600,000
Subtotal	692,510,118	163,912,258
E&D, S&A, Field Overhead	138,502,024	32,782,452
Contingencies	207,753,035	49,173,677
Total Project First Cost	1,038,765,177 Approximately 1,038,765,000	245,868,387 Approximately 245,868,000

OPERATION AND MAINTENANCE

Staff

A staff should operate and maintain the proposed Lower Rio Trinidad Dam project during the day and then run the facility remotely at night. The full-time staff should consist of 9 people, including a station manager, a multi-skilled supervisor, 2 leaders (Electronics/Instrumentation, Electrical/Mechanical), 4 craftsmen and a laborer. A part-time staff would be required for two to three months each year to perform general maintenance and overhaul of the project. The part-time staff may consist of three mechanics and three electricians. The annual staffing costs are estimated to be $350,000. The annual staffing costs for the proposed Rio Indio projects are estimated to be $500,000.

Ordinary Maintenance

Ordinary maintenance and care is required and includes minor repair materials, lubricants and other supplies needed by project staff. It is estimated that the costs of ordinary maintenance is $18,000 per year for the access road and $100,000 per year for the main project facilities. Fuel consumption for the pumps is estimated at $648,000. This estimate considers the growth in demand for water over time and the variability in inflows to Gatun Lake as well as the proposed Lower Rio Trinidad project. An estimated $288,000 would be needed for rock placement to account for settling of the project. The total ordinary maintenance is $1,054,000. The total ordinary maintenance for the proposed Rio Indio project is estimated to be $320,000.

Major Replacements

The average service life of gates, electrical equipment, pumps, trash racks and other features would be less than the total useful life of the project (100-years). To estimate the major replacement costs necessary during the 50-year planning period for this proposed project, it is assumed that specific items should cost the same as at present. No allowance is made for salvageable fixed parts. Table 42 - 7 presents the service life, number of times each component can be replaced during the 50-year planning period, the future costs of each item, and the present worth of the replacement costs for the major components. Based on these values, the present worth of the proposed replacements is $2,260,400 and the average annual replacement costs is $272,000. The average annual replacement costs for the proposed Rio Indio project are estimated to be $91,000.

Table 42 - 7 Major Replacement Costs

Component	Service Life (years)	Number of Times Replaced During Planning Period	Future Costs ($)	Present Worth of Replacement Costs ($)
Roads	50	1	12,435,000	43,000
Bridges	50	1	1,800,000	6,200
Pump Station				
Pumps	25	2	21,006,000	654,200
Sluice Gates	50	1	1,275,525	4,400
Sluice Trash Racks	50	1	458,850	1,600
Electrical Controls	25	2	2,100,000	65,400
Fuel Tanks, etc.	50	1	450,000	1,600
Misc Equip & Comm.	25	2	3,183,000	99,100
Slurry Trench	25	2	40,462,500	1,260,100
Spillway				
Bridge Girders	50	1	280,676	1,000
Tainter Gates	50	1	2,280,000	7,900
Tainter Gate Hoists	50	1	1,200,000	4,200
Tainter Gate Op Sys.	50	1	360,000	1,200
Stoplogs	50	1	475,950	1,600
Misc. Mech. Items	25	2	1,500,000	46,700
Electrical Controls	25	2	1,650,000	51,400
Transmission Lines	50	1	3,135,000	10,800
Total			94,052,500	2,260,400
Average Annual Replacement Costs				272,000

Annual Costs

The project first costs for the proposed Lower Rio Trinidad project are estimated at $1,038,765,000. The total project first costs, including $245,868,000 for the Rio Indio project (see Volume One), are estimated to be $1,284,633,000. These total project first costs were distributed across the development period using generalized curves for contractor earnings for large, heavy construction jobs. Interest on the proposed Rio Indio project first costs is computed from mid-year throughout the 22-year development period from initiation of Planning and Design until the Lower Rio Trinidad area is filled. Interest during construction for the Lower Rio Trinidad project is computed from mid-year throughout its 13-year development period until lake filling was. The interest during construction at 12 percent would be $838,455,000 for Lower Rio Trinidad, and $1,222,371,000 for Rio Indio - for a total interest during construction of $2,060,826,000. These costs are added to the total project first costs for total project investment costs of $3,345,459,000. A capital recovery factor for the 50-year planning period is applied to get the annual average investment costs of $402,849,000. Annual operation and maintenance costs are added. Major replacement costs are estimated and converted to an annual cost by discounting the future replacement costs of major components of the project back to completion of the project construction. Table 42 - 8 contains a summary of the $405,436,000 total annual costs.

Table 42 - 8 Summary of Annual Costs

Item	Costs ($)
Total Project First Costs - Lower Rio Trinidad	1,038,765,000
Total Project First Costs – Rio Indio	245,868,000
Interest During Construction – Lower Rio Trinidad	838,455,000
Interest During Construction – Rio Indio	1,222,371,000
Total Project Investment Costs	3,345,459,000
Annual Average Investment Costs	402,849,000
Operation and Maintenance Costs	
Staff Costs – Lower Rio Trinidad	350,000
Staff Costs – Rio Indio	500,000
Ordinary Maintenance Costs – Lower Rio Trinidad	1,054,000
Ordinary Maintenance Costs – Rio Indio	320,000
Major Replacement Costs – Lower Rio Trinidad	272,000
Major Replacement Costs – Rio Indio	91,000
Total Average Annual Costs	405,436,000

Annual Benefits

NAVIGATION

The procedures and assumptions used in estimating the benefits are described in Volume One. The following paragraphs present the results of the economic investigations for the proposed Lower Rio Trinidad and Rio Indio projects. The 50-year period for the economic analyses of this proposal is 2024 to 2073

The proposed Lower Rio Trinidad and Rio Indio projects should increase the reliability of providing water to accommodate the total daily number of lockages demanded. Table 42 - 9 provides the increase in the hydrologic reliability of providing the sum of the demands for both navigation and M&I water supply keyed to years. The hydrologic reliability percentages are obtained from the data used to develop Table 42 - 9.(Please change this link to Figure 42-3) The 99.6 percent level of reliability for this proposal is used to estimate the water supply benefits for navigation and the net change in reliability is used to estimate the reliability benefits for navigation and M&I water uses.

Table 42 - 9 Panama Canal Hydrologic Reliability
(Based on Period of Record from January 1948 to July 1998)

Current Demand Ratio	Year	Demand in Daily Average Number of Lockages (Navigation and M&I)	Hydrologic Reliability	
			Existing System (%)	With Lower Rio Trinidad & Rio Indio [1/] (%)
1	2000	38.68 [2/]	99.60	100.0
	2010	45.11	98.91	100.0
1.2		46.42	98.76	100.0
	2015	46.82	98.64	100.0
	2020	47.61	98.41	100.0
	2025	48.52	98.14	100.0
	2030	49.55	97.83	100.0
	2035	50.72	97.48	100.0
	2040	52.02	97.10	100.0
	2045	53.49	96.65	100.0
1.4		54.15	96.45	100.0
	2050	55.13	95.89	99.95
	2055	56.98	94.83	99.83
	2060	59.05	93.65	99.83
	2065	61.37	92.32	99.64
1.6		61.89	92.02	99.61
	2070	63.97	90.47	99.23
1.8		69.63	86.27	98.19

[1/] The lake behind the Lower Rio Trinidad Dam would fluctuate from the normal operating lake level at EL. 33.53 m MSL down to the minimum operating lake level at EL. 22.86 m MSL and the lake behind the Rio Indio Dam would fluctuate from the normal operating lake level at EL. 80 m MSL down to the minimum operating lake level at EL. 50 m MSL.

[2/] 2000 Daily Demand is Average of 1993-1997.

With the proposed Lower Rio Trinidad and Rio Indio projects, water supply shortages for navigation should continue. The demand for the M&I purposes should always be met first. As these demands grow, the amount of water available to meet the demands for navigation should decrease. Thus, the benefits for the additional water supply are estimated at the value for navigation. With the addition of the proposed Lower Rio Trinidad and Rio Indio projects, these shortages would be less frequent. With a hydrologic reliability of 99.6 percent, the project should increase the amount of water supplied by 23.27 equivalent lockages. The 99.6 percent hydrologic reliability should occur after the year 2066, with an equivalent daily average number of lockages of 61.96. Benefits for these amounts of additional water are attributable to navigation since the amount of M&I water demanded would be provided first. Therefore, all shortages are attributable to navigation. The benefits are estimated using the toll revenue per lockage and the increased daily average number of lockages. The average annual benefit for water supply is $234,227,000. Table 42 - 10 provides the estimate of daily shortages under the existing system, the remaining daily shortages with the proposed Lower Rio Trinidad and Rio Indio projects in operation, the annual benefits for meeting shortages and the average annual benefits.

Table 42 - 10 Benefits for Additional Water Supply for Navigation

Year	Daily Shortages In Lockages Under Existing System	Remaining Daily Shortages	Annual Benefits For Navigation ($)
2023	9.51	0.00	196,137,742
2030	10.87	0.00	224,201,428
2040	13.34	0.00	275,146,640
2050	16.45	0.00	339,265,866
2060	20.36	0.00	419,965,798
2070	25.29	2.01	479,980,512
Average Annual Benefits			234,227,000
With the Lower Rio Trinidad project operating between 22.86 and 33.53 m and the Rio Indio project operating at 50 m, the system should provide a total of 61.96 lockages at the 99.6 percent level of reliability or 23.27 more lockages than the existing system.			

With the proposed Lower Rio Trinidad and Rio Indio projects, the reliability of the system to provide water demanded by navigation and M&I water would be improved. Using the increase in hydrologic reliability, the forecast number of vessels converted to a daily average number of lockages, the toll revenue for each average lockage, and a project discount rate of 12 percent, the average annual benefits for navigation reliability attributable to the proposed Lower Rio Trinidad and Rio Indio projects is $19,417,000. Table 42 - 11 provides the forecast daily average number of lockages, the forecast value per daily lockage, the annual benefits for increased reliability, and the average annual benefits.

Table 42 - 11 Average Annual Reliability Benefits For Navigation

Year	Daily Average Number of Lockages	Value Per Lockage ($)	Annual Benefits For Navigation ($)
2023	40.0	2,260,000	14,560,000
2030	40.0	2,260,000	17,911,000
2040	40.0	2,260,000	23,993,000
2050	40.0	2,260,000	33,468,000
2060	40.0	2,260,000	44,039,000
2070	40.0	2,260,000	72,258,000
Average Annual Benefits			19,417,000

M&I WATER SUPPLY

The future demand for water supply for M&I purposes is based upon the growth in population. The ACP provided a forecast for the area surrounding the Panama Canal. The current usage is estimated at 4.0 equivalent lockages per day; an equivalent lockage is 55 million gallons of water. One equivalent lockage is added to the forecast to account for the burgeoning tourist industry, beginning in the year 2010. The increased reliability of the system to provide water supply for navigation similarly provides the same increase in reliability to provide water for M&I

purposes. Using the increased hydrologic reliability of the system with the addition of the proposed Lower Rio Trinidad and Rio Indio projects, the current costs to the ACP to process water ($0.69 per 1,000 gallons), the number of daily lockages demanded, and a project discount rate of 12 percent, the average annual benefits for M&I reliability are $3,555,000. Table 42 - 12 displays the population forecast, the resulting number of equivalent lockages per day, and the benefits for M&I water supply.

Table 42 - 12 Average Annual Reliability Benefits For M&I Water Supply

Year	Population	Equivalent Lockages per Day	Annual M&I Water Supply Benefits ($)
2023	2,294,000	8.15	2,004,000
2030	2,688,000	9.55	2,877,000
2040	3,384,000	12.02	4,841,000
2050	4,259,000	15.13	8,500,000
2060	5,360,000	19.05	14,089,000
2070	6,746,000	23.97	29,095,000
Average Annual Benefits			3,555,000

HYDROPOWER

The amount of hydropower energy that can be produced by the system of Gatun Lake and Madden Lake should decline over time as the demands for navigation and M&I water supply increase. With the inclusion of the Lower Rio Trinidad project, the system will loose hydropower generation at Gatun Lake and Madden Lake due to the change in the operation of the system. With the inclusion of the Rio Indio Dam project, however, the system can produce additional megawatt hours of hydropower for a net gain in hydropower generation. The value for hydropower energy used in this analysis is $0.070 / kWh. On an average annual basis, the proposed project should have benefits of $3,031,000. Table 42 - 13 provides the net additional megawatt hours of hydropower generation and the resulting benefits.

Table 42 - 13 Average Annual Benefits For Hydropower Generation

Year	Net Generation [1] (MWh)	Annual Benefits For Hydropower ($)
2023	45,237	3,167,000
2030	43,841	3,069,000
2040	41,380	2,897,000
2050	37,855	2,650,000
2060	32,245	2,257,000
2070	24,598	1,722,000
Average Annual Benefits		3,031,000

[1/] Lose of net generation of Gatun and Madden hydropower plants with the operation of the Lower Rio Trinidad project.

SUMMARY OF ANNUAL BENEFITS

As shown in Table 42 - 14, total average annual benefits for the proposed Lower Rio Trinidad and Rio Indio projects would be $260,230,000.

Table 42 - 14 Summary of Annual Benefits

Benefit Category	Average Annual Benefits ($)
Navigation – Water Supply	234,227,000
Navigation – Reliability	19,417,000
M&I - Reliability	3,555,000
Hydropower	3,031,000
Total	260,230,000

To perform an analysis of benefits versus costs, a common point in time is selected. This common point is at the completion of filling of the project, the end of the year 2022. In these analyses, it is important to note that the average annual benefits or average annual costs are the amortized value of the sum of the present worth of either the benefits or costs at the point of comparison. The development sequence for the proposed Lower Rio Trinidad and Rio Indio Dam projects would be to develop the Rio Indio Dam project first (2001 – 2010) and then the Lower Rio Trinidad Dam project (2009 – 2022).

The benefits attributable to the proposed Rio Indio Dam project begin to accrue in 2010 when the reservoir is filled. The operation of Gatun Lake during the construction of the proposed Lower Rio Trinidad Dam project would be the same as described in Section 5. The Rio Indio Dam project benefits for the period 2011 to 2022 is escalated by the project discount rate, 12 percent, in order to estimate the total present worth of $4,446,416,000 in the year 2022. The average annual benefits for the proposed Rio Indio Dam project accruing during the construction of the proposed Lower Rio Trinidad Dam project are estimated to be $535,423,000.

To estimate the interest during construction, similar calculations are made for the costs of each proposed project. For the proposed Rio Indio Dam project, interest during construction is taken from year 2001 to year 2022 and the interest during construction for the proposed Lower Rio Trinidad Dam project is from the year 2009 to the year 2022.

The sequence of development of the two projects is crucial to the estimate of average annual benefits and costs. If the Lower Rio Trinidad Dam project is developed first, then the average annual costs double in size and the average annual benefits reduce to less than half of the values that are estimated for the development sequence of Rio Indio and then Lower Rio Trinidad. This occurs because the first costs for the Lower Rio Trinidad Dam project are four times the cost for the Rio Indio Dam project ($812M vs. $245M). The estimate of interest during construction changes from approximately $4B to $2B. Likewise, the Rio Indio Dam project provides approximately 80 percent of the total average annual benefits of the combined projects ($212M of $258M). The estimate of benefits for the first project during the period of construction of the other project changes from $150M to $600M.

Total average annual benefits and average annual costs are estimated, and the ratio of benefits to costs and the net benefits (net of costs) are computed. In the first instance, the analysis determines the feasibility of the proposal. The net benefits determine which proposal provides the greatest value for the investment dollars. Table 42 - 15 provides the benefit to cost ratio and the net benefits.

Table 42 - 15 Economic Evaluation

Item	Value ($)
Average Annual Benefits	
Lower Rio Trinidad	260,230,000
Rio Indio	535,423,000
Total Average Annual Benefits	795,653,000
Average Annual Costs	
Lower Rio Trinidad	227,725,000
Rio Indio	177,712,000
Total Average Annual Costs	405,437,000
Benefit to Cost Ratio	2.0
Net Benefits	390,217,000

Internal Rate of Return

An internal rate of return analysis for this proposed project was performed. To accomplish this analysis, the annual construction costs are used as the investment, and the undiscounted benefits are used as return cash flows. The internal rate of return is 23.0 percent.

Socio-Economic Impacts

The description of the environmental setting is based on field observations made while conducting field reconnaissance throughout Gatun Lake, specifically the Lower Rio Trinidad and Rio Indio areas with ACP personnel. Autoridad Nacional del Ambiente (ANAM), ACP, Asociacion Nacional para la Conservacion de la Naturaleza (ANCON), Electrical Transmission Agency, Smithsonian Tropical Research Institute (STRI), and Directorate of Mineral Resources personnel were interviewed to gain information on site characteristics and potential activities that could affect the project. In addition, extrapolations of the 2000 census data were used, and a review of the Informe de Cobertura Boscosa 1992 were used to determine the extent of forest cover.

Environmental Setting

This alternative combines two projects, the Lower Rio Trinidad (lake level (22.9 - 33.5 m) and Rio Indio (lake level 50 – 80 m). This combination will provide additional storage of water for Gatun Lake and 23.27 additional lockages per day on a continual basis. The project area consists of 23,630 ha within Gatun Lake, which is sparsely populated and has a topography of rolling hills and low regions near Gatun Lake and 5,600 ha within the Rio Indio watershed. The Rio Indio project would include a rock fill dam,an ungated spillway, outlet works, an interbasin transfer tunnel and two hydropower plants. Near Rio Indio, the area is sparsely populated with terrain and topography of steep hills, as well as coastal regions. The Lower Rio Trinidad and Rio Indio are west of the Panama Canal and flow northward from the Continental Divide. The watershed above the Lower Rio Trinidad and the Rio Indio the dam project covers approximately 1,052 km^2 and 381 km^2 respectively. The incremental impoundment area, which covers approximately 7,712, consists of approximately 50 percent of forested land, 30 percent of pasture land (used by ranchers), 10 percent of cropland, and 10 percent of newly slashed and burned land. Gatun Lake's normal pool level is 26.7 m. The lake level during field observations (August 2001) was approximately 25.4 m.

LAND USE

The Lower Rio Trinidad project area encompasses the southwestern portion of Gatun Lake and areas along its shores. The areas to be flooded or partially flooded include the town of Escobal (population – 1,653), Nuevo Provenir (population – 121), Cuipo (population – 249), Ciricito (population – 72), La Arenosa (population – 242), La Garterita (population – 138), La Gartera (population – 348), and a few small isolated establishments.

Some areas along the shores of the Lower Rio Trinidad have been deforested. Approximately 65 percent of the lakeshore areas are forested, mostly with secondary growth. Farms and ranches of various sizes, as well as teak and African mahogany plantations, occupy the remaining lands. Farm crops include maize, rice, beans, sugar, coffee, mangos, pineapples, and tobacco. Ranchers raise cows, horses, chickens, hogs, and tilapia. Some of the farmers and ranchers operate commercial enterprises, while others rely on cash crops and subsistence farming. No significant ore deposits or mineral resources are located in the project area.

Approximately 2,300 people inhabit the Rio Indio project area; they live in the towns of Tres Hermanas (population – 200), Los Cedros (population – 80), El Coquillo (popoulation – 150), El Limon (population – 140), Los Uveros (population – 140), and La Boca de Uracillo (population – 110), and in nearly 30 smaller settlements. Downstream from the dam site at El Limon there are 14 communities with a combined population of approximately 600. The largest of these is La Boca del Rio Indio with a population of more than 150.

Farms and ranches of various sizes, as well as some teak plantations, occupy approximately 60 percent of the land in the Rio Indio project area. Farm crops include maize, rice, beans, sugar, coffee, and tobacco. Ranches raise horses, cows, chickens, and hogs. Some of the farmers and ranchers run small commercial enterprises, or rely on cash crop and subsistence farming.

INFRASTRUCTURE

During site investigations in the Lower Rio Trinidad area, the town of Escobal was the largest settlement visited. Escobal has businesses, schools, churches, cemeteries, medical centers, residences, and paved roadways of good condition. A new and improved roadway (Highway 35) is adjacent to the project area near Escobal. Other establishments in the project area Nuevo Provenir; Cuipo; Ciricito; La Arenosa; La Garterita; La Gartera; and a few small isolated establishments have elementary schools, small cemeteries, churches and meeting centers, medical clinics, and a few small businesses (i.e. general stores). The towns and villages depend on Gatun Lake or groundwater wells for their potable water supply. Each community also had docks, small ports, and other boat access facilities. Goods are transported from one town to another by boat. No treatment of community waste is provided. Wastewater from showers and washing is discharged into the environment; some of it may eventually reach the Lower Rio Trinidad portion of Gatun Lake. Disposal of domestic waste is the responsibility of individual homeowners: some homes have septic tanks, while others have an outdoor latrine (a hole in the ground). There are some health problems, such as hepatitis, dysentery, dermatitis, intestinal parasites, and respiratory illnesses, which are attributable to the present waste disposal methods. No major industries or meat processing plants are located in the project area. The project area is traversed by unpaved horseback riding trails that link the various communities and by unpaved roads used by the ACP for maintenance. Due to the relatively isolated location of the project area, these roads are extremely important to the residents for transportation, community cohesion, commerce, and communication with neighboring communities.

In the Rio Indio project area, towns of El Limon, El Silencio, San Cristobal, and Piedra Amarilla have elementary schools. Several towns have cemeteries, churches, and medical centers. All these towns obtain water from rivers or groundwater wells. Some have electricity (from small generators) and limited telephone service. No treatment of community waste is provided. Wastewater from showers and washing is discharged into the environment; some of it may eventually reach Rio Indio and its tributaries. Disposal of domestic waste is the responsibility of individual homeowners; each home has an outdoor latrine. There are some known health problems, such as hepatitis, diarrhea, dermatitis, intestinal parasites, and respiratory illnesses that are attributed to the present waste disposal methods. No known major industries or meat processing plants are located in the project area. The only roads in the project area are unpaved and poorly maintained, and are usable only in the dry season (mid-December through

March). The roads are rarely graded and receive little attention from either the Ministry of Public Works or the local government. These roads are extremely important to the residents for transportation, community cohesion, commerce, and communication with neighboring communities because of the relatively isolated location of the project area.

TERRESTRIAL HABITAT

The terrestrial habitat in the Lower Rio Trinidad project area of Gatun Lake consists of tropical forest ecosystems, mostly secondary growth forests with patches of primary forest. About 65 percent of the land along the Lower Rio Trinidad of Gatun Lake is forested and probably supports diverse wildlife populations. The Lower Rio Trinidad areas of Gatun Lake also contain islands inhabited by wildlife. Some of the wildlife species do not interact with species on the mainland; others migrate between the island and the mainland. The species interrelationships are of great interest to scientists studying tropical ecosystems. Slash and burn activities have opened tracts of land for farming and cattle grazing; however, the majority of the lakeshore is forested to the edge of the water. Terrestrial areas are used by migratory species as wintering, breeding, and feeding grounds. The complex and diverse tropical ecosystems offer habitat to connect a variety of wildlife communities and may provide critical wildlife habitat to many native species.

In Rio Indio, forests along the river that could support diverse wildlife populations cover about 90 percent of the areas along the Rio Indio and its tributaries. The forests also extend to the mountainous areas above the Rio Indio impoundment. As a result of slash and burn activities, there are no large contiguous tracts of forests at lower elevations in the impoundment.

ANIMALS ON ENDANGERED LIST

ANAM, Resolution 002-80 enacted on June 7, 1995 declared, 33 mammals, 39 birds, and 11 reptiles and amphibians are in danger of becoming extinct in Panama. Although their presence has not been confirmed to date, some of the listed species of interest on the threatened list might be found in the project area. The manatee is an aquatic mammal known to inhabit Gatun Lake around the Barro Colorado Island; however, it has not been sighted in the project area.

AQUATIC HABITAT

Gatun Lake, one of the world's largest manmade lakes, was created during the construction of the Panama Canal. The lake's water depth and quality vary widely. Aquatic habitat ranges from inundated forests to clear water in areas distant from shipping lanes. The Lower Rio Trinidad areas of Gatun Lake provide habitat for a variety of wildlife species, both resident and migratory, as well as for native and introduced fish and other aquatic species.

Rio Indio has characteristics typical of streams in mountainous regions. Its water is clean and cool, and its bottom ranges from sand to boulders, with numerous riffles, runs, and pools. Tributaries to Rio Indio include four major streams: Rio El Torno, Rio Uracillo, Rio Teria, and Rio Riacito, and 20 smaller streams. The river is approximately 16 km long, its width ranges from 3 m (in the dry season) to 10 m. The tributaries appear to support some fish communities; information about these communities is limited.

WETLANDS

Areas that contain hydric soils and hydrophytic plant communities, and that are subject to hydric conditions are termed wetlands. Wetlands occur in topographic area where water remains pooled long enough to produce hydric soil conditions and wetland plant communities. Wetlands in the Lower Rio Trinidad project area consist of shallow water habitats and lands subject to frequent flooding. Shallow water areas along the banks of the Lower Rio Trinidad area of Gatun Lake receive sunlight to a depth of approximately 1 m. Sunlight stimulates growth of submergent, emergent, or floating mats of aquatic vegetation. Wetlands in the project area are stressed from excessive sediments, municipal waste, agricultural runoff, and other debris carried in the runoff.

Wetlands in the Rio Indio project area consist of forested riparian habitat and are limited by their relatively steep topography. The width of the riparian habitat within the impoundment area varies from approximately 5 to 50 m. Approximately 90 percent of the streams both above and below the dam site along the Rio Indio and its tributaries are bordered by forested riparian habitat.

AIR QUALITY

Air quality in the project area is generally good, except during the slash and burn activities. At the end of the dry season in March or early April, areas of forest and secondary growth are burned and cleared for agricultural use. During this period, the air is filled with smoke and ash, which may be transported by winds to the Lower Rio Trinidad area of Gatun Lake. Based on observations in the Rio Indio project area, approximately 10 percent (or 400 ha) of forested land is burned annually. Air quality monitoring has not been implemented within the project area.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

Barro Colorado Island is an international center for tropical research and one of the first biological reserves established in the Neotropics. From 1923 through 1940, a scientific committee of the U.S. National Academy of Sciences administered the biological reserve/laboratory. In 1940, by an Act of the United States Congress, the facility was renamed the Panama Canal Zone Biological Area, and in 1946, the responsibility for its maintenance was assigned to the Smithsonian Institution. With the Panama Canal Treaty Implementation in 1977, the island was granted the category of National Monument and to date it continues to be managed by the Smithsonian Institute. It should also be noted that most of the Atlantic region of Panama is within the interest and objectives of the Mesoamerican Biological Corridor, an international project to conserve biodiversity.

In the pre-Columbian period, Rio Indio was a language frontier; the inhabitants on each side of the river spoke a different native language. During the Spanish colonial period, the river served as a political boundary. The project area has a high potential to be rich in archaeological and historical remains.

Environmental Impacts

TERRESTRIAL HABITAT

The impacts of the project on terrestrial habitat in the Lower Rio Trinidad area of Gatun Lake could be substantial. The boundary between two types of habitats, in this case between a forest and a lake, is called an ecotone. Ecotones are inhabited by a variety of species from neighboring habitats, and are unique, with high species diversity. Considering the proposed operating levels for both impoundments, between El. 22.9 - 33.5 m MSL, as the normal zone of operation, erosion of the shoreline may be substantial as pool levels rise and fall. Terrestrial habitats that would be inundated above the El. 26. 7 m MSL (existing level) to the El. 30.5 m MSL proposed normal pool level consists of 21,912 ha for the Lower Rio Trinidad project. The placement of a dam structure, access roads and pump stations would permanently impact terrestrial habitat. Wildlife species that are able to relocate to suitable areas will compete with similar species for resources; species that are not able to relocate will not survive. As a result, competition for natural resources in surrounding habitat areas will increase. This is considered a secondary impact to terrestrial habitat outside the proposed zone of inundation and construction.

The terrestrial impacts of the Rio Indio project, which is located in area of relatively high quality forest habitat, would be substantial. With the creation of the lake, the migratory routes of some species could be adversely affected. Forested areas along lower elevations would be lost as a result of the impoundment. The only forests that would remain near the Rio Indio reservoir and its drainage basin would be confined to the higher elevations, where the vegetation and species may be completely different from those found on lower elevations. Natural communities are linked together by complex interactions and relationships among various species, therefore impacts to upper-forested areas may occur resulting from the inundation of the lower forests.

ANIMALS ON ENDANGERED LIST

The severity of impacts on endangered species cannot be determined at this time, because although it is expected that some of the listed species can be found in the region, it is not known which of the listed species inhabit the proposed project area. Some endangered and/or threatened species may use the Lower Rio Trinidad area of Gatun Lake during some or all parts of their life cycle.

WATER QUANTITY

The impacts of the Lower Trinidad project on water quantity would be substantial. The increase in the volume of water could have negative impacts to lakeshore communities, as well as on existing ecosystems. The same is true if the lake level is lowered and maintained at 22.9 m.

The impacts of the Rio Indio project area on water quality would also be substantial. The volume of water will increase, making fresh water available in the surrounding areas during the dry season. The impacts downstream from the dam would be significant. Sediment loads would be deposited upstream from the dam as water velocity slows. Downstream from the dam the water will be released at an increased velocity, causing erosion of banks and river bottoms.

Seasonal flooding could be significantly reduced. It would also be possible to periodically release water in appropriate amounts to avoid problems with water quality and temperature downstream. The cumulative impact downstream from the dam site depends on the amount of water being released.

WATER QUALITY

Project impacts on water quality are not known. Damming the Lower Rio Trinidad could increase the amounts of nutrients and debris in this portion of Gatun Lake. A pilot plant tilapia farm is in the project area and may affect water quality. The rate nutrients and debris enter the lake determines the severity of the impact on water quality. Project implementation could cause an increase in turbidity, which would interfere with photosynthesis and deprive plants and other aquatic species sunlight. Aquatic plants and organisms serve to maintain water quality. The dam could interfere with the circulation of freshwater throughout the Gatun Lake environment. Species inhabiting specific depths could be impacted when lake depth increases to 33.5 m and/or decreases to 22.9 m.

The impacts of the Rio Indio project on water quality could be positive. The people living downstream from the dam and around the impoundment would have access to a higher quality water supply. Water quality in the impoundment area would differ from water quality released downstream from the dam. If the water in the impoundment area does not circulate periodically, it could become anoxic. A change in temperature, dissolved oxygen, turbidity, or pH could change water quality.

DOWNSTREAM AQUATIC FAUNAL HABITAT

The impacts of the project on aquatic faunal habitat could be substantial. The project may affect the breeding and nursery habitats of many aquatic species. Impacts to fish spawning areas may be detrimental when turbidity, nutrient content, and depth of the water suddenly increase or decrease, altering the conditions needed for successful fish hatching. Plant populations may decrease due to fluctuating water depths, clarity, and quality. Invertebrate populations may decline, which could reduce the food supply for fish and other aquatic species.

Impacts to downstream aquatic faunal communities in the Rio Indio project area could be substantial, because the dam structure will prevent their migration throughout the riverine habitat. The dam structure would be designed for multi-level releases to maintain a water level downstream from the dam site. The dam should act as a large sediment trap; thus, the released water would have low turbidity, which would result in better visibility and increased predation on the fish species. Aquatic faunal habitats downstream would be deprived of the beneficial nutrients and silts that were transported in the sediment. Native riverine fish species may be negatively impacted as a result of the project; the extent of the impact is not known.

FUTURE LAKE AQUATIC PLANT COMMUNITY

The impact of the project on future aquatic plant communities depends on the water quality and the stability of water levels. Plant species in the Lower Rio Trinidad portion of Gatun Lake could be impacted by fluctuating water levels. Aquatic plant communities could be impacted during project implementation; however, they could re-establish after conditions stabilize.

The severity of impact due to the Rio Indio project will depend on water level fluctuations. Since water levels are anticipated to fluctuate widely, large portions of the shores would be covered with mud, allowing neither aquatic nor terrestrial plants could thrive.

AQUATIC FAUNA INHABITING AFFECTED AREAS

The proposed project impacts could have some unavoidable, adverse environmental impacts on aquatic fauna in the Lower Rio Trinidad project area and associated rivers and tributaries. These impacts should be identified and minimized with appropriate mitigation measures to be discussed in a feasibility level study. Gatun Lake has populations of peacock bass and tilapia, both introduced species that have adapted well. However, several native riverine species that formerly occupied the impoundment have disappeared.

The impacts of the Rio Indio project on aquatic fauna in the Rio Indio and its upstream tributaries could be substantial, since the habitat area would change from riverine to lacustrine. Some aquatic species would continue to inhabit the area; however, non-native fish species would become dominant in the impoundment area and native riverine species would be pushed upstream or extirpated. Other manmade lakes in the Republic of Panama have been stocked with peacock bass and tilapia. The impoundment area would probably be stocked with these species to promote sport fishing and to provide the local communities with fish for food.

WETLANDS

The impacts to wetlands could be significant. Inundation of wetlands could cause them to become aquatic habitat. The changes in water depth caused by the project may lead to increased or decreased sedimentation and turbidity, which could hamper the biological processes in the wetlands and decrease their productivity. Such impacts could be detrimental to the health and sustainability of the Lower Rio Trinidad area of Gatun Lake. Fish and other aquatic species use shallow water areas as spawning grounds, as well as habitat for juvenile aquatic species that survive in the shallows until large enough to venture into deeper water. These wetlands are vital to the sustainability of this portion of Gatun Lake, including the Lower Rio Trinidad area.

The impacts to wetlands, both upstream and downstream, from the Rio Indio project area could be significant. Owing to the topography of the project area, a number of wetlands could be impacted. It is possible that although the reservoir level will fluctuate, new wetlands could develop in the littoral zones. Downstream from the dam site, wetlands along the minimal flows zone would survive; wetlands that depend on seasonal flooding for survival may be adversely affected.

AIR QUALITY

During project implementation, emissions from construction equipment, as well as from slash and burn activities, could cause deterioration of air quality. After project implementation, the air quality may be impacted by the operation of the power generation facilities and the pumping station.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

The potential impacts on cultural resources and historic properties from the Rio Indio project can be defined and mitigated, particularly in the La Boca de Uracillo area, which is near previously identified archaeological sites. The project area is relatively large and is known to contain pre-Columbian sites; therefore, the presence of cultural resources and historic properties is highly probable. Prior to construction, surveys to locate cultural resources and historic properties should be conducted, and the important sites should be preserved or salvaged as appropriate.

SOCIO-ECONOMIC IMPACTS

The socio-economic impacts of the project could be substantial. The relocation of the towns and other small communities along the lakeshore would be an important issue. The average monthly income of families in the project area ranges from less than $100 to $200 per month. No indigenous groups are known to reside in the impact area. Land use would be greatly impacted by the inundation of pastures and agricultural lands to expand the impoundment. The relocation of agricultural and ranching activities would be an important issue, because approximately 10 percent of the land in the impoundment area is used for farming and ranching. After the water level is raised, additional agricultural land could be lost due to the creation of islands from isthmuses. The incremental surface area of the proposed lake is 7,712 ha; another 1,318 ha from the Lower Trinidad project and 760 ha from the Rio Indio project will be occupied by the dam and construction areas, including permanent disposal areas.

During construction, the influx of workers could create a temporary demand for additional housing, which could result in an increase in housing values near the dam site. However, after completion of the project, the workers could leave, the housing demands could drop, and the housing values could return to pre-construction levels. Currently, all residents have access to public schools and health centers. During construction, these services should continue to be available, and additional public and community services may be offered. After construction, these services would return to the normal level.

To construct the dam, some existing roads must be improved and some new roads must be built. However, some paved and unpaved roads within the impoundment area would be eliminated, which may change traffic patterns and could cause some communities to lose overland transportation, communication, cohesion, and commerce with other communities. During construction, the traffic volumes over both new and existing roads systems would increase; however, following completion of construction, the traffic volumes could decline. Noise levels would temporarily increase during construction and could negatively impact noise-sensitive receptors; after construction, noise levels may remain elevated due to the power generation facility and pump stations.

The communities that receive people displaced by the project could be negatively impacted by overcrowding and by competition for jobs, land, and working areas. Construction of the dams would permanently displace people and disrupt community cohesion through the division of communities, separation of families, and loss of livelihood. Following the completion of the impoundment, the tourism trade in the affected region, including sport fishing and ecotourism, could increase.

Additional Environmental Information Required

This section identifies the subject areas for which additional data are required to evaluate in further detail, the scope and magnitude of the potential effects of the Lower Rio Trinidad and Rio Indio alternative. The subject areas are discussed by impact category.

SOCIO-ECONOMIC IMPACTS

Conduct a SIA. The SIA would consist of three tasks: scoping, assessment, and mitigation and monitoring. The following information should be developed:

- Business, Industrial, and Agricultural Activities;
- Employment;
- Land Use;
- Property Values;
- Public and Community Facilities and Services (including utilities and schools);
- Transportation;
- Housing;
- Health (vector routes);
- Population;
- Community Cohesion; and,
- Recreational Resources.

TERRESTRIAL AND AQUATIC HABITAT

- Prepare site-specific habitat maps to ensure that the major types of aquatic habitat are identified and quantified.
- Conduct field studies to locate rare and unique habitats such as wetlands, primary forests, roosting sites, foraging areas, old growth, and migration flyways.
- Determine the present quality and ecosystem value of existing habitats within the Gatun Lake project area.
- Coordinate with local experts to identify and evaluate aquatic and terrestrial habitat areas.
- Prepare species inventory lists for each site area, identifying their status as native or exotic and whether they are threatened and/or endangered species.
- Conduct additional research into water currents and estimated turbidity levels to evaluate impacts to the shallow areas along Barro Colorado Island.
- Address cumulative effects caused by natural flow diversions.

ANIMALS ON THE ENDANGERED LIST

- Compile habitat maps to assess the availability and quality of suitable habitats for the animals on the endangered and/or threatened species list.
- Establish field methodology to assess wildlife habitat values.
- Conduct site surveys to determine the presence of selected species or their habitats.
- Develop candidate mitigation measures for the appropriate project alternatives to be considered in the Conceptual Phase.

- Coordinate with local experts on the presence of endangered species.

WATER QUALITY

- Since limited water quality data are available for the Gatun Lake area, compile information on total suspended solids, conductivity, total dissolved solids, dissolved oxygen, nutrients, pH, and coliform bacteria.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

- Information regarding cultural resources and historic properties in the project area is incomplete. Additional evaluation studies should be completed to identify any such resources and/or properties.

Evaluation Matrices

Table 42 - 16 Developmental Effects

Evaluation Criteria	Function	Measure [1/]	Importance [2/]	Composite [3/]
Water Contribution (Water Yield)	Meets M&I Demands	10	10	100
	Supplements Existing System	10	10	100
	Satisfies Future Canal Needs/Expansion	4	10	40
	Additional Hydropower Potential	1	5	5
Technical Viability	Design Constraints	2	6	12
	Feasibility of Concept	2	6	12
Operational Issues	Compatibility	8	6	48
	Maintenance Requirements	4	2	8
	Operational Resources Required	4	2	8
Economic Feasibility	Net Benefits	10	9	90
	Total			423

[1/] Measure - A numerical from 0 to 10 value representing the degree or level the alternative satisfies the criteria. Value of 10 indicates the most significant beneficial impact and 0 the most significant adverse impact.
[2/] Importance - A weighting factor from 0 to 10 to balance the significance of a criteria to the others.
[3/] Composite - the product of the measure and importance.

Table 42 - 17 Environmental Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Terrestrial Habitat	3	8	24
Animals on Extinction List	2	10	20
Water Quantity Impacts – Lake	8	10	80
Water Quantity Impacts -- Downstream	4	7	28
Water Quality	5	10	50
Downstream Aquatic Fauna Habitat	3	8	24
Future Lake Aquatic Plant Community	6	8	48
Aquatic Faunal Inhabiting Affected Area and Upstream Tributaries	4	5	20
Potential for Fishing on Lake	6	6	36
Wetlands	3	4	12
Air Quality	5	3	15
Cultural Resources and Historic Properties	3	10	30
Total			387

[1/] Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
[2/] Importance - 1 to 10 increasing in importance.
[3/] Composite - the product of the measure and importance.

Table 42 - 18 Socio-Economic Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Land Use	1	7	7
Relocation of People	2	10	20
Relocation of Agricultural/Ranching Activities	2	6	12
Post-Construction Business	6	5	30
Post-Construction on Existing Employment	6	5	30
Property Values During Construction	7	4	28
Property Values Post-Construction	5	5	25
Public/Community Services During Construction	6	4	24
Public/Community Services Post-Construction	5	8	40
Traffic Volumes over Existing Roadway System During Construction	3	5	15
Traffic Volumes over New Roadway System Post-Construction	5	5	25
Noise-Sensitive Resources or Activities	4	4	16
Communities Receiving Displaced People	1	8	8
Community Cohesion	1	8	8
Tourism	6	5	30
Total			318

[1/] Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
[2/] Importance - 1 to 10 increasing in importance.
[3/] Composite - the product of the measure and importance.

Pertinent Data

Table 42 - 19 presents pertinent data for the proposed Lower Rio Trinidad project.

Table 42 - 19 Pertinent Data for Operating Scenario 7

GENERAL	Gatun	Rio Trinidad	Rio Indio
Dam Site, above Gatun Dam		10 km	
Drainage Area above Dam Site	1,261.5 km^2	1,051.5 km^2	381 km^2
Average Annual Flow at Dam Site	50.4 CMS	39.6 CMS	25 CMS
LAKE			
EL. of Maximum Operating Lake Level	26.67 m MSL	33.53 m MSL	80 m MSL
EL. of Maximum Flood Storage Lake Level	26.74 m MSL	34.14 m MSL	82.5 m MSL
EL. of Minimum Operating Lake Level	25.91 m MSL	22.86 m MSL	50 m MSL
Useable Storage between Max. and Min. levels	214 MCM	1809.2 MCM	993 MCM
Area at Maximum Operating Lake Level	29,410 ha	21,912 ha	4,280 ha
Area at Maximum Flood Storage Lake Level	29,451 ha	22,830 ha	4,440 ha
Area at Minimum Operating Lake Level	28,987 ha	9,019 ha	2,360 ha
Top Clearing EL.	33.5 m MSL	33.53 m MSL	80 m MSL
Lower Clearing EL.	22.9 m MSL	25 m MSL	50 m MSL
EMBANKMENTS			
Dam – Rock Fill Embankment			
Top EL. of Dam	34.5 m MSL	34.5 m MSL	83.5 m MSL
Fixed Crest Width	13m	13 m	13 m
Height above Lowest Foundation	18 m	28 m	73.5 m
Overall Length of Dam	varies m	4480 m	891 m
SPILLWAY			
Type of Spillway	Gated Ogee	Gated Ogee	Uncontrolled Ogee
Number of Gates	14	8	-
Width of Gates	13.72 m	18.33 m	-
Net Length	192.02 m	149.35 m	-
Total Length	246.27 m	173.6 m	120 m
EL. of Crest	21.03 m MSL	25.91 m MSL	80.0 m MSL
Maximum Discharge	5150 CMS	6038 CMS	920 CMS

RIO INDIO ONLY	
INTER-BASIN TRANSFER TUNNEL	
Tunnel diameter	3 m
Tunnel length	5.2 km
Inlet invert	60 m MSL
Outlet invert	40 m MSL
Tunnel capacity	42.5 CMS
HYDROPOWER PLANTS	
Dam	
Type of hydropower plant construction	Reinforced concrete
Number of units	2
Capacity of each unit	12.5 MW
Inter-basin Transfer Tunnel	
Type of hydropower plant construction	Reinforced concrete
Number of units	1
Capacity of unit	5 MW
CONSTRUCTION / POWERHOUSE DIVERSION	
Diversion length	1,500 m
Horseshoe tunnel dimensions	8 m X 8 m
Inlet invert	10 m
Outlet invert	7 m
MINIMUM FLOW CONDUIT	
Conduit diameter	1.2 m
Conduit length	800 m
Inlet invert	10 m
Outlet invert	8 m
Conduit capacity	2.5 CMS
EMBANKMENTS	
Dam	
Type of dam	Rock fill embankment
Top EL. of dam	83.5 m
Fixed crest width	13 m
Height	73.5 m
Overall length of dam	891 m
Saddle dam (North)	
Type of saddle dam	Earth / rock fill embankment
Top EL. of saddle dam	83.5 m MSL
Fixed crest width	13 m
Overall length of saddle dam	255 m
Saddle dam (South)	
Type of saddle dam	Earth / rock fill embankment
Top EL. of saddle dam	83.5 m MSL
Fixed crest width	13 m
Overall length of saddle dam	272 m

Plate 42 - 1 Project Location Map

LOWER TRINIDAD / RIO INDIO

Project Location Map

SECTION 43

Lower Rio Trinidad 22.9m to 33.5m
Upper Rio Indio 50m

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

Synopsis

The development plan presented herein combines a dam and a lake in the Trinidad basin within the Panama Canal watershed at Gatun Lake, southwest of Gatun Locks and a dam and lake on the Rio Indio, west of Lake Gatun. Water impounded in the Lower Rio Trinidad Lake adds storage to the Panama Canal system of lakes. This additional storage would be enhanced with the incorporation of a pumping plant into the Lower Rio Trinidad project. This facility allows storage of excess water from Gatun Lake and extends usage of the waters contained in the Lower Rio Trinidad Lake. Water impounded at the Upper Rio Indio site should supply new water for use in the Panama Canal System and can be transferred via a tunnel to the Lower Rio Trinidad Lake.

The Rio Trinidad watershed is located on the western side of the Panama Canal watershed. The proposed dam site is located within Gatun Lake across the Trinidad arm near the town of Escobal. The proposed dam extends from Punta Mala, on the west shore of Gatun Lake, to Guacha Island, then across to the eastern shore of the Trinidad arm, just south of the South Range Point lighthouse. This alignment follows closely the proposed path found in the Study and Report on Increasing the Water Supply of the Panama Canal (referred to as the Tudor Report), prepared by Tudor Engineering Company, San Francisco, California 1962, for the Panama Canal Company. Plate 43 - 1 shows the location of the proposed Lower Rio Trinidad Dam project. The structures for the proposed Lower Rio Trinidad project consist of a rock fill dam constructed by underwater deposition of fill materials, a large pumping plant, and a gated spillway. This spillway should have 11 gate bays, each measuring 18.33 m wide. The pumping plant consists of the pumping station; intake and outflow facilities are separated from the lakes above and below the Lower Rio Trinidad dam by large gate structures. The total project first costs of the proposed Lower Rio Trinidad project are estimated at $1,038,765,000.

The Upper Rio Indio watershed is located adjacent to the western side of the Panama Canal watershed. The proposed Upper Rio Indio dam site is 25 km inland from the Atlantic Ocean and near the mountain Cerro Tres Hermanas. Plate 43- 1 shows the location of the proposed Upper Rio Indio project. The structures for this project consists of a rock fill dam, two saddle dams, an uncontrolled ogee spillway, inter-basin transfer facilities, two hydropower plants, and other outlet works. The tunnel should transfer water from Rio Indio Lake to the Panama Canal watershed as needed for canal operations. The total project first cost of the proposed Upper Rio Indio project is estimated at $199,177,000.

The Lower Rio Trinidad poses great construction difficulties because of the extremely large quantities of underwater fill required for construction of the dam. It requires extensive drilling and site investigation prior to construction and, because of the uncertainties inherent with this type of construction; extensive unforeseen costs may be encountered during construction. Also, the spillway and pumping plant must be constructed in island settings where the structures and appurtenances practically engulf the island areas. This poses extreme space limitations on the construction effort and is very costly.

The proposed Lower Rio Trinidad Dam project, in conjunction with the Rio Indio Dam project, should contribute greatly to the hydrologic reliability of the Panama Canal. The project should also increase the ACP's ability to serve its customers by reducing draft restrictions and the light loading of vessels, especially during periods of low water availability. The existing hydrologic reliability of the Panama Canal, based on the period of record from January 1948 through July

1998 and current demands (38.68 lockages), is approximately 99.6 percent. The hydrologic reliability with the demand increasing to 120 percent of the current level (46.42 lockage) is 98.8 percent. With construction of the proposed Lower Rio Trinidad and Rio Indio Dam projects, the existing high hydrologic reliability may be continued as demand for lockages increases up to 32.6 percent above current demand levels (up to 12.62 lockages).

Site Selection

The Lower Rio Trinidad dam site project definition and description developed with a view toward maximizing the water impounded, while minimizing the volume of material required for construction of the dam and minimizing the number of saddle dams required to contain the lake. The site chosen for the Lower Rio Trinidad Dam is 10 km south of Gatun Locks and 14 km southwest of the navigation channel. The dam would be approximately 4 km northeast the town of Escobal. This site should accommodate construction of a dam with a maximum operating lake level at EL. 30.5 m MSL. Flood storage would be accommodated between EL.s 30.5 and 28.7 m MSL.

The proposed Upper Rio Indio dam site to maximize the water impounded, while minimizing the volume of material required for construction of the dam, the number of saddle dams required to contain the lake, and the impact on the existing populated areas in the lower Rio Indio Basin. To accomplish these ends it is desirable to locate the dam immediately above the confluence of the Lower Rio Trinidad and the Rio Uracillo, as far downstream in the upper arm of the Rio Indio watershed as possible. The ideal location is where the surrounding hillsides are relatively steep and high, and the valley is relatively narrow, features that are afforded by the site chosen.

The Upper Rio Indio dam site is 29 km inland from the Atlantic Ocean and is 4 km upstream from the confluence of the Rio Indio and the Rio Uracillo. This site can accommodate construction of a dam with a normal operating lake level at EL. 50 m MSL and a maximum flood lake level at EL. 53 m MSL.

Hydrologic Considerations

Lower Rio Trinidad
The Rio Trinidad flows northward from the Continental Divide to the Gatun Lake. The headwater of the watershed begins at EL. 1,000 m MSL, approximately 75 km inland, and falls to El. 26 m MSL at Gatun Lake. The distribution of the average annual rainfall over the Rio Trinidad watershed varies from a high of 2,200 mm in the western part of the watershed to 2,000 mm on the eastern side of the watershed. The proposed Lower Rio Trinidad Lake site receives runoff from approximately 750 km^2 of the upper portion of the watershed. Rainfall runoff produces an average annual flow of 32 CMS at the proposed dam site.

The discharge at the Lower Rio Trinidad Dam site was obtained by drainage area ratio to the established record for Gatun. The Gatun Lake runoff is based on records developed by the U.S. Army Corps of Engineers Hydrologic Engineering Center and the ACP in a separate study.

Since the Lower Rio Trinidad Lake is located within Gatun Lake the monthly evaporation rates established for Gatun Lake are considered appropriate for the evaporation rates of Lower Rio Trinidad Lake.

Upper Rio Indio
The Rio Indio flows northward from the Continental Divide to the Atlantic Ocean. The headwaters of the watershed begin at EL. 1,000 m MSL, approximately 75 km inland, and falls to mean sea level at its mouth. The distribution of the average annual rainfall over the Upper Rio Indio watershed varies from a high of 4,000 mm at the coast to a low of 2,500 mm in the middle watershed area. It increases again to over 3,000 mm in the Continental Divide. The proposed Rio Indio Lake receives runoff from approximately 256 km^2 of the upper portion of the watershed. Rainfall runoff produces an average annual flow of 16.8 CMS at the proposed dam site.

The calculated discharge at the Upper Rio Indio Dam site is extrapolated, recorded, and correlated stream flow data of the Boca de Uracillo hydrologic station. This station began operation in 1979 and is located on the Rio Indio, approximately 6 km downstream from the dam site. Data established from a statistical correlation with the discharge data of the Rio Indio at Limon, 3 km downstream from the dam site, using standard hydrologic techniques, completed missing data and increased the period of record. Utilization of the double mass curve method satisfactorily verified the consistency of the data measured and correlated.

Due to the proximity of Rio Indio to Gatun Lake, and because of the absence of site-specific information, the monthly evaporation rates established for Gatun Lake are considered appropriate for the evaporation rates of Upper Rio Indio Lake.

Geologic Considerations

Lower Rio Trinidad
The proposed Lower Rio Trinidad Dam site was investigated in 1962 by Geo-Recon, Inc. of Seattle, Washington, as part of the Tudor report. The investigation consisted of seismic velocity and electrical resistivity profiles in conjunction with four test borings (all located in the lake and drilled by the Panama Canal Company). The results of the geophysical surveys reportedly compared well with the logs of the test borings in the deep-water areas (up to 23 m deep) of Gatun Lake. In June 1963, Tudor Engineering submitted a report including additional foundation investigations. The foundation investigations were made by the firm Shannon & Wilson, Inc., Soil Mechanics and Foundation Engineers, from Seattle, Washington, and consisted of 77 cone penetrometer borings, 24 classification borings, 11 undisturbed sample borings, and 6 field vane shear borings. The investigations submitted by Shannon & Wilson, Inc were recently reanalyzed in <u>Geology of the Proposed Dam Across Trinidad Arm of Gatun Lake</u>, by Mr. Pastora Franceschi S., for the Geotechnical Section of the Panama Canal Authority.

In the lake areas, the investigations disclosed that overburden material included recent lake deposits, the Atlantic Muck Formation, alluvial deposits, and residual deposits. Between the west shore and Guacha Island these deposits consist of soft to very soft clay, silt, sand and peat (Atlantic Muck Formation) overlying soft to hard deposits of clay, silt, sand and gravel derived both from alluvial deposition and the weathering of bedrock. The upper two phases of the Atlantic Muck Formation, judged to be the most compressible portion of the formation, was found to have an average thickness of about 18.3 m and a maximum thickness of 22.9 m. Recent, soft lake deposits ranging from 1.2 to 2.4 m thick were found overlying the Atlantic Muck Formation. In the length between Guacha Island and Tern Island, the Atlantic Muck Formation was either not found, or was very thin. In this area, Recent-aged soft sediments (averaging 2 m thick) were found to overlay residual soil and weathered rock. Atlantic Muck Formation, where present, occurred between the Recent-aged material and the residual soil, and was a maximum 5 m thick. Between Tern Island and the east mainland, only recent lake sediments (1.5 m thick) overlying residual clay were found above the conglomerate of the Bohio Formation.

Guacha, Tern and Booby Islands, all located within Gatun Lake, were each found to have an overlying stratum of soft overburdened and weathered rock of variable thickness. In general, firm bedrock was found available below EL. 22.9 m MSL and the islands were judged to offer suitable foundation conditions for control structures.

Firm bedrock under both the land and the lake was found to consist of low velocity sedimentary rock composed primarily of sandstone and the Bohio Formation. Two areas containing abrupt changes in bedrock velocities were located during the survey. One of the areas was a narrow zone located on Guacha Island that was interpreted as a possible shear zone in rock of similar type. The second area was an abrupt change in bedrock velocity on Tern Island that was interpreted as a possible fault contact between two formations, or between different lithologic units of the same formation. The top of the bedrock on land was interpreted from the geophysical results to be weathered to below lake level. The core borings in the lake determined the weathered zone of bedrock to range from 1.2 to 3.1 m in thickness.

Satisfactory foundation conditions exist for construction of a pumping station, and a spillway at the Lower Rio Trinidad Dam site. Serious consideration, however, must be given to problems that would be caused by the anticipated settlement and instability of the embankment materials. Additionally, it is assumed that all concrete aggregates may be obtained from commercial sources.

Upper Rio Indio
The proposed Upper Rio Indio project is located in an area of the Isthmus of Panama underlain by Oligocene-aged sedimentary rocks of the Caimito Formation. Three members of the Caimito Formation are recognized: the lower, the middle and the upper. The deposits of each of these members are mainly marine, but are lithologically heterogeneous. The lower member is composed of conglomerate and tuffaceous sandstone. The middle member consists chiefly of tuffaceous sandstone, some of which is calcareous, and lenticular limestone. The upper, principal member consists of tuff, agglomeratic tuff, tuffaceous siltstone, and discontinuous sandy tuffaceous limestone. In general, all members are hard, thinly to thickly bedded, and closely to moderately jointed. The lower member weathers to greater depths. A summary of test data developed in 1966, as part of the studies for a sea level canal, listed compressive strengths for samples of Caimito Formation material varying between 79,450 and 5,955,257 kg/m^2. The same 1966 studies assigned an allowable bearing capacity of 195,300 kg/m^2 for the material of the Caimito Formation. The abutments at the project site may consist of Miocene volcanic rocks, possibly of the Tucue Formation.

The Caimito Formation material should make an acceptable foundation for an earth and rock fill dam, however, it is unacceptable for use as concrete aggregate and only marginally acceptable for use as fill in some of the less important zones the dam. Development of this project requires core drilling early during planning studies to identify the foundation and abutment materials and to determine the general suitability for use as construction material. In addition, the cores should be of sufficient depth to check for the occurrence of any soluble limestone strata that may underlie the dam foundation.

The proposed inter-basin transfer tunnel connecting the Upper Rio Indio Lake to the Panama Canal watershed is probably located very near the contact of the Caimito Formation and the overlying Miocene-aged volcanic rocks. Many springs occur in the area of the proposed tunnel inlets and outlets, and groundwater flowing in volcanic rock above impervious strata of the Caimito Formation may be the cause. In addition, a 1921 drawing shows two coal mines in the general area of the tunnel inlets. Further development of this project would require drilling of cores near the proposed tunnel inlets and outlets early during planning studies to determine the general relationship between the tunnel alignments and the sedimentary / volcanic rock contact, coal or peat beds, and the water table.

In the absence of detailed geologic mapping for the proposed Upper Rio Indio Dam site, a degree of extrapolation is necessary. Available general geologic mapping and general data were the basis of predictions that rock, encountered at a shallow depth and of sufficient quality, could serve as foundation for the dam and appurtenant structures. Furthermore, assumptions for this report are: required excavation should make available sufficient rock for fill, and the immediate area contains enough impervious materials and concrete aggregate for use in the construction of the proposed project.

Lake Operation

The operating scenario considered in this study for periods when water would be transferred from Lower Rio Trinidad Lake to Gatun Lake for canal operations is detailed in Section 42 – Lower Rio Trinidad 22.9m to 33.5m, Rio Indio 50 –80m. The following is a reiteration of the tabulated pool levels contained in that narrative.

Table 43 - 1 Lake Operating Options

Lake Level (m MSL)	Lower Rio Trinidad	Gatun
Normal Operating Lake Level	33.53	26.67
Minimum Operating Lake Level	22.86	25.91
Maximum Flood Lake Level	34.14	27.13

Under this scenario the Upper Rio Indio Lake would be operated in a “run-of-the–river” mode, transferring all flows above the invert of the interbasin transfer tunnel, EL. 45.5 m MSL, would be directed to the Lower Rio Trinidad Lake for storage and navigation use. This transfer of water between Upper Rio Indio and Lower Rio Trinidad Lakes would be made via a tunnel constructed beneath the divide separating the two basins. The tunnel would be sized to carry all but the greatest flood flows from the Upper Rio Indio basin. The maximum flood flows would be passed over the fixed crest spillway to the Lower Rio Indio. Table 43-2 shows the lake levels affecting the Upper Rio Indio design for this scenario.

Table 43 - 2 Lake Operating Levels

Lake Level (m MSL)	Upper Rio Indio
Normal Operating Lake Level	50
Minimum Operating Lake Level	45.5
Maximum Flood Lake Level	52.0

Project Features

GENERAL

The structures for the proposed Lower Rio Trinidad project should consist of: a rock fill dam, a large pumping plant, and a gated spillway. Modification of one existing saddle dam and construction of two additional saddle dams is also required. Plate 43 - 1 shows the dam site in downstream left bank perspective and indicates the location of the gated spillway and the pumping plant.

The structures for the Rio Indio project consist of a rock fill dam, two saddle dams, an uncontrolled ogee spillway, inter-basin transfer facilities, two hydropower plants, and outlet works. The project details would be as depicted in Section 37, Plate 37 - 2.

The following paragraph provides a description of the proposed structures and improvements for these projects.

Design was performed only to the extent necessary to establish, with reasonable accuracy, the principal dimensions, elevations, and costs of the proposed project. Separate documentation was provided to the ACP that contained assumptions and design calculations for the reconnaissance level investigations of these structures. If this project is carried into the planning studies, optimization of the project features and improvements must be accomplished.

EMBANKMENTS

Lower Rio Trinidad Dam

The proposed dam consists of an embankment with the top at EL. 31.50 m MSL and with a crest width of 13 m with a final crest of 7 m upon completion of all settlement of the embankment and bridge work. The left abutment of the embankment will be located at Universal Transverse Mercator Grid, Zone 17, Clark 1866 Spheroid Coordinates 1015858 north and 614864 east. The right abutment will be 1013937 north and 618229 east coordinates. The normal lake El. 30.48 m while the ground surface elevations along the axis of the dam vary from El. 2 m MSL in the lake bottom to EL. 39 m MSL on Guacho Island and El. 38 m MSL on Tern Island. The Gatun Lake subgrade supporting the embankment occupies a broad flat valley having sides, which slope, upward from the valley at grades up to 40 percent. Water depths are 21.3 to 26.3 m over 80 percent of the site. The Atlantic Muck Formation, consisting of very soft organic clays, silts and peats varying in thickness from 7.6 m to 48.7 m, underlies approximately two thirds of the alignment subgrade. The Atlantic Muck Formation in the old river channel is further underlain by soft silts, sand and clay strata.

The critical challenge for design espoused by the Tudor Report and others is the depth of subgrade degradation during the initial fill placements. The materials will lose much of its natural strength when disturbed and will only regain strength after the effects of consolidation of a surcharge fill. However, complete restoration of strength can only be assumed to a depth of 5 to 7 m. If the effects of the subgrade disturbance extend appreciably deeper, then an extremely weak material will be under the more stable subgrade and surcharge creating a condition of lateral instability.

Because of the inability to accurately analyze this condition, a test fill was performed on the western end of the alignment. In early 1963, 1,000-cy bottom-dump barges deposited some 168,000 cy of blasted rock from the cut widening project, extending some 305 m. One hundred fifty five meters of the fill was placed to a height of 11 m while the remaining 150 m was filled to 5 m. The differential heights were use to simulate initial and intermediate fill placement effects. Divers were then used to observe the performance of the fills placed along the alignment. The mechanisms of failure within the subgrade were caused by impact and static loadings. The impact of the initial placements caused severe destruction of the surface materials creating lateral displacements up to 5 m. However, when a continuous blanket of fill had been established and subsequent fill was placed, then conventional failures such as slip circle shear failures and horizontal shears creating large mud waves outward from embankment were observed. Therefore, to predict the behavior of the embankment during construction and for the long term, it is imperative that a foundation mat be established to such a depth to prevent subgrade rupture with subsequent fill placement. The Tudor report recommended that a 5 m thick minimum crushed rock blanket with maximum sizes of 20 cm be placed initially to act as the supporting blanket. Special barge dumping methods were to be employed so loads would not fall as an integral mass, which would create destructive forces on the subgrade.

The placement of a large hydraulic structure on a deep-seated weak foundation is the most challenging of geotechnical endeavors. It is virtually impossible to analyze with great deal of certainty and the owner must be prepared to accept possible additional costs during construction and long term maintenance due to the potential for lateral instabilities and high degrees of settlement. The Tudor Report has predicted some 2.5 to 3 m of predicted settlement below the crest elevation for a construction duration of 7-years and an additional 2.5 to 3 m of maximum settlement below the crest for the 50-year service life of the project. These settlements are predicted where the Atlantic Muck and underlying compressible materials are the thickest. These movements are reduced as the fill approaches the mainlands and the two islands. This implies that significant differential settlements are predicted within these approaches as well. The key to any successful construction and maintenance of this embankment will be to establish a blanket mat atop the subgrade where subsequent fill can be economically placed without fear of rupturing the foundation to greater depths. Any significant lateral failure of the embankment during construction or productive use will render that alignment unsuitable. Additional embankment sections must be established upstream or downstream to reestablish the embankment section to the proper elevation. This repair will take considerable time and prevent its use as a road. Based on these considerations, these recommendations are presented for ultimate costs considerations in comparison to alternatives with a greater degree of performance certainty.

The divers observed that the test fill had trouble placing the fill in the correct locations within the alignment and the lift thickness varied significantly over the fill cross section. It is imperative that the blanket fill be placed intact with the least subgrade disturbance in order for the embankment to act as monolithic mass. Therefore, the initial 5 m of fill will be barged to the site and placed by lowering a clamshell to the subgrade surface. The positioning of the barges must be strictly controlled by survey positioning systems established on land. The initial fill should have a maximum size of 20 cm and the percent fines should be controlled to remain fairly intact during placement. Materials with a significant size differential and a large fine content can create weak shear zones with the embankment. The subsequent fill materials above this zone can be placed by bottom dumped barges or clamshells from El. 8 to 21 m MSL. The material above El. 21 m MSL must be placed by clamshell due to the draft and door operations of the barges. These materials will be more random in gradation having a maximum size of 30 cm and a greater degree of fines. The materials placed below El. 27 m MSL will assume a side slope of 1 V:15 H. A 15 m berm will be constructed and the materials will continue to be placed by clam shell and spread with a dozer to El. 34.5 m MSL, assuming a side slope of 1 V : 3 H and a crest width of 13 m. The flatter side slopes are needed to distribute bearing pressures and to reduce the lateral displacements. This configuration should also reduce the construction and total settlements predicted by the Tudor report and provide acceptable factors of safety for lateral stability during fill placement. The side slope berms and extra crest width will facilitate the future fill placements of up to 3 m over the life of the project. The road surface atop the dam embankment will remain gravel surfaced for the foreseeable future due to future fill placements. The dam will be approximately 30 m high, and the overall length 4,473 m. The top of the dam will be 5 m above the normal Gatun Lake level. The total volume of fill material required to construct and maintain the main dam to El. 34.5 m MSL is approximately 39,883,250 M^3. Water access from the main channel to Guacha and Tern Islands will be built during construction. After access roads have been constructed, fill placements from the east mainland to Tern and Gaucha Islands could be delivered by truck and placed by end-dumping from the east mainland. This technique could prove beneficial if a material source was found near the Gatun Lock area. The side slopes and overall embankment configuration was offered for ease of calculation, to reduce the foundation pressure on the soft subgrade and to account for the lateral displacement of embankment materials. The increased foundation base should help the structure survive a relatively minor seismic event.

The methods of subgrade stabilization and embankment strengthening offered in the powerpoint presentations from the ACP Engineering Division are examples of many ideas for enhancing the performance of the embankment during construction and post construction. The use of wick drains have been an effective tool for accelerating consolidations under a mass loading. However, the Atlantic Muck materials will not readily transmit water to the drains, therefore the spacing of the drains must be much closer than that implied and the effectiveness of the drains will be restricted to the top 15 to 20 feet of the foundation subgrade. The drains must be effectively tied into the foundation blanket for continuity of the drainage path. There are concerns by the use of vibro-flotation or stone columns techniques above the mat. The mat will not effectively dampen these compaction forces and some rupture of the mat could be possible. A safer reinforcing technique could be the use of reinforcing within the embankment section, such as high strength geogrids placed in layers. All reinforcing techniques are expensive but could be offset by the reduction in fill quantities ultimately required. Any reinforcing selected for use in production must be part of a comprehensive test fill program to demonstrate its effectiveness.

The Tudor Report identified considerable leakage to be expected from the completed embankment. Since loss of any water from storage is a significant reduction in benefits, the seepage must be prevented. Therefore a bentonite slurry trench should be installed within the centerline of the embankment. The trench will be a minimum of 3 feet wide and extend to several meters below the original lake bottom. The trench can be excavated using rockmill techniques. Since the embankment will undergo significant settlement, both total and differential, it is likely that the trench will be sheared and will require replacement within the deeper portions of the lake during the life of the project.

Upper Rio Indio Dam

The Upper Rio Indio dam would be an embankment with the top at EL. 53.0 m MSL and with a crest width of 13 m. The left abutment of the embankment would be located at Universal Transverse Mercator Grid, Zone 17, Clark 1866 Spheroid Coordinates 990717 north and 591922 east. The right abutment would be 991200 north and 592330 east coordinates. The embankment would be constructed with an impervious earth and rock fill core encased in rock fill, and the final side slopes would be 2 H : 1 V. The dam at its highest point would be approximately 43.5 m high, and the overall length would be 632 m. Further study would determine the actual side slopes and crest width and would be contingent upon the need for vehicular access across the embankment, the size and quality of the rock fill, and the detailed design of the embankment. Plate 38 - 3 presents a typical section of the embankment at the dam, incorporating upstream and downstream cofferdams within the section. The estimated quantity of fill to complete this embankment is 1,534,905 cm.

Foundation grouting would be required across the entire base of the dam and up a portion of the valley walls. A blend of bentonite and native fill materials in a core trench can provide seepage cutoff in the embankment foundations. A concrete or bentonite cutoff wall can also provide seepage cutoff.

The crest width and side slopes are presented here for comparison purposes between projects. The actual crest width and side slopes would be determined during further study and are contingent upon the need for vehicular access across the embankments, the size and quality of the fill materials available for use, and the detailed design for the embankments.

Saddle Dams

As noted in the Tudor Report, the existing Caño Saddle Dam No. 4 located along the western shoreline of the Lower Rio Trinidad Arm of Gatun Lake should need to be raised and/or strengthened to accommodate the higher lake levels. Immediately to the north of this location, two additional smaller saddle dams are required. All would be built to provide a minimum El. 34.5 m MSL. The total volume of fill material required for these three dams is 50,000 M^3

The actual side slopes and crest widths would be determined during further study and would be contingent upon the need for vehicular access across the embankment, the size and quality of the rock fill, and the detailed design of the embankment. A typical section of the embankment at the saddle dams and main dam would be similar to that shown for the embankments for the Upper Rio Indio project, Volume One, Section 5 of this report.

SPILLWAY

Spillways would be required at two of the dam sites, Upper Rio Indio and Lower Rio Trinidad under this scenario.

Lower Rio Trinidad

Under normal flow conditions water passes from Lower Rio Trinidad Lake to Gatun Lake through a gated spillway. This spillway should have 8 gate bays, each 18.33 m wide. The gate bays would be separated/flanked by 3 m wide reinforced concrete piers (9 piers in all), which should provide support for the gates and operating machinery, as well as providing support for a roadway bridge over the top of the spillway. Each of the 8 spillway gates should have a nominal width of 18.33 m and a height of 8.53 m, providing 0.3 m freeboard above the maximum lake operating level. The overall length of the spillway, from out-to-out of piers is 173.64 m. The spillway sills would be placed at the minimum lake operating level, EL. 25.91 m MSL.

A bridge across the tops of the spillway piers would be constructed as a part of the roadway across the top of the dam. The roadway must be approximately 7 m wide thus allowing for two-way traffic and providing ready access to the spillway gate operating machinery.

For this study, stop logs for servicing the gates, guides, etc. may be placed either from the roadway or from barges using floating cranes. Also, it should be noted that, with the spillway sill at the prescribed level, stoplogs are required both upstream and downstream to allow work to be done on the gates and sills in the dry.

The spillway would be situated along the axis of the dam approximately centered in Guacha Island. This allows the construction to be performed completely within a dry construction cut requiring a minimum of construction dewatering. Once the concrete structures are completed, the entrance and exit channels to the spillway can be opened.

Upper Rio Indio

For Upper Rio Indio, an uncontrolled ogee spillway, with a length of 113.11 m, and a crest of EL. 50 m MSL is required. The spillway crest would be 3 m below the elevation of the top of the dam. The maximum discharge from the spillway would be 618 CMS at a maximum flood lake level at EL. 52 m MSL. The spillway design discharge is equivalent to a 1 in 1,000 frequency unregulated flow at the dam site. The spillway would be located within the abutment adjacent to the left end of the dam and consist of a mass concrete sill section embedded in the natural rock. A sloped and/or stepped, natural rock cut tailrace channel should transfer flow to the adjacent Rio Uracillo tributary. The tailrace channel extends from the sill section to its confluence with the Rio Uracillo. The task of dissipating energy at the downstream end of the tailrace channel requires excavation of a stilling basin into the rock adjacent to the natural channel. See Plate 37- 2 for the location of the spillway and Plate 37 - 4 for a typical section at the spillway.

PUMPING PLANT

A large pumping plant is included in this scenario at the Lower Rio Trinidad dam. This pumping facility provides for pumping in two directions, allowing Lower Rio Trinidad Lake to be drawn down to a level below that of Gatun Lake during extremely dry months, and providing the capability of pumping excess water from Gatun Lake into Lower Rio Trinidad Lake during the flood season. Water thus stored would be available for navigation during the dry season. The pumping plant is configured to provide pumping to EL. 33.53 m MSL in Lower Rio Trinidad Lake. For the purpose of this study the pumping plant is located in the northwest segment of Tern Island. See Table 43-3 for the controlling head and flow data used for this study.

This plant should consist of six 1407 HP pumps, each capable of pumping slightly more than 62 CMS for a total plant pumping capacity of 373 CMS at a total dynamic head of 4.6 m. The pumping units would be mounted in a reinforced concrete housing and arranged in a row perpendicular to the axis of the dam, with intake and outlet channels on either side. The channels would be separated from the Lower Rio Trinidad and Gatun Lakes by large concrete walls containing low-level sluiceways and gates for controlling flows into and away from the pumping plant. These sluiceways are configured to provide average entry velocities of approximately 7.7 MPS. The channels are configured to provide this velocity or less and require no special armoring of walls or inverts for scour protection. The channel invert would be at EL. 20 m. MSL, or 13.5 m. below the centerline of the pump outlets. This may provide sufficient water depth at maximum pumping to buffer the erosive effects of the very large outflows required.

In conjunction with this facility a roadway bridge would be required to connect the pumping station structure to the banks on either side of the intake and exit channels thus continuing the roadway across the facility. This bridge should also provide both operational and maintenance access to the pumping plant. As configured for this study, the bridge must have two 15 m long spans with steel girders and a concrete bridge deck on each side of the pumping station. It shall have a 7 m wide travel way and include one bridge bent including a cap, two round columns and a spread footing, located within each channel section.

Table 43 - 3 Pumping Data

Pumping Cycle	**Head** (m.)	**Average Daily Flow** (M^3/sec)
Lower Rio Trinidad (Elev. 22.86) to Gatun Lake (Elev. 25.91)	3.05	127.43
Gatun Lake (Elev. 26.67) to Lower Rio Trinidad (Elev. 33.53)	6.86	56.64

IMPOUNDMENT

The lake formed by the proposed Lower Rio Trinidad Dam should have a normal operating lake El. 33.53 m MSL. The surface area at the normal operating lake level is 21,912 ha. At the maximum flood level, EL. 34.14 m MSL, the surface area is 22,830 ha. With the minimum operating level at EL. 22.86 m MSL, the surface area is 9,019 ha. It should be noted that the current operating levels of Gatun Lake vary up to EL. 26.67 m MSL; therefore areas below the maximum Gatun Lake level are already subject to inundation.

The lake formed by the proposed Upper Rio Indio Dam should have a normal operating lake level at EL. 50 m MSL. The surface area at the normal operating lake level is 863.8 ha. At the maximum flood lake level, EL. 52 m MSL, the surface area is 897.6 ha. With the minimum operating lake level at EL. 45.5 m MSL, the surface area would be approximately 732 ha.

CLEARING AND/OR GRUBBING

Clearing and grubbing is required for all areas above the existing Gatun Lake needed for construction of the dam (embankments and spillway), access roads, and disposal and staging areas. For the Lower Rio Trinidad Lake area, clearing is required for the 3,700 ha in the lake area between the maximum operating lake level of Gatun Lake and EL. 30.5 m MSL.

For the Upper Rio Indio Lake, clearing is required in all areas necessary for construction of the dam (embankments and spillway), inter-basin transfer facilities, outlet works, hydropower plants, access roads, and disposal and staging areas would require clearing and grubbing. Only the 900 ha in the lake area between the normal operating lake level, EL. 50 m MSL, and the minimum operating lake level, EL. 45.5 m MSL require clearing. The transmission lines also require clearing.

ACCESS ROUTE

Access to the lake site and the various construction sites was evaluated from the main population centers, Colon on the Atlantic coast and Panama City on the Pacific coasts.

The route from Colon is westward across the Panama Canal and then southwestward along existing roads that follow the westernmost boundary of Gatun Lake to Cape Mala, near the western abutment of the dam. A very short access road is required from the existing road to the dam site. This route requires crossing the Panama Canal near the Gatun Locks using the existing lock gate bridge. This bridge is narrow and operates only intermittently since canal operations take precedence over roadway traffic. It may be undersized and may lack the load carrying capacity needed for heavy construction materials and equipment loads anticipated.

Access to the spillway and pumping station construction sites would be by water since these structures are to be placed on Guacha Island. A water access route is a possible means of conveyance for much, if not all, of the construction equipment and materials. This requires offloading facilities be constructed near the west abutment of the dam on Guacha Island, and near the eastern abutment site in the vicinity of South Range Point.

Since much of the construction for this project would be in the existing lake or on an island, it is concluded land and water are both required. Plate 43 - 1 shows the general location of the proposed features and the possible land and water access available or to be provided.

For access to the Upper Rio Indio site, it is concluded that the route from Panama City westward across the Bridge of the Americas, then southwestward along the Inter-American Highway, and then westward along existing roads to Ciri Grande, may be best. This route requires that the road between Panama City and Ciri Grande be upgraded over much of its length and the route west of Ciri Grande must traverse the mountains. The proposed access road would be 26 km in length, and bridges and / or culverts would be required at 15 streams. Plate 43-1 shows the portion of the proposed access road from Ciri Grande to the construction sites.

In addition to providing dam construction access, this new corridor into the country west of the Panama Canal benefit those living in the region, providing access to the main centers of commerce in the southern part of the country. It should also provide continuous access along the new power transmission lines from the dam site to the connection with the power grid.

Sources of Construction Material

Lower Rio Trinidad
The bottom 5 m layer of the dam embankments shall be constructed with material less than 8 in. maximum size, and with no more than 5 percent passing the #200 screen. Such a material would require crushing and processing across a grizzly to remove oversize rock, and washing to remove fines. Material for this bottom layer must be reasonably well graded so as to prevent the removal of the finer fraction by piping. The overlying main portion of the embankment would be constructed with (-12 in.) sized material. This material should also require crushing and processing across a grizzly to remove oversize rock.

The majority of the materials used for the embankment construction would be obtained from upland sources adjacent to the Gaillard Cut, transported to the site by barge and clam shelled along the proposed embankment alignment. The initial materials would be obtained from the existing disposal sites for the Gaillard Cut widening above Pedro Miguel Locks. Based on the information received from the ACP, these sites contain approximately 5.5 million M^3 of suitable excavated rock. However, this rock is not stockpiled in an orderly manner, is randomly mixed with unsuitable material and is covered with unsuitable material. All the rock materials, from whatever source, should need to be crushed, graded and loaded on trucks for transport to a loading facility adjacent to the canal at the Cucaracha Reach on the east side, or the mouth of the Mandinga River on the west side. These loading facilities should require excavation into the bank area and bulkheaded for crane support and barge placement. Working stockpiles would be maintained next to the transfer points to facilitate the loading process. Additional materials within the immediate area should come from the Third Locks excavation adjacent to the Pedro Miguel Locks. These materials would be drilled and blasted in place, excavated, and then transported to one of the transfer facilities for processing. Additional materials should come from newly developed quarry sources in areas such as Hodges Hill, Escabor Hill, Contractor Hill, and others within 10 km of the transfer points. Each of these new sources would require extensive excavation to remove the overburden and soft rock materials. These materials would be stockpiled adjacent to the work area for restoration once the rock fill materials have been acquired. The suitable rock materials would be blasted, crushed and graded and trucked to the transfer points. All material would be loaded onto barges, transported to the dam site and clam shelled within the dam limits.

Cement is available within the country. Rock obtained from developed quarries may be used to produce concrete aggregates on-site, or they may be obtained from commercial quarries. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) need to be fabricated outside the Republic of Panama and imported for final assembly and installation at the proposed dam site.

Upper Rio Indio
Rock removed from the spillway at the Upper Rio Indio site can used as fill in the embankment portion of the dam. Impervious materials might be obtained from outside the project area; however, for this study it is assumed that these materials would be available locally in sufficient

quantity to supply the project needs. If further study indicates that impervious materials are unavailable locally, then other materials, such as roller compacted concrete, would be considered for construction of the dam.

Cement is available within the Republic of Panama. Rock obtained from developed quarries may be used to produce concrete aggregates on-site, or they may be obtained from commercial quarries. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) need to be fabricated outside the country and imported for final assembly and installation at the proposed dam site.

Real Estate Requirements

The proposed Lower Rio Trinidad Lake site is located within the Panama Canal Zone and is presently managed and controlled by the ACP. Construction of this proposed project requires acquisition of 800 ha. Table 43 - 4 shows the amount of land required for the various project features. Real estate for access roads is included in the estimated quantities for the other items listed in the table.

Table 43 - 4 Real Estate Requirements – Lower Rio Trinidad

Project Feature	Land Required (ha)
Lake	0
Dam Site	0
Staging Area	200
Housing and Facilities	200
Disposal Area	400
Total	800

The proposed Upper Rio Indio project site is located in the Cocle, Colon, and Panama Provinces. Construction of this proposed project requires acquisition of approximately 5,600 ha. Table 43 - 5 shows the amount of land required for the various project features. Real estate for access roads is included in the estimated quantities for the other items listed in the table.

Table 43 - 5 Real Estate Requirements – Upper Rio Indio

Project Feature	Land Required (ha)
Lake	900
Dam Site	200
Staging Area	200
Housing and Facilities	200
Disposal Area	400
Total	1,900

Relocations

The Lower Rio Trinidad Lake site is located within the existing former Panama Canal Zone. Structures and facilities established along the waters edge in the Rio Trinidad arm between the existing Gatun Lake levels and EL. 30 m MSL need to be relocated or modified. This includes a major portion of the town of Escobal. Additionally, there are a few small communities and isolated individual structures along the lake shore with very limited access by land.

The Upper Rio Indio Lake site is located in a sparsely settled region with few roads and utilities. This area is devoted primarily to subsistence farming and ranching. Structures and individuals located in the lake area below EL. 55 m MSL require relocation because of the normal lake inundation and to secure the lake perimeter for flood considerations. The required relocations include the two towns in the lake area (Los Uveros, and Tres Hermanas), 12 other small settlements, and numerous isolated structures. The two towns have elementary schools, churches, electricity, and limited telephone coverage.

Development Sequence

Each of the component lake projects are designed and can be constructed as a stand-alone facility. If the Upper Rio Indio facilities are constructed first and placed into service before the Lower Rio Trinidad facilities, the interbasin transfer tunnel can be used to navigational advantage while the Lower Rio Trinidad project is being completed. During the interim the Upper Rio Indio project should help control flooding on the Lower Rio Indio and can contribute to the electric power output of the country.

The development sequence for each individual project follows roughly the same progression. This progression is summarized below with pertinent site-specific notations as appropriate.

Each project must be evaluated to assure that the plan presented includes all of the features required to function. Each project must be assessed as to its effectiveness in providing navigation water to the Panama Canal, with due recognition of any secondary benefits. Environmental assessments of the proposed projects need to be made to assure environmental acceptability of the project features. These environmental assessments begin during the planning studies phase and continue into the final design, advertising and award phases. Environmental coordination begins with planning studies and continues through the completion of construction. After completion of the final design, plans and specifications must be prepared for the advertising and award phase.

Project implementation begins with land acquisition and construction of the access facilities. Lands for the housing and facilities project feature, which includes the access roads, need to be acquired initially. Lands for the dam site, staging area, disposal area, and lake can then be acquired.

Socio-economic programs must begin shortly before construction of the dam. The relocation of the small settlements and isolated structures must be accomplished. Socio-economic programs to assist those individuals impacted by the construction of the proposed project should continue throughout the construction phase.

Construction of the Upper Rio Indio Dam begins with the clearing and grubbing of the construction sites and clearing the perimeter of the lake area. Materials used for the embankment construction can obtained from upland sources then transported to the site.

Upstream and downstream cofferdams are required for construction of the Upper Rio Indio Dam and appurtenant facilities. These shall be configured to form a portion of the finished dam.

Limited cofferdams would be required to accomplish construction of the spillway and pumping station. These efforts may be accomplished simultaneously. Following completion of the pumping plant and spillway, the channels connecting these structures to the lake areas upstream and downstream may be excavated. Where possible, materials removed from these sites would be placed directly into the dam.

Once the western leg of the dam, pumping station and spillway are completed, the eastern leg may be constructed, thus completing the dam. The pool may then be raised. Upon completion of this phase of construction, all facilities must undergo trial operations, before being commissioned for service.

Considering the construction methods required and the nature of the work, it is estimated that development of the Lower Rio Trinidad and Rio Indio Dam projects may be completed in approximately the time spans indicated in Figures 43-2 and 43-3, below, from initial planning to lake filling. Assuming that the development of the two projects is overlapped by 1 year the total development time is approximately 22 years.

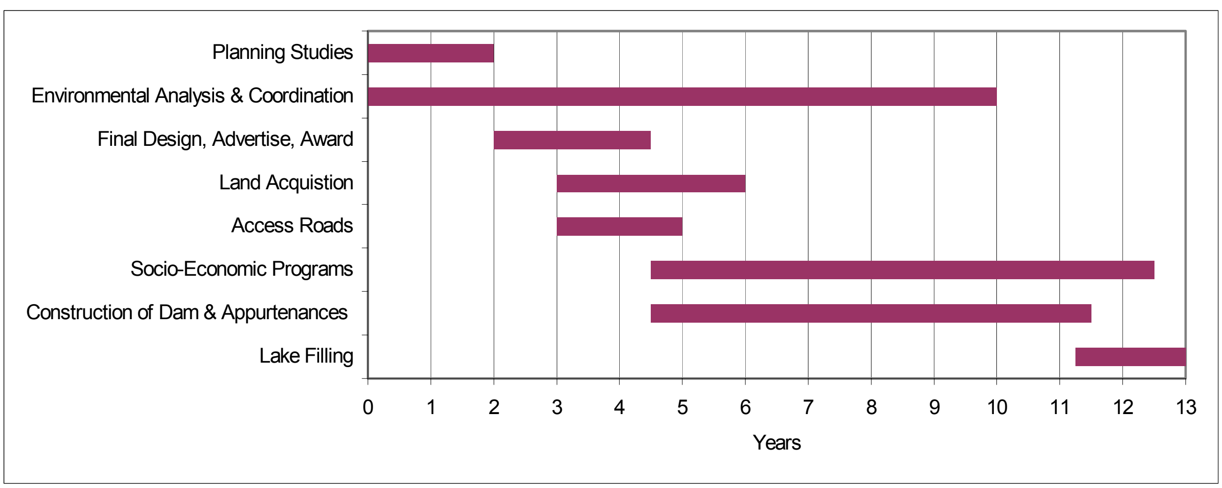


Figure 43 - 1 Development Sequence – Rio Trinidad

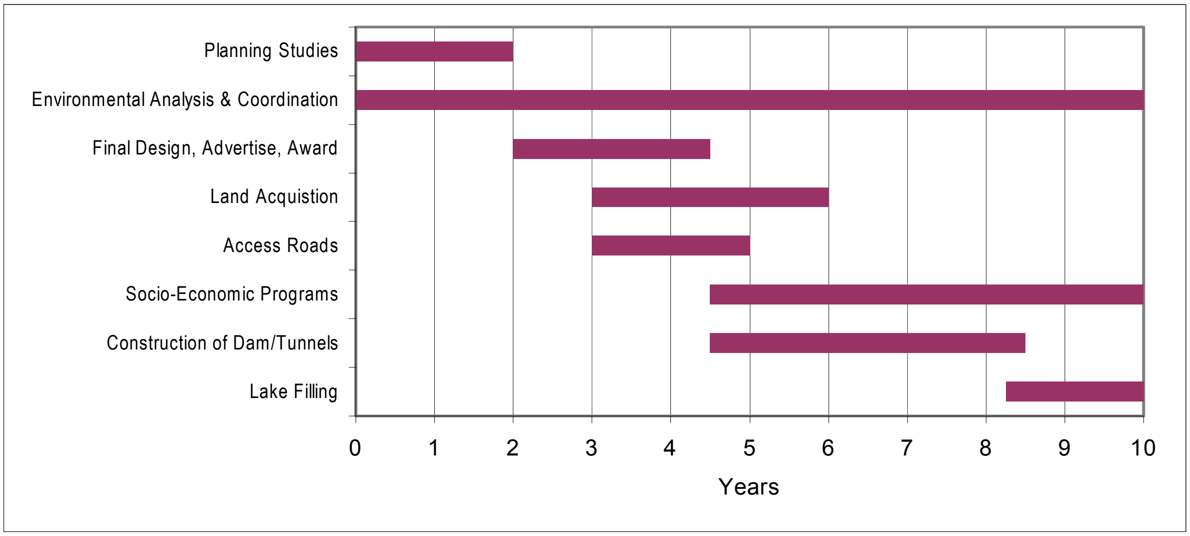


Figure 43 - 2 Development Sequence – Upper Rio Indio

Hydrologic Reliability

In order to determine the effect of the proposed lakes on the hydrologic reliability of the Panama Canal, the existing HEC-5 model is modified to include the Lower Rio Trinidad Lake with pumpback operation and diversion from Upper Rio Indio Lake. The existing Gatun Lake parameters (surface areas, storages, and local inflows) are reduced by the proportion that Lower Rio Trinidad would capture.

HEC-5 model simulations are conducted for both the existing canal system and the Scenario 8 operating system demand levels. The period of simulation considered 52 years (January 1948 through December 1999) of hydrologic record. Figure 43 - 3 presents the resulting hydrologic reliability for two configurations with demands increasing up to 180 percent of current demands. These configurations are:

- Existing system,
- Scenario 8 – Upper Rio Indio Lake has a normal operating level of 50 m MSL and should operate as a "run-of-river" dam, transferring flows to Lower Rio Trinidad via 4.5 m interbasin transfer tunnel; Lower Rio Trinidad Lake fluctuating between the normal operating lake level, EL. 33.53 m MSL and the minimum operating lake level, EL. 22.86 m MSL, with pumping capability to and from Gatun Lake; and Gatun Lake fluctuating between the normal operating lake level, EL. 26.67m MSL, and the minimum operation lake level, EL. 25.91m

The horizontal axis along the bottom of Figure 43 - 3 reflects demands as a ratio of the 5-year average from 1993 to 1997, and the axis along the top reflects demands in lockages (assuming 55 million gallons per lockage).

As shown in Figure 43 - 3, the existing hydrologic reliability of the Panama Canal, based on the period of record of 52-years, is 99.6 percent, while the hydrologic reliability, with a demand ratio of 1.8, is 86.3 percent. This period of record includes the worst drought on record for the area, which occurred in 1998. The hydrologic reliability, with a demand ratio of 1.0, is 100 percent for operating Scenario 8, and the hydrologic reliability, with a demand ratio of 1.8, is 94.65 percent. Figure 43 - 3 displays the number of lockages associated with various levels of reliability.

Without additional water supplies, the hydrologic reliability of the canal system should decrease. With the construction of the proposed Lower Rio Trinidad Pumpback, and Upper Rio Indio Dams projects using Scenario 8 operation, the existing high hydrologic reliability can be continued as demand for water increases to 32.6 percent (12.62 lockages) above current demand levels.

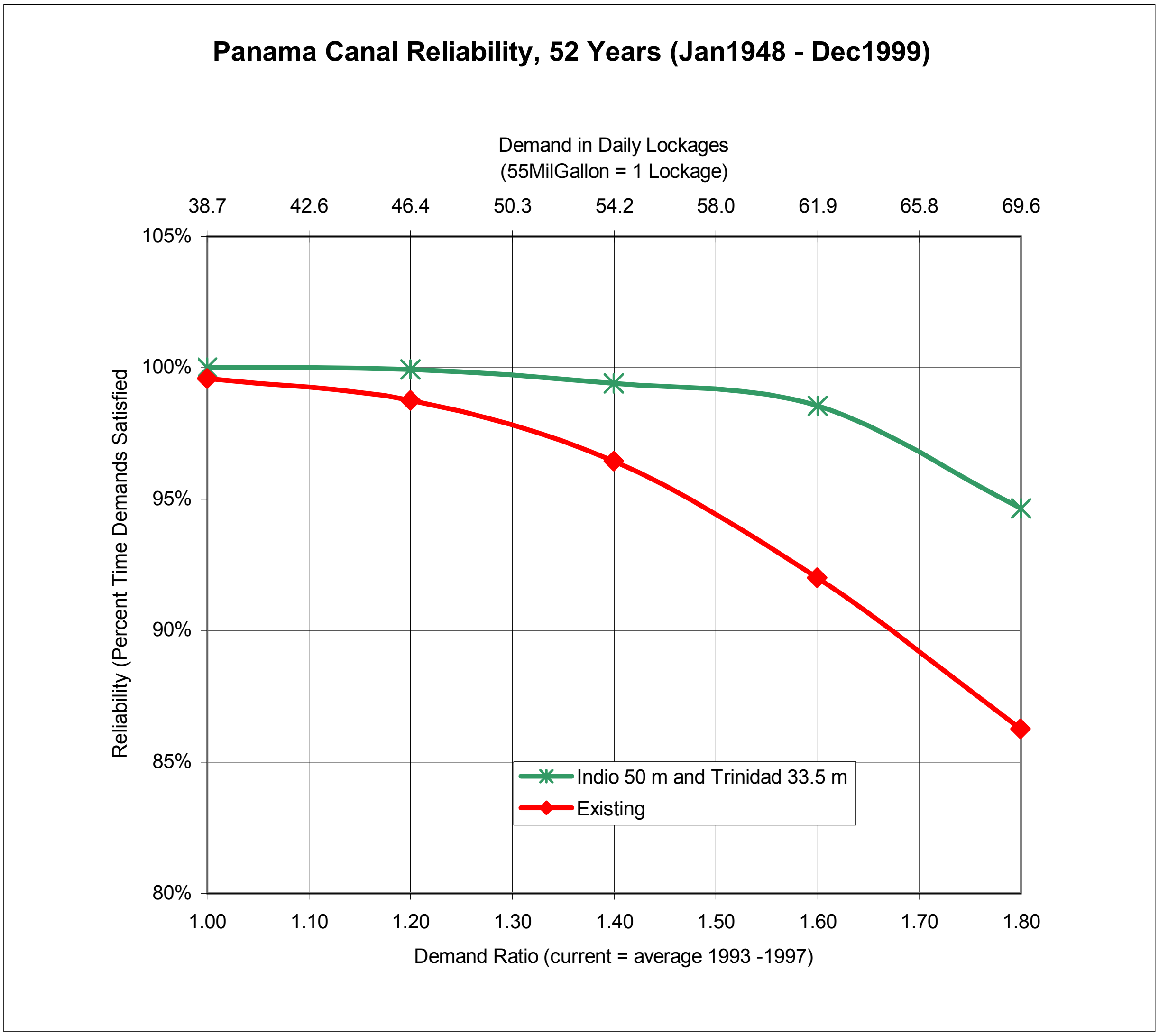


Figure 43 - 3 Panama Canal Hydrologic Reliability

Project Costs

GENERAL

The quantities estimated for the various items of work required for the construction of this project are derived from the layouts shown on Plates 36-2 through 36-8. The unit prices applied to these quantities are based on: historical information from previous estimates prepared for similar construction by the ACP; estimates for similar construction in the Mobile District; information gathered from Mobile District Construction Division personnel in Panama; and the book Feasibility Studies For Small Scale Hydropower Additions, A Guide Manual, written by The Hydrologic Engineering Center of the U.S. Army Corps of Engineers.

Engineering and design is estimated to be 12 percent while supervision and administration is estimated to be 6 percent of the construction cost items. An allowance of 2 percent of the construction cost items is allowed for field overhead (construction camp, contractor facilities, etc.). An allowance of 25 percent is included for contingencies.

FIRST COSTS

The total project first costs are estimated to be $1,237,942,000. Table 43 - 6 provides a summary of the first costs for the principal features. Separate documentation provided to the ACP includes a detailed cost estimate containing the sub-features of the work.

Table 43 - 6 Summary of First Costs

Item	Lower Rio Trinidad Costs ($)	Rio Indio Costs ($)
Lands and Relocations	2,000,000	4,750,000
Access Roads	9,574,000	7,810,000
Clearing and / or Grubbing	559,375	2,957,500
Cofferdam	850,000	4,850,665
Dam	643,786,212	15,226,374
Spillway	8,057,504	42,070,303
Intakes	N/A	7,701,295
Saddle Dikes	2,593,390	N/A
Pumping Station	22,999,637	N/A
Diversion Tunnel	N/A	4,714,622
Inter-basin Transfer Tunnels	N/A	27,806,250
Transfer Intake Rio Indio-Gatun	N/A	371,194
Hydropower Plants	N/A	7,926,380
Transmission Lines	2,090,000	6,600,000
Subtotal	692,510,118	132,784,583
E&D, S&A, Field Overhead	138,502,024	26,556,917
Contingencies	207,753,035	39,835,375
Total Project First Cost	1,038,765,177 Approximately 1,038,765,000	199,176,875 Approximately 199,177,000

OPERATION AND MAINTENANCE

Staff

A staff should operate and maintain the proposed Lower Rio Trinidad Dam project during the day and then run the facility remotely at night. The full-time staff should consist of 9 people, including a station manager, a multi-skilled supervisor, 2 leaders (Electronics/Instrumentation, Electrical/Mechanical), 4 craftsmen and a laborer. A part-time staff would be required for two to three months each year to perform general maintenance and overhaul of the project. The part-time staff may consist of three mechanics and three electricians. The annual staffing costs are estimated to be $350,000. The annual staffing costs for the proposed Upper Rio Indio project are estimated to be $500,000.

Ordinary Maintenance

Ordinary maintenance and care is required and include minor repair materials, lubricants and other supplies needed by project staff. The costs of ordinary maintenance are $18,000 per year for the access road and $100,000 per year for the main project facilities. Fuel consumption for the pumps is estimated at $648,000. This estimate considers the growth in demand for water over time and the variability in inflows to Gatun Lake, as well as the proposed Lower Rio Trinidad project. An estimated $288,000 would be needed for rock placement to account for settling of the project. The total ordinary maintenance is $1,054,000. The total ordinary maintenance costs for the proposed Upper Rio Indio project are estimated to be $320,000.

Major Replacements

The average service life of gates, electrical equipment, pumps, trash racks and other features is less than the total useful life of the proposed project (100 years). To estimate the major replacement costs necessary during the 50-year planning period, it is assumed that specific items should cost the same as at present. No allowance is made for salvageable fixed parts. Table 43-7 presents the service life, number of times each component should be replaced during the 50-year planning period, the future costs of each item, and the present worth of the replacement costs for the major components for the proposed Upper Rio Indio project. Based on these values, the present worth of the proposed replacements is $273,000 and the average annual replacement costs is $33,000. The average annual replacement cost for the proposed Lower Rio Trinidad project is estimated to be $272,000.

Table 43 - 7 Major Replacement Costs

Component	Service Life (years)	Number of Times Replaced During Planning Period	Future Costs ($)	Present Worth of Replacement Costs ($)
Roads	50	1	8,250,000	28,500
Bridges	50	1	3,375,000	11,700
Intakes				
Head Gates	50	1	801,900	2,800
Minimum Flow Gates	50	1	90,000	300
Stoplogs	50	1	378,300	1,300
Trash Racks	25	2	121,500	400
Access Stairs	50	1	66,750	200
Hydropower Plant				
Turbines & Generators	33	1	4,798,200	114,000
Station Elec. Equip.	33	1	1,713,600	40,700
Switchyard Equipment	33	1	1,193,400	28,400
Misc. Plant Equipment	33	1	440,640	10,500
Transmission Lines	50	1	9,900,000	34,300
Total			31,129,290	273,000
Average Annual Replacement Costs				33,000

Annual Costs

The project first costs for the proposed Lower Rio Trinidad project are estimated at $1,038,765,000. The total project first costs, including the $199,177,000 costs for the Upper Rio Indio project (see Volume One), are estimated at $1,237,942,000. These total project first costs are distributed across the development period using generalized curves for contractor earnings for large, heavy construction jobs. Interest on the proposed Upper Rio Indio project first costs is computed from mid-year throughout the 22-year development period. Interest during construction for the Lower Rio Trinidad project is computed from mid-year throughout its 13-year development. The interest during construction, at 12 percent, is $838,455,000 for Lower Rio Trinidad, and $1,001,634,000 for Rio Indio - for a total interest during construction of $1,840,089,000. These costs are added to the total project first costs - for total project investment costs of $3,078,031,000. A capital recovery factor for the 50-year planning period is applied to get the annual average investment costs of $370,646,000. Annual operation and maintenance costs are added. Major replacement costs are estimated and converted to an annual cost by discounting the future replacement costs of major components of the project back to completion of the project construction. Table 43-8 contains a summary of the $373,175,000 total annual costs.

Table 43 - 8 Summary of Annual Costs

Item	Costs ($)
Total Project First Costs - Lower Rio Trinidad	1,038,765,000
Total Project First Costs – Rio Indio	199,177,000
Interest During Construction – Lower Rio Trinidad	838,455,000
Interest During Construction – Rio Indio	1,001,634,000
Total Project Investment Costs	3,078,031,000
Annual Average Investment Costs	370,646,000
Operation and Maintenance Costs	
Staff Costs – Lower Rio Trinidad	350,000
Staff Costs – Rio Indio	500,000
Ordinary Maintenance Costs – Lower Rio Trinidad	1,054,000
Ordinary Maintenance Costs – Rio Indio	320,000
Major Replacement Costs – Lower Rio Trinidad	272,000
Major Replacement Costs – Rio Indio	33,000
Total Average Annual Costs	373,175,000

Annual Benefits

NAVIGATION

The procedures and assumptions used in estimating the benefits are described in Volume One. The following paragraphs present the results of the economic investigations for the proposed Lower Rio Trinidad and Upper Rio Indio projects. The 50-year period for the economic analysis of this proposal is 2024 to 2073.

The proposed Lower Rio Trinidad and Upper Rio Indio projects increase the reliability of providing water to accommodate the total daily number of lockages demanded. Table 43-9 provides the increase in the hydrologic reliability of providing the sum of the demands for both navigation and M&I water supply keyed to years. The hydrologic reliability percentages are obtained from the data used to develop Figure 43 - 3. The 99.6 percent level of reliability for this proposal is used to estimate the water supply benefits for navigation and the net change in reliability is used to estimate the reliability benefits for navigation and M&I water uses.

Table 43 - 9 Panama Canal Hydrologic Reliability
(Based on Period of Record from January 1948 to July 1998)

Current Demand Ratio	Year	Demand in Daily Average Number of Lockages (Navigation and M&I)	Hydrologic Reliability	
			Existing System (%)	With Lower Rio Trinidad & Rio Indio [1/] (%)
1	2000	38.68 [2/]	99.60	100.0
	2010	45.11	98.91	99.95
1.2		46.42	98.76	99.93
	2015	46.82	98.64	99.90
	2020	47.61	98.41	99.85
	2025	48.52	98.14	99.79
	2030	49.55	97.83	99.72
	2035	50.72	97.48	99.64
	2040	52.02	97.10	99.55
	2045	53.49	96.65	99.45
1.4		54.15	96.45	99.40
	2050	55.13	95.89	99.30
	2055	56.98	94.83	99.03
	2060	59.05	93.65	99.03
	2065	61.37	92.32	98.61
1.6		61.89	92.02	98.55
	2070	63.97	90.47	97.50
1.8		69.63	86.27	94.65

[1/] The lake behind the Lower Rio Trinidad Dam would fluctuate from the normal operating lake level at EL. 33.53 m MSL down to the minimum operating lake level at EL. 22.86 m MSL and the lake behind the Upper Rio Indio Dam would operate at EL. 50 m MSL.

[2/] 2000 Daily Demand is Average of 1993-1997.

With the proposed Lower Rio Trinidad and Upper Rio Indio projects, water supply shortages for navigation should continue. The demand for the M&I purposes should always be met first. As these demands grow, the amount of water available to meet the demands for navigation should decrease. Thus, the benefits for the additional water supply are estimated at the value for navigation. With the addition of the proposed Lower Rio Trinidad and Upper Rio Indio projects, these shortages would be less frequent. With a hydrologic reliability of 99.6 percent, the proposed project should increase the amount of water supplied by 12.62 equivalent lockages. The 99.6 percent hydrologic reliability should occur after the year 2037, with an equivalent daily average number of lockages of 51.30. Benefits for the additional water is attributable to navigation since the amount of M&I water demanded would be provided first. Therefore, all shortages are attributable to navigation. The benefits are estimated using the toll revenue per lockage and the increased daily average number of lockages. The average annual benefits for water supply are $223,530,000. Table 43-10 provides the estimate of daily shortages under the existing system, the remaining daily shortages with the proposed Lower Rio Trinidad and Upper Rio Indio projects in operation, the annual benefits for meeting shortages and the average annual benefits.

Table 43 - 10 Benefits for Additional Water Supply for Navigation

Year	Daily Shortages In Lockages Under Existing System	Remaining Daily Shortages	Annual Benefits For Navigation ($)
2023	9.51	0.00	196,137,742
2030	10.87	0.00	224,201,428
2040	13.34	0.72	260,286,862
2050	16.45	3.83	260,286,862
2060	20.36	7.74	260,286,862
2070	25.29	12.67	260,286,862
Average Annual Benefits			223,530,000
With the Lower Rio Trinidad project operating between 22.86 and 33.53 m and the Upper Rio Indio project operating at 50 m, the system should provide a total of 51.30 lockages at the 99.6 percent level of reliability or 12.62 more lockages than the existing system.			

With the proposed Lower Rio Trinidad and Upper Rio Indio projects, the reliability of the system to provide the water demanded by navigation and M&I water would be improved. Using the increase in hydrologic reliability, the forecast number of vessels converted to a daily average number of lockages, the toll revenue for each average lockage, and a project discount rate of 12 percent, the average annual benefits for navigation reliability attributable to the proposed Lower Rio Trinidad and Upper Rio Indio projects would be $16,822,000. Table 43-11 provides the forecast daily average number of lockages, the forecast value per daily lockage, the annual benefits for increased reliability, and the average annual benefits.

Table 43 - 11 Average Annual Reliability Benefits For Navigation

Year	Daily Average Number of Lockages	Value Per Lockage ($)	Annual Benefits For Navigation ($)
2023	40.0	2,260,000	13,017,000
2030	40.0	2,260,000	15,601,000
2040	40.0	2,260,000	20,292,000
2050	40.0	2,260,000	28,077,000
2060	40.0	2,260,000	37,425,000
2070	40.0	2,260,000	57,988,000
Average Annual Benefits			16,822,000

M&I WATER SUPPLY

The future demand for water supply for M&I purposes is based upon the growth in population. The ACP provided a forecast for the area surrounding the Panama Canal. The current usage is estimated at 4.0 equivalent lockages per day; an equivalent lockage is 55 million gallons of water. One equivalent lockage is added to the forecast to account for the burgeoning tourist industry, beginning in the year 2010. The increased reliability of the system to provide water supply for navigation similarly provides the same increase in reliability to provide water for M&I

purposes. Using the increased hydrologic reliability of the system with the addition of the proposed Lower Rio Trinidad and Upper Rio Indio projects, the current costs to the ACP to process finished water ($0.69 per 1,000 gallons), the number of daily lockages demanded, and a project discount rate of 12 percent, the average annual benefits for M&I reliability are $3,061,000. Table 43-12 displays the population forecast, the resulting number of equivalent lockages per day, and the benefits for M&I water supply.

Table 43 - 12 Average Annual Reliability Benefits For M&I Water Supply

Year	Population	Equivalent Lockages per Day	Annual M&I Water Supply Benefits ($)
2023	2,294,000	8.15	1,791,000
2030	2,688,000	9.55	2,506,000
2040	3,384,000	12.02	4,094,000
2050	4,259,000	15.13	7,131,000
2060	5,360,000	19.05	11,973,000
2070	6,746,000	23.97	23,349,000
Average Annual Benefits			3,061,000

HYDROPOWER

The amount of hydropower energy that can be produced by the system of Gatun Lake and Madden Lake should decline over time as the demands for navigation and M&I water supply increase. With the inclusion of the Lower Rio Trinidad project, the system will loose hydropower generation at Gatun Lake and Madden Lake due to the change in the operation of the system. The inclusion of the Upper Rio Indio Dam project, however, will not produce enough additional megawatt hours of hydropower to offset those losses in hydropower generation. Thus, the system will have a net decrease in hydropower production. The value for hydropower energy used in this analysis is $0.070 / kWh. On an average annual basis, the proposed project should have loses of ($1,206,000). Table 43-13 provides the net additional megawatt hours of hydropower generation and the resulting benefits.

Table 43 - 13 Average Annual Benefits For Hydropower Generation

Year	Net Generation [1] (MWh)	Annual Benefits For Hydropower ($)
2023	(16,980)	(1,189,000)
2030	(17,097)	(1,197,000)
2040	(17,302)	(1,211,000)
2050	(18,098)	(1,267,000)
2060	(20,572)	(1,440,000)
2070	(22,747)	(1,592,000)
Average Annual Benefits		(1,206,000)

[1/] Net generation of Gatun, Madden and Rio Indio above generation of Gatun and Madden hydropower plants.

SUMMARY OF ANNUAL BENEFITS

As shown in Table 43-14, total average annual benefits for the proposed Lower Rio Trinidad and Upper Rio Indio projects is $242,207,000.

Table 43 - 14 Summary of Annual Benefits

Benefit Category	Average Annual Benefits ($)
Navigation – Water Supply	223,530,000
Navigation – Reliability	16,822,000
M&I - Reliability	3,061,000
Hydropower	(1,206,000)
Total	242,207,000

To perform an analysis of benefits versus costs, a common point in time is selected. This common point is at the completion of filling of the project, the end of the year 2022. In these analyses, it is important to note that the average annual benefits or average annual costs are the amortized value of the sum of the present worth of either the benefits or costs at the point of comparison. The development sequence for the proposed Lower Rio Trinidad and Upper Rio Indio Dam projects would be to develop the Rio Indio Dam project first (2001 – 2010) and then the Lower Rio Trinidad Dam project (2009 – 2022).

The benefits attributable to the proposed Lower Rio Trinidad project begin to accrue in 2014 when the reservoir is filled. Thus, the Lower Rio Trinidad project benefits for the period 2014 to 2022 are escalated by the project discount rate, 12 percent, in order to estimate the total present worth of $1,270,111,000, in the year 2022. The average annual benefits for the proposed Lower Rio Trinidad project accrued during the construction of the proposed Rio Indio project are estimated at $152,943,000.

To estimate the interest during construction, similar calculations are made for the costs of each proposed project. For the proposed Lower Rio Trinidad project, interest during construction is taken from year 2001 to year 2022 and the interest during construction for the proposed Rio Indio project is taken from the year 2013 to the year 2022.

Total average annual benefits and average annual costs are estimated, and the ratio of benefits to costs and the net benefits (net of costs) computed. In the first instance, the analysis determines the feasibility of the proposal. The net benefits determine which proposal provides the greatest value for the investment dollars. Table 43-15 provides the benefit to cost ratio and the net benefits.

Table 43 - 15 Economic Evaluation

Item	Value ($)
Average Annual Benefits	
Lower Rio Trinidad	242,207,000
Rio Indio	152,943,000
Total Average Annual Benefits	395,150,000
Average Annual Costs	
Lower Rio Trinidad	227,725,000
Rio Indio	145,451,000
Total Average Annual Costs	373,175,000
Benefit to Cost Ratio	1.06
Net Benefits	21,975,000

Internal Rate of Return

An internal rate of return analysis for this proposed project was performed. To accomplish this analysis, the annual construction costs are used as the investment, and the undiscounted benefits are used as return cash flows. The internal rate of return is 12.2 percent.

Socio-Economic Impacts

The description of the environmental setting is based on field observations made while conducting field reconnaissance throughout Gatun Lake, specifically the Lower Rio Trinidad and Rio Indio areas with ACP personnel. Autoridad Nacional del Ambiente (ANAM), ACP, Asociacion Nacional para la Conservacion de la Naturaleza (ANCON), Electrical Transmission Agency, Smithsonian Tropical Research Institute (STRI), and Directorate of Mineral Resources personnel were interviewed to gain information on site characteristics and potential activities that could affect the project. In addition, extrapolations of the 2000 census data were used, and a review of the Informe de Cobertura Boscosa 1992 were used to determine the extent of forest cover.

Environmental Setting

This alternative combines three projects, the Lower Rio Trinidad (lake level 22.9 - 33.5 m) and Rio Indio (lake level 50 m). This project will provide additional storage of water for to Gatun Lake and 12.62 additional lockages per day on a continual basis.. The project area encompasses the additional area to be flooded and surrounding areas and consists of 23,630 ha within Gatun Lake. The area near Gatun Lake is sparsely populated and has a topography of rolling hills, and low regions near Gatun Lake. The Upper Rio Indio portion of the project would consist of a rock fill dam, outlet works, unregulated spillway, an interbasin transfer tunnel, two hydropower facilities, and required access and maintenance roads and power transmission lines. The project area would require approximately 1,898 ha along the eastern leg of the Upper Rio Indio. Near Rio Indio, the area is sparsely populated with a topography of steep hills, as well as coastal regions. The Lower Rio Trinidad and Rio Indio are west of the Panama Canal and flow northward from the Continental Divide into Gatun Lake. The watershed above the Lower Rio Trinidad and the Upper Rio Indio dam project covers approximately 1,052 km^2 and 256 km^2 respectively. The incremental impoundment area, which covers approximately 7,712 ha, consists of approximately 60-50 percent of forested land, 20-30 percent of pasture land (used by ranchers), 10 percent cropland, and 10 percent newly slashed and burned land. Gatun Lake’s normal pool level is 26.7 m. The lake level during field observations (August 2001) was approximately 25.4 m.

LAND USE

The Lower Rio Trinidad project area encompasses the southwestern portion of Gatun Lake and areas along its shores. The areas to be flooded or partially flooded include the town of Escobal (population – 1,653), Nuevo Provenir (population – 121), Cuipo (population – 249), Ciricito (population – 72), La Arenosa (population – 242), La Garterita (population – 138), La Gartera (population – 348), and a few small isolated establishments. communities

Some areas along the shores of the Lower Rio Trinidad of Gatun Lake have been deforested. Approximately 65 percent of the lakeshore areas are forested, mostly with secondary growth. Farms and ranches of various sizes, as well as teak plantations and African mahogany plantations, occupy the remaining land. Farm crops include maize, rice, beans, sugar, coffee, mangos, pineapples, and tobacco. Ranchers raise cows, horses, chickens, and hogs, and tilapia. Some of the farmers and ranchers operate commercial enterprises, while others rely on cash crops and subsistence farming. No significant ore deposits or mineral resources are located in the project area.

The Upper Rio Indio project area is inhabited by about 2,300 people, residing in the towns of Tres Hermanas (population – 200), Los Cedros (population – 80), El Coquillo (popoulation – 150), El Limon (population – 140), Los Uveros (population – 140), and La Boca de Uracillo (population – 110), and in approximately 30 smaller settlements. Downstream from the dam site, at El Limon, are 14 communities with a combined population of approximately 600. The largest of these is La Boca del Rio Indio with a population of more than 150.

Farms and ranches of various sizes, as well as some teak plantations, occupy approximately 60 percent of the land in the project area. Farm crops include maize, rice, beans, sugar, coffee, and tobacco. Ranches raise horses, cows, chickens, and hogs. Some of the farmers and ranchers run small commercial enterprises, or rely on cash crop and subsistence farming.

INFRASTRUCTURE

During site investigations in the Lower Rio Trinidad area, the town of Escobal was the largest settlement visited. Escobal has businesses, schools, churches, cemeteries, medical centers, residences, and paved roadways of good condition. A new and improved roadway (Highway 35) is adjacent to the project area near Escobal. Other establishments in the project area are: Nuevo Provenir; Cuipo; Ciricito; La Arenosa; La Garterita; La Gartera; and a few small isolated establishments. Most of the communities have elementary schools, small cemeteries, churches and meeting centers, medical clinics, and a few small businesses (i.e. general stores). The towns and villages depend on Gatun Lake or groundwater wells for their potable water supply. Each community also had docks, small ports, and other boat access facilities. Goods are transported from one town to another by boat. The town depends on Gatun Lake or groundwater wells for their potable water supply. No treatment of community waste is provided. Wastewater from showers and washing is discharged into the environment; some of it may eventually reach the Lower Rio Trinidad portion of Gatun Lake. Disposal of domestic waste is the responsibility of individual homeowners; some homes have septic tanks, while others have an outdoor latrine (a hole in the ground). There are some health problems, such as hepatitis, dysentery, dermatitis, intestinal parasites, and respiratory illnesses, which are attributable to the present waste disposal methods. No major industries or meat processing plants are located in the project area. The project area is transversed traversed by unpaved horseback riding trails that link the various communities and by unpaved roads used by the ACP for maintenance. These roads are extremely important to the residents for transportation, community cohesion, commerce, and communication with neighboring communities because of the relatively isolated location of the project area.

In the Upper Rio Indio project area, towns of El Limon, El Silencio, San Cristobal, and Piedra Amarilla have elementary schools. Several towns have cemeteries, churches, and medical centers. All these towns obtain water from rivers or groundwater wells. Some have electricity (from small generators) and limited telephone service. No treatment of community waste is provided. Wastewater from showers and washing is discharged into the environment; some of it might eventually reach Rio Indio and its tributaries. Disposal of domestic waste is the responsibility of individual homeowners; each home has an outdoor latrine. There are some known health problems, such as hepatitis, diarrhea, dermatitis, intestinal parasites, and respiratory illnesses that are attributed to the present waste disposal methods. No known major industries or poultry or beef processing plants are located in the project area. The only roads in the project area are unpaved and poorly maintained, and are usable only in the dry season (mid-December through March). The roads are rarely graded and receive little attention from either the Ministry of Public Works or the local government. Due to the relatively isolated location of the project area, these roads are extremely important to the residents for transportation, community cohesion, commerce, and communication with neighboring communities.

TERRESTRIAL HABITAT

The terrestrial habitat in the Lower Rio Trinidad project area portion of Gatun Lake consistss of tropical forest ecosystems, mostly secondary growth forests with large secondary growth and patches of primary forest. About 60-65 percent of the land along the Lower Rio Trinidad of Gatun Lake is forested and probably supportscovered with forests that could support diverse wildlife populations. The Lower Rio Trinidad areas portion of Gatun Lake also contains islands inhabited by wildlife. Some of the wildlife species do not interact with species on the mainland; others migrate between the island and the mainland. The species interrelationships are of great interest to scientists studying tropical ecosystems. Slash and burn activities have opened tracts of land for farming and cattle grazing; however, the majority of the lakeshore is forested to the edge of the water. Terrestrial areas are used by migratory species as wintering, breeding, and feeding grounds. The complex and diverse tropical ecosystems offers habitats to connect a variety of wildlife communities and may provide critical habitats to many native species.

In the Upper Rio Indio project area, forests along the river, which supports diverse wildlife populations, covers about 90 percent of the lands along the river and its tributaries. The forests also extend to the mountainous areas above the Upper Rio Indio impoundment. As a result of slash and burn activities, there are no large contiguous tracts of forests at lower elevations in the impoundment.

ANIMALS ON ENDANGERED LIST

ANAM, Resolution 002-80 enacted on June 7, 1995 declared 33 mammals, 39 birds, and 11 reptiles and amphibians are in danger of becoming extinct in Panama. Although their presence has not been confirmed to date, some of the listed species of interest on the threatened list might be found in the project area. The manatee is an aquatic mammal known to inhabit Gatun Lake around the Barro Colorado Island; however, it has not been sighted in the project area.

AQUATIC HABITAT

Gatun Lake, one of the world's largest manmade lakes, was created during the construction of the Panama Canal. The lake's water depth and quality vary widely. Aquatic habitat ranges from inundated forests to clear waterthe water is clear in areas distant from the shipping lanes. The Lower Rio Trinidad areas portion of Gatun Lake provides habitat for a variety of wildlife species, both resident and migratory, for native or introduced fish, and other aquatic species.

Upper Rio Indio in the project area has characteristics typical of streams in mountainous regions. Its water is clean and cool, and its bottom ranges from sand to boulders, with numerous riffles, runs, and pools. Tributaries to Rio Indio include four major streams: Rio El Torno, Rio Uracillo, Rio Teria, and Rio Riacito, and 20 smaller streams. The river is approximately 16 km long, its width ranges from 3 m (in the dry season) to 10 m. The tributaries appear to support some fish communities; however, information about these communities is limited.

WETLANDS

Areas that contain hydric soils and hydrophytic plant communities, and that are subject to hydric conditions are termed wetlands. Wetlands occur in topographic areas where water remains pooled long enough to produce hydric soil conditions and wetland plant communities. Wetlands in the Lower Rio Trinidad project area consist ofare shallow water habitats and are lands subject to frequent flooding. Shallow water areas along the banks of the Lower Rio Trinidad area portion of Gatun Lake receive sunlight to a depth of approximately 1 m. Sunlight stimulates growth of submergent, emergent, or floating mats of aquatic vegetation. Wetlands in the project area are currently stressed due to excessive sediments, municipal waste, agricultural runoff, and other debris carried in the runoff.

Wetlands in the Rio Indio project area consist of forested riparian habitat and are limited by their relatively steep topography. The width of the riparian habitat within the impoundment area varies from approximately 5-50 meters. Approximately 90 percent of the streams both above and below the dam site along the Rio Indio and its tributaries are bordered by forested riparian habitat.

AIR QUALITY

Air quality in the project area is generally good, except during the slash and burn activities. At the end of the dry season in March or early April, areas of forest and secondary growth are burned and cleared for agricultural use. During this period, the air is filled with smoke and ash, which may be transported by winds to the Lower Rio Trinidad area of and Gatun Lake. Based on observations in the Rio Indio project area, approximately 10 percent (or 400 ha) of forested land is burned annually. Air quality monitoring has not been implemented within the project area.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

Barro Colorado Island is an international center for tropical research and one of the first biological reserves established in the Neotropics. From 1923 through 1940, a scientific committee of the U.S. National Academy of Sciences administered the biological reserve/laboratory. In 1940, by an Act of the United States Congress, the facility was renamed the Panama Canal Zone Biological Area, and in 1946, the responsibility for its maintenance was assigned to the Smithsonian Institution. With the Panama Canal Treaty Implementation in 1977, the island was granted the category of National Monument and to date it continues to be managed by the Smithsonian Institute. It should also be noted that most of the Atlantic region of Panama is within the interest and objectives of the Mesoamerican Biological Corridor, an international project to conserve biodiversity.

In the pre-Columbian period, Rio Indio was a language frontier; the inhabitants on each side of the river spoke a different native language. During the Spanish colonial period, the river served as a political boundary. The project area has a high potential to be rich in archaeological and historical remains.

Environmental Impacts

TERRESTRIAL HABITAT

The impacts of the project on the terrestrial habitat in the Lower Rio Trinidad area portion of Gatun Lake could be substantial. The boundary between two types of habitats, in this case between a forest and a lake, is called an ecotone. Ecotones are inhabited by a mixture variety of species from the neighboring habitats, but and are unique, with high species diversity. Considering the proposed operating levels for both impoundments, between 22.9 - 33.5 m, as the normal zone of operation, there may be substantial erosion of the shoreline as pool levels rise and fall. Terrestrial habitats that would be inundated above the 26.7 m (existing level) to the 33.5 m proposed normal pool level consists of 21,912 ha for the Lower Rio Trinidad project. The placement of a dam structure, access roads and pump stations would permanently impact terrestrial habitat. Wildlife species that are able to relocate to suitable areas will compete with similar species for resources; species that are not able to relocate will not survive. As a result, competition for natural resources in surrounding habitat areas will increase. This is considered a secondary impact to terrestrial habitat outside the proposed zone of inundation and construction. Permanently raising of the Lower Rio Trinidad could impact the wildlife habitat of the project area.

The terrestrial impacts of the Rio Indio project, which is located in area of relatively high quality forest habitat, would be substantial. With the creation of the lake, the migratory routes of some species could be adversely affected. Forested areas along lower elevations would be lost as a result of the impoundment. The only forests that would remain near the Upper Rio Indio reservoir and its drainage basin would be found in higher elevations, where the vegetation and species may be completely different from those found on lower elevations. Natural communities are linked together by complex interactions and relationships among various species, therefore impacts to upper forested areas may occur due to the inundation of the lower forests.

ANIMALS ON ENDANGERED LIST

The severity of impacts on endangered species cannot be determined at this time, because although it is expected that some of the listed species may be found in the region, it is not known which of the listed species inhabit the proposed project area. Some endangered and/or threatened species may use the Lower Rio Trinidad area portion of Gatun Lake during some or all parts of their life cycle.

WATER QUANTITY

The impacts of the Lower Rio Trinidad project on water quantity would be substantial. The increase in the volume of water could have negative impacts to lakeshore communities as well as on existing ecosystems. The same is true if the lake level is lowered and maintained at 22.9 m.

The impacts of the Upper Rio Indio project area on water quality would also be substantial. The volume of water will increase, making fresh water available in the surrounding areas during the dry season. The impacts downstream from the dam would be significant. Sediment loads would be deposited upstream from the dam as water velocity slows. Water from the dam would be released at an increased velocity, which could cause erosion of banks and river bottoms. Seasonal flooding could be significantly reduced. Also, periodically releasing water, in appropriate amounts, would avoid problems with water quality and temperature downstream. The cumulative impact downstream from the dam site depends on the amount of water being released.

WATER QUALITY

Project impacts on water quality are not known. Damming the Lower Rio Trinidad could increase the amounts of nutrients and debris in this portion of Gatun Lake. A pilot plant tilapia farm is in the project area and may affect water quality. The rate nutrients and debris enter the lake will determine the severity of the impact on water quality. Project implementation could cause an increase in turbidity, which would interfere with photosynthesis and deprive plants and other aquatic species from sunlight. Aquatic plants and organisms serve to maintain water quality. The dam would interfere with the circulation of freshwater throughout the Gatun Lake environment. Species inhabiting specific depths could be impacted when lake depth increases to 33.5 m and/or decreases to 22.9 m.

The impacts of the Rio Indio project on water quality could be positive. The people living downstream from the dam and around the impoundment would have access to a water supply of higher quality. Water quality in the impoundment area would differ from water released downstream from the dam. If the water in the impoundment area does not circulate or turn over periodically, it could become anoxic. A change in temperature, dissolved oxygen, turbidity, or pH could change water quality.

DOWNSTREAM AQUATIC FAUNAL HABITAT

The impacts of the project on aquatic faunal habitat could be substantial. The project may affect the breeding and the nursery habitat of many aquatic species. Impacts to fish spawning areas may be detrimental when turbidity, nutrient content, and depth of the water suddenly increase or decrease, by altering the conditions needed for a successful hatching of the fishfish hatch. Plant populations may decrease as a result of fluctuating water depths, clarity, and quality. the increase in water depth and decrease in sunlight; therefore, iInvertebrate populations may decline, which could reduce the food supply for fish and other aquatic species.

Impacts to downstream aquatic faunal communities in the Upper Rio Indio project area could be substantial, because the dam structure will prevent their migration throughout the riverine habitat. The dam structure would be designed for multi-level releases to maintain a water level downstream from the dam site. The dam would act as a large sediment trap; the released water would have low turbidity, which could result in better visibility and increased predation on the fish species. Aquatic faunal habitats downstream would be deprived of the beneficial nutrients and silts that were transported in the sediment. Native riverine fish species may be negatively impacted as a result of the project. The extent of the impact is not known.

FUTURE LAKE AQUATIC PLANT COMMUNITY

The impacts of the project on future aquatic plant communities depend on water quality and stability of water levels. Plant species in the Lower Rio Trinidad portion of Gatun Lake could be impacted by fluctuating water levels. the increase in water depth. Aquatic plant communities could be impacted during project implementation; however, they could re-establish after conditions stabilize.

The severity of impacts from the Upper Rio Indio project will depend on water level fluctuations. Since water levels are anticipated to fluctuate widely, large portions of the shores would be covered with mud, allowing neither aquatic nor terrestrial plants could thrive.

AQUATIC FAUNA INHABITING AFFECTED AREAS

The proposed project impacts could have some unavoidable, adverse environmental impacts on aquatic fauna in the Lower Rio Trinidad and associated rivers and tributaries. These impacts should be identified and minimized with appropriate mitigation measures (to be discussed in a feasibility level study). The impacts of the project on aquatic fauna inhabiting the Lower Rio Trinidad and the affected areas could be important. If aquatic faunas were able to thrive in the newly created reservoir, they would be beneficially affected by having their habitat enlarged. Some unavoidable, adverse environmental impacts could occur, these impacts should be identified, and appropriate mitigation measures addressed in feasibility level studies, should the alternative be recommended for further consideration. Gatun Lake has populations of peacock bass and tilapia, both introduced species that have adapted well. However, several native riverine species, which formerly occupied the impoundment, have disappeared.
The Lower Rio Trinidad project would also take part of Gatun Lake; therefore, the peacock bass and tilapia would already be present.

The impacts of the Upper Rio Indio project on aquatic fauna in the Rio Indio and its upstream tributaries could be substantial, since the habitat area would change from riverine to lacustrine. Some aquatic species would continue to inhabit the area; non-native fish species could become dominant in the impoundment area and native riverine species could be pushed upstream or extirpated. Other manmade lakes in the Republic of Panama have been stocked with peacock bass and tilapia. The impoundment area would probably be stocked with these species to promote sport fishing and to provide the local communities with fish for food.

WETLANDS

The impacts to wetlands could be significant. Inundation of wetlands could cause them to become aquatic habitat. The changes in water depth caused by the project may lead to increased or decreased sedimentation and turbidity, which could hamper the biological processes in the wetlands and decrease their productivity. Such impacts could be detrimental to the health and sustainability of the Lower Rio Trinidad area portion of Gatun Lake. Fish and other aquatic species use shallow water areas as spawning grounds, as well as habitat for juvenile aquatic species who survive in the shallow waters until large enough to venture into deeper water. These wetlands are vital to the sustainability of this portion of Gatun Lake, including the Lower Rio Trinidad area..

The impacts to wetlands both upstream and downstream from the Upper Rio Indio project area could be significant. Owing to the topography of the project area, a number of wetlands could be impacted. It is possible that although the reservoir level will fluctuate, new wetlands could develop in the littoral zones. Downstream from the dam site, wetlands along the minimal flow zone would survive; wetlands that depend on seasonal flooding for survival may be adversely affected.

AIR QUALITY

During project implementation, emissions from construction equipment, as well as from slash and burn activities, could cause deterioration of air quality. After project implementation, the air quality may be impacted by the operation of the power generation facility and the pumping stations.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

The potential impacts on cultural resources and historic properties from the Upper Rio Indio project can be defined and mitigated. In the La Boca de Uracillo area in particular, there are previously identified archaeological sites. The project area is relatively large and is known to contain pre-Columbian sites; therefore, the presence of cultural resources and historic properties is highly probable. Prior to construction, surveys to locate cultural resources and historic artifacts would be conducted, and the important sites would be preserved or salvaged as appropriate.

SOCIO-ECONOMIC IMPACTS

The socio-economic impacts of the project could be substantial. The relocation of the towns and other small communities along the lakeshore would be an important issue. The average monthly income of families in the project area ranges from less than $100 to $200 per month. No indigenous groups are known to reside in the impact area. Land use would be greatly impacted by the inundation of pastures and agricultural lands to expand the impoundment. The relocation of agricultural and ranching activities would be critical, because approximately 10 percent of the land in the impoundment area is used for farming and ranching. After the water level is raised, additional agricultural land could be lost as islands are created from isthmuses. The incremental surface area of the proposed lake is 7,712 ha; another 1,318 ha from the Lower Trinidad project and 634 ha from the Upper Rio Indio project will be occupied by the dam and construction areas including permanent disposal areas.

During construction, the influx of workers could create a temporary demand for additional housing, resulting in an increase in housing values near the dam site. However, after completion of the project, the workers could leave, the housing demands could drop, and the housing values could return to pre-construction levels. Currently, all residents have access to public schools and health centers. During construction, these services should continue to be available, and additional public and community services may be offered. After construction, these services would return to the normal level.

To construct the dam, some existing roads must be improved and some new roads must be built. However, some paved and unpaved roads within the impoundment area would be eliminated, which could change traffic patterns and could cause some communities to lose overland transportation, communication, cohesion, and commerce with other communities. During construction, the traffic volumes over both new and existing roads systems would increase; however, following completion of construction, the traffic volumes could decline. Noise levels would temporarily increase during construction and could negatively impact noise-sensitive receptors; after construction noise levels may remain elevated as a result of the power generation facility and pump stations.

Communities receiving people displaced by the project could be negatively impacted by overcrowding and by competition for jobs, land, and working areas. Construction of the dams would permanently displace some people and disrupt lives through the division of communities, separation of families, and loss of livelihood. Following completion of the impoundment, the tourism trade in the affected region, including sport fishing and ecotourism, could increase.

Additional Environmental Information Required

This section identifies the subject areas for which additional data are required to evaluate in further detail, the scope and magnitude of the potential effects of the Lower Rio Trinidad and Upper Rio Indio alternative. The subject areas are discussed by impact category.

SOCIO-ECONOMIC IMPACTS

Conduct a SIA. The SIA would consist of three tasks: scoping, assessment, and mitigation and monitoring. The following information should be developed:

- Business, Industrial, and Agricultural Activities;
- Employment;
- Land Use;
- Property Values;
- Public and Community Facilities and Services (including utilities and schools);
- Transportation;
- Housing;
- Health (vector routes);
- Population;
- Community Cohesion; and,
- Recreational Resources.

TERRESTRIAL AND AQUATIC HABITAT

- Prepare site-specific habitat maps to ensure that the major types of aquatic habitat are identified and quantified.
- Conduct field studies to locate rare and unique habitats, such as wetlands, primary forests, roosting sites, foraging areas, old growth, and migration flyways.
- Determine the present quality and ecosystem value of existing habitats within the Gatun Lake project area.
- Coordinate with local experts to identify and evaluate aquatic and terrestrial habitat areas.
- Prepare species inventory lists for each site area, identifying their status as native or exotic and whether they are threatened and or endangered species.
- Conduct additional research into water currents and estimated turbidity levels to evaluate impacts to the shallow areas along Barro Colorado Island.
- Address cumulative effects caused by natural flow diversions.

ANIMALS ON THE ENDANGERED LIST

- Compile habitat maps to assess the availability and quality of suitable habitats for the animals on the endangered and/or threatened species list.
- Establish field methodology to assess wildlife habitat values.
- Conduct site surveys to determine the presence of selected species or their habitats.
- Develop candidate mitigation measures for the appropriate project alternatives to be considered in the Conceptual Phase.

- Coordinate with local experts on the presence of endangered species.

WATER QUALITY

- Since limited water quality data are available for the Gatun Lake area, compile information on TSS, conductivity, TDS, dissolved oxygen, nutrients, pH, and coliform bacteria.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

- Information regarding cultural resources and historic properties in the project area is incomplete. Additional evaluation studies should be completed to identify any such resources and/or properties.

Evaluation Matrices

In accordance with evaluation procedures described in Section 4, the following tables reflect the conclusions derived for this alternative. A summary table with ranking is provided in Volume One. Tables 43 - 16 through 43 - 18 present the evaluation of the proposed Lower Rio Trinidad project as related to developmental effects, environmental effects, and socio-economic effects.

Table 43 - 16 Developmental Effects

Evaluation Criteria	Function	Measure [1/]	Importance [2/]	Composite [3/]
Water Contribution (Water Yield)	Meets M&I Demands	10	10	100
	Supplements Existing System	4	10	40
	Satisfies Future Canal Needs/Expansion	0	10	0
	Additional Hydropower Potential	0	5	0
Technical Viability	Design Constraints	2	6	12
	Feasibility of Concept	2	6	12
Operational Issues	Compatibility	8	6	48
	Maintenance Requirements	4	2	8
	Operational Resources Required	4	2	8
Economic Feasibility	Net Benefits	1	9	9
	Total			237

[1/] Measure - A numerical from 0 to 10 value representing the degree or level the alternative satisfies the criteria. Value of 10 indicates the most significant beneficial impact and 0 the most significant adverse impact.
[2/] Importance - A weighting factor from 0 to 10 to balance the significance of a criteria to the others.
[3/] Composite - the product of the measure and importance.

Table 43 - 17 Environmental Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Terrestrial Habitat	3	8	24
Animals on Extinction List	2	10	20
Water Quantity Impacts – Lake	8	10	80
Water Quantity Impacts -- Downstream	4	7	28
Water Quality	5	10	50
Downstream Aquatic Fauna Habitat	3	8	24
Future Lake Aquatic Plant Community	6	8	48
Aquatic Faunal Inhabiting Affected Area and Upstream Tributaries	4	5	20
Potential for Fishing on Lake	6	6	36
Wetlands	4	4	16
Air Quality	5	3	15
Cultural Resources and Historic Properties	3	10	30
Total			391

[1/] Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
[2/] Importance - 1 to 10 increasing in importance.
[3/] Composite - the product of the measure and importance.

Table 43 - 18 Socio-Economic Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Land Use	1	7	7
Relocation of People	2	10	20
Relocation of Agricultural/Ranching Activities	2	6	12
Post-Construction Business	6	5	30
Post-Construction on Existing Employment	6	5	30
Property Values During Construction	7	4	28
Property Values Post-Construction	5	5	25
Public/Community Services During Construction	6	4	24
Public/Community Services Post-Construction	5	8	40
Traffic Volumes over Existing Roadway System During Construction	3	5	15
Traffic Volumes over New Roadway System Post-Construction	5	5	25
Noise-Sensitive Resources or Activities	4	4	16
Communities Receiving Displaced People	1	8	8
Community Cohesion	1	8	8
Tourism	6	5	30
Total			318

[1/] Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
[2/] Importance - 1 to 10 increasing in importance.
[3/] Composite - the product of the measure and importance.

Pertinent Data

Table 43 - 19 presents pertinent data for the proposed Lower Rio Trinidad project.

Table 43 - 19 Pertinent Data for Operating Scenario 8

GENERAL	**Gatun**	**Rio Trinidad**	**Rio Indio**
Drainage Area above Dam Site	1,261.5 km^2	1,051.5 km^2	256 km^2
Average Annual Flow at Dam Site	50.4 CMS	39.6 CMS	16.8 CMS
LAKE			
Elevation of Maximum Operating Lake Level	26.67 m MSL	33.53 m MSL	50.0 m MSL
Elevation of Maximum Flood Storage Lake Level	26.74 m MSL	34.14 m MSL	53.0 m MSL
Elevation of Minimum Operating Lake Level	25.91 m MSL	22.86 m MSL	45.5 m MSL
Useable Storage between Max. and Min. levels	214 MCM	1809.2 MCM	35.6 MCM
Area at Maximum Operating Lake Level	29,410 ha	21,912 ha	2,134 ha
Area at Maximum Flood Storage Lake Level	29,451 ha	22,830 ha	2,218 ha
Area at Minimum Operating Lake Level	28,987 ha	9,019 ha	732 ha
Top Clearing Elevation	33.5 m MSL	33.53 m MSL	50 m MSL
Lower Clearing Elevation	25 m MSL	22.9 m MSL	45 m MSL
EMBANKMENTS			
Dam – Rock Fill Embankment			
Top Elevation of Dam	34.5 m MSL	34.5 m MSL	53 m MSL
Fixed Crest Width	13 m	13 m	13 m
Height above Lowest Foundation	18 m	28 m	38.5 m
Overall Length of Dam	varies m	4480 m	632 m
SPILLWAY			
Type of Spillway	Gated Ogee	Gated Ogee	Uncontrolled Ogee
Number of Gates	14	8	-
Width of Gates	13.72 m	18.33 m	-
Net Length	192.02 m	149.35 m	-
Total Length	246.27 m	238m	113 m
Elevation of Crest	21.03 m MSL	25.91 m MSL	50.0 m MSL
Maximum Discharge	5150 CMS	6038 CMS	618 CMS

UPPER RIO INDIO ONLY	
INTER-BASIN TRANSFER TUNNEL	
Tunnel diameter	4.5 m
Tunnel length	7651 m
Inlet invert	45.5 m MSL
Outlet invert	40 m MSL
Tunnel capacity	37.9 CMS
HYDROPOWER PLANTS	
Dam	
Type of hydropower plant construction	Reinforced concrete
Number of units	1
Capacity of each unit	5 MW
Inter-basin Transfer Tunnel	
Type of hydropower plant construction	Reinforced concrete
Number of units	1
Capacity of unit	2 MW
CONSTRUCTION / POWERHOUSE DIVERSION	
Diversion length	800 m
Horseshoe tunnel dimensions	7 m
Inlet invert	12 m
Outlet invert	10 m
MINIMUM FLOW CONDUIT	
Conduit diameter	600 mm
Conduit length	800 m
Inlet invert	12 m
Outlet invert	10 m
Conduit capacity	1.7 CMS
EMBANKMENTS	
Dam	
Type of dam	Rock fill embankment
Top elevation of dam	53 m
Fixed crest width	13 m
Height	38.5 m
Overall length of dam	632 M

LOWER TRINIDAD / UPPER RIO INDIO

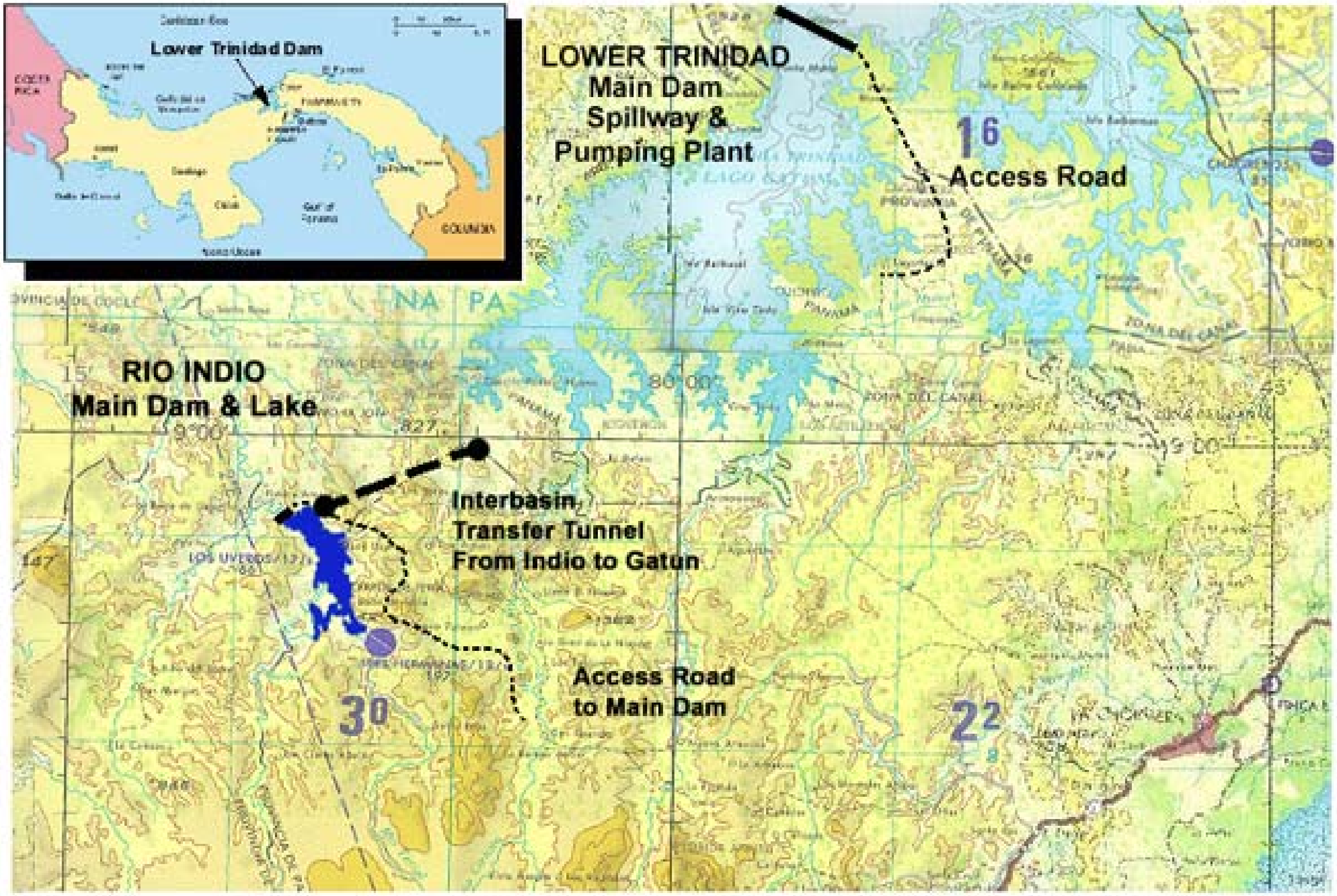


Plate 43 - 1 Project Location Map

SECTION 44

Lower Rio Trinidad 22.9m to 33.5m
Rio Caño Quebrado 22.9m to 33.5m
Rio Indio 50m to 80m

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

Synopsis

The development plan presented herein combines a dam and a lake in the Trinidad basin within the Panama Canal watershed at Gatun Lake, southwest of Gatun Locks; a dam and lake on the Rio Caño Quebrado basin of the Panama Canal watershed within Gatun Lake; and a dam and lake on the Rio Indio to the west of Lake Gatun. Water impounded in the Lower Rio Trinidad and Rio Caño Quebrado Lakes should add storage to the Panama Canal system of lakes. This additional storage would be further enhanced by incorporation of a pumping plant into the Lower Rio Trinidad Dam. This facility allows storage of excess water from Gatun Lake and extends usage of the waters contained in the Lower Rio Trinidad and Rio Caño Quebrado Lakes. Water impounded at the Rio Indio site should supply new water for use in the Panama Canal System and would be transferred via a tunnel to the Lower Rio Trinidad Lake.

The Rio Trinidad watershed is located on the western side of the Panama Canal watershed. The proposed dam site is located within Gatun Lake across the Trinidad arm near the town of Escobal. The proposed dam extends from Punta Mala, on the west shore of Gatun Lake, to Guacha Island, then across to the eastern shore of the Trinidad arm, just south of the South Range Point lighthouse. This alignment follows closely the proposed path found in the Study and Report on Increasing the Water Supply of the Panama Canal (referred to as the Tudor Report), prepared by Tudor Engineering Company, San Francisco, California 1962, for the Panama Canal Company (PCC). Plate 44 - 1 shows the location of the proposed Lower Rio Trinidad Dam project. The structures for the proposed Lower Rio Trinidad project consist of a rock fill dam constructed by underwater deposition of fill materials, a large pumping plant, and a gated spillway. This spillway should have 11 gate bays, each measuring 18.33 m wide. The pumping plant consists of the pumping station; intake and outflow facilities are separated from the lakes above and below the Lower Rio Trinidad dam by large gate structures. The total project first costs of the proposed Lower Rio Trinidad project are estimated at $1,038,765,000.

The Rio Caño Quebrado watershed comprises a portion of the western side of the Panama Canal watershed. The proposed dam site would be located within Gatun Lake across the Rio Caño Quebrado arm near the city of La Laguna and would be constructed in two parts. The first section of the dam should extend from Punta Manguito on the west shore of the Rio Caño Quebrado arm of Gatun Lake in a northwest-southeast orientation to the eastern shore of the Rio Caño Quebrado arm. The second section should extend in an east-west orientation across the Rio Caño Quebrado eastern arm just north of the mouth of the Rio Paja. The lake formed by these dams should communicate directly with Lower Rio Trinidad Lake at all operational levels. Plate 44 - 1 shows the location of the proposed Rio Caño Quebrado Dam project. The main features required for the proposed Rio Caño Quebrado project would be two sections of rock fill dam and a dug channel connecting between Rio Caño Quebrado and Lower Rio Trinidad Lakes. The total project first costs of the proposed Rio Caño Quebrado project are estimated at $23,596,000.

The Rio Indio watershed is located adjacent to the western side of the Panama Canal watershed. The proposed Rio Indio dam site is 25 km inland from the Atlantic Ocean and near the mountain Cerro Tres Hermanas. Plate 44 - 1 shows the location of the proposed Rio Indio project. The structures for this project consists of a rock fill dam, two saddle dams, an uncontrolled ogee spillway, inter-basin transfer facilities, two hydropower plants, and other outlet works. The tunnel should transfer water from Rio Indio Lake to the Panama Canal watershed as needed for canal operations. The total project first cost of the proposed Rio Indio project is estimated at $245,868,000.

The Lower Rio Trinidad poses great construction difficulties because of the extremely large quantities of underwater fill required for construction of the dam. It requires extensive drilling and site investigation prior to construction and, because of the uncertainties inherent with this type of construction; extensive unforeseen costs may be encountered during construction. Also, the spillway and pumping plant must be constructed in island settings where the structures and appurtenances practically engulf the island areas. This poses extreme space limitations on the construction effort and is very costly.

The proposed Lower Rio Trinidad and Rio Caño Quebrado Dam projects, in conjunction with the Rio Indio Dam project, should contribute greatly to the hydrologic reliability of the Panama Canal to serve its customers and should reduce the need for imposing draft restrictions and resulting light loading of vessels during traditional periods of low water availability. The existing hydrologic reliability of the Panama Canal, based on the period of record from January 1948 through July 1998 and current demands (38.68 lockages), is approximately 99.6 percent. The hydrologic reliability with the demand increasing to 120 percent of the current level (46.42 lockage) would be 98.8 percent. With construction of the proposed Lower Rio Trinidad, Rio Caño Quebrado, and Rio Indio projects, the existing high hydrologic reliability could be continued as demand for lockages increases up to 10 percent above current demand levels (up to 4.06 lockages).

Site Selection

The Lower Rio Trinidad dam project definition and description is developed with a view toward maximizing the water impounded, while minimizing the volume of material required for construction of the dam and minimizing the number of saddle dams required to contain the lake. The site chosen for the dam is 10 km south of Gatun Locks and 14 km southwest of the navigation channel. The dam would be approximately 4 km northeast the town of Escobal. This site can accommodate construction of a dam with a maximum operating lake level of EL. 30.5 m MSL. Flood storage accommodations are between EL. 30.5 and 28.7 m MSL. The proposed Rio Caño Quebrado dam site is recommended in previous reports and is chosen as a potential alternative for this study. The project definition and description are developed with a view toward maximizing the water impounded, while minimizing the volume of material required for construction of the dam and minimizing the number of saddle dams required to contain the lake. The project area is also reviewed for other possible dam sites that might be more feasible.

The site chosen for the proposed Rio Caño Quebrado Dam would be approximately 22 km southeast of Gatun Locks and 14 km northwest of the Pedro Miguel Locks. The dam would be approximately 7 km southwest of Barro Colorado Island and 4 km northeast of the town of La Laguna. This site should accommodate construction of a dam with a maximum operating lake level at EL. 30.5 m MSL. Flood storage would be accommodated above the normal operating levels between EL. 30.5 and 24.8 m MSL.

The proposed Rio Indio Dam site is chosen to maximize the water impounded, while minimizing the volume of material required for construction of the dam and the number of saddle dams required. To maximize the water impounded, it is desirable to locate the dam as far downstream in the Rio Indio watershed as possible. The ideal location is where the surrounding hillsides are relatively steep and high, and the valley is relatively narrow. However, the downstream portion of the Rio Indio watershed does not contain any sites that meet these criteria, as it is comprised of rolling hills and valleys.

The site chosen for the proposed Rio Indio Dam is approximately 25 km inland from the Atlantic Ocean and near the mountain named Cerro Tres Hermanas. This site can accommodate construction of a dam with a normal operating lake level at EL. 80 m MSL and a maximum flood lake level at EL. 82.5 m MSL.

The site chosen for the proposed Rio Indio Dam would be approximately 25 km inland from the Atlantic Ocean and would be near the mountain named Cerro Tres Hermanas. This site should accommodate construction of a dam with a normal operating lake level at EL. 80 m MSL and a maximum flood lake level at EL. 82.5 m MSL.

Hydrologic Considerations

Lower Rio Trinidad
The Rio Trinidad flows northward from the Continental Divide to the Gatun Lake. The headwater of the watershed begins at EL. 1,000 m MSL, approximately 75 km inland, and falls to El. 26 m MSL at Gatun Lake. The distribution of the average annual rainfall over the Rio Trinidad watershed varies from a high of 2,200 mm in the western part of the watershed to 2,000 mm on the eastern side of the watershed. The proposed Lower Rio Trinidad Lake site receives runoff from approximately 750 km^2 of the upper portion of the watershed. Rainfall runoff produces an average annual flow of 32 CMS at the proposed dam site.

The discharge at the Lower Rio Trinidad Dam site is obtained by drainage area ratio to the established record for Gatun. The Gatun Lake runoff is based on records developed by the U.S. Army Corps of Engineers Hydrologic Engineering Center and the PCC in a separate study.

Since the Lower Rio Trinidad Lake is located within Gatun Lake the monthly evaporation rates established for Gatun Lake are considered appropriate for the evaporation rates of Lower Rio Trinidad Lake.

Rio Caño Quebrado
Three major rivers flow northward from the Continental Divide into Rio Caño Quebrado Lake; Rio Caño Quebrado, Paja and Los Hules. The headwaters of the watershed begin at EL. 1,000 m MSL approximately 75 km inland and fall to El. 26 m MSL at Gatun Lake. The average distribution of annual rainfall over the Rio Caño Quebrado watershed varies from 2,200 mm in the western part of the watershed to 2,000 mm on the eastern side. The proposed Rio Caño Quebrado Lake should receive runoff from approximately 310 km^2 of the existing Panama Canal watershed. Rainfall runoff produces an average annual flow of 10.2 CMS at the dam site.

Rio Indio
The Rio Indio flows northward from the Continental Divide to the Atlantic Ocean. The headwaters of the watershed begin at EL. 1,000 m MSL, approximately 75 km inland, and falls to mean sea level at its mouth. The distribution of the average annual rainfall over the Rio Indio

watershed varies from a high of 4,000 mm at the coast to a low of 2,500 mm in the middle watershed area. It increases again to over 3,000 mm in the Continental Divide. The proposed Rio Indio Lake receives runoff from approximately 381 km^2 of the upper portion of the watershed. Rainfall runoff produces an average annual flow of 25 CMS at the proposed dam site.

The calculated discharge at the Rio Indio Dam site is extrapolated, recorded, and correlated stream flow data of the Boca de Uracillo hydrologic station. This station began operation in 1979 and is located on the Rio Indio, approximately 2.5 km upstream from the dam site. Data established from a statistical correlation with the discharge data of the Rio Ciri Grande at Los Cañones, using standard hydrologic techniques, completed missing data and increased the period of record. Utilization of the double mass curve method satisfactorily verified the consistency of the data measured and correlated.

Due to the proximity of Rio Indio to Gatun Lake, and because of the absence of site-specific information, the monthly evaporation rates established for Gatun Lake are considered appropriate for the evaporation rates of Rio Indio Lake.

Geologic Considerations

Lower Rio Trinidad
The proposed Lower Rio Trinidad dam site is investigated in 1962 by Geo-Recon, Inc. of Seattle, Washington, as part of the Tudor report. The investigation consisted of seismic velocity and electrical resistively profiles in conjunction with four test borings (all located in the lake and drilled by the PCC). The results of the geophysical surveys reportedly compared well with the logs of the test borings in the deep-water areas (up to 23 m deep) of Gatun Lake. In June 1963, Tudor Engineering submitted a second report including additional foundation investigations. The foundation investigations are made by the firm Shannon & Wilson, Inc., Soil Mechanics and Foundation Engineers, from Seattle, Washington, and consisted of 77 cone penetrometer borings, 24 classification borings, 11 undisturbed sample borings, and 6 field vane shear borings. The investigations submitted by Shannon & Wilson, Inc. where recently reanalyzed in Geology of the Proposed Dam Across Trinidad Arm of Gatun Lake, by Mr. Pastora Franceschi S., for the Geotechnical Section of the Panama Canal Authority (ACP).

In the lake areas the investigations disclosed that overburden material included recent lake deposits, Atlantic Muck Formation, alluvial deposits, and residual deposits. Between the west shore and Guacha Island these deposits consist of soft to very soft clay, silt, sand and peat (Atlantic Muck Formation) overlying soft to hard deposits of clay, silt, sand and gravel derived both from alluvial deposition and the weathering of bedrock. The upper two phases of the Atlantic Muck Formation, judged to be the most compressible portion of the formation, is found to have an average thickness of about 18.3 m and a maximum thickness of 22.9 m. Recent, soft lake deposits ranging from 1.2 to 2.4 m thick are found overlying the Atlantic Muck Formation. In the length between Guacha Island and Tern Island, the Atlantic Muck Formation is either not found, or is very thin. In this area, Recent-aged soft sediments (averaging 2 m thick) are generally found to overlay residual soil and weathered rock. Atlantic Muck, where present, occurred between the Recent-aged material and the residual soil, and is a maximum 5 m thick. Between Tern Island and the east mainland, only recent lake sediments (1.5 m thick) overlying residual clay are found above the conglomerate of the Bohio Formation.

Guacha, Tern and Booby Islands are each found to have an overlying stratum of soft overburdened and weathered rock of variable thickness. In general, firm bedrock is found available below EL. 22.9 m MSL and the islands are judged to offer suitable foundation conditions for control structures.

Firm bedrock under both the land and the lake is found to consist of low velocity sedimentary rock composed primarily of sandstone of the Bohio Formation. Two areas containing abrupt changes in bedrock velocities are located during the survey. One of the areas is a narrow zone located on Guacha Island that is interpreted as a possible shear zone in rock of similar type. The second area is an abrupt change in bedrock velocity on Tern Island that is interpreted as a possible fault contact between two formations, or between different lithologic units of the same formation. The top of the bedrock on land is interpreted from the geophysical results to be weathered to below lake level. The core borings in the lake determined the weathered zone of bedrock to range from 1.2 to 3.1 m in thickness.

It is judged that satisfactory foundation conditions exist for construction of a pumping station and a spillway at the Lower Rio Trinidad site. Serious consideration, however, must be given to problems that would be caused by the anticipated settlement and instability of the embankment materials.

Rio Indio

The proposed Rio Indio Dam project is located in an area of the Isthmus of Panama underlain by Oligocene-aged sedimentary rocks of the Caimito Formation. Three members of the Caimito Formation are recognized: the lower, the middle and the upper. The deposits of each of these members are mainly marine, but are lithologically heterogeneous. The lower member is composed of conglomerate and tuffaceous sandstone. The middle member consists chiefly of tuffaceous sandstone, some of which is calcareous, and lenticular limestone. The upper, principal member consists of tuff, agglomeratic tuff, tuffaceous siltstone, and discontinuous sandy tuffaceous limestone. In general, all members are hard, thinly to thickly bedded, and closely to moderately jointed. The lower member weathers to greater depths. A summary of test data developed in 1966, as part of the studies for a sea level canal, listed compressive strengths for samples of Caimito Formation material varying between 79,450 and 5,955,257 kg/m^2. The same 1966 studies assigned an allowable bearing capacity of 195,300 kg/m^2 for the material of the Caimito Formation.

The report required an investigative visit to the proposed site for the Rio Indio Dam. The investigation found moderately hard siltstone, fitting the description of strata of the principal member of the Caimito Formation, exposed along the riverbed at the proposed site. This siltstone makes an acceptable foundation for an earth and rock fill dam. It is unacceptable for use as concrete aggregate and only marginally acceptable for use as fill in some of the less important zones of an earth and rock fill dam. Due to dense vegetation, it is unknown whether sedimentary or volcanic material underlies the ridges that form the proposed abutments. Further development of this project requires drilling cores in each abutment during planning studies to identify the abutment material and its general suitability for construction use. In addition, the cores must be of sufficient depth to check for the occurrence of any soluble limestone strata that may underlie the dam foundation.

The proposed inter-basin transfer tunnel connecting the Rio Indio Lake to the Panama Canal watershed is probably located very near the contact of the Caimito Formation and the overlying Miocene volcanic rocks. Many springs occur in the area of the proposed tunnel inlets and outlets, caused by groundwater flowing in volcanic rock above impervious strata of the Caimito Formation. In addition, a 1921 drawing shows two coal mines in the general area of the tunnel inlets. Further development of this project requires drilling cores near the proposed tunnel inlets and outlets early during planning studies to determine the general relationship between the tunnel alignments and the sedimentary/volcanic rock contact, coal or peat beds, and the water table.

In the absence of detailed geologic mapping for the proposed Rio Indio Dam site, a degree of extrapolation is necessary. Available general geologic mapping and general data were the basis of predictions that rock, encountered at a shallow depth and of sufficient quality can serve as foundation for the dam and appurtenant structures. Furthermore, assumptions for this report are: excavation should produce sufficient rock for fill; and the immediate area contains adequate impervious materials and concrete aggregate for use in the construction.

Lake Operation

Two operating mechanisms are included in this study for periods when water would be transferred from Lower Rio Trinidad Lake to Gatun Lake for canal operations. The first should consist of allowing the water surface of the lake to fluctuate from the normal operating lake level at EL. 33.53 m MSL down to the minimum operating lake level at Gatun Lake, EL. 25.91 m MSL, providing 798 MCM of useable storage. Thereafter, the Lower Rio Trinidad Lake would be drawn down by pumping, allowing further fluctuation from the normal minimum Gatun operating lake level at EL. 25.91 m MSL down to the minimum Lower Rio Trinidad lake level, EL. 22.86 m MSL. This should provide an additional 655 MCM of usable storage. The maximum flood level at Lower Rio Trinidad Lake would be at EL. 34.14 m MSL. Flood storage would be accommodated between EL. 22.86 and 34.14 m MSL, by seasonally varying lake elevation of the Lower Rio Trinidad Lake, first by natural means, and then by pumping from Gatun Lake. Trinidad Lake rule curve is designed to function similar to the rule curve for Madden Lake. Table 44-1 shows the lake levels for the two affected pools.

Table 44-1 Lake Operating Levels

Lake Level (m MSL)	Lower Rio Trinidad And Rio Caño Quebrado	Gatun
Normal Operating Lake Level	33.53	26.67
Minimum Operating Lake Level	22.86	25.91
Maximum Flood Lake Level	34.14	27.13

The operating scenario for periods that require water transferal from Rio Indio Lake to the Panama Canal watershed for canal operations allow the water surface of the lake to fluctuate from the normal operating lake level, EL. 80 m MSL, to the minimum operating lake level, EL. 50 m MSL and provides 993,000,000 M^3 of usable storage. The maximum flood lake level is at EL. 82.5 m MSL. The volume between the maximum flood lake level and the normal operating lake level can store floodwaters and reduce peak flood flows. Areas along the Rio Indio downstream of the dam should realize some reduction in flooding. Table 44 - 2 shows the lake levels for the lake at Rio Indio.

Table 44 - 2 Lake Operating Levels – Rio Indio

Lake Level (m MSL)	Rio Indio
Normal Operating Lake Level	80
Minimum Operating Lake Level	50
Maximum Flood Lake Level	82.5

Project Features

GENERAL

The structures for the proposed Lower Rio Trinidad project should consist of a rock fill dam, a large pumping plant, and a gated spillway. Modification of one existing saddle dam and construction of two additional saddle dams is also required.

The structures for the proposed Rio Caño Quebrado project should consist of a rock fill dam in two distinct sections, and a dug channel connecting Rio Caño Quebrado Lake to Lower Rio Trinidad Lake at lower pool levels. Plate 44 - 2 depicts the location of the dam and the gated spillway.

The structures for the proposed Rio Indio project consist of a rock fill dam, two saddle dams, an uncontrolled ogee spillway, interbasin transfer facilities, two hydropower plants, and outlet works. Plate 44 - 2 depicts the site plan. The following paragraph provides a description of the proposed structures and improvements for these projects.

Design was performed only to the extent necessary to establish, with reasonable accuracy, the principal dimensions, elevations, and costs of the proposed project. Separate documentation is provided to the ACP that contained assumptions and design calculations for the reconnaissance level investigations of these structures. If this project is carried into the planning studies, optimization of the project features and improvements must be accomplished.

EMBANKMENTS

Lower Rio Trinidad Dam
The proposed dam consists of an embankment with the top at EL. 31.50 m MSL and with a crest width of 13 m with a final crest of 7 m upon completion of all settlement of the embankment and bridge work. The left abutment of the embankment will be located at Universal Transverse Mercator Grid, Zone 17, Clark 1866 Spheroid Coordinates 1015858 north and 614864 east. The right abutment will be 1013937 north and 618229 east coordinates. The normal lake El. 30.48 m MSL while the ground surface elevations along the axis of the dam vary from El. 2 m MSL in the lake bottom to El. 39 m MSL on Guacho Island and El. 38 m MSL on Tern Island. The Gatun Lake subgrade supporting the embankment occupies a broad flat valley having sides, which slope, upward from the valley at grades up to 40 percent. Water depths are 21.3 to 26.3 m over 80 percent of the site. The Atlantic Muck Formation, consisting of very soft organic clays, silts and peats varying in thickness from 7.6 m to 48.7 m, underlies approximately

two thirds of the alignment subgrade. The Atlantic Muck Formation in the old river channel is further underlain by soft silts, sand and clay strata.

The critical challenge for design espoused by the Tudor Report and others is the depth of subgrade degradation during the initial fill placements. The materials will lose much of its natural strength when disturbed and will only regain strength after the effects of consolidation of a surcharge fill. However, complete restoration of strength can only be assumed to a depth of 5-7 m. If the effects of the subgrade disturbance extend appreciably deeper, then an extremely weak material will be under the more stable subgrade and surcharge creating a condition of lateral instability.

Due to the inability to accurately analyze this condition, a test fill was performed on the western end of the alignment. In early 1963, 1,000-cy bottom-dump barges deposited some 168,000 cy of blasted rock from the cut widening project, extending some 305 m. 155 m of the fill was placed to a height of 11 m while the remaining 150 m was filled to 5 m. The differential heights were use to simulate initial and intermediate fill placement effects. Divers were then used to observe the performance of the fills placed along the alignment. The mechanisms of failure within the subgrade were caused by impact and static loadings. The impact of the initial placements caused severe destruction of the surface materials creating lateral displacements up to 5 m. However, when a continuous blanket of fill had been established and subsequent fill was placed, then conventional failures such as slip circle shear failures and horizontal shears creating large mud waves outward from embankment were observed. Therefore, to predict the behavior of the embankment during construction and for the long term, it is imperative that a foundation mat be established to such a depth to prevent subgrade rupture with subsequent fill placement. The Tudor recommended that a 5 m thick minimum crushed rock blanket with maximum sizes of 20 cm be placed initially to act as the supporting blanket. Special barge dumping methods were to be employed so loads would not fall as an integral mass, which would create destructive forces on the subgrade.

The placement of a large hydraulic structure on a deep-seated weak foundation is the most challenging of geotechnical endeavors. It is virtually impossible to analyze with great deal of certainty and the owner must be prepared to accept possible additional costs during construction and long term maintenance due to the potential for lateral instabilities and high degrees of settlement. The Tudor Report has predicted some 2.5 - 3 m of predicted settlement below the crest elevation for a construction duration of 7-years and an additional 2.5 to 3 m of maximum settlement below the crest for the 50-year service life of the project. These settlements are predicted where the Atlantic Muck and underlying compressible materials are the thickest. These movements are reduced as the fill approaches the mainlands and the two islands. This implies that significant differential settlements are predicted within these approaches as well. The key to any successful construction and maintenance of this embankment will be to establish a blanket mat atop the subgrade where subsequent fill can be economically placed without fear of rupturing the foundation to greater depths. Any significant lateral failure of the embankment during construction or productive use will render that alignment unsuitable. Additional embankment sections must be established upstream or downstream to reestablish the embankment section to the proper elevation. This repair will take considerable time and prevent its use as a road. Based on these considerations, our recommendations were presented for ultimate costs considerations in comparison to alternatives with a greater degree of performance certainty.

The divers observed that the test fill had trouble placing the fill in the correct locations within the alignment and the lift thickness varied significantly over the fill cross section. It is imperative that the blanket fill be placed intact with the least subgrade disturbance in order for the embankment to act as monolithic mass. Therefore, the initial 5 m of fill will be barged to the site and placed by lowering a clamshell to the subgrade surface. The positioning of the barges must be strictly controlled by survey positioning systems established on land. The initial fill should have a maximum size of 20 cm and the percent fines should be controlled to remain fairly intact during placement. Materials with a significant size differential and a large fine content can create weak shear zones with the embankment. The subsequent fill materials above this zone can be placed by bottom dumped barges or clamshells from El. 8 to 21 m MSL. The material above El. 21 m MSL must be placed by clamshell due to the draft and door operations of the barges. These materials will be more random in gradation having a maximum size of 30 cm and a greater degree of fines. The materials placed below El. 27 m MSL will assume a side slope of 1 V:15 H. A 15 m berm will be constructed and the materials will continue to be placed by clam shell and spread with a dozer to El. 34.5 m MSL, assuming a side slope of 1 V : 3 H and a crest width of 13 m. The flatter side slopes are needed to distribute bearing pressures and to reduce the lateral displacements. This configuration should also reduce the construction and total settlements predicted by the Tudor report and provide acceptable factors of safety for lateral stability during fill placement. The side slope berms and extra crest width will facilitate the future fill placements of up to 3 m over the life of the project. The road surface atop the dam embankment will remain gravel surfaced for the foreseeable future due to future fill placements. The dam will be approximately 30 m high, and the overall length 4,473 m. The top of the dam will be 5 m above the normal Gatun Lake level. The total volume of fill material required to construct and maintain the main dam to El. 34.5 m MSL is approximately 39,883,250 M^3. Water access from the main channel to Guacha and Tern Islands will be built during construction. After access roads have been constructed, fill placements from the east mainland to Tern and Gaucha Islands could be delivered by truck and placed by end-dumping from the east mainland. This technique could prove beneficial if a material source was found near the Gatun Lock area. The side slopes and overall embankment configuration was offered for ease of calculation, to reduce the foundation pressure on the soft subgrade and to account for the lateral displacement of embankment materials. The increased foundation base should help the structure survive a relatively minor seismic event.

The methods of subgrade stabilization and embankment strengthening offered in the powerpoint presentations from the ACP Engineering Division are examples of many ideas for enhancing the performance of the embankment during construction and post construction. The use of wick drains have been an effective tool for accelerating consolidations under a mass loading. However, the Atlantic Muck materials will not readily transmit water to the drains, therefore the spacing of the drains must be much closer than that implied and the effectiveness of the drains will be restricted to the top 15 to 20 feet of the foundation subgrade. The drains must be effectively tied into the foundation blanket for continuity of the drainage path. There are concerns over the use of vibro-flotation or stone columns techniques above the mat. The mat will not effectively dampen these compaction forces and some rupture of the mat could be possible. A safer reinforcing technique could be the use of reinforcing within the embankment section, such as high strength geogrids placed in layers. All reinforcing techniques are expensive but could be offset by the reduction in fill quantities ultimately required. Any reinforcing selected for use in production must be part of a comprehensive test fill program to demonstrate its effectiveness.

The Tudor Report identified considerable leakage to be expected from the completed embankment. Since loss of any water from storage is a significant reduction in benefits, the seepage must be prevented. Therefore a bentonite slurry trench should be installed within the centerline of the embankment. The trench will be a minimum of 3 feet wide and extend to several meters below the original lake bottom. The trench can be excavated using rockmill techniques. Since the embankment will undergo significant settlement, both total and differential, it is likely that the trench will be sheared and will require replacement within the deeper portions of the lake during the life of the project.

Rio Caño Quebrado Dam

The Rio Caño Quebrado dam should consist of two sections, the west and east embankments, with the top at EL. 34.50 m MSL and with a crest width of 13 m. The left abutment of the embankment would be at Universal Transverse Mercator Grid, Zone 17, Clark 1866 Spheroid Coordinates 1004554 north and 632455 east. The right abutment would be 1004595 north and 632599 east coordinates. The embankments would be constructed by depositing cohesive materials along the alignment of the proposed dam until the stacked material reached its natural angle of repose and the consolidation, within the subgrade, is stabilized. The assumed side slopes would be 10 H : 1 V within the submerged sections transitioning to 2 H : 1 V in the portions traversing the existing islands. The subgrade is extremely soft and considerable displacement would be anticipated as evidenced by the original construction experience at Gatun Dam. The dam would be approximately 16 m high, and the overall length would be 404 m. The top of the dam would be 4.3 m above the maximum normal operating level in Gatun Lake. The total volume of fill material required to construct the embankments would be approximately 244,150 M^3 for the west embankment and 114,500 M^3 for the east embankment.

Rio Indio Dam

The Rio Indio Dam would be constructed as an embankment, with the top at EL. 83.5 m MSL and with a crest width of 13 m. The left abutment of the embankment would be located at Universal Transverse Mercator Grid, Zone 17, Clark 1866 Spheroid Coordinates 994408 north and 589644 east. The right abutment would be 994801 north and 590432 east coordinates. The embankment would be constructed with an impervious earth and rock fill core encased in rock fill, and the final side slopes would be 2 horizontal on 1 vertical. The dam at its highest point shall be approximately 73.5 m high - the overall length 891 m. Further study should determine the actual side slopes and crest width and contingent upon the need for vehicular access across the embankment, the size and quality of the rock fill, and the detailed design of the embankment. Plate 42 - 3 presents a typical section of the embankment at the dam, incorporating upstream and downstream cofferdams within the section.

Foundation grouting would be required across the entire base of the dam and up a portion of the valley walls. A blend of bentonite and native fill materials in a core trench may provide seepage cutoff in the embankment foundations. A concrete or bentonite cutoff wall can also provide seepage cutoff.

The crest width and side slopes are presented for comparison purposes between the various projects. The actual crest width and side slopes would be determined during further study and contingent upon the need for vehicular access across the embankments, the size and quality of the fill materials available for use, and the detailed design for the embankments.

Saddle Dams

As noted in the Tudor Report, the existing Caño Saddle Dam No. 4, located along the western shoreline of the Trinidad Arm of Gatun Lake, needs to be raised and/or strengthened to accommodate the higher lake levels. Immediately to the north of this location, two additional smaller saddle dams are required. All saddle dams must be built to provide a minimum top El. 31 m MSL. The total volume of fill material required for these three dams is 50,000 M^3

The actual side slopes and crest widths would be determined during further study and are contingent upon the need for vehicular access across the embankment, the size and quality of the rock fill, and the detailed design of the embankment. A typical section of the embankment at the saddle dams and main dam is similar to that shown for the embankments for the Rio Indio project, Volume One of this report.

SPILLWAYS

Spillways are required at two of the dam sites, Rio Indio and Lower Rio Trinidad under this scenario. The Lower Rio Trinidad spillway should handle all flows into the Rio Caño Quebrado area.

Lower Rio Trinidad

Under normal flow conditions water passes from Lower Rio Trinidad Lake to Gatun Lake through a gated spillway. This spillway should have 8 gate bays, each 18.33 m wide. The gate bays would be separated/flanked by 3 m wide reinforced concrete piers (9 piers in all), which should provide support for the gates and operating machinery, as well as providing support for a roadway bridge over the top of the spillway. Each of the 8 spillway gates should have a nominal width of 18.33 m and a height of 8.53 m, providing 0.3 m freeboard above the maximum lake operating level. The overall length of the spillway, from out-to-out of piers is 173.64 m. The spillway sills would be placed at the minimum lake operating level, EL. 25.91 m MSL.

A bridge across the tops of the spillway piers would be constructed as a part of the roadway across the top of the dam. The roadway must be approximately 7 m wide thus allowing for two-way traffic and providing ready access to the spillway gate operating machinery.

For this study, stop logs for servicing the gates, guides, etc. may be placed either from the roadway or from barges using floating cranes. Also, it should be noted that, with the spillway sill at the prescribed level, stoplogs are required both upstream and downstream to allow work to be done on the gates and sills in the dry.

The spillway would be situated along the axis of the dam approximately centered in Guacha Island. This allows the construction to be performed completely within a dry construction cut requiring a minimum of construction dewatering. Once the concrete structures are completed, the entrance and exit channels to the spillway can be opened.

Rio Indio Dam

At the Rio Indio dam an uncontrolled ogee spillway with a length of 120 m and a crest at EL. 80 m MSL would be required. The spillway crest would be 3.5 m below the elevation of the top of the dam. The maximum discharge from the spillway would be 920 CMS at a maximum flood lake level at EL. 82.5 m MSL. The spillway design discharge is equivalent to a 1 in 1,000 frequency unregulated flow at the dam site. The spillway would be located within the abutment adjacent to the left end of the dam and would consist of a mass concrete sill section embedded in the natural rock. A sloped and/or stepped, natural rock cut tailrace channel would return flow to the existing stream. The tailrace channel would extend from the sill section to its confluence with the natural stream some distance downstream from the toe of the dam. The task of dissipating energy at the downstream end of the tailrace channel requires excavation of a stilling basin into the rock adjacent to the natural channel. See Plate 44 - 2 for the location of the spillway and Plate 44- 4 for a typical section at the spillway.

Foundation grouting would be required across the entire base of the dam and up a portion of the valley walls. A blend of bentonite and native fill materials in a core trench may provide seepage cutoff in the embankment foundations. A concrete or bentonite cutoff wall can also provide seepage cutoff.

PUMPING PLANT

A large pumping plant is included in this scenario at the Lower Rio Trinidad dam. This pumping facility provides for pumping in two directions, allowing Lower Rio Trinidad Lake to be drawn down to a level below that of Gatun Lake during extremely dry months, and providing the capability of pumping excess water from Gatun Lake into Lower Rio Trinidad Lake during the flood season. Water thus stored would be available for navigation during the dry season. The pumping plant is configured to provide pumping to EL. 33.53 m MSL in Lower Rio Trinidad Lake. For the purpose of this study the pumping plant is located in the northwest segment of Tern Island. See Table 44-3 for the controlling head and flow data used for this study.

This plant should consist of six 1407 HP pumps, each capable of pumping slightly more than 62 CMS for a total plant pumping capacity of 373 CMS at a total dynamic head of 4.6 m. The pumping units would be mounted in a reinforced concrete housing and arranged in a row perpendicular to the axis of the dam, with intake and outlet channels on either side. The channels would be separated from the Lower Rio Trinidad and Gatun Lakes by large concrete walls containing low-level sluiceways and gates for controlling flows into and away from the pumping plant. These sluiceways are configured to provide average entry velocities of approximately 7.7 MPS. The channels are configured to provide this velocity or less and require no special armoring of walls or inverts for scour protection. The channel invert would be at EL. 20 m. MSL, or 13.5 m. below the centerline of the pump outlets. This may provide sufficient water depth at maximum pumping to buffer the erosive effects of the very large outflows required.

In conjunction with this facility a roadway bridge would be required to connect the pumping station structure to the banks on either side of the intake and exit channels thus continuing the roadway across the facility. This bridge should also provide both operational and maintenance access to the pumping plant. As configured for this study, the bridge must have two 15 m long spans with steel girders and a concrete bridge deck on each side of the pumping station. It shall have a 7 m wide travel way and include one bridge bent including a cap, two round columns and a spread footing, located within each channel section.

Table 44-3 Pumping Data

Pumping Cycle	Head (m.)	Average Daily Flow (M^3/sec)
Lower Rio Trinidad (Elev. 22.86) to Gatun Lake (Elev. 25.91)	3.05	127.43
Gatun Lake (Elev. 26.67) to Lower Rio Trinidad (Elev. 33.53)	6.86	56.64

IMPOUNDMENT

The lake formed by the Lower Rio Trinidad Dam under this scenario should have a normal operating lake El. 33.53 m MSL. The surface area at the normal operating lake level would be approximately 17,650 ha. At the maximum flood level, EL. 34.44 m MSL, the surface area would be approximately 17,850 ha. With the minimum operating level at EL. 22.86 m MSL, the surface area would be approximately 12,000 ha. It should be noted that the current operating levels of Gatun Lake vary up to EL. 26.67 m MSL; therefore areas below the maximum Gatun Lake level are already subject to inundation.

The lake formed by the proposed Rio Caño Quebrado Dam should have a normal operating lake level at EL. 33.53 m MSL. The surface area in the Rio Caño Quebrado impoundment at the normal operating lake level would be approximately 2,490 ha. At the maximum flood lake level, EL. 34.44 m MSL, the surface area is 2,610 ha. With the minimum operating lake level at EL. 22.86 m MSL the surface area is 1,460 ha.

The lake formed by the proposed Rio Indio Dam should have a normal operating lake level at EL. 80 m MSL. The surface area at the normal operating lake level would be approximately 4,280 ha. At the maximum flood lake level, EL. 82.5 m MSL, the surface area is 4,440 ha. With the minimum operating lake level at EL. 50 m MSL, the surface area is 2,360 ha.

CLEARING AND/OR GRUBBING

Clearing and grubbing is required for all areas above the existing Gatun Lake that are required for construction of the dam (embankments and spillway), access roads, and disposal and staging areas. For the Lower Rio Trinidad Lake area, clearing is required for the 3,700 ha in the lake area between the maximum operating lake level of Gatun Lake and EL. 30.5 m MSL.

For the Rio Indio Lake, clearing is required in all areas necessary for construction of the dam (embankments and spillway), inter-basin transfer facilities, outlet works, hydropower plants, access roads, and disposal and staging areas would require clearing and grubbing. Only the 650 ha in the lake area between the normal operating lake level, EL. 80 m MSL, and the minimum operating lake level, EL. 50 m MSL, require clearing. The transmission lines also require clearing.

ACCESS ROUTE

Lower Rio Trinidad

Access to the lake site and the various construction sites is evaluated from the main population centers, Colon on the Atlantic coast and Panama City on the Pacific coasts.

The route from Colon is westward across the Panama Canal and then southwestward along existing roads that follow the westernmost boundary of Gatun Lake to Cape Mala, near the western abutment of the dam. A very short access road is required from the existing road to the dam site. This route requires crossing the Panama Canal near the Gatun Locks using the existing lock gate bridge. This bridge is narrow and operates only intermittently since canal operations take precedence over roadway traffic. It may be undersized and may lack the load carrying capacity needed for heavy construction materials and equipment loads anticipated.

Access to the spillway and pumping station construction sites would be by water since these structures are to be placed on Guacha Island. A water access route is a possible means of conveyance for much, if not all, of the construction equipment and materials. This requires offloading facilities be constructed near the west abutment of the dam on Guacha Island, and near the eastern abutment site in the vicinity of South Range Point.

Since much of the construction for this project would be in the existing lake or on an island, it is concluded land and water are both required. Plate 44 - 1 shows the general location of the proposed features and the possible land and water access available or to be provided.

Rio Caño Quebrado

Access for Caño Quebrado can best be gained from the Panama City area via existing roads as far as the town of Santa Clara, located to the southeast of the Rio Caño Quebrado dam site. A new roadway would be required to the dam construction site from Santa Clara, a distance of 8 km. Also, roadway access would be required to the spillway site, located southwest on the side of the existing lake opposite the dam site. Roadway access to the town of La Laguna is available from this area. From a point just south of La Laguna, a new access road would be required around the south side of the existing lake to the spillway site. This route should require 5 km of new roadway.

Rio Indio

For access to the Rio Indio site it is concluded that the route from Panama City westward across the Bridge of the Americas, then southwestward along the Inter-American Highway, and then westward along existing roads to Ciri Grande, may be best. This route requires that the road between Panama City and Ciri Grande be upgraded over much of its length and the route west of Ciri Grande must traverse the mountains. The proposed access road would be 26 km in length, and bridges and/or culverts would be required at 15 streams. Table 44- 1 shows the portion of the access road from Ciri Grande to the construction sites.

In addition to providing dam construction access, this new corridor into the country west of the Panama Canal benefit those living in the region, providing access to the main centers of commerce in the southern part of the country. It should also provide continuous access along the new power transmission lines from the dam site to the connection with the power grid.

Sources of Construction Material

Lower Rio Trinidad
The bottom 5 m layer of the dam embankments shall be constructed with material less than 8 in. maximum size, and with no more than 5 percent passing the #200 screen. Such a material would require crushing and processing across a grizzly to remove oversize rock, and washing to remove fines. Material for this bottom layer must be reasonably well graded so as to prevent the removal of the finer fraction by piping. The overlying main portion of the embankment would be constructed with (-12 in.) sized material. This material should also require crushing and processing across a grizzly to remove oversize rock.

The majority of the materials used for the embankment construction would be obtained from upland sources adjacent to the Gaillard Cut, transported to the site by barge and clam shelled along the proposed embankment alignment. The initial materials would be obtained from the existing disposal sites for the Gaillard Cut widening above Pedro Miguel Locks. Based on the information received from the ACP, these sites contain approximately 5.5 million M^3 of suitable excavated rock. However, this rock is not stockpiled in an orderly manner, is randomly mixed with unsuitable material and is covered with unsuitable material. All the rock materials, from whatever source, would need to be crushed, graded and loaded on trucks for transport to a loading facility adjacent to the canal at the Cucaracha Reach on the east side, or the mouth of the Mandinga River on the west side. These loading facilities should require excavation into the bank area and bulkheaded for crane support and barge placement. Working stockpiles would be maintained next to the transfer points to facilitate the loading process. Additional materials within the immediate area should come from the Third Locks excavation adjacent to the Pedro Miguel Locks. These materials would be drilled and blasted in place, excavated, and then transported to one of the transfer facilities for processing. Additional materials should come from newly developed quarry sources in areas such as Hodges Hill, Escabor Hill, Contractor Hill, and others within 10 km of the transfer points. Each of these new sources should require extensive excavation to remove the overburden and soft rock materials. These materials would be stockpiled adjacent to the work area for restoration once the rock fill materials have been acquired. The suitable rock materials would be blasted, crushed and graded and trucked to the transfer points. All material would be loaded onto barges, transported to the dam site and clam shelled within the dam limits.

Cement is available within the country. Rock obtained from developed quarries may be used to produce concrete aggregates on-site, or they may be obtained from commercial quarries. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) need to be fabricated outside the Republic of Panama and imported for final assembly and installation at the proposed dam site.

Rio Indio
Rock removed from the spillway site can used as fill in the embankment portion of the dam. Impervious materials might be obtained from outside the project area; however, for this study it is assumed that these materials would be available locally in sufficient quantity to supply the project needs. If further study indicates that impervious materials are unavailable locally, then other materials, such as roller compacted concrete, would be considered for construction of the dam.

Cement is available within the Republic of Panama. Rock obtained from developed quarries may be used to produce concrete aggregates on-site, or they may be obtained from commercial quarries. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) need to be fabricated outside the country and imported for final assembly and installation at the proposed dam site.

Real Estate Requirements

The Lower Rio Trinidad Lake site is located within the former Panama Canal Zone and is presently managed and controlled by the ACP. Construction of this project requires the acquisition of 800 ha. Table 44 - 4 shows the amount of land required for the various project features. Real estate for access roads is included in the estimated quantities for the other items listed in the table.

Table 44 - 4 Real Estate Requirements

Project Feature	Land Required (ha)
Lake	0
Dam Site	0
Staging Area	200
Housing and Facilities	200
Disposal Area	400
Total	800

The proposed Rio Caño Quebrado Lake is located within the former Panama Canal Zone and is presently managed and controlled by the ACP. It is assumed that the future management of the Panama Canal should retain its authority and acquisition of lands for the lake area should not be required. Construction of this proposed project should require acquisition of approximately 800 ha. Table 44 - 5 shows the amount of land required for the project. Real estate for access roads is included in the estimated quantities for the other items listed in the table.

Table 44 - 5 Real Estate Requirements

Project Feature	Land Required (ha)
Lake	0
Dam Site	0
Staging Area	200
Housing and Facilities	200
Disposal Area	400
Total	800

The Rio Indio project site is located in the Cocle, Colon, and Panama Provinces. Construction of this proposed project requires the acquisition of 5,600 ha. Table 44 - 6 shows the amount of land required for the various project features. Real estate for access roads is included in the estimated quantities for the other items listed in the table.

Table 44 - 6 Rio Indio Real Estate Requirements

Project Feature	Land Required (ha)
Lake	4,600
Dam Site	200
Staging Area	200
Housing and Facilities	200
Disposal Area	400
Total	5,600

Relocations

The proposed Lower Rio Trinidad Lake site is located within the existing former Panama Canal Zone. Structures and facilities established along the waters edge in the Rio Trinidad arm, between the existing Gatun Lake levels and EL. 30 m MSL, need to be relocated or modified. This includes a major portion of the town of Escobal. Additionally, there are a few small communities and isolated individual structures along the lakeshore with very limited access by land.

The Rio Caño Quebrado Lake site is located within the existing former Panama Canal Zone. Structures and facilities established along the waters edge in the Rio Caño Quebrado arm between the existing Gatun Lake level and EL. 30 m MSL should need to be relocated or modified. Additionally, there are a few small communities and isolated individual structures along the lakeshore with very limited access by land.

The proposed Rio Indio Lake site is located in a sparsely settled region with few roads and utilities. This area is devoted primarily to subsistence farming and ranching. Structures and individuals located in the lake area below EL. 85 m MSL require relocation because of the normal lake inundation, and to secure land on the lake perimeter for flood considerations. The required relocations include the five towns (El Limon, Los Uveros, La Boca de Urcelillo, Aguila, and Tres Hermanas), approximately 30 other small settlements, and numerous isolated structures. The five towns all have elementary schools, churches, electricity, and limited telephone coverage.

Development Sequence

Each component of the lake projects is designed and can be constructed as a stand-alone facility. If the Rio Indio facilities are constructed first and placed into service before the Lower Rio Trinidad facilities, the interbasin transfer tunnel can be used to navigational advantage while the Lower Rio Trinidad project is being completed. During the interim the Rio Indio project should help control flooding on the Lower Rio Indio and can contribute to the electric power output of the country.

The development sequence for each individual project follows roughly the same progression. This progression is summarized below with pertinent site-specific notations as appropriate.

Each project must be evaluated to assure that the plan presented includes all of the features required to function. Each project must be assessed as to its effectiveness in providing navigation water to the Panama Canal, with due recognition of any secondary benefits. Environmental assessments of the proposed projects need to be made to assure environmental acceptability of the project features. These environmental assessments begin during the planning studies phase and continue into the final design, advertising and award phases. Environmental coordination begins with planning studies and continues through the completion of construction. After completion of the final design, plans and specifications must be prepared for the advertising and award phase.

Project implementation begins with land acquisition and construction of the access facilities. Lands for the housing and facilities project feature, which includes the access roads, need to be acquired initially. Lands for the dam site, staging area, disposal area, and lake can then be acquired.

Socio-economic programs must begin shortly before construction of the dam. The relocation of the small settlements and isolated structures must be accomplished. Socio-economic programs to assist those individuals impacted by the construction of the proposed project should continue throughout the construction phase.

Construction of the Rio Indio Dam begins with the clearing and grubbing of the construction sites and clearing the perimeter of the lake area. Materials used for the embankment construction can obtained from upland sources then transported to the site.

Upstream and downstream cofferdams are required for construction of the Rio Indio Dam and appurtenant facilities. These shall be configured to form a portion of the finished dam.

Limited cofferdams would be required to accomplish construction of the spillway and pumping station. These efforts may be accomplished simultaneously. Following completion of the pumping plant and spillway, the channels connecting these structures to the lake areas upstream and downstream may be excavated. Where possible, materials removed from these sites would be placed directly into the dam.

Once the western leg of the dam, pumping station and spillway are completed, the eastern leg may be constructed, thus completing the dam. The pool may then be raised. Upon completion of this phase of construction, all facilities must undergo trial operations, before being commissioned for service.

Considering the construction methods required and the nature of the work, it is estimated that development of the Lower Rio Trinidad and Rio Indio Dam projects may be completed in approximately the time spans indicated in Figures 37-2 and 37-3, below, from initial planning to lake filling. Assuming that the development of the two projects is overlapped by 1 year the total development time is approximately 22 years.

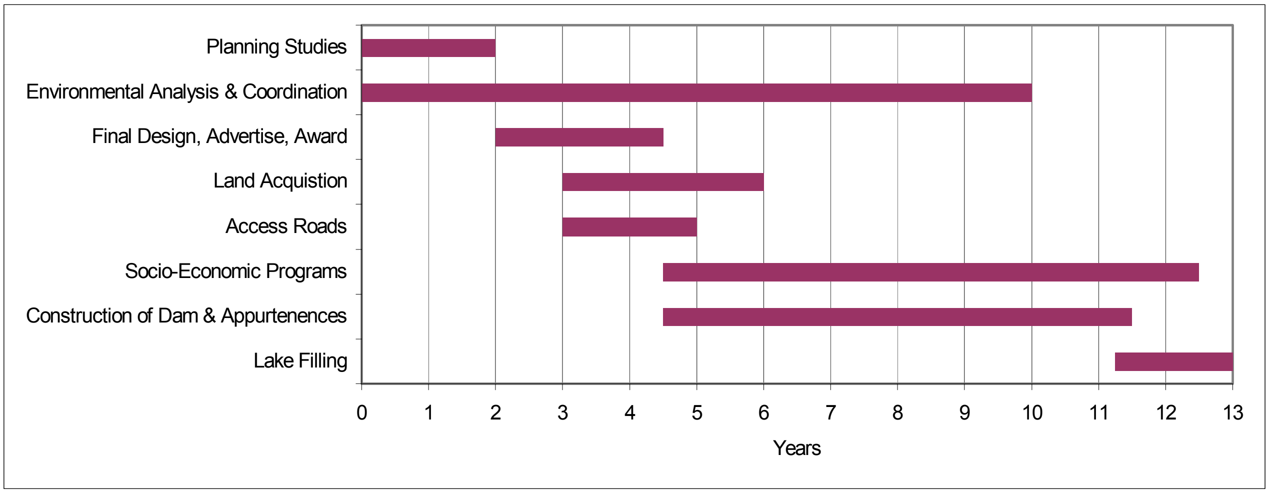


Figure 44 - 1 Development Sequence – Lower Rio Trinidad

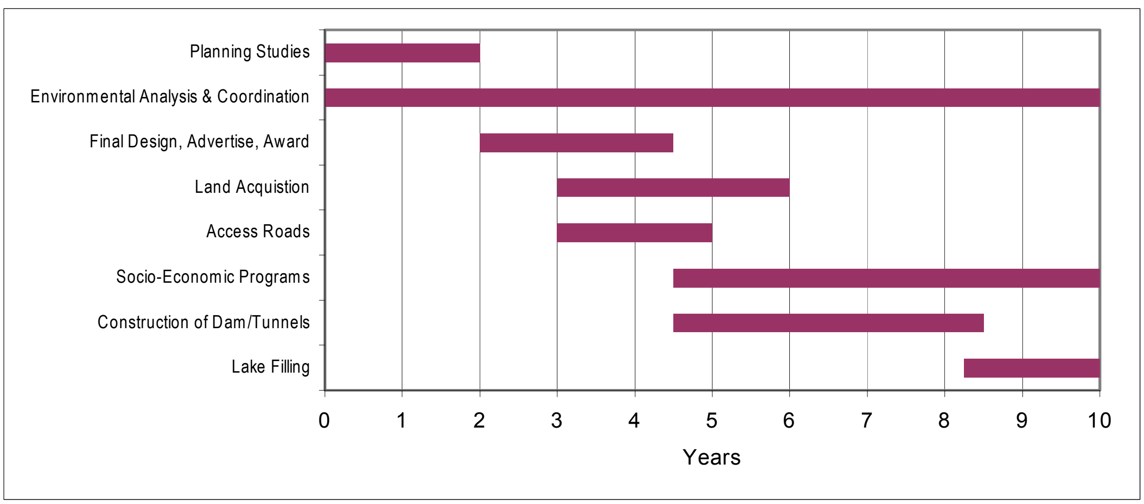


Figure 44 - 2 Development Sequence – Rio Indio

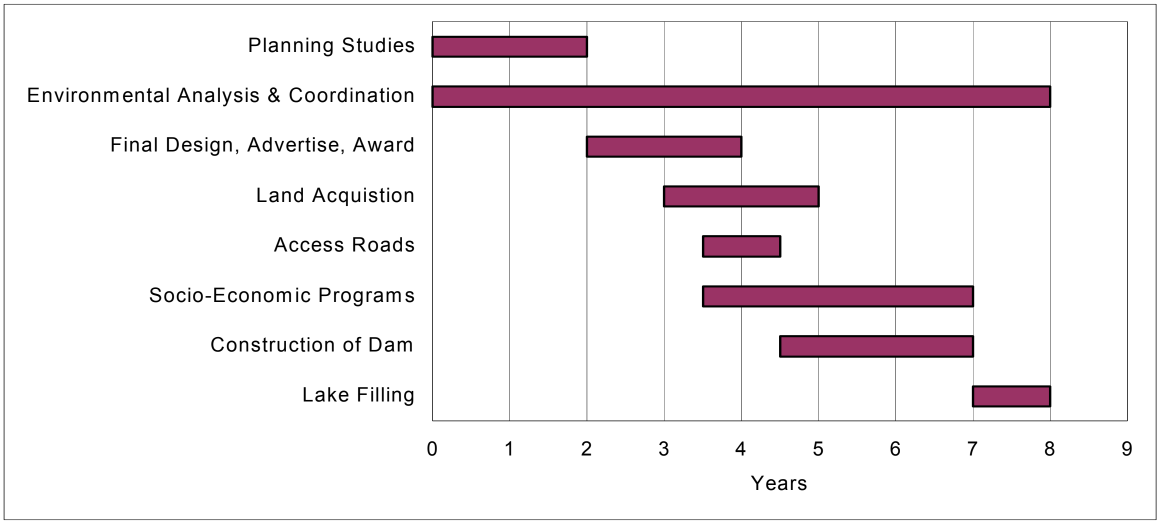


Figure 44 - 3 Development Sequence – Rio Caño Quebrado (Concurrent with Lower Rio Trinidad)

Hydrologic Reliability

In order to determine the effect of the proposed Lower Rio Trinidad, Rio Caño Quebrado and Rio Indio Lakes on the hydrologic reliability of the Panama Canal, the existing HEC-5 model is modified to include the Lower Rio Trinidad Lake with pumpback operation and diversion from Rio Indio Lake. The existing Gatun Lake parameters (surface areas, storages, and local inflows) are reduced by the proportion that Lower Rio Trinidad and Rio Caño Quebrado Lakes should capture.

HEC-5 model simulations are conducted for both the existing canal system and the Scenario 7 operating system providing water to the Panama Canal watershed. The simulations considered proportionally increasing demands to 180 percent of current demand levels. The period of simulation considered 52-years (January 1948 through December 1999) of hydrologic record, see Figure 44 - 4. These configurations are:

- Existing system,
- Scenario 9 Rio Indio Lake fluctuating between the normal operation lake at EL. 80 m MSL and the minimum operation lake level at EL. 50 m MSL, with a 3 m diversion tunnel; Lower Rio Trinidad and Rio Caño Quebrado Lake fluctuating between the normal operating lake level of EL. 33.52 m MSL and the minimum operating lake level of EL. 22.86 m MSL with pumping capability to and from Gatun Lake; and Gatun Lake fluctuating between the normal operating lake level of EL. 26.67 m MSL and the minimum operation lake level of EL. 25.91 m MSL.

The horizontal axis along the bottom of Figure 44 - 4 reflects demands as a ratio of the 5-year average from 1993 to 1997, and the axis along the top reflects demands in lockages (assuming 55 million gallons per lockage).

As shown in Figure 44 - 4, the existing hydrologic reliability of the Panama Canal based on the period of record of 52-years is 99.6 percent, while the hydrologic reliability with a demand ratio of 1.8 is 86.3 percent. This period of record includes the worst drought on record for the area, which occurred in 1998. The hydrologic reliability with a demand ratio of 1.0 would be 100 percent for operating Scenario 9, and the hydrologic reliability with a demand ratio of 1.8 would be 98.52 percent. Figure 44 - 4displays the number of lockages associated with various levels of reliability.

Without additional water supplies, the hydrologic reliability of the canal system should decrease. With the construction of the proposed Lower Rio Trinidad Pumpback, Rio Caño Quebrado Dam and Rio Indio Dam projects using Scenario 9 operation, the existing high hydrologic reliability may continue as demand for water increases up to 63.1 percent (24.41 lockages) above current demand levels.

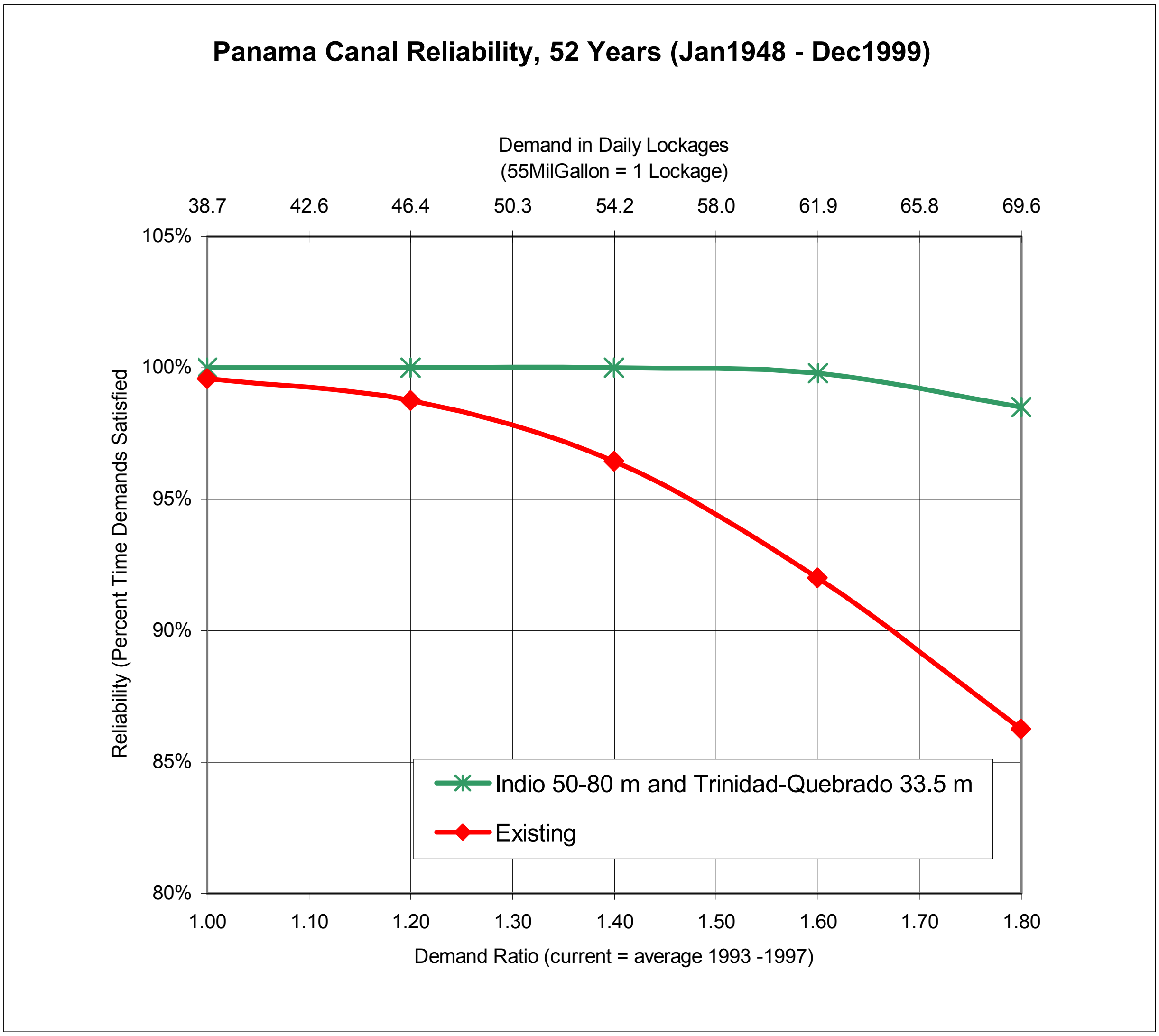


Figure 44 - 4 Panama Canal Hydrologic Reliability

Project Costs

GENERAL

The quantities estimated for the various items of work required for the construction of this project are derived from the layouts shown on Plates 36-2 through 36-8. The unit prices applied to these quantities are based on: historical information from previous estimates prepared for similar construction by the ACP; estimates for similar construction in the Mobile District; information gathered from Mobile District Construction Division personnel in Panama; and the book Feasibility Studies For Small Scale Hydropower Additions, A Guide Manual, written by The Hydrologic Engineering Center of the U.S. Army Corps of Engineers.

Engineering and design is estimated to be 12 percent while supervision and administration is estimated to be 6 percent of the construction cost items. An allowance of 2 percent of the construction cost items is allowed for field overhead (construction camp, contractor facilities, etc.). An allowance of 25 percent is included for contingencies.

FIRST COSTS

The total project first costs are estimated at $1,308,229,000. Table 44 - 7 provides a summary of the first costs for the principal features. Separate documentation provided to the ACP includes a detailed cost estimate containing the sub-features of the work.

Table 44 - 7 Summary of First Costs

	Trinidad	Rio Indio	Rio Caño Quebrado
Item	Costs ($)	Costs ($)	Costs ($)
Lands and Relocations	2,000,000	14,000,000	2,000,000
Access Roads	9,574,000	8,030,000	6,690,000
Clearing and/or Grubbing	559,375	3,566,250	792,500
Cofferdam	850,000	4,850,665	N/A
Dam	643,786,212	22,723,329	2,966,970
Spillway	8,057,504	43,387,450	N/A
Intakes	N/A	7,701,295	N/A
Saddle Dams	2,593,390	4,241,143	N/A
Transfer Ditch	N/A	N/A	3,281,400
Pumping Station	22,999,637	N/A	N/A
Diversion Tunnel	N/A	14,732,944	N/A
Interbasin Transfer Tunnel	N/A	11,595,800	N/A
Transfer Intake Rio Indio-Gatun	N/A	365,258	N/A
Hydropower Plants	N/A	22,118,125	N/A
Transmission Lines	2,090,000	6,600,000	N/A
Subtotal	692,510,118	163,912,259	15,730,870
E&D, S&A, Field Overhead	138,502,024	32,782,450	3,146,174
Contingencies	207,753,035	49,173,675	4,719,261
Total Project First Cost	1,038,765,177 Approximately 1,038,765,000	245,868,387 Approximately 245,686,000	23,596,305 Approximately 23,596,000

OPERATION AND MAINTENANCE

Staff

A staff should operate and maintain the proposed Lower Rio Trinidad Dam project during the day and then run the facility remotely at night. The full-time staff should consist of 9 people, including a station manager, a multi-skilled supervisor, 2 leaders (Electronics/Instrumentation, Electrical/Mechanical), 4 craftsmen and a laborer. A part-time staff would be required for two to three months each year to perform general maintenance and overhaul of the project. The part-time staff may consist of three mechanics and three electricians. The annual staffing costs are estimated to be $350,000. The staff for the Lower Rio Trinidad project would be sufficient to operate and maintain the Rio Caño Quebrado project. The annual staffing costs for the proposed Rio Indio project are estimated to be $500,000.

Ordinary Maintenance

Ordinary maintenance and care is required and includes minor repair materials, lubricants and other supplies needed by project staff. It is estimated that the costs of ordinary maintenance would be $18,000 per year for the access road and $100,000 per year for the main project facilities. Fuel consumption for the pumps is estimated to cost $648,000. This estimate considers the growth in demand for water and the variability in inflows to Gatun Lake as well as the proposed Lower Rio Trinidad project. An estimated $288,000 would be needed for rock placement to account for the settling of structures. The total ordinary maintenance is $1,054,000. The estimate for the Lower Rio Trinidad project includes the Rio Caño Quebrado project. The ordinary maintenance costs for the propose Rio Indio project are estimated to be $320,000.

Major Replacements

The average service life of gates, electrical equipment, pumps, trash racks and other features would be less than the total useful life of the proposed project (100-years). To estimate the major replacement costs for the 50-year project planning period, it is assumed that specific items would cost the same as at present. No allowance is made for salvageable fixed parts. Table 44- 8 presents the service life, number of times each component should be replaced during the 50-year planning period, the future costs of each item, and the present worth of the replacement costs for the major components. Based on these values, the present worth of the replacements is $2,260,400 and the average annual replacement cost would be $272,000. There would be no major replacements needed for the Rio Caño Quebrado project. The average annual replacement costs for the proposed Rio Indio project would be $91,000.

Table 44 - 8 Major Replacement Costs

Component	Service Life (years)	Number of Times Replaced During Planning Period	Future Costs ($)	Present Worth of Replacement Costs ($)
Roads	50	1	12,435,000	43,000
Bridges	50	1	1,800,000	6,200
Pump Station				
Pumps	25	2	21,006,000	654,200
Sluice Gates	50	1	1,275,525	4,400
Sluice Trash Racks	50	1	458,850	1,600
Electrical Controls	25	2	2,100,000	65,400
Fuel Tanks, etc.	50	1	450,000	1,600
Misc Equip & Comm.	25	2	3,183,000	99,100
Slurry Trench	25	2	40,462,500	1,260,100
Spillway				
Bridge Girders	50	1	280,676	1,000
Tainter Gates	50	1	2,280,000	7,900
Tainter Gate Hoists	50	1	1,200,000	4,200
Tainter Gate Op Sys.	50	1	360,000	1,200
Stoplogs	50	1	475,950	1,600
Misc. Mech. Items	50	1	1,500,000	46,700
Electrical Controls	25	2	1,650,000	51,400
Transmission Lines	25	2	3,135,000	10,800
Total			94,052,500	2,260,400
Average Annual Replacement Costs				272,000

Annual Costs

The project first costs for the proposed Lower Rio Trinidad project are estimated to be $1,038,765,000. The project first costs for the proposed Rio Caño Quebrado project are estimated to be $23,596,000. The total project first costs that include the $245,868,000 costs for the Rio Indio project are estimated at $1,308,229,000. These total project first costs are distributed across the development period using generalized curves for contractor earnings for large, heavy construction jobs. Interest on the proposed Rio Indio project first costs is computed from mid-year throughout the 22-year development period from initiation of Planning and Design until the Lower Rio Trinidad area is filled. Interest during construction for the Lower Rio Trinidad project is computed from mid-year throughout its 13-year development period until lake filling is complete. The interest during construction at 12 percent is $838,455,000 for Lower Rio Trinidad, $10,811,000 for the Rio Caño Quebrado project and $1,222,371,000 for Rio Indio for a total of $2,071,637,000. These costs are added to the total project first costs for total project investment costs of $3,379,866,000. A capital recovery factor for the 50-year planning period is applied to get the annual average investment costs of $406,992,000. Annual operation and maintenance costs are added. Major replacement costs are estimated and are converted to an annual cost by discounting the future replacement costs of major components of the project back to completion of the project construction. Table 44 - 9 contains a summary of the $409,579,000 total annual costs.

Table 44 - 9 Summary of Annual Costs

Item	Costs ($)
Total Project First Costs - Lower Rio Trinidad	1,038,765,000
Total Project First Costs – Rio Indio	245,868,000
Total Project First Costs – Rio Caño Quebrado	23,596,000
Interest During Construction – Lower Rio Trinidad	838,455,000
Interest During Construction – Rio Indio	1,222,371,000
Interest During Construction – Rio Caño Quebrado	10,811,000
Total Project Investment Costs	3,379,866,000
Annual Average Investment Costs	406,992,000
Operation and Maintenance Costs	
.... Staff Costs – Lower Rio Trinidad	350,000
....Staff Costs – Rio Indio	500,000
Ordinary Maintenance Costs – Lower Rio Trinidad	1,054,000
.... Ordinary Maintenance Costs – Rio Indio	320,000
. Major Replacement Costs – Lower Rio Trinidad	272,000
..................Major Replacement Costs – Rio Indio	91,000
Total Average Annual Costs	409,579,000

Annual Benefits

NAVIGATION

The procedures and assumptions used in estimating the benefits are described in Volume One. The following paragraphs present the results of the economic investigations for the proposed Lower Rio Trinidad, Rio Caño Quebrado and Rio Indio projects. The 50-year period for the economic analysis of this proposal is 2024 to 2073.

The proposed Lower Rio Trinidad, Rio Caño Quebrado and Rio Indio projects should increase the reliability of providing water to accommodate the total daily number of lockages demanded. Table 44 - 10 provides the increase in the hydrologic reliability of providing the sum of the demands for both navigation and M&I water supply keyed to years. The hydrologic reliability percentages are obtained from the data used to develop Figure 44 - 4. The 99.6 percent level of reliability for this proposal is used to estimate the water supply benefits for navigation and the net change in reliability is used to estimate the reliability benefits for navigation and M&I water uses.

Table 44 - 10 Panama Canal Hydrologic Reliability
(Based on Period of Record from January 1948 to July 1998)

Current Demand Ratio	Year	Demand in Daily Average Number of Lockages (Navigation and M&I)	Hydrologic Reliability	
			Existing System (%)	With Lower Rio Trinidad, Rio Caño Quebrado & Rio Indio [1/] (%)
1	2000	38.68 [2/]	99.60	100.0
	2010	45.11	98.91	100.0
1.2		46.42	98.76	100.0
	2015	46.82	98.64	100.0
	2020	47.61	98.41	100.0
	2025	48.52	98.14	100.0
	2030	49.55	97.83	100.0
	2035	50.72	97.48	100.0
	2040	52.02	97.10	100.0
	2045	53.49	96.65	100.0
1.4		54.15	96.45	100.0
	2050	55.13	95.89	99.97
	2055	56.98	94.83	99.91
	2060	59.05	93.65	99.91
	2065	61.37	92.32	99.81
1.6		61.89	92.02	99.80
	2070	63.97	90.47	99.45
1.8		69.63	86.27	98.52

[1/] The lakes behind the Lower Rio Trinidad and Rio Caño Quebrado Dams should fluctuate from the normal operating lake level at EL. 33.53 m MSL down to the minimum operating lake level at EL. 22.86 m MSL and the lake behind the Rio Indio Dam should fluctuate from the normal operating lake level at EL. 80 m MSL down to the minimum operating lake level at EL. 50 m MSL.

[2/] 2000 Daily Demand is Average of 1993-1997.

With the proposed Lower Rio Trinidad, Rio Caño Quebrado and Rio Indio projects, water supply shortages for navigation should continue. The demand for the M&I purposes should always be met first. As these demands grow, the amount of water available to meet the demands for navigation should decrease. Thus, the benefits for the additional water supply are estimated at the value for navigation. With the addition of the proposed Lower Rio Trinidad, Rio Caño Quebrado and Rio Indio projects, these shortages should occur less frequently. With a hydrologic reliability of 99.6 percent, the proposed project should increase the amount of water supplied by approximately 24.41 equivalent lockages. The 99.6 percent hydrologic reliability should occur after the year 2068 with an equivalent daily average number of lockages of 63.09. Benefits for these amounts of additional water are attributable to navigation since the amount of M&I water demanded would be provided first. Therefore, all shortages would be attributable to navigation. The benefits are estimated using the toll revenue per lockage and the increased daily average number of lockages. The average annual benefits for water supply would be $234,652,000. Table 44 - 11 provides the estimate of daily shortages under the existing system, the remaining daily shortages with the proposed Lower Rio Trinidad, Rio Caño Quebrado and Rio Indio projects in operation, the annual benefits for meeting shortages and the average annual benefits.

Table 44 - 11 Benefits for Additional Water Supply for Navigation

Year	Daily Shortages In Lockages Under Existing System	Remaining Daily Shortages	Annual Benefits For Navigation ($)
2023	9.51	0.00	196,137,742
2030	10.87	0.00	224,201,428
2040	13.34	0.00	275,146,640
2050	16.45	0.00	339,265,866
2060	20.36	0.00	419,965,798
2070	25.29	0.88	503,407,982
Average Annual Benefits			234,652,000
With the Lower Rio Trinidad and Rio Caño Quebrado projects operating between 22.86 and 33.53 m and the Rio Indio project operating between 50 and 80 m, the system should provide a total of 63.09 lockages at the 99.6 percent level of reliability or 24.41 more lockages than the existing system.			

With the proposed Lower Rio Trinidad, Rio Caño Quebrado and Rio Indio projects, the reliability of the system to provide all of the water demanded by navigation and M&I water can be improved. Using the increase in hydrologic reliability, the forecast number of vessels converted to a daily average number of lockages, the toll revenue for each average lockage, and a project discount rate of 12 percent, the average annual benefits for navigation reliability attributable to the proposed Lower Rio Trinidad, Rio Caño Quebrado and Rio Indio projects is $19,452,000. Table 44 - 12 provides the forecast daily average number of lockages, the forecast value per daily lockage, the annual benefits for increased reliability, and the average annual benefits.

Table 44 - 12 Average Annual Reliability Benefits For Navigation

Year	Daily Average Number of Lockages	Value Per Lockage ($)	Annual Benefits For Navigation ($)
2023	40.0	2,260,000	14,562,000
2030	40.0	2,260,000	17,913,000
2040	40.0	2,260,000	23,998,000
2050	40.0	2,260,000	33,669,000
2060	40.0	2,260,000	44,727,000
2070	40.0	2,260,000	74,108,000
Average Annual Benefits			19,452,000

M&I WATER SUPPLY

The future demand for water supply for M&I purposes is based upon the growth in population. The ACP provided a forecast for the area surrounding the Panama Canal. The current usage is estimated at 4.0 equivalent lockages per day; an equivalent lockage is 55 million gallons of water. One equivalent lockage is added to the forecast to account for the burgeoning tourist industry, beginning in the year 2010. The increased reliability of the system to provide water supply for navigation similarly provides the same increase in reliability to provide water for M&I purposes. Using the increased hydrologic reliability of the system with the addition of the proposed Lower Rio Trinidad, Rio Caño Quebrado and Rio Indio projects, the current costs to the ACP to process finished water ($0.69 per 1,000 gallons), the number of daily lockages demanded, and a project discount rate of 12 percent, the average annual benefits for M&I reliability is $3,565,000. Table 44 - 13 displays the population forecast, the resulting number of equivalent lockages per day, and the benefits for M&I water supply.

Table 44 - 13 Average Annual Reliability Benefits For M&I Water Supply

Year	Population	Equivalent Lockages per Day	Annual M&I Water Supply Benefits ($)
2023	2,294,000	8.15	2,004,000
2030	2,688,000	9.55	2,877,000
2040	3,384,000	12.02	4,842,000
2050	4,259,000	15.13	8,551,000
2060	5,360,000	19.05	14,309,000
2070	6,746,000	23.97	29,840,000
Average Annual Benefits			3,565,000

HYDROPOWER

The amount of hydropower energy that can be produced by the system of Gatun Lake and Madden Lake should decline over time as the demands for navigation and M&I water supply increase. With the inclusion of the Lower Rio Trinidad project, the system will loss hydropower generation at Gatun Lake and Madden Lake due to the change in the operation of the system.

With the inclusion of the Rio Indio Dam project, however, the system can produce additional megawatt hours of hydropower for a net gain in hydropower generation. The value for hydropower energy used in this analysis is $0.070/kWh. On an average annual basis, the proposed project should have benefits of $2,888,000. Table 44 - 14 provides the net additional megawatt hours of hydropower generation and the resulting benefits.

Table 44 - 14 Average Annual Benefits For Hydropower Generation

Year	Net Generation [1] (MWh)	Annual Benefits For Hydropower ($)
2023	43,048	3,013,000
2030	41,753	2,923,000
2040	39,470	2,763,000
2050	36,280	2,540,000
2060	31,403	2,198,000
2070	23,940	1,676,000
Average Annual Benefits		2,888,000
[1] Net generation of Gatun, Madden, and Rio Indio above generation of Gatun and Madden hydropower plants.		

SUMMARY OF ANNUAL BENEFITS

As shown in Table 44 - 15, total average annual benefits for the proposed Lower Rio Trinidad, Rio Caño Quebrado and Rio Indio projects is $260,557,000.

Table 44 - 15 Summary of Annual Benefits

Benefit Category	Average Annual Benefits ($)
Navigation – Water Supply	234,6521,000
Navigation – Reliability	19,452,000
M&I – Reliability	3,565,000
Hydropower	2,888,000
Total	260,557,000

To perform an analysis of benefits versus costs, a common point in time is selected. This common point is at the completion of filling of the project, the end of the year 2022. In these analyses, it is important to note that the average annual benefits or average annual costs are the amortized value of the sum of the present worth of either the benefits or costs at the point of comparison. The development sequence for the proposed Lower Rio Trinidad and Rio Indio Dam projects would be to develop the Rio Indio Dam project first (2001 – 2010) and then the Lower Rio Trinidad Dam project (2009 – 2022).

The benefits attributable to the proposed Rio Indio project begin to accrue in 2010 when the reservoir is filled. Thus, the Rio Indio project benefits for the period 2011 to 2022 are escalated by the project discount rate, 12 percent, in order to estimate their total present worth of $4,446,416,000, in the year 2022. The average annual benefits for the Rio Indio project, accruing during the construction of the Lower Rio Trinidad project, are estimated at $535,423,000.

To estimate the interest during construction, similar calculations are made for the costs of each proposed project. For the proposed Rio Indio project, interest during construction is taken from year 2001 to year 2022 and the interest during construction for the proposed Lower Rio Trinidad project is taken from the year 2009 to the year 2022.

The sequence of development of the two projects is crucial to the estimate of average annual benefits and costs. If the Lower Rio Trinidad Dam project is developed first, then the average annual costs double in size and the average annual benefits reduce to less than half of the values that are estimated for the development sequence of Rio Indio and then Lower Rio Trinidad. This occurs because the first costs for the Lower Rio Trinidad Dam project are four times the cost for the Rio Indio Dam project ($812M vs. $245M). The estimate of interest during construction changes from approximately $4B to $2B. Likewise, the Rio Indio Dam project provides approximately 80 percent of the total average annual benefits of the combined projects ($212M of $258M). The estimate of benefits for the first project during the period of construction of the other project changes from $150M to $600M.

Total average annual benefits and average annual costs are estimated, and the ratio of benefits to costs and the net benefits (net of costs) are computed. In the first instance, the analysis determines the feasibility of the proposal. The net benefits determine which proposal provides the greatest value for the investment dollars. Table 44 - 16 provides the benefit to cost ratio and the net benefits.

Table 44 - 16 Economic Evaluation

Item	Value ($)
Average Annual Benefits	
Lower Rio Trinidad and Rio Caño Quebrado	260,557,000
Rio Indio	535,423,000
Total Average Annual Benefits	795,980,000
Average Annual Costs	
Lower Rio Trinidad	227,725,000
Rio Indio	177,712,000
Rio Caño Quebrado	4,143,000
Total Average Annual Costs	409,580,000
Benefit to Cost Ratio	1.9
Net Benefits	386,400,000

Internal Rate of Return

An internal rate of return analysis for this proposed project is performed. To accomplish this analysis, the annual construction costs are used as the investment, and the undiscounted benefits are used as return cash flows. The internal rate of return would be 23.1 percent.

Socio-Economic Impacts

The description of the environmental setting is based on field observations made while conducting field reconnaissance throughout Gatun Lake, specifically the Lower Rio Trinidad and Rio Indio areas with ACP personnel. Autoridad Nacional del Ambiente (ANAM), ACP, Asociacion Nacional para la Conservacion de la Naturaleza (ANCON), Electrical Transmission Agency, Smithsonian Tropical Research Institute (STRI), and Directorate of Mineral Resources personnel were interviewed to gain information on site characteristics and potential activities that could affect the project. In addition, extrapolations of the 2000 census data were used, and a review of the Informe de Cobertura Boscosa 1992 were used to determine the extent of forest cover.

Environmental Setting

This alternative combines three projects, the Lower Rio Trinidad (lake level (22.9 - 33.5 m) with Rio Caño Quebrado (lake level 22.9 - 33.5 m), and Rio Indio (lake level 50 - 80 m). This project will provide additional storage of water for Gatun Lake and 24.41 additional lockages per day on a continual basis. The project area consists of 27,259 ha within Gatun Lake and 5,600 ha within the Rio Indio watershed. The area near Gatun Lake is sparsely populated and has topography of rolling hills, and low regions near Gatun Lake. Near Rio Indio, the area is sparsely populated with terrains consisting of steep hills, as well as coastal regions. The Lower Rio Trinidad, Rio Caño Quebrado, and Rio Indio are west of the Panama Canal and flow northward from the Continental Divide into Gatun Lake. The watershed above the Lower Rio Trinidad with Rio Caño Quebrado and the Rio Indio dam project covers approximately 1052 km^2 and 381 km^2 respectively. The incremental impoundment area, which covers approximately 23,355 ha, consists of approximately 50 percent of forested land, 30 percent of pasture land (used by ranchers), 10 percent of cropland, and 10 percent of newly slashed and burned land. Gatun Lake's normal pool level is 26.7 m. The lake level during field observations (August 2001) was approximately 25.4 m.

LAND USE

The Lower Rio Trinidad project area encompasses the southwestern portion of Gatun Lake and areas along its shores. The areas to be flooded or partially flooded include the town of Escobal (population – 1,653), Nuevo Provenir (population – 121), Cuipo (population – 249), Ciricito (population – 72), La Arenosa (population – 242), La Garterita (population – 138), La Gartera (population – 348), and a few small isolated establishments.

The Rio Caño Quebrado project proposes to maintain the impoundment at pool levels between 22.9 and 33.5 m. The normal pool level is 26.67 m. La Laguna (population 246) and Pueblo Nuevo (population 47) are the only towns on the Rio Caño Quebrado arm. The lake is also used for fishing, bathing, and transportation. Houses in La Laguna and Pueblo Nuevo are constructed of forest products and/or of concrete.

Some areas along the shores of the Lower Rio Trinidad and Rio Caño Quebrado have been deforested. Approximately 65 percent of the lakeshore areas are forested, mostly with secondary growth. Farms and ranches of various sizes, as well as teak and African mahogany plantations, occupy the remaining land. Farm crops include maize, rice, beans, sugar, coffee, mangos, pineapples, and tobacco. Ranchers raise cows, horses, chickens, hogs, and tilapia. Some of the farmers and ranchers operate commercial enterprises, while others rely on cash crops and subsistence farming. No significant ore deposits or mineral resources are located along the Rio Caño Quebrado arm of Gatun Lake.

The Rio Indio project area is inhabited by about 2,300 people, residing in the towns of: Tres Hermanas (population – 200), Los Cedros (population – 80), El Coquillo (popoulation – 150), El Limon (population – 140), Los Uveros (population – 140), and La Boca de Uracillo (population – 110), and in approximately 30 smaller settlements. Downstream from the site, at El Limon, are 14 communities with a combined population of approximately 600. The largest of these is La Boca del Rio Indio, which has a population of more than 150.

Approximately 60 percent of the land in the project area is occupied by farms and ranches of various sizes as well as some teak plantations. Farm crops include maize, rice, beans, sugar, coffee, and tobacco. Ranches raise horses, cows, chickens, and hogs. Some of the farmers and ranchers run small commercial enterprises, or rely on cash crop and subsistence farming.

INFRASTRUCTURE

During site investigations in the Lower Rio Trinidad area, the town of Escobal was the largest settlement visited. Escobal has businesses, schools, churches, cemeteries, medical centers, residences, and paved roadways of good condition. A new and improved roadway (Highway 35) is adjacent to the project area near Escobal. Other establishments in the project area Nuevo Provenir; Cuipo; Ciricito; La Arenosa; La Garterita; La Gartera; and a few small isolated establishments have elementary schools, small cemeteries, churches and meeting centers, medical clinics, and a few small businesses (i.e. general stores). The towns and villages depend on Gatun Lake or groundwater wells for their potable water supply. Each community also had docks, small ports, and other boat access facilities. Goods are transported from one town to another by boat. No treatment of community waste is provided. Wastewater from showers and washing is discharged into the environment; some of it may eventually reach the Lower Rio Trinidad portion of Gatun Lake. Disposal of domestic waste is the responsibility of individual homeowners; some homes have septic tanks, while others have an outdoor latrine (a hole in the ground). There are some health problems, such as hepatitis, dysentery, dermatitis, intestinal parasites, and respiratory illnesses, which are attributable to the present waste disposal methods. No major industries or meat processing plants are located in the project area. The project area is traversed by unpaved horseback riding trails that link the various communities and by unpaved roads used by the ACP for maintenance. These roads are extremely important to the residents for transportation, community cohesion, commerce, and communication with neighboring communities because of the relatively isolated location of the project area.

In the Rio Caño Quebrado project area, La Laguna and Pueblo Nuevo have access to cemeteries, churches, and medical centers, and rely on Gatun Lake or groundwater wells for their drinking water supply. Most homes have electricity and limited telephone service. No treatment of community waste is provided. Wastewater from showers and washing is discharged into the environment; some of it may reach Gatun Lake. Disposal of domestic waste is the responsibility of individual homeowners; some homes have a septic system or an outdoor latrine. There are some health problems, such as hepatitis, diarrhea, dermatitis, intestinal parasites, and respiratory illnesses that are attributed to the present waste disposal methods. No known major industries or meat processing plants are located in the project area. La Laguna is accessible by a poorly maintained unpaved road that is usable only in the dry season (mid-December through March). The roads are rarely graded and receive little attention from either the Ministry of Public Works or the local government. Pueblo Nuevo is accessible only by an unpaved trail. These roads are extremely important to the residents for transportation, community cohesion, commerce, and communication with neighboring communities because of the relatively isolated location of the project area.

In the Rio Indio project area, the towns of El Limon, El Silencio, San Cristobal, and Piedra Amarilla have elementary schools. Several towns have cemeteries, churches, and medical centers. All these towns obtain water from rivers or groundwater wells. Some have electricity (from small generators) and limited telephone service. No treatment of community waste is provided. Wastewater from showers and washing is discharged into the environment; some of it might eventually reach Rio Indio and its tributaries. Disposal of domestic waste is the responsibility of individual homeowners; each home has an outdoor latrine. There are some known health problems, such as hepatitis, diarrhea, dermatitis, intestinal parasites, and respiratory illnesses which are attributed to the present waste disposal methods. No known major industries or meat processing plants are located in the project area. The only roads in the project area are unpaved and poorly maintained, and are usable only in the dry season (mid-December through March). The roads are rarely graded and receive little attention from either the Ministry of Public Works or the local government. These roads are extremely important to the residents for transportation, community cohesion, commerce, and communication with neighboring communities because of the relatively isolated location of the project area.

TERRESTRIAL HABITAT

The terrestrial habitat in the Lower Rio Trinidad and Rio Caño Quebrado project areas of Gatun Lake consists of tropical forest ecosystems, mostly secondary growth forests with patches of primary forest. About 65 percent of the lands along the Lower Rio Trinidad and Rio Caño Quebrado areas of Gatun Lake are forested and supports diverse wildlife populations. This area of Gatun Lake also contains islands inhabited by wildlife. Some of the wildlife species do not interact with species on the mainland; others migrate between the island and the mainland. The species interrelationships are of great interest to scientists studying tropical ecosystems. Slash and burn activities have opened tracts of land for farming and cattle grazing. The majority of the lakeshore is forested to the edge of the water. Terrestrial areas are used by migratory species as wintering, breeding, and feeding grounds. The complex and diverse tropical ecosystems offer habitat to connect a variety of wildlife communities and may provide critical wildlife habitat to many native species.

In Rio Indio, forests along the river that could support diverse wildlife populations cover about 90 percent of the areas along the Rio Indio and its tributaries. The forests also extend to the mountainous areas above the Rio Indio impoundment. As a result of slash and burn activities, there are no large contiguous tracts of forests at lower elevations in the impoundment.

ANIMALS ON ENDANGERED LIST

ANAM, Resolution 002-80 enacted on June 7, 1995, declared 33 mammals, 39 birds, and 11 reptiles and amphibians are in danger of becoming extinct in Panama. Although their presence has not been confirmed to date, some of the listed species of interest on the threatened list might be found in the project area. The manatee is an aquatic mammal known to inhabit Gatun Lake around the Barro Colorado Island; however, it has not been sighted in the project area.

AQUATIC HABITAT

Gatun Lake, one of the world's largest manmade lakes, was created during the construction of the Panama Canal. The lake's water depth and quality vary widely. Aquatic habitat ranges from inundated forests to clear water in areas distant from shipping lanes. The Lower Rio Trinidad and Rio Caño Quebrado areas of Gatun Lake provide habitat for a variety of wildlife species, both resident and migratory, as well as for native or introduced fish, and other aquatic species.

Rio Indio in the project area has characteristics typical of streams in mountainous regions. Its water is clean and cool, and its bottom ranges from sand to boulders, with numerous riffles, runs, and pools. Tributaries to Rio Indio include four major streams: Rio El Torno, Rio Uracillo, Rio Teria, and Rio Riacito, and 20 smaller streams. The river is approximately 16 km long, its width ranges from 3 m (in the dry season) to 10 m. The tributaries appear to support some fish communities; however, information about these communities is limited.

WETLANDS

Areas that contain hydric soils and hydrophytic plant communities, and that are subject to hydric conditions are termed wetlands. Wetlands occur in topographic areas where water remains pooled long enough to produce hydric soil conditions and wetland plant communities. Wetlands in the Lower Rio Trinidad and Rio Caño Quebrado project areas consist of shallow water habitats and lands subject to frequent flooding. Shallow water areas along the banks of the Lower Rio Trinidad and Rio Caño Quebrado areas of Gatun Lake receive sunlight to a depth of approximately 1 m. Sunlight stimulates growth of submergent, emergent, or floating mats of aquatic vegetation. Wetlands in the project area are stressed due to excessive sediments, municipal waste, agricultural runoff, and other debris carried in the runoff.

Wetlands in the Rio Indio project area consist of forested riparian habitat and are limited by their relatively steep topography. The width of the riparian habitat within the impoundment area varies from approximately 5 - 50 m. Approximately 90 percent of the streams both above and below the dam site along the Rio Indio and its tributaries are bordered by forested riparian habitat.

AIR QUALITY

Air quality in the project area is generally good, except during the slash and burn activities. At the end of the dry season (in March or early April), areas of forest and secondary growth are burned and cleared for agricultural use. During this period, the air is filled with smoke and ash, which may be transported by winds to the Lower Rio Trinidad and Rio Caño Quebrado areas of Gatun Lake. Based on observations in the Rio Indio project area, approximately 10 percent (or 400 hectares) of forested land is burned annually. Air quality monitoring has not been implemented within the project area.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

Barro Colorado Island is an international center for tropical research and one of the first biological reserves established in the Neotropics. From 1923 through 1940, a scientific committee of the U.S. National Academy of Sciences administered the biological reserve/laboratory. In 1940, by an Act of the United States Congress, the facility was renamed the Panama Canal Zone Biological Area, and in 1946, the responsibility for its maintenance was assigned to the Smithsonian Institution. With the Panama Canal Treaty Implementation in 1977, the island was granted the category of National Monument and to date it continues to be managed by the Smithsonian Institute. It should also be noted that most of the Atlantic region of Panama is within the interest and objectives of the Mesoamerican Biological Corridor, an international project to conserve biodiversity.

In the pre-Columbian period, Rio Indio was a language frontier; the inhabitants on each side of the river spoke a different native language. During the Spanish colonial period, the river served as a political boundary. The project area has a high potential to be rich in archaeological and historical remains.

Environmental Impacts

TERRESTRIAL HABITAT

The impacts of the project on terrestrial habitat in the Lower Rio Trinidad and Rio Caño Quebrado areas of Gatun Lake could be substantial. The boundary between two types of habitats, in this case between a forest and a lake, is called an ecotone. Ecotones are inhabited by a variety of species from neighboring habitats, and are unique, with high species diversity. Considering the proposed operating levels for both impoundments, between 22.9 - 33.5 m as the normal zone of operation there may be substantial erosion of the shoreline as pool levels rise and fall. Terrestrial habitat that would be inundated above the 26.7 m (existing level) to the 30.5 m proposed normal pool level consists of 21,912 ha for the Lower Rio Trinidad project. The permanent raising of the water level in Rio Caño Quebrado Lake will impact wildlife habitat as approximately 3,443 ha of additional land will be inundated. The placement of a dam structure, access roads and pump stations would permanently impact terrestrial habitat. Wildlife species that are able to relocate to suitable areas will compete with similar species for resources; species that are not able to relocate will not survive. As a result, competition for natural resources in surrounding habitat areas will increase. This is considered a secondary impact to terrestrial habitat outside the proposed zone of inundation and construction.

The terrestrial impacts of the Rio Indio project, which is located in area of relatively high quality forest habitat, would be substantial. With the creation of the lake, the migratory routes of some species could be adversely affected. Forested areas along lower elevations would be lost as a result of the impoundment. The only forests that would remain near the Rio Indio reservoir and its drainage basin would be confined to the higher elevations, where the vegetation and species may be completely different from those found at lower elevations. Natural communities are linked together by complex interactions and relationships among various species, therefore impacts to upper forested areas may occur resulting from the inundation of the lower forests.

ANIMALS ON ENDANGERED LIST

The severity of impacts on endangered species cannot be determined at this time, because although it is expected that some of the listed species are found in the region, it is not known which of the listed species inhabit the proposed project area. Some endangered and/or threatened species may use the Lower Rio Trinidad and Rio Caño Quebrado areas of Gatun Lake during some or all parts of their life cycle.

WATER QUANTITY

The impacts of the Lower Rio Trinidad and Rio Caño Quebrado projects on water quantity would be substantial. The increase in the volume of water could have negative impacts to lakeshore communities as well as on existing ecosystems. The same is true if the lake level is lowered and maintained at 22.9 m.

The impacts of the Rio Indio project area on water quality would also be substantial. The volume of water will increase, making fresh water available during the dry season. The impacts downstream from the dam would be significant. Sediment loads would be deposited upstream from the dam as water velocity slows. Downstream from the dam the water will be released at an increased velocity, causing erosion of banks and river bottoms. Seasonal flooding could be significantly reduced. It would also be possible to periodically release water in appropriate amounts to avoid problems with water quality and temperature downstream. The cumulative impacts downstream from the dam site depend on the amount of water being released.

WATER QUALITY

Project impacts on water quality are not known. Damming the Lower Rio Trinidad and Rio Caño Quebrado could increase the amounts of nutrients and debris in this portion of Gatun Lake. A pilot plant tilapia farm is in the project area and may affect water quality. The rate nutrients and debris enter the lake will determine the severity of their impact on water quality. Project implementation could cause an increase in turbidity, which would interfere with photosynthesis and deprive plants and other aquatic species from sunlight. Aquatic plants and organisms serve to maintain water quality. The dam would interfere with the circulation of freshwater throughout the Gatun Lake environment. Species inhabiting specific depths could be impacted when the lake depth increases to 33.5 m and/or decreases to 22.9 m.

The impacts of the Rio Indio project on water quality could be positive. The people living downstream from the dam and around the impoundment would have access to a higher quality water supply. Water quality in the impoundment area would differ from water released downstream from the dam. If the water in the impoundment area does not circulate or turn over periodically, it could become anoxic. A change in temperature, dissolved oxygen, turbidity, or pH could change water quality.

DOWNSTREAM AQUATIC FAUNAL HABITAT

The impacts of the project on aquatic faunal habitat could be substantial. The project may affect the breeding and nursery habitat of many aquatic species. Impacts to fish spawning areas may be detrimental when turbidity, nutrient content, and depth of the water suddenly increase or decrease, by altering the conditions needed for successful fish hatching. Plant populations may decrease due to fluctuating water depths, clarity, and quality. Invertebrate populations may decline, which could reduce the food supply for fish and other aquatic species.

Impacts to downstream aquatic faunal communities in the Rio Indio project area could be substantial, because the dam structure will prevent migration throughout the riverine habitat. The dam structure would be designed for multi-level releases to maintain a water level downstream from the dam site. The dam would act as a large sediment trap; thus, the released water could have low turbidity, which could result in better visibility and increase predation on the fish species. Aquatic faunal habitats downstream would be deprived of the beneficial nutrients and silts that were transported in the sediment. Native riverine fish species may be negatively impacted as a result of the project; the extent of the impact is not known.

FUTURE LAKE AQUATIC PLANT COMMUNITY

The impact of the project on future aquatic plant communities depends on water quality and stability of water levels. Plant species in the Lower Rio Trinidad and Rio Caño Quebrado portions of Gatun Lake could be impacted by fluctuating water levels. Aquatic plant communities could be impacted during project implementation; however, they could re-establish after conditions stabilize.

The severity of impacts from the Rio Indio project will depend on water level fluctuations. Since water levels are anticipated to fluctuate widely, large portions of the shores would be covered with mud, allowing neither aquatic nor terrestrial plants could thrive.

AQUATIC FAUNA INHABITING AFFECTED AREAS

The proposed project could have some unavoidable, adverse environmental impacts on aquatic fauna in the Lower Rio Trinidad, Rio Caño Quebrado, and associated rivers and tributaries. These impacts should be identified and minimized with appropriate mitigation measures (to be discussed in a feasibility level study). Gatun Lake has populations of peacock bass and tilapia, both introduced species that have adapted well. However, several native riverine species that formerly occupied the impoundment have disappeared.

The impacts of the Rio Indio project on aquatic fauna could be substantial, since the habitat area would change from riverine to lacustrine. Some aquatic species would continue to inhabit the area; however, non-native fish species would become dominant in the impoundment area and native riverine species would be pushed upstream or extirpated. Other manmade lakes in the Republic of Panama have been stocked with peacock bass and tilapia, both of which have adapted well. The impoundment area would probably be stocked with these species to promote sport fishing and to provide the local communities with fish for food.

WETLANDS

The impacts to wetlands could be significant. Inundation of wetlands could cause them to become aquatic habitat. The changes in water depth caused by the project may lead to increased or decreased sedimentation and turbidity, which could hamper the biological processes in the wetlands and decrease their productivity. Such impacts could be detrimental to the health and sustainability of the Lower Rio Trinidad and Rio Caño Quebrado areas of Gatun Lake. Fish and other aquatic species use shallow water areas as spawning grounds, as well as habitat for juvenile aquatic species who survive in the shallows until large enough to venture into deeper water. These wetlands are vital to the sustainability of this portion of Gatun Lake, including the Lower Rio Trinidad and Rio Caño Quebrado areas.

The impacts to wetlands both upstream and downstream from the Rio Indio project area could be significant. Owing to the topography of the project area, a number of wetlands could be impacted. It is possible that although the reservoir level will fluctuate, new wetlands could develop in the littoral zones. Downstream from the dam site, wetlands along the minimal flow zone would survive; wetlands that depend on seasonal flooding for survival may be adversely affected.

AIR QUALITY

During project implementation, emissions from construction equipment, as well as from slash and burn activities, could cause deterioration of air quality. After project implementation, the air quality may be impacted by the operation of the power generation facility and the pumping stations.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

The potential impacts on cultural resources and historic properties from the Rio Indio project can be defined and mitigated. In the La Boca de Uracillo area in particular, there are previously identified archaeological sites. The project area is relatively large and is known to contain pre-Columbian sites; therefore, the presence of cultural resources and historic properties is highly probable. Prior to construction, surveys to locate cultural resources and historic artifacts would be conducted, and the important sites would be preserved or salvaged as appropriate.

SOCIO-ECONOMIC IMPACTS

The socio-economic impacts of the project could be substantial. The relocation of the towns and other small communities along the lakeshore would be an important issue. The average monthly income of families in the project area ranges from less than $100 to $200 per month. No indigenous groups are known to reside in the impact area. Land use would be greatly impacted by the inundation of pastures and agricultural lands to expand the impoundment. The relocation of agricultural and ranching activities would be critical, because approximately 10 percent of the land in the impoundment area is used for farming and ranching. After the water level is raised, additional agricultural land could be lost as islands are created from isthmuses. The incremental surface area of the proposed lake is 11,155 ha; another 1,504 ha from the Lower Trinidad Rio

Caño Quebrado project and 760 ha from the Rio Indio project will be occupied by the dam and construction areas, including permanent disposal areas.

During construction, the influx of workers could create a temporary demand for additional housing, resulting in an increase in housing values near the dam site. However, after completion of the project, the workers could leave, the housing demands could drop, and the housing values could return to pre-construction levels. Currently, all residents have access to public schools and health centers. During construction, these services should continue to be available, and additional public and community services may be offered. After construction, these services would return to the normal level.

To construct the dam, some existing roads must be improved and some new roads must be built. However, some paved and unpaved roads within the impoundment area would be eliminated, which could change traffic patterns and could cause some communities to lose overland transportation, communication, cohesion, and commerce with other communities. During construction, the traffic volumes over both new and existing roads systems would increase; however, following completion of construction, the traffic volumes could decline. Noise levels would temporarily increase during construction and could negatively impact noise-sensitive receptors; after construction noise levels may remain elevated as a result of the power generation facility and pump stations.

Communities receiving people displaced by the project could be negatively impacted by overcrowding and by competition for jobs, land, and working areas. Construction of the dams would permanently displace some people and disrupt lives through the division of communities, separation of families, and loss of livelihood. Following completion of the impoundment, the tourism trade in the affected region, including sport fishing and ecotourism, could increase.

Additional Environmental Information Required

This section identifies the subject areas for which additional data are required to evaluate in further detail, the scope and magnitude of the potential effects of the Lower Rio Trinidad and Rio Indio alternative. The subject areas are discussed by impact category.

SOCIO-ECONOMIC IMPACTS

Conduct a SIA. The SIA would consist of three tasks: scoping, assessment, and mitigation and monitoring. The following information should be developed:

- Business, Industrial, and Agricultural Activities;
- Employment;
- Land Use;
- Property Values;
- Public and Community Facilities and Services (including utilities and schools);
- Transportation;
- Housing;
- Health (vector routes);
- Population;

- Community Cohesion; and,
- Recreational Resources.

TERRESTRIAL AND AQUATIC HABITAT

- Prepare site-specific habitat maps to ensure that the major types of aquatic habitat are identified and quantified.
- Conduct field studies to locate rare and unique habitats, such as wetlands, primary forests, roosting sites, foraging areas, old growth, and migration flyways.
- Determine the present quality and ecosystem value of existing habitats within the Gatun Lake project area.
- Coordinate with local experts to identify and evaluate aquatic and terrestrial habitat areas.
- Prepare species inventory lists for each site area, identifying their status as native or exotic and whether they are threatened and or endangered species.
- Conduct additional research into water currents and estimated turbidity levels to evaluate impacts to the shallow areas along Barro Colorado Island.
- Address cumulative effects caused by natural flow diversions.

ANIMALS ON THE ENDANGERED LIST

- Compile habitat maps to assess the availability and quality of suitable habitats for the animals on the endangered and/or threatened species list.
- Establish field methodology to assess wildlife habitat values.
- Conduct site surveys to determine the presence of selected species or their habitats.
- Develop candidate mitigation measures for the appropriate project alternatives to be considered in the Conceptual Phase.
- Coordinate with local experts on the presence of endangered species.

WATER QUALITY

- Since limited water quality data are available for the Gatun Lake area, compile information on total suspended solids, conductivity, total dissolved solids, dissolved oxygen, nutrients, pH, and coliform bacteria.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

- Information regarding cultural resources and historic properties in the project area is incomplete. Additional evaluation studies should be completed to identify any such resources and/or properties.

Evaluation Matrices

In accordance with evaluation procedures described in Volume One, the following tables reflect the conclusions derived for this alternative. A summary table with ranking is provided in Volume One. Tables 44 - 17 through 44 - 19 present the evaluation of the proposed Lower Rio Trinidad project as related to developmental effects, environmental effects, and socio-economic effects.

Table 44 - 17 Developmental Effects

Evaluation Criteria	Function	Measure [1/]	Importance [2/]	Composite [3/]
Water Contribution (Water Yield)	Meets M&I Demands	10	10	100
	Supplements Existing System	10	10	100
	Satisfies Future Canal Needs/Expansion	5	10	50
	Additional Hydropower Potential	1	5	5
Technical Viability	Design Constraints	2	6	12
	Feasibility of Concept	2	6	12
Operational Issues	Compatibility	8	6	48
	Maintenance Requirements	4	2	8
	Operational Resources Required	4	2	8
Economic Feasibility	Net Benefits	10	9	90
	Total			433

[1/] Measure - A numerical from 0 to 10 value representing the degree or level the alternative satisfies the criteria. Value of 10 indicates the most significant beneficial impact and 0 the most significant adverse impact.
[2/] Importance - A weighting factor from 0 to 10 to balance the significance of a criteria to the others.
[3/] Composite - the product of the measure and importance.

Table 44 - 18 Environmental Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Terrestrial Habitat	2	8	16
Animals on Extinction List	2	10	20
Water Quantity Impacts – Lake	8	10	80
Water Quantity Impacts -- Downstream	4	7	28
Water Quality	5	10	50
Downstream Aquatic Fauna Habitat	3	8	24
Future Lake Aquatic Plant Community	6	8	48
Aquatic Faunal Inhabiting Affected Area and Upstream Tributaries	4	5	20
Potential for Fishing on Lake	6	6	36
Wetlands	2	4	8
Air Quality	5	3	15
Cultural Resources and Historic Properties	3	10	30
Total			375

[1/] Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
[2/] Importance - 1 to 10 increasing in importance.
[3/] Composite - the product of the measure and importance.

Table 44 - 19 Socio-Economic Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Land Use	2	7	14
Relocation of People	1	10	10
Relocation of Agricultural/Ranching Activities	1	6	6
Post-Construction Business	6	5	30
Post-Construction on Existing Employment	6	5	30
Property Values During Construction	7	4	28
Property Values Post-Construction	5	5	25
Public/Community Services During Construction	6	4	24
Public/Community Services Post-Construction	5	8	40
Traffic Volumes over Existing Roadway System During Construction	3	5	15
Traffic Volumes over New Roadway System Post-Construction	5	5	25
Noise-Sensitive Resources or Activities	4	4	16
Communities Receiving Displaced People	1	8	8
Community Cohesion	1	8	8
Tourism	6	5	30
Total			309

[1/] Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
[2/] Importance - 1 to 10 increasing in importance.
[3/] Composite - the product of the measure and importance.

Pertinent Data

Table 44 - 20 presents pertinent data for the proposed Lower Rio Trinidad project.

Table 44 - 20 Pertinent Data for Operating Option 1

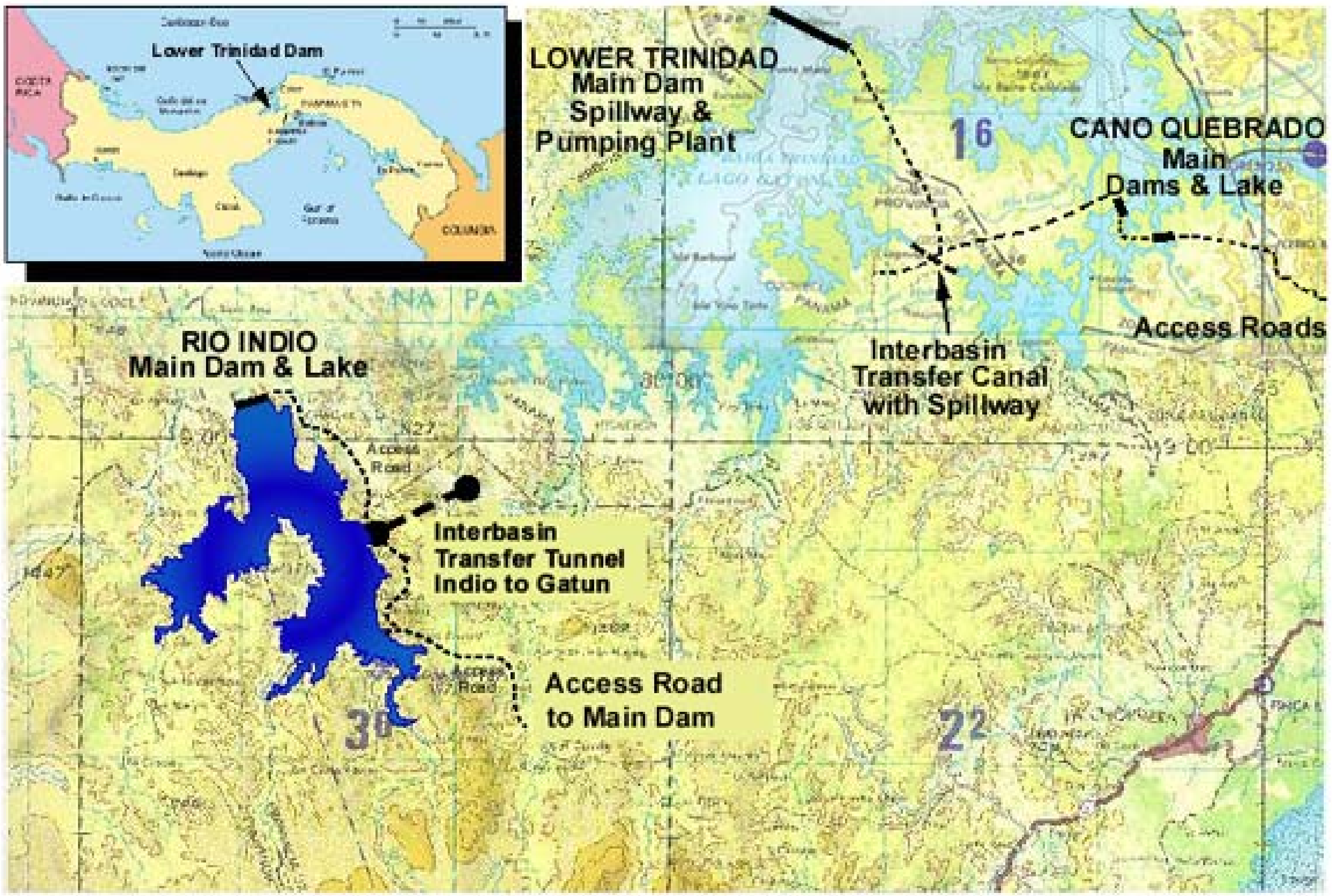
GENERAL	Gatun	Trinidad and Quebrado	Rio Indio
Drainage Area above Dam Site	1,261.5 km^2	1,051.5 km^2	381256 km^2
Average Annual Flow at Dam Site	50.4 CMS	39.6 CMS	25 CMS
LAKE			
Elevation of Maximum Operating Lake Level	26.67 m MSL	33.53 m MSL	80.0 m MSL
Elevation of Maximum Flood Storage Lake Level	26.74 m MSL	34.14 m MSL	82.5 m MSL
Elevation of Minimum Operating Lake Level	25.91 m MSL	22.86 m MSL	50 m MSL
Useable Storage between Max. and Min. levels	200.4 MCM	2052.9 MCM	993 MCM
Area at Maximum Operating Lake Level	27,514 ha	25,355 ha	4,280 ha
Area at Maximum Flood Storage Lake Level	27,550 ha	26,459 ha	4,440 ha
Area at Minimum Operating Lake Level	27,321 ha	10,170 ha	2,360 ha
Top Clearing Elevation	33.5 m MSL	33.53 m MSL	80 m MSL
Lower Clearing Elevation	25 m MSL	25m MSL	50 m MSL
EMBANKMENTS			
Dam – Rock Fill Embankment			
Top Elevation of Dam	34.5 m MSL	34.5 m MSL	83.5 m MSL
Fixed Crest Width	13 m	13 m	13 m
Height above Lowest Foundation	18 m	28 m	73.5 m
Overall Length of Dam	varies m	4480/422 m	891 m
SPILLWAY			
Type of Spillway	Gated Ogee	Gated Ogee	Uncontrolled Ogee
Number of Gates	14	8	-
Width of Gates	13.72 m	18.33 m	-
Net Length	192.02 m	149.35 m	-
Total Length	246.27 m	238m	120 m
Elevation of Crest	21.03 m MSL	25.91 m MSL	80.0 m MSL
Maximum Discharge	5150 CMS	6038 CMS	920 CMS

INDIO ONLY	
INTER-BASIN TRANSFER TUNNEL	
Tunnel diameter	3.0 m
Tunnel length	5.2 m
Inlet invert	60 m MSL
Outlet invert	40 m MSL
Tunnel capacity	42.5 CMS
HYDROPOWER PLANTS	
Dam	
Type of hydropower plant construction	Reinforced concrete
Number of units	2
Capacity of each unit	12.5 MW
Inter-basin Transfer Tunnel	
Type of hydropower plant construction	Reinforced concrete
Number of units	1
Capacity of unit	5 MW
CONSTRUCTION/POWERHOUSE DIVERSION	
Diversion length	1500 m
Tunnel diameter	8 m x 8 m
Inlet invert	10 m
Outlet invert	8 m
MINIMUM FLOW CONDUIT	
Conduit diameter	1.2 m
Conduit length	800 m
Inlet invert	10 m
Outlet invert	8 m
Conduit capacity	2.5 CMS

EMBANKMENTS	
Dam	
Type of dam	Rock fill embankment
Top elevation of dam	83.5m
Fixed crest width	13 m
Height	38.5 m
Overall length of dam	632m
Saddle dam (North)	
Type of saddle dam	Earth/rock fill embankment
Top elevation of saddle dam	83.5 m MSL
Fixed crest width	13 m
Overall length of saddle dam	255 m
Saddle dam (South)	
Type of saddle dam	Earth/rock fill embankment
Top elevation of saddle dam	83.5 m MSL
Fixed crest width	13 m
Overall length of saddle dam	272 m

Plate 44 - 1 Project Location

LOWER TRINIDAD / CAÑO QUEBRADO / RIO INDIO



Project Location Map

SECTION 45

Lower Rio Trinidad 22.9m to 33.5m
Rio Caño Quebrado 22.9m to 33.5m
Upper Rio Indio 50m

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

Synopsis

The development plan presented herein combines a dam and a lake in the Trinidad basin within the Panama Canal watershed at Gatun Lake southwest of Gatun Locks, a dam and lake on the Rio Caño Quebrado basin of the Panama Canal watershed within Gatun Lake, and a dam and lake on the Rio Indio to the west of Lake Gatun. Water impounded in the Lower Rio Trinidad and Rio Caño Quebrado Lakes should add storage to the Panama Canal system of lakes. This additional storage would be further enhanced by incorporation of a pumping plant into the Lower Rio Trinidad Dam. This facility allows storage of excess water from Gatun Lake and extended usage of the waters contained in the Lower Rio Trinidad and Rio Caño Quebrado Lakes. Water impounded at the Rio Indio site should comprise new water for use in the Panama Canal System and would be transferred via a tunnel to the Lower Rio Trinidad Lake.

The Rio Trinidad watershed is located on the western side of the Panama Canal watershed. The proposed dam site is located within Gatun Lake across the Trinidad arm near the town of Escobal. The proposed dam extends from Punta Mala, on the west shore of Gatun Lake, to Guacha Island, then across to the eastern shore of the Trinidad arm, just south of the South Range Point lighthouse. This alignment follows closely the proposed path found in the Study and Report on Increasing the Water Supply of the Panama Canal (referred to as the Tudor Report), prepared by Tudor Engineering Company, San Francisco, California 1962, for the Panama Canal Company. Plate 45 - 1 shows the location of the proposed Lower Rio Trinidad Dam project. The structures for the proposed Lower Rio Trinidad project consist of a rock fill dam constructed by underwater deposition of fill materials, a large pumping plant, and a gated spillway. This spillway should have 11 gate bays, each measuring 18.33 m wide. The pumping plant consists of the pumping station; intake and outflow facilities are separated from the lakes above and below the Lower Rio Trinidad dam by large gate structures. The total project first costs of the proposed Lower Rio Trinidad project are estimated at $1,038,765,000.

The Rio Caño Quebrado watershed comprises a portion of the western side of the Panama Canal watershed. The dam site is located within Gatun Lake across the Rio Caño Quebrado arm near the city of La Laguna and would be constructed in two parts. The first section of the dam should extend from Punta Manguito on the west shore of the Rio Caño Quebrado arm of Gatun Lake in a northwest-southeast orientation to the eastern shore of the Rio Caño Quebrado arm. The second section should extend in an east-west orientation across the Rio Caño Quebrado eastern arm just north of the mouth of the Rio Paja. The lake formed by these dams would be communicate directly with Lower Rio Trinidad Lake at all operational levels.
Plate 45 - 1 shows the location of the proposed Rio Caño Quebrado Dam project. The main features required for the proposed Rio Caño Quebrado project would be the two sections of rock fill dam and a dug channel connecting between Rio Caño Quebrado and Lower Rio Trinidad Lakes. The total project first costs of the proposed Rio Caño Quebrado project are estimated at $23,596,000.

The Rio Indio watershed is located adjacent to the western side of the Panama Canal watershed. The proposed Rio Indio dam site is 25 km inland from the Atlantic Ocean and near the mountain Cerro Tres Hermanas. Plate 45- 1 shows the location of the proposed Rio Indio project. The structures for this project consists of a rock fill dam, two saddle dams, an uncontrolled ogee spillway, inter-basin transfer facilities, two hydropower plants, and other outlet works. The tunnel should transfer water from Rio Indio Lake to the Panama Canal watershed as needed for canal operations. The total project first cost of the proposed Rio Indio project is estimated at $199,177,000.

The Lower Rio Trinidad poses great construction difficulties because of the extremely large quantities of underwater fill required for construction of the dam. It requires extensive drilling and site investigation prior to construction and, because of the uncertainties inherent with this type of construction; extensive unforeseen costs may be encountered during construction. Also, the spillway and pumping plant must be constructed in island settings where the structures and appurtenances practically engulf the island areas. This poses extreme space limitations on the construction effort and is very costly.

The proposed Lower Rio Trinidad and Rio Caño Quebrado Dam projects, in conjunction with the Rio Indio Dam project, should contribute greatly to the hydrologic reliability of the Panama Canal to serve its customers and should reduce the need for imposing draft restrictions and resulting light loading of vessels during traditional periods of low water availability. The existing hydrologic reliability of the Panama Canal, based on the period of record from January 1948 through July 1998 and current demands (38.68 lockages), is approximately 99.6 percent. The hydrologic reliability with the demand increasing to 120 percent of the current level (46.42 lockage) would be 98.8 percent. With construction of the proposed Lower Rio Trinidad, Rio Caño Quebrado, and Rio Indio projects, the existing high hydrologic reliability could be continued as demand for lockages increases up to 39.92 percent above current demand levels (up to 15.44 lockages).

Site Selection

The Lower Rio Trinidad dam project definition and description is developed with a view toward maximizing the water impounded, while minimizing the volume of material required for construction of the dam and minimizing the number of saddle dams required to contain the lake. The site chosen for the dam is 10 km south of Gatun Locks and 14 km southwest of the navigation channel. The dam would be approximately 4 km northeast the town of Escobal. This site can accommodate construction of a dam with a maximum operating lake level of EL. 30.5 m MSL. Flood storage accommodations are between EL. 30.5 and 28.7 m MSL. The proposed Rio Caño Quebrado dam site is recommended in previous reports and is chosen as a potential alternative for this study. The project definition and description are developed with a view toward maximizing the water impounded, while minimizing the volume of material required for construction of the dam and minimizing the number of saddle dams required to contain the lake. The project area is also reviewed for other possible dam sites that might be more feasible.

The site chosen for the proposed Rio Caño Quebrado Dam would be approximately 22 km southeast of Gatun Locks and 14 km northwest of the Pedro Miguel Locks. The dam would be approximately 7 km southwest of Barro Colorado Island and 4 km northeast of the town of La Laguna. This site should accommodate construction of a dam with a maximum operating lake level at EL. 30.5 m MSL. Flood storage would be accommodated above the normal operating levels between EL. 24.8 and 30.5 m MSL.

The proposed Upper Rio Indio dam site is chosen to maximize the water impounded, while minimizing the volume of material required for construction of the dam, the number of saddle dams required to contain the lake, and the impact on the existing populated areas in the lower

Rio Indio Basin. To accomplish these ends it is desirable to locate the dam immediately above the confluence of the Lower Rio Trinidad and the Rio Uracillo, as far downstream in the upper arm of the Rio Indio watershed as possible. The ideal location is where the surrounding hillsides are relatively steep and high, and the valley is relatively narrow, features afforded by the site chosen.

The proposed Upper Rio Indio dam site is 29 km inland from the Atlantic Ocean and 4 km upstream from the confluence of the Rio Indio and the Rio Uracillo. This site should accommodate construction of a dam with a normal operating lake level at EL. 50 m MSL and a maximum flood lake level at EL. 53 m MSL.

Hydrologic Considerations

Lower Rio Trinidad
The Rio Trinidad flows northward from the Continental Divide to the Gatun Lake. The headwater of the watershed begins at EL. 1,000 m MSL, approximately 75 km inland, and falls to El. 26 m MSL at Gatun Lake. The distribution of the average annual rainfall over the Rio Trinidad watershed varies from a high of 2,200 mm in the western part of the watershed to 2,000 mm on the eastern side of the watershed. The proposed Lower Rio Trinidad Lake site receives runoff from approximately 750 km^2 of the upper portion of the watershed. Rainfall runoff produces an average annual flow of 32 CMS at the proposed dam site.

The discharge at the Lower Rio Trinidad Dam site was obtained by drainage area ratio to the established record for Gatun. The Gatun Lake runoff is based on records developed by the U.S. Army Corps of Engineers Hydrologic Engineering Center and the PCC in a separate study.

Since the Lower Rio Trinidad Lake is located within Gatun Lake the monthly evaporation rates established for Gatun Lake are considered appropriate for the evaporation rates of Trinidad Lake.

Rio Caño Quebrado
Three major rivers flow northward from the Continental Divide into Rio Caño Quebrado Lake; Rio Caño Quebrado, Paja and Los Hules. The headwaters of the watershed begin at EL. 1,000 m MSL approximately 75 km inland and fall to El. 26 m MSL at Gatun Lake. The average distribution of annual rainfall over the Rio Caño Quebrado watershed varies from 2,200 mm in the western part of the watershed to 2,000 mm on the eastern side. The proposed Rio Caño Quebrado Lake should receive runoff from approximately 310 km^2 of the existing Panama Canal watershed. Rainfall runoff produces an average annual flow of 10.2 CMS at the dam site.

Upper Rio Indio
The Upper Rio Indio flows northward from the Continental Divide to the Atlantic Ocean. The headwaters of the watershed begin at EL. 1,000 m MSL approximately 75 km inland and fall to mean sea level at its mouth. The distribution of the average annual rainfall over the Rio Indio watershed varies from a high of 4,000 mm at the coast to a low of 2,500 mm in the middle watershed area. It increases again to over 3,000 mm in the Continental Divide. The proposed Indio Lake should receive runoff from approximately 256 km^2 of the upper portion of the

watershed. Rainfall runoff produces an average annual flow of 16.8 CMS at the proposed dam site.

The calculated discharge at the Rio Indio dam site is extrapolated, recorded, and correlated stream flow data from the Boca de Uracillo hydrologic station. This station began operation in 1979 and is located on the Rio Indio, approximately 6 km upstream from the dam site. Data established from a statistical correlation, with the discharge data of the Rio Indio at Limon, 3 km downstream from the dam site, using standard hydrologic techniques, completed missing data and increased the period of record. Utilization of the double mass curve method satisfactorily verified the consistency of the data measured and correlated.

Due to the proximity of Upper Rio Indio to Gatun Lake, and because of the absence of site-specific information, the monthly evaporation rates established for Gatun Lake are considered appropriate for the evaporation rates of Indio Lake.

Geologic Considerations

Lower Rio Trinidad

The proposed Lower Rio Trinidad Dam site was investigated in 1962 by Geo-Recon, Inc. of Seattle, Washington, as part of the Tudor report. The investigation consisted of seismic velocity and electrical resistivity profiles in conjunction with four test borings (all located in the lake and drilled by the Panama Canal Company). The results of the geophysical surveys reportedly compared well with the logs of the test borings in the deep-water areas (up to 23 m deep) of Gatun Lake. In June 1963, Tudor Engineering submitted a report including additional foundation investigations. The foundation investigations were made by the firm Shannon & Wilson, Inc., Soil Mechanics and Foundation Engineers, from Seattle, Washington, and consisted of 77 cone penetrometer borings, 24 classification borings, 11 undisturbed sample borings, and 6 field vane shear borings. The investigations submitted by Shannon & Wilson, Inc were recently reanalyzed in Geology of the Proposed Dam Across Trinidad Arm of Gatun Lake, by Mr. Pastora Franceschi S., for the Geotechnical Section of the Panama Canal Authority.

In the lake areas, the investigations disclosed that overburden material included recent lake deposits, Atlantic Muck Formation, alluvial deposits, and residual deposits. Between the west shore and Guacha Island these deposits consist of soft to very soft clay, silt, sand and peat (Atlantic Muck Formation) overlying soft to hard deposits of clay, silt, sand and gravel derived both from alluvial deposition and the weathering of bedrock. The upper two phases of the Atlantic Muck Formation, judged to be the most compressible portion of the formation, was found to have an average thickness of about 18.3 m and a maximum thickness of 22.9 m. Recent, soft lake deposits ranging from 1.2 to 2.4 m thick were found overlying the Atlantic Muck Formation. In the length between Guacha Island and Tern Island, the Atlantic Muck Formation was either not found, or was very thin. In this area, Recent-aged soft sediments (averaging 2 m thick) were found to overlay residual soil and weathered rock. Atlantic Muck Formation, where present, occurred between the Recent-aged material and the residual soil, and was a maximum 5 m thick. Between Tern Island and the east mainland, only recent lake sediments (1.5 m thick) overlying residual clay were found above the conglomerate of the Bohio Formation.

Guacha, Tern and Booby Islands, all located within Gatun Lake, were each found to have an overlying stratum of soft overburdened and weathered rock of variable thickness. In general, firm bedrock was found available below EL. 22.9 m MSL and the islands were judged to offer suitable foundation conditions for control structures.

Firm bedrock under both the land and the lake was found to consist of low velocity sedimentary rock composed primarily of sandstone and the Bohio Formation. Two areas containing abrupt changes in bedrock velocities were located during the survey. One of the areas was a narrow zone located on Guacha Island that was interpreted as a possible shear zone in rock of similar type. The second area was an abrupt change in bedrock velocity on Tern Island that was interpreted as a possible fault contact between two formations, or between different lithologic units of the same formation. The top of the bedrock on land was interpreted from the geophysical results to be weathered to below lake level. The core borings in the lake determined the weathered zone of bedrock to range from 1.2 to 3.1 m in thickness.

Satisfactory foundation conditions exist for construction of a pumping station, and a spillway at the Lower Rio Trinidad Dam site. Serious consideration, however, must be given to problems that would be caused by the anticipated settlement and instability of the embankment materials. Additionally, it is assumed that all concrete aggregates may be obtained from commercial sources.

Rio Caño Quebrado
The main dam portion of the proposed Rio Caño Quebrado project is located in an area where volcanic rocks of the Tucue Formation are encountered at the surface. The rocks of the Tucue Formation consist of lava flows, breccias, tuffs and plugs, and are andesitic or basaltic in nature. These rocks show a wide variation in quality, from high quality extrusive lava flows, to weathered and lesser quality volcanic tuffs. It is anticipated most of the strata of the Tucue Formation should make satisfactory rock fill for a dam, but a significant amount may not be satisfactory for concrete aggregate. Volcanic rocks of the Tucue Formation may also contain constituents that are reactive with alkalies found in cement. Neither weathered rock nor rock with reactive materials would be satisfactory for concrete aggregate. It is recommended that cores be drilled early during the planning studies to determine general depths of weathering and to determine the suitability of the rock for use as concrete aggregate.

Oligocene-aged sedimentary rocks of the Caimito Formation underlie the inter-basin transfer basin canal and spillway portions of the project. Three members of the Caimito Formation are recognized; the lower, middle and upper. The deposits of each of these members are mainly marine, but they are lithologically heterogeneous. The lower member is composed of conglomerate and tuffaceous sandstone. The middle member consists chiefly of tuffaceous sandstone, some of which is calcareous, and lenticular limestone. The upper, principal member consists of tuff, agglomeratic tuff, tuffaceous siltstone, and discontinuous sandy tuffaceous limestone. In general, the rocks of all members are hard, thinly to thickly bedded, and closely to moderately jointed. It is not known which member of the Caimito Formation underlies the project area. It is considered that it should make an acceptable foundation for the canal and spillway. The Caimito Formation would be unacceptable for use as concrete aggregate and may be only marginally acceptable for use as fill in an earth and rock fill dam.

In the absence of detailed geologic mapping for the proposed Rio Caño Quebrado project, a degree of extrapolation is necessary. It is predicted that rock at the proposed construction locations outside the lake would be encountered at a shallow depth and would be of sufficient quality to serve as foundation for the appurtenant structures.

Upper Rio Indio
The proposed Upper Rio Indio project is located in an area of the Isthmus of Panama underlain by Oligocene-aged sedimentary rocks of the Caimito Formation. Three members of the Caimito Formation are recognized: the lower, the middle and the upper. The deposits of each of these members are mainly marine, but are lithologically heterogeneous. The lower member is composed of conglomerate and tuffaceous sandstone. The middle member consists chiefly of tuffaceous sandstone, some of which is calcareous, and lenticular limestone. The upper, principal member consists of tuff, agglomeratic tuff, tuffaceous siltstone, and discontinuous sandy tuffaceous limestone. In general, all members are hard, thinly to thickly bedded, and closely to moderately jointed. The lower member weathers to greater depths. A summary of test data developed in 1966, as part of the studies for a sea level canal, listed compressive strengths for samples of Caimito Formation material varying between 79,450 and 5,955,257 kg/m^2. The same 1966 studies assigned an allowable bearing capacity of 195,300 kg/m^2 for the material of the Caimito Formation. The abutments at the project site may consist of Miocene volcanic rocks, possibly of the Tucue Formation.

It is believed that the Caimito Formation material should make an acceptable foundation for an earth and rock fill dam, however, it is be unacceptable for use as concrete aggregate and only marginally acceptable for use as fill. Further development of this project should require drilling of cores early during the planning studies to identify the foundation and abutment materials and to determine their general suitability for use as construction material. In addition, the cores should be of sufficient depth to check for the occurrence of any soluble limestone strata that may underlie the dam foundation.

The proposed inter-basin transfer tunnel connecting the Upper Rio Indio Lake to the Panama Canal watershed is also located very near the contact of the Caimito Formation and the overlying Miocene volcanic rocks. Groundwater flowing in volcanic rock above impervious strata of the Caimito Formation may cause problems. Further development of this project should require drilling of cores near the proposed tunnel inlets and outlets early during planning studies to determine the general relationship between the tunnel alignments, the sedimentary/volcanic rock, and the water table.

In the absence of detailed geologic mapping for the proposed Upper Rio Indio dam site, a degree of extrapolation is necessary. Available general geologic mapping and general data are the basis of predictions that rock, encountered at a shallow depth and of sufficient quality, could serve as foundation for the dam and appurtenant structures. Furthermore, assumptions for this report are: the required excavation should make available sufficient rock for fill, and the immediate area contains available impervious materials and concrete aggregate for use in the construction of the proposed project.

Lake Operation

The operating scenario considered in this study for periods when water would be transferred from Lower Rio Trinidad Lake to Gatun Lake for canal operations is detailed in Section 42 – Lower Rio Trinidad 22.9m to 33.5m, Rio Caño Quebrado 22.9m to 33.5m. Water impounded in the Rio Caño Quebrado Lake would be transmitted to Gatun Lake via the Lower Rio Trinidad facilities. Following is a reiteration of the tabulated pool levels contained in Section 42.

Table 45 - 1 Lake Operating Levels

Lake Level (m MSL)	Lower Rio Trinidad And Rio Caño Quebrado	Gatun
Normal Operating Lake Level	33.53	26.67
Minimum Operating Lake Level	22.86	25.91
Maximum Flood Lake Level	34.14	27.13

Under this scenario the Upper Rio Indio Lake would operate in a “run-of-the–river” mode, transferring all flows above the invert of the interbasin transfer tunnel, EL. 45.5 m MSL, to the Lower Trinidad Lake for storage and subsequent use for navigation. This transfer of water between Upper Rio Indio and Lower Trinidad Lakes would be made via a tunnel constructed beneath the divide separating the two basins. The tunnel shall be sized to carry all but the greatest flood flows from the Upper Rio Indio basin. The maximum flood flows would be passed over the fixed crest spillway to the Lower Rio Indio. Table 45-2 shows the lake levels affecting the Upper Rio Indio design for this scenario.

Table 45 - 2 Lake Operating Levels – Upper Rio Indio

Lake Level (m MSL)	Upper Rio Indio
Normal Operating Lake Level	50
Minimum Operating Lake Level	45.5
Maximum Flood Lake Level	52.0

Project Features

GENERAL

The structures for the proposed Lower Rio Trinidad project should consist of a rock fill dam, a large pumping plant, and a gated spillway. Modification of one existing saddle dam and construction of two additional saddle dams is also required.

The structures for the proposed Upper Rio Indio project should consist of a rock fill dam, an uncontrolled ogee spillway, inter-basin transfer facilities, two hydropower plants, and outlet works.

Design was performed only to the extent necessary to establish, with reasonable accuracy, the principal dimensions, elevations, and costs of the proposed project. Separate documentation was provided to the ACP that contained assumptions and design calculations for the reconnaissance level investigations of these structures. If this project is carried into the planning studies, optimization of the project features and improvements must be accomplished.

EMBANKMENTS

Lower Rio Trinidad Dam
The proposed dam consists of an embankment with the top at EL. 31.50 m MSL and with a crest width of 13 m with a final crest of 7 m upon completion of all settlement of the embankment and bridge work. The left abutment of the embankment will be located at Universal Transverse Mercator Grid, Zone 17, Clark 1866 Spheroid Coordinates 1015858 north and 614864 east. The right abutment will be at 1013937 north and 618229 east coordinates. The normal lake elevation is 30.48 m while the ground surface elevations along the axis of the dam vary from El. 2 m MSL in the lake bottom to El. 39 m MSL on Guacho Island and El. 38 m MSL on Tern Island. The Gatun Lake subgrade supporting the embankment occupies a broad flat valley having sides, which slope, upward from the valley at grades up to 40 percent. Water depths are 21.3 to 26.3 m over 80 percent of the site. The Atlantic Muck Formation, consisting of very soft organic clays, silts and peats varying in thickness from 7.6 m to 48.7 m, underlies approximately two thirds of the alignment subgrade. The Atlantic Muck Formation in the old river channel is further underlain by soft silts, sand and clay strata.

The critical challenge for design espoused by the Tudor Report and others is the depth of subgrade degradation during the initial fill placements. The materials will lose much of its natural strength when disturbed and will only regain strength after the effects of consolidation of a surcharge fill. However, complete restoration of strength can only be assumed to a depth of 5 to 7 m. If the effects of the subgrade disturbance extend appreciably deeper, then an extremely weak material will be under the more stable subgrade and surcharge creating a condition of lateral instability.

Due to the inability to accurately analyze this condition, a test fill was performed on the western end of the alignment. In early 1963, 1,000-cy bottom-dump barges deposited some 168,000 cy of blasted rock from the cut widening project, extending some 305 m. 155 m of the fill was placed to a height of 11 m while the remaining 150 m was filled to 5 m. The differential heights were use to simulate initial and intermediate fill placement effects. Divers were then used to observe the performance of the fills placed along the alignment. The mechanisms of failure within the subgrade were caused by impact and static loadings. The impact of the initial placements caused severe destruction of the surface materials creating lateral displacements up to 5 m. However, when a continuous blanket of fill had been established and subsequent fill was placed, then conventional failures such as slip circle shear failures and horizontal shears creating large mud waves outward from embankment were observed. Therefore, to predict the behavior of the embankment during construction and for the long term, it is imperative that a foundation mat be established to such a depth to prevent subgrade rupture with subsequent fill placement. The Tudor report recommended that a 5 m thick minimum crushed rock blanket with maximum sizes of 20 cm be placed initially to act as the supporting blanket. Special barge dumping methods were to be employed so loads would not fall as an integral mass, which would create destructive forces on the subgrade. These recommendations were offered by the Tudor Engineering Company in their final report.

The placement of a large hydraulic structure on a deep-seated weak foundation is the most challenging of geotechnical endeavors. It is virtually impossible to analyze with great deal of certainty and the owner must be prepared to accept possible additional costs during construction and long term maintenance due to the potential for lateral instabilities and high degrees of settlement. The Tudor Report has predicted some 2.5 to 3 m of predicted settlement below the crest elevation for a construction duration of 7-years and an additional 2.5 to 3 m of maximum settlement below the crest for the 50-year service life of the project. These settlements are predicted where the Atlantic Muck and underlying compressible materials are the thickest. These movements are reduced as the fill approaches the mainlands and the two islands. This implies that significant differential settlements are predicted within these approaches as well. The key to any successful construction and maintenance of this embankment will be to establish a blanket mat atop the subgrade where subsequent fill can be economically placed without fear of rupturing the foundation to greater depths. Any significant lateral failure of the embankment during construction or productive use will render that alignment unsuitable. Additional embankment sections must be established upstream or downstream to reestablish the embankment section to the proper elevation. This repair will take considerable time and prevent its use as a road. Based on these considerations, these recommendations are presented for ultimate costs considerations in comparison to alternatives with a greater degree of performance certainty.

The divers observed that the test fill had trouble placing the fill in the correct locations within the alignment and the lift thickness varied significantly over the fill cross section. It is imperative that the blanket fill be placed intact with the least subgrade disturbance in order for the embankment to act as monolithic mass. Therefore, the initial 5 m of fill will be barged to the site and placed by lowering a clamshell to the subgrade surface. The positioning of the barges must be strictly controlled by survey positioning systems established on land. The initial fill should have a maximum size of 20 cm and the percent fines should be controlled to remain fairly intact during placement. Materials with a significant size differential and a large fine content can create weak shear zones with the embankment. The subsequent fill materials above this zone can be placed by bottom dumped barges or clamshells from El. 8 to 21 m MSL. The material above El. 21 m MSL must be placed by clamshell due to the draft and door operations of the barges. These materials will be more random in gradation having a maximum size of 30 cm and a greater degree of fines. The materials placed below El. 27 m MSL will assume a side slope of 1 V:15 H. A 15 m berm will be constructed and the materials will continue to be placed by clam shell and spread with a dozer to El. 34.5 m MSL, assuming a side slope of 1 V : 3 H and a crest width of 13 m. The flatter side slopes are needed to distribute bearing pressures and to reduce the lateral displacements. This configuration should also reduce the construction and total settlements predicted by the Tudor report and provide acceptable factors of safety for lateral stability during fill placement. The side slope berms and extra crest width will facilitate the future fill placements of up to 3 m over the life of the project. The road surface atop the dam embankment will remain gravel surfaced for the foreseeable future due to future fill placements. The dam will be approximately 30 m high, and the overall length 4,473 m. The top of the dam will be 5 m above the normal Gatun Lake level. The total volume of fill material required to construct and maintain the main dam to 34.5 m is approximately 39,883,250 M^3. Water access from the main channel to Guacha and Tern Islands will be built during construction. After access roads have been constructed, fill placements from the east mainland to Tern and Gaucha Islands could be delivered by truck and placed by end-dumping from the east mainland. This technique could prove beneficial if a material source was found near the Gatun Lock area. The side slopes and overall embankment configuration was offered for ease of calculation, to reduce the foundation pressure on the soft subgrade and to account for the lateral displacement of embankment materials. The increased foundation base should help the structure survive a relatively minor seismic event.

The methods of subgrade stabilization and embankment strengthening offered in the powerpoint presentations from the ACP Engineering Division are examples of many ideas for enhancing the performance of the embankment during construction and post construction. The use of wick drains have been an effective tool for accelerating consolidations under a mass loading. However, we feel that the Atlantic Muck materials will not readily transmit water to the drains, therefore the spacing of the drains must be much closer than that implied and the effectiveness of the drains will be restricted to the top 15 to 20 feet of the foundation subgrade. The drains must be effectively tied into the foundation blanket for continuity of the drainage path. There are concerns over the use of vibro-flotation or stone columns techniques above the mat. The mat will not effectively dampen these compaction forces and some rupture of the mat could be possible. A safer reinforcing technique could be the use of reinforcing within the embankment section, such as high strength geogrids placed in layers. All reinforcing techniques are expensive but could be offset by the reduction in fill quantities ultimately required. Any reinforcing selected for use in production must be part of a comprehensive test fill program to demonstrate its effectiveness.

The Tudor Report identified considerable leakage to be expected from the completed embankment. Since loss of any water from storage is a significant reduction in benefits, the seepage must be prevented. Therefore a bentonite slurry trench should be installed within the centerline of the embankment. The trench will be a minimum of 3 feet wide and extend to several meters below the original lake bottom. The trench can be excavated using rockmill techniques. Since the embankment will undergo significant settlement, both total and differential, it is likely that the trench will be sheared and will require replacement within the deeper portions of the lake during the life of the project.

Rio Caño Quebrado Dam

The Rio Caño Quebrado dam should consist of two sections, the west and east embankments, with the top at EL. 34.50 m MSL and with a crest width of 13 m. The left abutment of the embankment would be at Universal Transverse Mercator Grid, Zone 17, Clark 1866 Spheroid Coordinates 1004554 north and 632455 east. The right abutment would be 1004595 north and 632599 east coordinates. The embankments would be constructed by depositing cohesive materials along the alignment of the proposed dam until the stacked material reached its natural angle of repose and the consolidation, within the subgrade, is stabilized. The assumed side slopes would be 10 H : 1 V within the submerged sections transitioning to 2 H : 1 V in the portions traversing the existing islands. The subgrade is extremely soft and considerable displacement would be anticipated as evidenced by the original construction experience at Gatun Dam. The dam would be approximately 16 m high, and the overall length would be 404 m. The top of the dam would be 4.3 m above the maximum normal operating level in Gatun Lake. The total volume of fill material required to construct the embankments would be approximately 244,150 M^3 for the west embankment and 114,500 M^3 for the east embankment.

Upper Rio Indio Dam

The Upper Rio Indio dam would be an embankment with the top at EL. 53.0 m MSL and with a crest width of 13 m. The left abutment of the embankment would be located at Universal Transverse Mercator Grid, Zone 17, Clark 1866 Spheroid Coordinates 990717 north and 591922 east. The right abutment would be 991200 north and 592330 east coordinates. The embankment shall be constructed with an impervious earth and rock fill core encased in rock fill, and the final side slopes would be 2 H : 1 V. The dam at its highest point would be 43.5 m high, and the overall length 632 m. Further study is needed to determine the actual side slopes and crest width and is contingent on the need for vehicular access across the embankment, the size and quality of the rock fill, and the detailed design of the embankment. Plate 37 - 3 presents a typical section of the embankment at the dam, incorporating upstream and downstream cofferdams within the section. The estimated quantity of fill to complete this embankment is 1,534,905 cm.

Foundation grouting is required across the entire base of the dam and on a portion of the valley walls. A blend of bentonite and native fill materials in a core trench provide seepage cutoff in the embankment foundations. A concrete or bentonite cutoff wall can also provide seepage cutoff. The crest widths and side slopes presented here are for comparison purposes between projects. The actual crest widths and side slopes shall be determined during further study and are contingent on the need for vehicular access across the embankments, the size and quality of the fill materials available for use, and the detailed design for the embankments.

The crest width and side slopes are presented here for comparison purposes between projects. The actual crest width and side slopes would be determined during further study and are contingent upon the need for vehicular access across the embankments, the size and quality of the fill materials available for use, and the detailed design for the embankments.

Saddle Dams

As noted in the Tudor Report, the existing Rio Caño Quebrado Saddle Dam No. 4 located along the western shoreline of the Trinidad Arm of Gatun Lake should need to be raised and/or strengthened to accommodate the higher lake levels. Immediately to the north of this location, two additional smaller saddle dams would be required. All would be built to provide a minimum top El. 34 m MSL. The total volume of fill material required for these three dams should approximately 50,000 M^3

The actual side slopes and crest widths would be determined during further study and would be contingent upon the need for vehicular access across the embankment, the size and quality of the rock fill, and the detailed design of the embankment. A typical section of the embankment at the saddle dams and main dam would be similar to that shown for the embankments for the Upper Rio Indio project, Section 5 of this report. Upper Rio Indio

SPILLWAYS

Spillways are required at Upper Rio Indio and Lower Rio Trinidad.

Lower Rio Trinidad

Under normal flow conditions water passes from Lower Rio Trinidad Lake to Gatun Lake through a gated spillway. This spillway should have 8 gate bays, each 18.33 m wide. The gate bays would be separated/flanked by 3 m wide reinforced concrete piers (9 piers in all), which should provide support for the gates and operating machinery, as well as providing support for a roadway bridge over the top of the spillway. Each of the 8 spillway gates should have a nominal width of 18.33 m and a height of 8.53 m, providing 0.3 m freeboard above the maximum lake operating level. The overall length of the spillway, from out-to-out of piers is 173.64 m. The spillway sills would be placed at the minimum lake operating level, EL. 25.91 m MSL.

A bridge across the tops of the spillway piers would be constructed as a part of the roadway across the top of the dam. The roadway must be approximately 7 m wide thus allowing for two-way traffic and providing ready access to the spillway gate operating machinery.

For this study, stop logs for servicing the gates, guides, etc. may be placed either from the roadway or from barges using floating cranes. Also, it should be noted that, with the spillway sill at the prescribed level, stoplogs are required both upstream and downstream to allow work to be done on the gates and sills in the dry.

The spillway would be situated along the axis of the dam approximately centered in Guacha Island. This allows the construction to be performed completely within a dry construction cut requiring a minimum of construction dewatering. Once the concrete structures are completed, the entrance and exit channels to the spillway can be opened.

Upper Rio Indio
At Upper Rio Indio, an uncontrolled ogee spillway, with a length of 113.11 m and a crest at EL. 50 m MSL, is required. The spillway crest would be 3 m below the elevation of the top of the dam. The maximum discharge from the spillway would be 618 CMS at a maximum flood lake level at EL. 52 m MSL. The spillway design discharge is equivalent to a 1 in 1,000 frequency unregulated flow at the dam site. The spillway site is located within the abutment adjacent to the left end of the dam and should consist of a mass concrete sill section embedded in the natural rock. A sloped and/or stepped, natural rock cut tailrace channel would transfer flow to the adjacent Rio Uracillo tributary. The tailrace channel extends from the sill section to its confluence with the Rio Uracillo. The task of dissipating energy at the downstream end of the tailrace channel requires excavation of a stilling basin into the rock adjacent to the natural channel. See Plate 36- 2 for the location of the spillway and Plate 36 - 4 for a typical section at the spillway.

PUMPING PLANT

A large pumping plant would be included in this scenario at the Lower Rio Trinidad dam. This pumping facility should provide for pumping in two directions, allowing Lower Rio Trinidad Lake to be drawn down to a level below that of Gatun Lake during extremely dry months, and providing the capability of pumping excess water from Gatun Lake into Lower Rio Trinidad Lake during flood season. Water thus stored would be available for navigation during the dry season. The pumping plant was configured to provide pumping to EL. 33.53 m MSL in Lower Rio Trinidad Lake. For lake elevations below this level the plant might be reduced somewhat in size, however it was considered that the higher-level configuration should provide an estimate of the overall construction cost well within the scope of this study. See Table 45-3 for the controlling head and flow data used for this study.

This plant should consist of 6, 1407 hp pumps, each capable of pumping slightly more than 62 cubic meters per second (cms) for a total plant pumping capacity of 373 cms at a total dynamic head of 4.6 m. The pumping units would be mounted in a reinforced concrete housing and would be arranged in a row perpendicular to the axis of the dam, with intake and outlet channels on either side. It was assumed that these channels would be excavated primarily in solid rock. The channels should separated from the Lower Rio Trinidad and Gatun Lakes by large concrete walls containing sluice gates for controlling flows into the pumping plant. For this study these sluiceways were configured to provide average entry velocities of approximately 7.7 meters per second. The channels were configured so as to provide this velocity or less and should therefore require no special armoring of walls or inverts for scour protection. As configured for this study the outlet channel invert would be at approximate EL. 20 m. MSL, or

13.5 m. below the centerline of the pump outlets. This should provide sufficient water depth at maximum pumping to buffer the erosive effects of the very large outflows required.

In conjunction with this facility a roadway bridge would be required to connect the pumping station structure to the banks on either side of the intake and exit channels thus continuing the roadway across the facility. This bridge should also provide both operational and maintenance access to the pumping plant. As configured for this study, the bridge should have two 15 m-long spans with steel girders and a concrete bridge deck on each side of the pumping station. It should have a 7 m. wide travel way and should include one bridge bent including a cap, two round columns and a spread footing, located within each channel section.

Table 45 - 3 Pumping Data

Pumping Cycle	**Head** (m.)	**Average Daily Flow** (M^3/sec)
Lower Rio Trinidad (Elev. 22.86) to Gatun Lake (Elev. 25.91)	3.05	127.43
Gatun Lake (Elev. 26.67) to Lower Rio Trinidad (Elev. 33.53)	6.86	56.64

IMPOUNDMENT

The lake formed by the proposed Lower Rio Trinidad Dam under this scenario should have a normal operating lake, EL. 33.53 m MSL. The surface area at the normal operating lake level is 21,912 ha. At the maximum flood level, EL. 34.44 m MSL, the surface area is 22,830 ha. With the minimum operating level, EL. 22.86 m MSL, the surface area is 9,019 ha. It should be noted that the current operating levels of Gatun Lake vary to EL. 26.67 m MSL; therefore areas below the maximum Gatun Lake level are already subject to inundation.

The lake formed by the proposed Rio Caño Quebrado Dam should have a normal operating lake level at EL. 33.53 m MSL. The surface area in the Rio Caño Quebrado impoundment at the normal operating lake level would be approximately 3,443 ha. At the maximum flood lake level, EL. 34.14 m MSL, the surface area would be approximately 3,629 ha. With the minimum operating lake level at EL. 22.86 m MSL the surface area would be approximately 1,151 ha.

The lake formed by the proposed Upper Rio Indio Dam should have a normal operating lake level at EL. 50 m MSL. The surface area at the normal operating lake level would be approximately 863.8 ha. At the maximum flood lake level, EL. 52 m MSL, the surface area would be approximately 897.6 ha. With the minimum operating lake level at EL. 45.5 m MSL, the surface area would be approximately 732 ha.

CLEARING AND/OR GRUBBING

Clearing and grubbing would be required for all areas above the existing Gatun Lake that are required for construction of the dam (embankments and spillway), access roads, and disposal and staging areas. For the Lower Rio Trinidad Lake area, clearing would be required for the 3,700 ha in the lake area between the maximum operating lake level of Gatun Lake and

EL. 33.5 m MSL. Clearing only would be required for the 740 ha in the Rio Caño Quebrado Lake area between the maximum operating lake level of Gatun Lake and EL. 33 m MSL.

For the Upper Rio Indio Lake, clearing would be required in all areas necessary for construction of the dam (embankments and spillway), inter-basin transfer facilities, outlet works, hydropower plants, access roads, and disposal and staging areas should require clearing and grubbing. Only the 900 ha in the lake area between the normal operating lake level at EL. 50 m MSL and the minimum operating lake level at EL. 45.5 m MSL should require clearing. The transmission lines should also require clearing.

ACCESS ROUTE

Lower Rio Trinidad
Access to the lake site and the various construction sites was evaluated from the main population centers, Colon on the Atlantic coast and Panama City on the Pacific coasts.

The route from Colon is westward across the Panama Canal and then southwestward along existing roads that follow the westernmost boundary of Gatun Lake to Cape Mala, near the western abutment of the dam. A very short access road is required from the existing road to the dam site. This route requires crossing the Panama Canal near the Gatun Locks using the existing lock gate bridge. This bridge is narrow and operates only intermittently since canal operations take precedence over roadway traffic. It may be undersized and may lack the load carrying capacity needed for heavy construction materials and equipment loads anticipated.

Access to the spillway and lock construction sites would be by water since these structures would be placed on Guacha Island. It was considered that a water access route for conveyance of much, if not all, of the construction equipment and materials could be used. This should require that offloading facilities be constructed near the west abutment of the dam, on Guacha Island, and near the eastern abutment site in the vicinity of South Range Point.

Since much of the construction for this project would be in the existing lake or on an island in the lake, it was concluded that both land and water access would be required. Plate 45 - 1 shows the general location of the proposed features and the possible land and water access available or to be provided.

Rio Caño Quebrado
Access for Rio Caño Quebrado can best be gained from the Panama City area by way of existing roads as far as the village of Santa Clara, located to the south and east of the Rio Caño Quebrado dam site. From Santa Clara, a new roadway would be required to the dam construction site, a distance of approximately 8 km. Roadway access should also be required to the spillway site, which would be located some distance to the south and west, and across the existing lake from the dam site. Existing roadway access in this area is now available to the village of La Laguna. From a point just south of La Laguna, a new access road would be required around the south side of the existing lake to the spillway site. This route requires approximately 5 km of additional new roadway.

Upper Rio Indio
For access to the Upper Rio Indio site it is concluded that the route from Panama City westward across the Bridge of the Americas, then southwestward along the Inter-American Highway, and

then westward along existing roads to Ciri Grande, may be best. This route requires that the road between Panama City and Ciri Grande be upgraded over much of its length and the route west of Ciri Grande must traverse the mountains. The proposed access road would be 26 km in length, and bridges and/or culverts would be required at 15 streams. Plate 45-1 shows the portion of the proposed access road from Ciri Grande to the construction sites.

In addition to providing construction access, this new corridor into the remote areas surrounding Gatun Lake should benefit to those living in the region. It should provide ready access to the main centers of commerce in the southern part of the country, as well as access to the lake for recreation interests.

Sources of Construction Material

Lower Rio Trinidad
The bottom 5 m layer of the dam embankments shall be constructed with material less than 8 in. maximum size, and with no more than 5 percent passing the #200 screen. Such a material should require crushing and processing across a grizzly to remove oversize rock, and washing to remove fines. Material for this bottom layer must be reasonably well graded so as to prevent the removal of the finer fraction by piping. The overlying main portion of the embankment would be constructed with (-12 in.) sized material. This material should also require crushing and processing across a grizzly to remove oversize rock.

The majority of the materials used for the embankment construction would be obtained from upland sources adjacent to the Gaillard Cut, transported to the site by barge and clam shelled along the proposed embankment alignment. The initial materials would be obtained from the existing disposal sites for the Gaillard Cut widening above Pedro Miguel Locks. Based on the information received from the ACP, these sites contain approximately 5.5 million M^3 of suitable excavated rock. However, this rock is not stockpiled in an orderly manner, is randomly mixed with unsuitable material and is covered with unsuitable material. All the rock materials, from whatever source, should need to be crushed, graded and loaded on trucks for transport to a loading facility adjacent to the canal at the Cucaracha Reach on the east side, or the mouth of the Mandinga River on the west side. These loading facilities should require excavation into the bank area and bulkheaded for crane support and barge placement. Working stockpiles would be maintained next to the transfer points to facilitate the loading process. Additional materials within the immediate area should come from the Third Locks excavation adjacent to the Pedro Miguel Locks. These materials would be drilled and blasted in place, excavated, and then transported to one of the transfer facilities for processing. Additional materials should come from newly developed quarry sources in areas such as Hodges Hill, Escabor Hill, Contractor Hill, and others within 10 km of the transfer points. Each of these new sources should require extensive excavation to remove the overburden and soft rock materials. These materials would be stockpiled adjacent to the work area for restoration once the rock fill materials have been acquired. The suitable rock materials would be blasted, crushed and graded and trucked to the transfer points. All material would be loaded onto barges, transported to the dam site and clam shelled within the dam limits.

Cement is available within the country. Rock obtained from developed quarries may be used to produce concrete aggregates on-site, or may be obtained from commercial quarries. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) need to be fabricated outside the Republic of Panama and imported for final assembly and installation at the proposed dam site.

Rio Caño Quebrado
The source of the embankment and other construction materials for Rio Caño Quebrado are expected to be the same as those for Lower Rio Trinidad.

Upper Rio Indio
Rock removed from the spillway site can used as fill in the embankment portion of the dam. Impervious materials might be obtained from outside the project area; however, for this study it is assumed that these materials would be available locally in sufficient quantity to supply the project needs. If further study indicates that impervious materials are unavailable locally, then other materials, such as roller compacted concrete, would be considered for construction of the dam.

Cement is available within the Republic of Panama. Rock obtained from developed quarries may be used to produce concrete aggregates on-site, or they may be obtained from commercial quarries. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) need to be fabricated outside.

Real Estate Requirements

The Lower Rio Trinidad Lake site is located within the former Panama Canal Zone and is presently managed and controlled by the ACP. Construction of this project requires the acquisition of 800 ha. Table 45 - 4 shows the amount of land required for the various project features. Real estate for access roads is included in the estimated quantities for the other items listed in the table.

Table 45 - 4 Real Estate Requirements

Project Feature	Land Required (ha)
Lake	0
Dam Site	0
Staging Area	200
Housing and Facilities	200
Disposal Area	400
Total	800

The proposed Rio Caño Quebrado Lake would be located within the former Panama Canal Zone and is presently managed and controlled by the ACP. Construction of this proposed project should require acquisition of approximately 800 ha. Table 45 - 5 shows the amount of land required for the various project features. Real estate for access roads is included in the estimated quantities for the other items listed in the table.

Table 45 - 5 Real Estate Requirements

Project Feature	Land Required (ha)
Lake	0
Dam Site	0
Staging Area	200
Housing and Facilities	200
Disposal Area	400
Total	800

The proposed Upper Rio Indio project would be located in the Cocle, Colon, and Panama Provinces. Construction of this project should require acquisition of approximately 1900 ha. Table 45 - 6 shows the amount of land required for the various project features. Real estate for access roads is included in the estimated quantities for the other items listed in the table.

Table 45 - 6 Real Estate Requirements

Project Feature	Land Required (ha)
Lake	900
Dam Site	200
Staging Area	200
Housing and Facilities	200
Disposal Area	400
Total	1,900

Relocations

The Lower Rio Trinidad Lake site is located within the existing former Panama Canal Zone. Structures and facilities established along the waters edge in the Trinidad arm between the existing Gatun Lake levels and EL. 30 m MSL should need to be relocated or modified. This should include a major portion of the Village of Escobal. Additionally, there are only a few small communities and isolated individual structures along the lakeshore with very limited access by land.

The Rio Caño Quebrado Lake site is located within the existing former Panama Canal Zone. Structures and facilities established along the waters edge in the Rio Caño Quebrado arm between the existing Gatun Lake level and EL. 30 m MSL should need to be relocated or modified. This region appears to have only a few settlements along the lakeshores and very limited access by land.

The Upper Rio Indio Lake site is located in a sparsely settled region with few roads and utilities. This area is devoted primarily to subsistence farming and ranching. Structures and individuals located in the lake area below EL. 55 m MSL should require relocation because of the normal lake inundation and the need to secure the lake perimeter for flood considerations. The required relocations should include the two towns in the lake area (Los Uveros, and Tres Hermanas), 12 other small settlements, and numerous isolated structures. The two towns have elementary schools, churches, electricity, and limited telephone coverage.

Development Sequence

Each component of the lake projects is designed and can be constructed as a stand-alone facility. If the Upper Rio Indio facilities are constructed first and placed into service before the Lower Rio Trinidad facilities, the interbasin transfer tunnel can be used to navigational advantage while the Lower Rio Trinidad project is being completed. During the interim the Upper Rio Indio project should help control flooding on the Lower Rio Indio and can contribute to the electric power output of the country.

The development sequence for each individual project follows roughly the same progression. This progression is summarized below with pertinent site-specific notations as appropriate.

Each project must be evaluated to assure that the plan presented includes all of the features required to function. Each project must be assessed as to its effectiveness in providing navigation water to the Panama Canal, with due recognition of any secondary benefits. Environmental assessments of the proposed projects need to be made to assure environmental acceptability of the project features. These environmental assessments begin during the planning studies phase and continue into the final design, advertising and award phases. Environmental coordination begins with planning studies and continues through the completion of construction. After completion of the final design, plans and specifications must be prepared for the advertising and award phase.

Project implementation begins with land acquisition and construction of the access facilities. Lands for the housing and facilities project feature, which includes the access roads, need to be acquired initially. Lands for the dam site, staging area, disposal area, and lake can then be acquired.

Socio-economic programs must begin shortly before construction of the dam. The relocation of the small settlements and isolated structures must be accomplished. Socio-economic programs to assist those individuals impacted by the construction of the proposed project should continue throughout the construction phase.

Construction of the Rio Indio Dam begins with the clearing and grubbing of the construction sites and clearing the perimeter of the lake area. Materials used for the embankment construction can obtained from upland sources then transported to the site.

Upstream and downstream cofferdams are required for construction of the Rio Indio Dam and appurtenant facilities. These shall be configured to form a portion of the finished dam.

Limited cofferdams would be required to accomplish construction of the spillway and pumping station. These efforts may be accomplished simultaneously. Following completion of the pumping plant and spillway, the channels connecting these structures to the lake areas upstream and downstream may be excavated. Where possible, materials removed from these sites would be placed directly into the dam.

Once the western leg of the dam, pumping station and spillway are completed, the eastern leg may be constructed, thus completing the dam. The pool may then be raised. Upon completion of this phase of construction, all facilities must undergo trial operations, before being commissioned for service.

Considering the construction methods required and the nature of the work, it is estimated that development of the Lower Rio Trinidad and Upper Rio Indio Dam projects may be completed in approximately the time spans indicated in Figures 45-1 and 45-3, below, from initial planning to lake filling. Assuming that the development of the two projects is overlapped by 1-year the total development time is approximately 22-years.

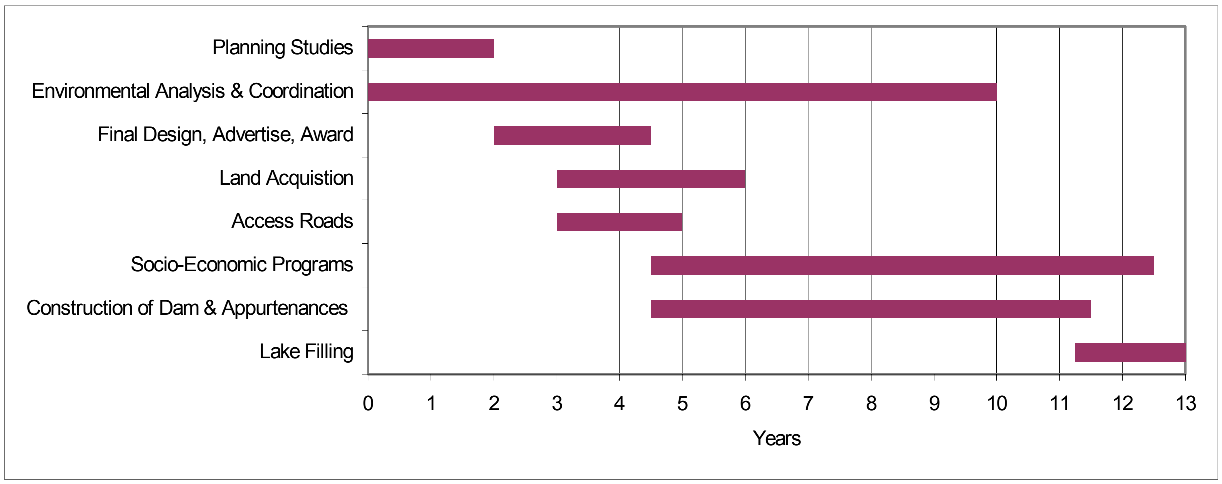


Figure 45 - 1 Development Sequence – Rio Trinidad

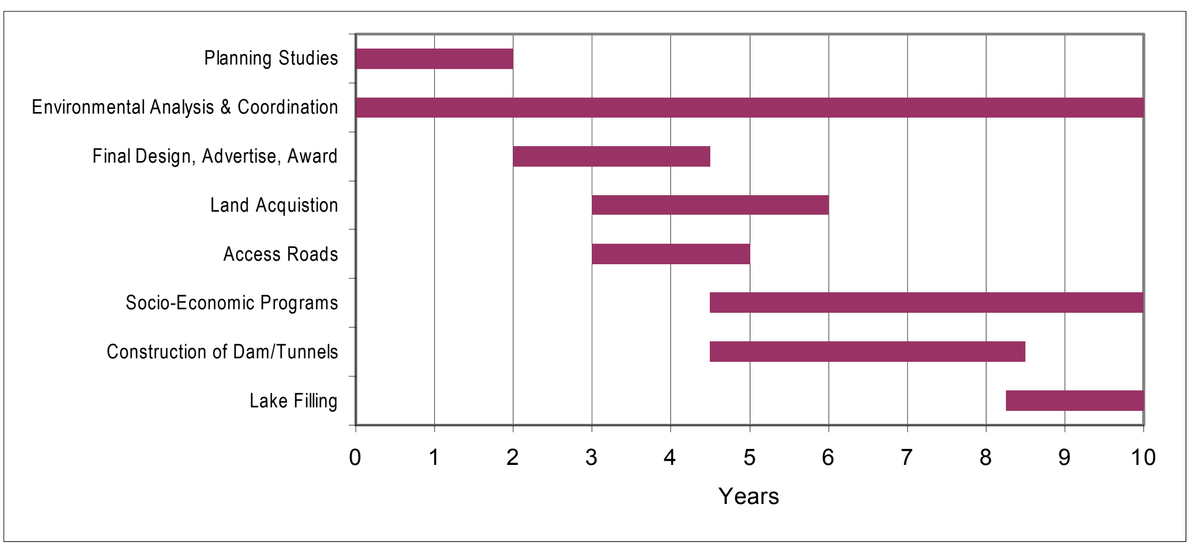


Figure 45 - 2 Development Sequence – Upper Rio Indio

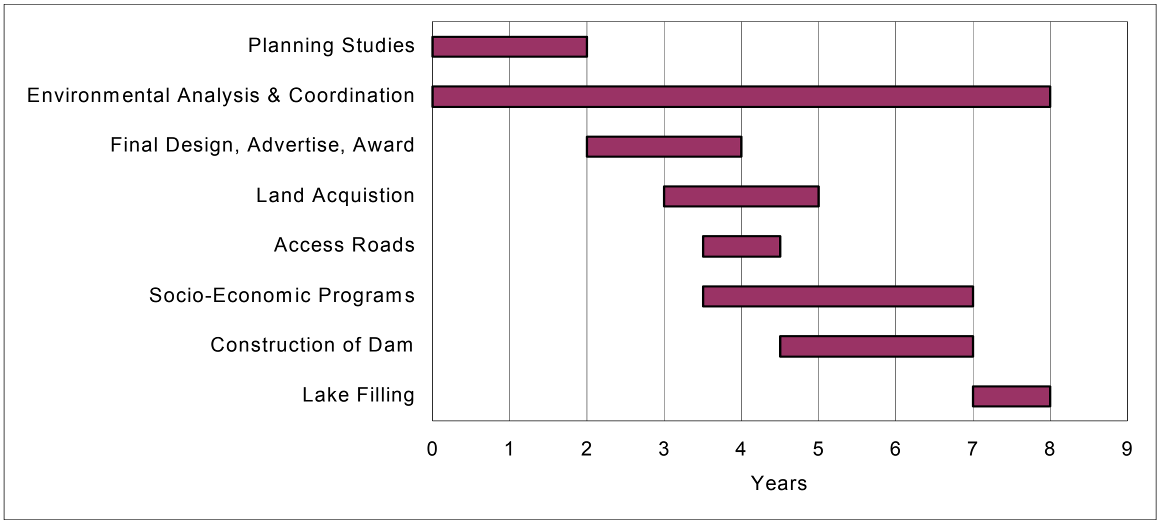


Figure 45 - 3 Development Sequence – Rio Caño Quebrado (Concurrent with Lower Rio Trinidad)

Hydrologic Reliability

In order to determine the effect of the proposed Lower Rio Trinidad, Rio Caño Quebrado and Upper Rio Indio Lakes on the hydrologic reliability of the Panama Canal, the existing HEC-5 model is modified to include the Lower Rio Trinidad Lake with pumpback operation and diversion from Rio Indio Lake. The existing Gatun Lake param (surface areas, storages, and local inflows) are reduced by the proportion that Lower Rio Trinidad Rio Caño Quebrado lakes should capture.

HEC-5 model simulations are conducted for both the existing canal system and the Scenario 10 operating system providing water to the Panama Canal watershed. The simulations considered proportionally increasing demands up to 180 percent of current demand levels, Figure 45 - 4. The period of simulation considered 52 years (January 1948 through December 1999) of hydrologic record. These configurations are:

- Existing system,
- Scenario 10 – Rio Indio Lake has a normal operating level of El. 50 m MSL and should operate as a “run-of-river” dam, transferring flows to Lower Rio Trinidad via 4.5 m interbasin transfer tunnel; Lower Rio Trinidad and Rio Caño Quebrado Lake fluctuating between the normal operating lake level, EL. 33.53 m MSL and the minimum operating lake level, EL. 22.86 m MSL with pumping capability to and from Gatun Lake; and Gatun Lake fluctuating between the normal operating lake level, EL. 26.67m MSL, and the minimum operation lake level, EL. 25.91m

The horizontal axis along the bottom of Figure 45 - 4 reflects demands as a ratio of the 5-year average from 1993 to 1997, and the axis along the top reflects demands in lockages (assuming 55 million gallons per lockage).

As shown in Figure 45 - 4, the existing hydrologic reliability of the Panama Canal, based on the period of record of 52-years, is approximately 99.6 percent, while the hydrologic reliability with a demand ratio of 1.8, is 86.3 percent. This period of record includes the worst drought on record for the area, which occurred in 1998. The hydrologic reliability, with a demand ratio of 1.0, is 100 percent for operating Scenario 10, and the hydrologic reliability, with a demand ratio of 1.8, is 95.46 percent. Figure 45 - 4displays the number of lockages associated with various levels of reliability.

Without additional water supplies, the hydrologic reliability of the canal system should decrease. With the construction of the proposed Lower Rio Trinidad Pumpback, and Upper Rio Indio Dams projects using Scenario 10 operation, the existing high hydrologic reliability can be continued as demand for water increases to 39.92 percent (15.44 lockages) above current demand levels.

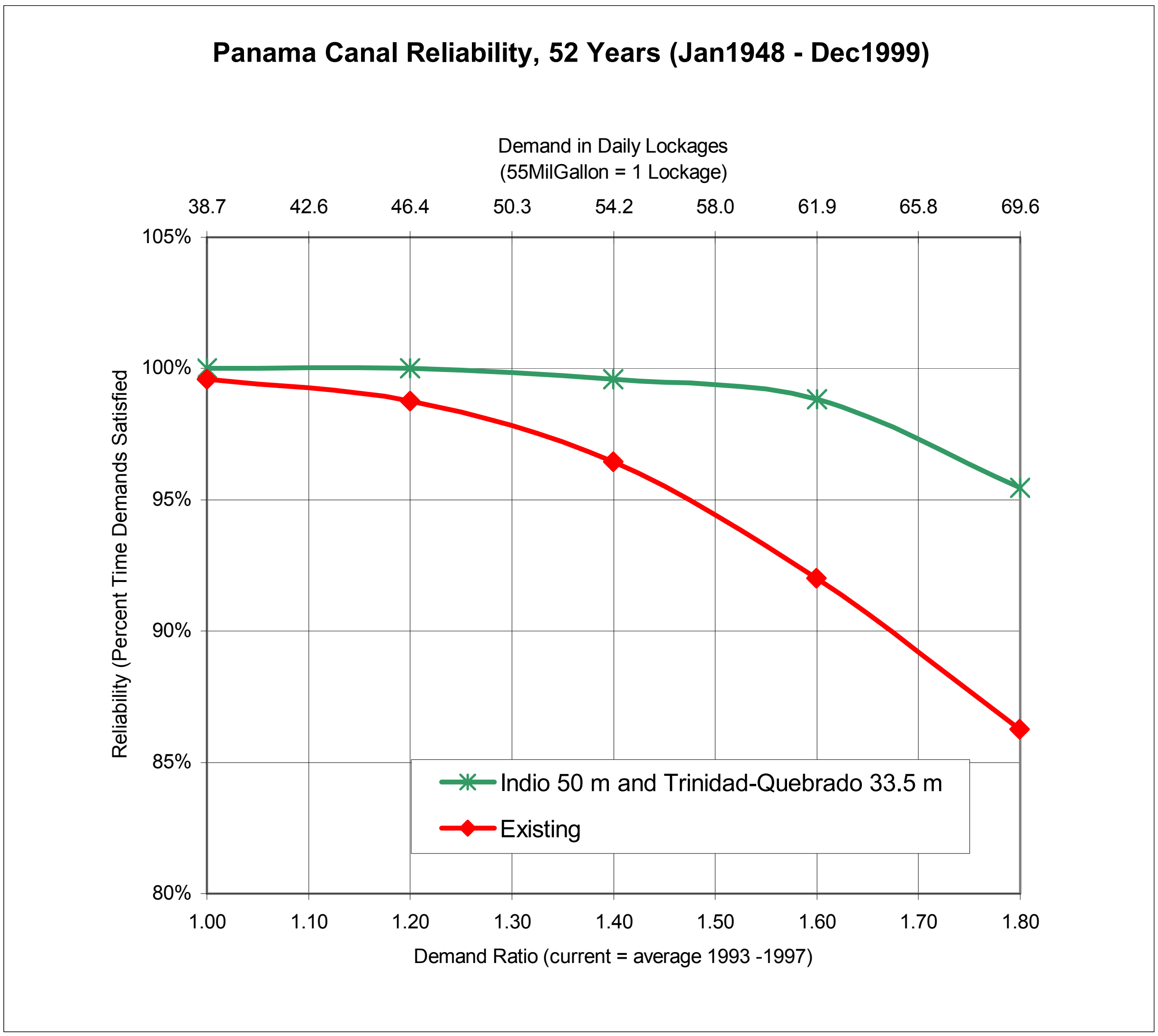


Figure 45 - 4 Panama Canal Hydrologic Reliability

Project Costs

GENERAL

The quantities estimated for the various items of work required for the construction of this project are derived from the layouts shown on the Plates in Section 40. The unit prices applied to these quantities are based on: historical information from previous estimates prepared for similar construction by the ACP; estimates for similar construction in the Mobile District; information gathered from Mobile District Construction Division personnel in Panama; and the book Feasibility Studies For Small Scale Hydropower Additions, A Guide Manual, written by The Hydrologic Engineering Center of the U.S. Army Corps of Engineers.

Engineering and design is estimated to be 12 percent while supervision and administration is estimated to be 6 percent of the construction cost items. An allowance of 2 percent of the construction cost items is allowed for field overhead (construction camp, contractor facilities, etc.). An allowance of 25 percent is included for contingencies.

FIRST COSTS

The total project first costs are estimated at $1,261,538,000. Table 45- 7 provides a summary of the first costs for the principal features. Separate documentation provided to the ACP includes a detailed cost estimate containing the sub-features of the work.

Table 45 - 7 Summary of First Costs

Item	Trinidad Costs ($)	Rio Indio Costs ($)	Rio Caño Quebrado Costs ($)
Lands and Relocations	2,000,000	4,750,000	2,000,000
Access Roads	9,574,000	7,810,000	6,690,000
Clearing and/or Grubbing	559,375	2,957,500	792,500
Cofferdam	850,000	4,850,665	N/A
Dam	643,786,212	15,226,374	2,966,970
Spillway	8,057,504	42,070,303	N/A
Intakes	N/A	7,701,295	N/A
Transfer Ditch	N/A	N/A	3,281,400
Saddle Dams	5,593,390	N/A	N/A
Pumping Station	22,999,637	N/A	N/A
Diversion Tunnel	N/A	4,714,622	N/A
Interbasin Transfer Tunnel	N/A	27,806,250	N/A
Transfer Intake Rio Indio-Gatun	N/A	371,194	N/A
Hydropower Plants	N/A	7,926,380	N/A
Transmission Lines	2,090,000	6,600,000	N/A
Subtotal	692,510,118	132,784,583	15,730,870
E&D, S&A, Field Overhead	138,502,024	26,556,917	3,146,174
Contingencies	207,753,035	39,835,375	4,719,261
Total Project First Cost	1,038,765,177 Approximately 1,038,765,000	199,176,875 Approximately 199,177,000	23,596,305 Approximately 23,596,000

OPERATION AND MAINTENANCE

Staff

A staff should operate and maintain the proposed Lower Rio Trinidad Dam project during the day and then run the facility remotely at night. The full-time staff should consist of 9 people, including a station manager, a multi-skilled supervisor, 2 leaders (Electronics/Instrumentation, Electrical/Mechanical), 4 craftsmen and a laborer. A part-time staff would be required for two to three months each year to perform general maintenance and overhaul of the project. The part-time staff may consist of three mechanics and three electricians. The annual staffing costs are estimated to be $350,000. The staff for the Lower Rio Trinidad project would be sufficient to operate and maintain the Rio Caño Quebrado project. The annual staffing costs for the proposed Upper Rio Indio project are estimated to be $500,000.

Ordinary Maintenance

Ordinary maintenance and care as required and should include minor repair materials, lubricants and other supplies needed by project staff. It is estimated that the costs of ordinary maintenance is $18,000 per year for the access road and $100,000 per year for the main project facilities. Fuel consumption for the pumps is estimated at $648,000. This estimate considers the growth in demand for water over time and the variability in inflows to Gatun Lake, as well as the proposed Lower Rio Trinidad project. An estimated $288,000 is needed for rock placement to account for settling of the project. The total ordinary maintenance is $1,054,000. The ordinary maintenance estimate for the Lower Rio Trinidad project is sufficient to include the Rio Caño Quebrado project. The total ordinary maintenance costs for the proposed Upper Rio Indio project are $320,000.

Major Replacements

The average service life of gates, electrical equipment, pumps, trash racks and other features would be less than the total useful life of the project (100-years). To estimate the major replacement costs necessary during the 50-year planning period for this proposed project, it is assumed that specific items should cost the same as at present. No allowance is made for salvageable fixed parts. Table 45-8 presents the service life, number of times each component can be replaced during the 50-year planning period, the future costs of each item, and the present worth of the replacement costs for the major components. Based on these values, the present worth of the proposed replacements is $2,260,400,000 and the average annual replacement costs is $272,000. The average annual replacement costs for the proposed Rio Indio project are estimated to be $33,000.

Table 45 - 8 Major Replacement Costs

Component	**Service Life** (years)	**Number of Times Replaced During Planning Period**	**Future Costs** ($)	**Present Worth of Replacement Costs** ($)
Roads	50	1	12,435,000	43,000
Bridges	50	1	1,800,000	6,200
Pump Station				
Pumps	25	2	21,006,000	654,200
Sluice Gates	50	1	1,275,525	4,400
Sluice Trash Racks	50	1	458,850	1,600
Electrical Controls	25	2	2,100,000	65,400
Fuel Tanks, etc.	50	1	450,000	1,600
Misc Equip & Comm.	25	2	3,183,000	99,100
Slurry Trench	25	2	40,462,500	1,260,100
Spillway				
Bridge Girders	50	1	280,676	1,000
Tainter Gates	50	1	2,280,000	7,900
Tainter Gate Hoists	50	1	1,200,000	4,200
Tainter Gate Op Sys.	50	1	360,000	1,200
Trashracks	50	1	475,950	1,600
Misc. Mech. Items	25	2	1,500,000	46,700
Electrical Controls	25	2	1,650,000	51,400
Transmission Lines	50	1	3,135,000	10,800
Total			94,052,500	2,260,400
Average Annual Replacement Costs				272,000

Annual Costs

The project first costs for the proposed Lower Rio Trinidad project are estimated at $1,038,765,000. The project first costs for the proposed Rio Caño Quebrado project are estimated at $23,596,000. The total project first costs including the $199,177,000 costs for the Upper Rio Indio project are estimated at $1,261,538,000. These total project first costs are distributed across the development period using generalized curves for contractor earnings for large, heavy construction jobs. Interest on the proposed Upper Rio Indio project first costs is computed from mid-year throughout the 22-year development period. Interest during construction for the Lower Rio Trinidad project is computed from mid-year throughout its 13-year development. The interest during construction, at 12 percent, is $838,455,000 for Lower Rio Trinidad, $10,811,000 for the Rio Caño Quebrado project, and $1,001,634 for Rio Indio - for a total interest during construction of $1,850,900,000. These costs are added to the total project first costs for total project investment costs of $3,112,438,000. A capital recovery factor for the 50-year planning period is applied to get the annual average investment costs of $374,789,000. Annual operation and maintenance costs are added. Major replacement costs are estimated and converted to an annual cost by discounting the future replacement costs of major components of the project back to completion of the project construction. Table 45 - 9 contains a summary of the $377,318,000 total annual costs.

Table 45 - 9 Summary of Annual Costs

Item	Costs ($)
Total Project First Costs - Lower Rio Trinidad	1,038,765,000
Total Project First Costs – Rio Indio	199,177,000
Total Project First Costs – Rio Caño Quebrado	23,596,000
Interest During Construction – Lower Rio Trinidad	838,455,000
Interest During Construction – Rio Indio	1,001,634,000
Interest During Construction – Rio Caño Quebrado	10,811,000
Total Project Investment Costs	3,112,438,000
Annual Average Investment Costs	374,789,000
Operation and Maintenance Costs	
Staff Costs – Lower Rio Trinidad	350,000
Staff Costs – Rio Indio	500,000
Ordinary Maintenance Costs – Lower Rio Trinidad	1,054,000
Ordinary Maintenance Costs – Rio Indio	320,000
Major Replacement Costs – Lower Rio Trinidad	272,000
Major Replacement Costs – Rio Indio	33,000
Total Average Annual Costs	377,318,000

Annual Benefits

NAVIGATION

The procedures and assumptions used in estimating the benefits are described in Volume One. The following paragraphs present the results of the economic investigations for the proposed Lower Rio Trinidad, Rio Caño Quebrado and Upper Rio Indio projects. The 50-year period for the economic analyses of this proposal is 2024 to 2073.

The proposed Lower Rio Trinidad, Rio Caño Quebrado and Upper Rio Indio projects should increase the reliability of providing water to accommodate the total daily number of lockages demanded. Table 45 - 10 provides the increase in the hydrologic reliability of providing the sum of the demands for both navigation and M&I water supply keyed to years. The hydrologic reliability percentages are obtained from the data used to develop Figure 45 - 4. The 99.6 percent level of reliability for this proposal is used to estimate the water supply benefits for navigation and the net change in reliability is used to estimate the reliability benefits for navigation and M&I water uses.

Table 45 - 10 Panama Canal Hydrologic Reliability
(Based on Period of Record from January 1948 to July 1998)

Current Demand Ratio	Year	Demand in Daily Average Number of Lockages (Navigation and M&I)	Hydrologic Reliability	
			Existing System (%)	With Lower Rio Trinidad, Rio Caño Quebrado & Rio Indio [1/] (%)
1	2000	38.68 [2/]	99.60	100.0
	2010	45.11	98.91	100.0
1.2		46.42	98.76	100.0
	2015	46.82	98.64	99.98
	2020	47.61	98.41	99.96
	2025	48.52	98.14	99.93
	2030	49.55	97.83	99.89
	2035	50.72	97.48	99.85
	2040	52.02	97.10	99.80
	2045	53.49	96.65	99.75
1.4		54.15	96.45	99.73
	2050	55.13	95.89	99.64
	2055	56.98	94.83	99.43
	2060	59.05	93.65	99.43
	2065	61.37	92.32	99.11
1.6		61.89	92.02	99.06
	2070	63.97	90.47	98.46
1.8		69.63	86.27	96.82

[1/] The lakes behind the Lower Rio Trinidad and Rio Caño Quebrado Dams should fluctuate from the normal operating lake level at EL. 33.53 m MSL down to the minimum operating lake level at EL. 22.86 m MSL and the lake behind the Upper Rio Indio Dam should operate at EL. 50 m MSL.

[2/] 2000 Daily Demand is Average of 1993-1997.

With the proposed Lower Rio Trinidad, Rio Caño Quebrado and Upper Rio Indio projects, water supply shortages for navigation should continue. The demand for the M&I purposes should always be met first. As these demands grow, the amount of water available to meet the demands for navigation should decrease. Thus, the benefits for the additional water supply are estimated at the value for navigation. With the addition of the proposed Lower Rio Trinidad, Rio Caño Quebrado and Upper Rio Indio projects, these shortages would be less frequent. With a hydrologic reliability of 99.6 percent, the proposed project should increase the amount of water supplied by approximately 15.44 equivalent lockages. The 99.6 percent hydrologic reliability should occur after the year 2045, with an equivalent daily average number of lockages of 54.12. Benefits for these amounts of additional water are attributable to navigation since the amount of M&I water demanded would be provided first. Therefore, all shortages are attributable to navigation. The benefits are estimated using the toll revenue per lockage and the increased daily average number of lockages. The average annual benefits for water supply are $230,707,000. Table 45 - 11 provides the estimate of daily shortages under the existing system, the remaining daily shortages with the proposed Lower Rio Trinidad, Rio Caño Quebrado and Rio Indio projects in operation, the annual benefits for meeting shortages and the average annual benefits.

Table 45 - 11 Benefits for Additional Water Supply for Navigation

Year	Daily Shortages In Lockages Under Existing System	Remaining Daily Shortages	Annual Benefits For Navigation ($)
2023	9.51	0.00	196,137,742
2030	10.87	0.00	224,201,428
2040	13.34	0.00	275,146,640
2050	16.45	1.01	318,345,079
2060	20.36	4.93	318,345,079
2070	25.29	9.85	318,345,079
Average Annual Benefits			230,707,000
With the Lower Rio Trinidad and Rio Caño Quebrado projects operating between 22.86 and 33.53 m and the Upper Rio Indio project operating at 50 m, the system should provide a total of 54.12 lockages at the 99.6 percent level of reliability or 15.44 more lockages than the existing system.			

With the proposed Lower Rio Trinidad, Rio Caño Quebrado and Upper Rio Indio projects, the reliability of the system to provide the water demanded by navigation and M&I water would be improved. Using the increase in hydrologic reliability, the forecast number of vessels converted to a daily average number of lockages, the toll revenue for each average lockage, and a project discount rate of 12 percent, the average annual benefits for navigation reliability attributable to the proposed Lower Rio Trinidad, Rio Caño Quebrado and Upper Rio Indio projects is $17,856,000. Table 45 - 12 provides the forecast daily average number of lockages, the forecast value per daily lockage, the annual benefits for increased reliability, and the average annual benefits.

Table 45 - 12 Average Annual Reliability Benefits For Navigation

Year	Daily Average Number of Lockages	Value Per Lockage ($)	Annual Benefits For Navigation ($)
2023	40.0	2,260,000	13,801,000
2030	40.0	2,260,000	16,570,000
2040	40.0	2,260,000	21,596,000
2050	40.0	2,260,000	29,774,000
2060	40.0	2,260,000	39,383,000
2070	40.0	2,260,000	61,547,000
Average Annual Benefits			17,856,000

M&I WATER SUPPLY

The future demand for water supply for M&I purposes is based upon the growth in population. The ACP provided a forecast for the area surrounding the Panama Canal. The current usage is estimated at 4.0 equivalent lockages per day; an equivalent lockage is 55 million gallons of water. One equivalent lockage is added to the forecast to account for the burgeoning tourist industry, beginning in the year 2010. The increased reliability of the system to provide water supply for navigation similarly provides the same increase in reliability to provide water for M&I purposes. Using the increased hydrologic reliability of the system with the addition of the proposed Lower Rio Trinidad, Rio Caño Quebrado and Upper Rio Indio projects, the current costs to the ACP to process finished water ($0.69 per 1,000 gallons), the number of daily lockages demanded, and a project discount rate of 12 percent, the average annual benefits for M&I reliability is $3,248,000. Table 45 - 13 displays the population forecast, the resulting number of equivalent lockages per day, and the benefits for M&I water supply.

Table 45 - 13 Average Annual Reliability Benefits For M&I Water Supply

Year	Population	Equivalent Lockages per Day	Annual M&I Water Supply Benefits ($)
2023	2,294,000	8.15	1,899,000
2030	2,688,000	9.55	2,661,000
2040	3,384,000	12.02	4,357,000
2050	4,259,000	15.13	7,562,000
2060	5,360,000	19.05	12,599,000
2070	6,746,000	23.97	24,782,000
Average Annual Benefits			3,248,000

HYDROPOWER

The amount of hydropower energy that can be produced by the system of Gatun Lake and Madden Lake should decline over time as the demands for navigation and M&I water supply increase. With the inclusion of the Lower Rio Trinidad and Rio Caño Quebrado projects, the system will loose hydropower generation at Gatun Lake and Madden Lake due to the change in the operation of the system. The inclusion of the Upper Rio Indio Dam project, however, will not produce enough additional megawatt hours of hydropower to offset those losses in hydropower generation. Thus, the system will have a net decrease in hydropower production. The value for hydropower energy used in this analysis is $0.070/kWh. On an average annual basis, the proposed project should have loses of ($1,345,000). Table 45 - 14 provides the net additional megawatt hours of hydropower generation and the resulting benefits.

Table 45 - 14 Average Annual Benefits For Hydropower Generation

Year	Net Generation [1] (MWh)	Annual Benefits for Hydropower ($)
2023	(19,202)	(1,344,000)
2030	(19,165)	(1,342,000)
2040	(19,099)	(1,337,000)
2050	(19,521)	(1,366,000)
2060	(21,432)	(1,500,000)
2070	(23,744)	(1,662,000)
Average Annual Benefits		(1,345,000)

[1] Net generation of Gatun, Madden, and Rio Indio above generation of Gatun and Madden hydropower plants.

SUMMARY OF ANNUAL BENEFITS

As shown in Table 45 - 15, total average annual benefits for the proposed Lower Rio Trinidad, Rio Caño Quebrado and Upper Rio Indio projects is $250,466,000.

Table 45 - 15 Summary of Annual Benefits

Benefit Category	Average Annual Benefits ($)
Navigation – Water Supply	230,707,000
Navigation – Reliability	17,856,000
M&I - Reliability	3,248,000
Hydropower	(1,345,000)
Total	250,466,000

To perform an analysis of benefits versus costs, a common point in time is selected. This common point is at the completion of filling of the project, the end of the year 2022. In these analyses, it is important to note that the average annual benefits or average annual costs are the amortized value of the sum of the present worth of either the benefits or costs at the point of comparison. The development sequence for the proposed Lower Rio Trinidad and Upper Rio Indio Dam projects would be to develop the Rio Indio Dam project first (2001 – 2010) and then the Lower Rio Trinidad Dam project (2009 – 2022).

The benefits attributable to the proposed Upper Rio Indio project should begin to accrue in 2010 when the reservoir is filled. Thus, the Upper Rio Indio project benefits for the period 2011 to 2022 are escalated by the project discount rate, 12 percent, in order to estimate their total present worth of $1,270,111,000, in the year 2022. The average annual benefits for the proposed Upper Rio Indio project accrued during the construction of the proposed Lower Rio Trinidad project are estimated at $152,943,000.

To estimate the interest during construction, similar calculations are made for the costs of each proposed project. For the proposed Upper Rio Indio project, interest during construction is taken from year 2001 to year 2022 and the interest during construction for the proposed Lower Rio Trinidad project is taken from the year 2009 to the year 2022.

To perform an analysis of benefits versus costs, a common point in time is selected. This common point is at the completion of filling of the project, the end of the year 2022. In these analyses, it is important to note that the average annual benefits or average annual costs are the amortized value of the sum of the present worth of either the benefits or costs at the point of comparison. The development sequence for the proposed Lower Rio Trinidad and Upper Rio Indio Dam projects would be to develop the Upper Rio Indio Dam project first (2001 – 2010) and then the Lower Rio Trinidad Dam project (2009 – 2022).

Total average annual benefits and average annual costs are then estimated, and the ratio of benefits to costs and the net benefits (net of costs) computed. In the first instance, the analysis determines the feasibility of the proposal. The net benefits determine which proposal provides the greatest value for the investment dollars. Table 45 - 16 provides the benefit to cost ratio and the net benefits.

Table 45 - 16 Economic Evaluation

Item	Value ($)
Average Annual Benefits	
Lower Rio Trinidad and Rio Caño Quebrado	250,466,000
Rio Indio	152,943,000
Total Average Annual Benefits	403,409,000
Average Annual Costs	
Lower Rio Trinidad	227,725,000
Rio Indio	145,451,000
Rio Caño Quebrado	4,143,000
Total Average Annual Costs	377,318,000
Benefit to Cost Ratio	1.07
Net Benefits	26,091,000

Internal Rate of Return

An internal rate of return analysis for this proposed project was performed. To accomplish this analysis, the annual construction costs are used as the investment, and the undiscounted benefits are used as return cash flows. The internal rate of return would be 12.9 percent.

Socio-Economic Impacts

The description of the environmental setting is based on field observations made while conducting field reconnaissance throughout Gatun Lake, specifically the Lower Rio Trinidad, Rio Caño Quebrado, and Rio Indio areas in company with ACP personnel. Autoridad Nacional del Ambiente (ANAM), ACP, Asociacion Nacional para la Conservacion de la Naturaleza (ANCON), Electrical Transmission Agency, Smithsonian Tropical Research Institute (STRI), and Directorate of Mineral Resources personnel were interviewed to gain information on site characteristics and potential activities that could affect the project. In addition, extrapolations of the 2000 census data were used, and a review of the Informe de Cobertura Boscosa 1992 were used to determine the extent of forest cover.

Environmental Setting

This alternative combines three projects, the Lower Rio Trinidad (lake level 22.9 - 33.5 m) with Rio Caño Quebrado (lake level 22.9 - 33.5 m), and Upper Rio Indio (lake level 50 m). This project will provide additional storage of water for Gatun Lake and 15.44 additional lockages per day on a continual basis. The project area consists of 27,259 ha within Gatun Lake and 1,898 ha within the Rio Indio watershed. The area near Gatun Lake is sparsely populated and has a topography of rolling hills, and low regions near Gatun Lake. Near Rio Indio, the area is sparsely populated with a topography consisting of steep hills, as well as coastal regions. The Lower Rio Trinidad, Rio Caño Quebrado, and Upper Rio Indio are west of the Panama Canal and flow northward from the Continental Divide into Gatun Lake. The watershed above the Lower Rio Trinidad with Rio Caño Quebrado and the Upper Rio Indio the dam project covers approximately 1,052 km^2 and 256 km^2 respectively. The incremental impoundment area which covers approximately 11,155 ha consists of approximately 50 percent of forested land, 30 percent of pasture land (used by ranchers), 10 percent of cropland, and 10 percent of newly slashed and burned land. Gatun Lake's normal pool level is 26.7 m. The lake level during field observations (August 2001) was approximately 25.4 m.

LAND USE

The Lower Rio Trinidad project area encompasses the southwestern portion of Gatun Lake and areas along its shores. The areas to be flooded or partially flooded include the town of Escobal (population – 1,653), Nuevo Provenir (population – 121), Cuipo (population – 249), Ciricito (population – 72), La Arenosa (population – 242), La Garterita (population – 138), La Gartera (population – 348), and a few small isolated establishments.

The Rio Caño Quebrado project proposes to maintain the impoundment at pool levels between 22.9 and 33.5 m. The normal pool level is 26.67 m. La Laguna (population 246) and Pueblo Nuevo (population 47) are the only towns on the Rio Caño Quebrado arm. The lake is also used for fishing, bathing, and transportation. Houses in La Laguna and Pueblo Nuevo are constructed of forest products and/or of concrete.

Some areas along the shores of the Lower Rio Trinidad and Rio Caño Quebrado have been deforested. Approximately 65 percent of the lakeshore areas are forested, mostly with secondary growth. Farms and ranches of various sizes, as well as teak and African mahogany plantations, occupy the remaining land. Farm crops include maize, rice, beans, sugar, coffee, mangos, pineapples, and tobacco. Ranchers raise cows, horses, chickens, hogs, and tilapia. Some of the farmers and ranchers operate commercial enterprises, others rely on cash crops and subsistence farming. No significant ore deposits or mineral resources are located along the Rio Caño Quebrado arm of Gatun Lake.

The Rio Indio project area is inhabited by about 2,300 people, residing in the towns of Tres Hermanas (population – 200), Los Cedros (population – 80), El Coquillo (popoulation – 150), El Limon (population – 140), Los Uveros (population – 140), and La Boca de Uracillo (population – 110), and in approximately 30 smaller settlements. Downstream from the dam site, at El Limon, are 14 communities with a combined population of approximately 600. The largest of these is La Boca del Rio Indio with a population of more than 150.

Approximately 60 percent of the land in the project area is occupied by farms and ranches of various sizes as well as some teak plantations. Farm crops include maize, rice, beans, sugar, coffee, and tobacco. Ranches raise horses, cows, chickens, and hogs. Some of the farmers and ranchers run small commercial enterprises, or rely on cash crop and subsistence farming.

INFRASTRUCTURE

During site investigations in the Lower Rio Trinidad area, the town of Escobal was the largest settlement visited. Escobal has businesses, schools, churches, cemeteries, medical centers, residences, and paved roadways of good condition. A new and improved roadway (Highway 35) is adjacent to the project area near Escobal. Other establishments in the project area Nuevo Provenir; Cuipo; Ciricito; La Arenosa; La Garterita; La Gartera; and a few small isolated establishments have elementary schools, small cemeteries, churches and meeting centers, medical clinics, and a few small businesses (i.e. general stores). The towns and villages depend on Gatun Lake or groundwater wells for their potable water supply. Each community also had docks, small ports, and other boat access facilities. Goods are transported from one town to another by boat. No treatment of community waste is provided. Wastewater from showers and washing is discharged into the environment; some of it may eventually reach the Lower Rio Trinidad portion of Gatun Lake. Disposal of domestic waste is the responsibility of individual homeowners; some homes have septic tanks, while others have an outdoor latrine (a hole in the ground). There are some health problems, such as hepatitis, dysentery, dermatitis, intestinal parasites, and respiratory illnesses, which are attributable to the present waste disposal methods. No major industries or meat processing plants are located in the project area. The project area is traversed by unpaved horseback riding trails that link the various communities and by unpaved roads used by the ACP for maintenance. These roads are extremely important to the residents for transportation, community cohesion, commerce, and communication with neighboring communities because of the relatively isolated location of the project area.

In the Rio Caño Quebrado project area, La Laguna and Pueblo Nuevo have access to cemeteries, churches, and medical centers, and rely on Gatun Lake or groundwater wells for their drinking water supply. Most homes have electricity and limited telephone service. No treatment of community waste is provided. Wastewater from showers and washing is discharged into the environment; some of it may reach Gatun Lake. Disposal of domestic waste is the responsibility of individual homeowners; some homes have a septic system or an outdoor latrine. There are some health problems, such as hepatitis, diarrhea, dermatitis, intestinal parasites, and respiratory illnesses that are attributed to the present waste disposal methods.

No known major industries or meat processing plants are located in the project area. La Laguna is accessible by a poorly maintained unpaved road that is usable only in the dry season (mid-December through March). The roads are rarely graded and receive little attention from either the Ministry of Public Works or the local government. Pueblo Nuevo is accessible only by an unpaved trail. These roads are extremely important to the residents for transportation, community cohesion, commerce, and communication with neighboring communities because of the relatively isolated location of the project area.

In the Upper Rio Indio project area, the towns of El Limon, El Silencio, San Cristobal, and Piedra Amarilla have elementary schools. Several towns have cemeteries, churches, and medical centers. All these towns obtain water from rivers or groundwater wells. Some have electricity (from small generators) and limited telephone service. No treatment of community waste is provided. Wastewater from showers and washing is discharged into the environment; some of it might eventually reach Rio Indio and its tributaries. Disposal of domestic waste is the responsibility of individual homeowners; each home has an outdoor latrine. There are some known health problems, such as hepatitis, diarrhea, dermatitis, intestinal parasites, and respiratory illnesses which are attributed to the present waste disposal methods. No known major industries or meat processing plants are located in the project area. The only roads in the project area are unpaved and poorly maintained, and are usable only in the dry season (mid-December through March). The roads are rarely graded and receive little attention from either the Ministry of Public Works or the local government. These roads are extremely important to the residents for transportation, community cohesion, commerce, and communication with neighboring communities because of the relatively isolated location of the project area.

TERRESTRIAL HABITAT

The terrestrial habitat in the Lower Rio Trinidad and Rio Caño Quebrado project areas of Gatun Lake consists of tropical forest ecosystems, mostly secondary growth forests with patches of primary forest. About 65 percent of the lands along the Lower Rio Trinidad and Rio Caño Quebrado areas of Gatun Lake are forested and supports diverse wildlife populations. This area of Gatun Lake also contains islands inhabited by wildlife. Some of the wildlife species do not interact with species on the mainland; others migrate between the island and the mainland. The species interrelationships are of great interest to scientists studying tropical ecosystems. Slash and burn activities have opened tracts of land for farming and cattle grazing. The majority of the lakeshore is forested to the edge of the water. Terrestrial areas are used by migratory species as wintering, breeding, and feeding grounds. The complex and diverse tropical ecosystems offer habitat to connect a variety of wildlife communities and may provide critical wildlife habitat to many native species.

In Upper Rio Indio, forests along the river that could support diverse wildlife populations cover about 90 percent of the areas along the Rio Indio and its tributaries. The forests also extend to the mountainous areas above the Rio Indio impoundment. As a result of slash and burn activities, there are no large contiguous tracts of forests at lower elevations in the impoundment.

ANIMALS ON ENDANGERED LIST

ANAM, Resolution 002-80 enacted on June 7, 1995, declared 33 mammals, 39 birds, and 11 reptiles and amphibians are in danger of becoming extinct in Panama. Although their presence has not been confirmed to date, some of the listed species of interest on the threatened list might be found in the project area. The manatee is an aquatic mammal known to inhabit Gatun Lake around the Barro Colorado Island; however, it has not been sighted in the project area.

AQUATIC HABITAT

Gatun Lake, one of the world's largest manmade lakes, was created during the construction of the Panama Canal. The lake's water depth and quality vary widely. Aquatic habitat ranges from inundated forests to clear water in areas distant from shipping lanes. The Lower Rio Trinidad and Rio Caño Quebrado areas of Gatun Lake provide habitat for a variety of wildlife species, both resident and migratory, as well as for native or introduced fish, and other aquatic species.

Rio Indio in the project area has characteristics typical of streams in mountainous regions. Its water is clean and cool, and its bottom ranges from sand to boulders, with numerous riffles, runs, and pools. Tributaries to Rio Indio include four major streams: Rio El Torno, Rio Uracillo, Rio Teria, and Rio Riacito, and 20 smaller streams. The river is approximately 16 km long, its width ranges from 3 m (in the dry season) to 10 m. The tributaries appear to support some fish communities; however, information about these communities is limited.

WETLANDS

Areas that contain hydric soils and hydrophytic plant communities, and that are subject to hydric conditions are termed wetlands. Wetlands occur in topographic areas where water remains pooled long enough to produce hydric soil conditions and wetland plant communities. Wetlands in the Lower Rio Trinidad and Rio Caño Quebrado project areas consist of shallow water habitats and lands subject to frequent flooding. Shallow water areas along the banks of the Lower Rio Trinidad and Rio Caño Quebrado areas of Gatun Lake receive sunlight to a depth of approximately 1 m. Sunlight stimulates growth of submergent, emergent, or floating mats of aquatic vegetation. Wetlands in the project area are stressed due to excessive sediments, municipal waste, agricultural runoff, and other debris carried in the runoff.

Wetlands in the Upper Rio Indio project area consist of forested riparian habitat and are limited by their relatively steep topography. The width of the riparian habitat within the impoundment area varies from approximately 5 - 50 m. Approximately 90 percent of the streams both above and below the dam site along the Rio Indio and its tributaries are bordered by forested riparian habitat.

AIR QUALITY

Air quality in the project area is generally good, except during the slash and burn activities. At the end of the dry season (in March or early April), areas of forest and secondary growth are burned and cleared for agricultural use. During this period, the air is filled with smoke and ash, which may be transported by winds to the Lower Rio Trinidad and Rio Caño Quebrado areas of Gatun Lake. Based on observations in the Rio Indio project area, approximately 10 percent (or 400 ha) of forested land is burned annually. Air quality monitoring has not been implemented within the project area.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

Barro Colorado Island is an international center for tropical research and one of the first biological reserves established in the Neotropics. From 1923 through 1940, a scientific committee of the U.S. National Academy of Sciences administered the biological reserve/laboratory. In 1940, by an Act of the United States Congress, the facility was renamed the Panama Canal Zone Biological Area, and in 1946, the responsibility for its maintenance was assigned to the Smithsonian Institution. With the Panama Canal Treaty Implementation in 1977, the island was granted the category of National Monument and to date it continues to be managed by the Smithsonian Institute. It should also be noted that most of the Atlantic region of Panama is within the interest and objectives of the Mesoamerican Biological Corridor, an international project to conserve biodiversity.

In the pre-Columbian period, the Upper Rio Indio was a language frontier; the inhabitants on each side of the river spoke a different native language. During the Spanish colonial period, the river served as a political boundary. The project area has a high potential to be rich in archaeological and historical remains.

Environmental Impacts

TERRESTRIAL HABITAT

The impacts of the project on terrestrial habitat in the Lower Rio Trinidad and Rio Caño Quebrado areas of Gatun Lake could be substantial. The boundary between two types of habitats, in this case between a forest and a lake, is called an ecotone. Ecotones are inhabited by a variety of species from neighboring habitats, and are unique, with high species diversity. Considering the proposed operating levels for both impoundments, between 22.9 - 33.5 m, as the normal zone of operation, erosion of the shoreline may be substantial as pool levels rise and fall. Terrestrial habitat that would be inundated above the 26.7 m (existing level) to the 30.5 m proposed normal pool level consists of 21,912 ha for the Lower Rio Trinidad project. The permanent raising of the water level in Rio Caño Quebrado Lake will impact wildlife habitat as approximately 3,443 ha of additional land will be inundated. The placement of a dam structure, access roads and pump stations would permanently impact terrestrial habitat. Wildlife species that are able to relocate to suitable areas will compete with similar species for resources; species that are not able to relocate will not survive. As a result, competition for natural resources in surrounding habitat areas will increase. This is considered a secondary impact to terrestrial habitat outside the proposed zone of inundation and construction.

The terrestrial impacts of the Rio Indio project, which is located in area of relatively high quality forest habitat, would be substantial. With the creation of the lake, the migratory routes of some species could be adversely affected. Forested areas along lower elevations would be lost as a result of the impoundment. The only forests that would remain near the Upper Rio Indio reservoir and its drainage basin would be confined to the higher elevations, where the vegetation and species may be completely different from those found at lower elevations. Natural communities are linked together by complex interactions and relationships among various species, therefore impacts to upper forested areas may occur resulting from the inundation of the lower forests.

ANIMALS ON ENDANGERED LIST

The severity of impacts on endangered species cannot be determined at this time, because although it is expected that some of the listed species are found in the region, it is not known which of the listed species inhabit the proposed project area. Some endangered and/or threatened species may use the Lower Rio Trinidad and Rio Caño Quebrado areas of Gatun Lake during some or all parts of their life cycle.

WATER QUANTITY

The impacts of the Lower Rio Trinidad and Rio Caño Quebrado projects on water quantity would be substantial. The increase in the volume of water could have negative impacts to lakeshore communities, as well as on existing ecosystems. The same is true if the lake level is lowered and maintained at 22.9 m.

The impacts of the Rio Indio project area on water quality would also be substantial. The volume of water will increase, making fresh water available during the dry season. The impacts downstream from the dam would be significant. Sediment loads would be deposited upstream from the dam as water velocity slows. Downstream from the dam the water will be released at an increased velocity, causing erosion of banks and river bottoms. Seasonal flooding could be significantly reduced. It would also be possible to periodically release water in appropriate amounts to avoid problems with water quality and temperature downstream. The cumulative impacts downstream from the dam site depend on the amount of water being released.

WATER QUALITY

Project impacts on water quality are not known. Damming the Lower Rio Trinidad and Rio Caño Quebrado could increase the amounts of nutrients and debris in this portion of Gatun Lake. A pilot plant tilapia farm is in the project area and may affect water quality. The rate nutrients and debris enter the lake will determine the severity of their impact on water quality. Project implementation could cause an increase in turbidity, which would interfere with photosynthesis and deprive plants and other aquatic species from sunlight. Aquatic plants and organisms serve to maintain water quality. The dam would interfere with the circulation of freshwater throughout the Gatun Lake environment. Species inhabiting specific depths could be impacted when lake depth increases to 33.5 m and/or decreases to 22.9 m.

The impacts of the Upper Rio Indio project on water quality could be positive. The people living downstream from the dam and around the impoundment would have access to a higher quality water supply. Water quality in the impoundment area would differ from water released downstream from the dam. If the water in the impoundment area does not circulate, it could become anoxic. A change in temperature, dissolved oxygen, turbidity, or pH could change water quality.

DOWNSTREAM AQUATIC FAUNAL HABITAT

The impacts of the project on aquatic faunal habitat could be substantial. The project may affect the breeding and nursery habitat of many aquatic species. Impacts to fish spawning areas may be detrimental when turbidity, nutrient content, and depth of the water suddenly increase or decrease, altering the conditions needed for successful fish hatching. Plant populations may decrease due to fluctuating water depths, clarity, and quality. Invertebrate populations may decline, which could reduce the food supply for fish and other aquatic species.

Impacts to downstream aquatic faunal communities in the Upper Rio Indio project area could be substantial, because the dam structure will prevent migration throughout the riverine habitat. The dam structure would be designed for multi-level releases to maintain a water level downstream from the dam site. The dam would act as a large sediment trap; thus, the released water would have low turbidity, which would result in better visibility and increase predation on the fish species. Aquatic faunal habitats downstream would be deprived of the beneficial nutrients and silts that were transported in the sediment. Native riverine fish species may be negatively impacted as a result of the project; the extent of the impact is not known.

FUTURE LAKE AQUATIC PLANT COMMUNITY

The impacts of the project on future aquatic plant communities depend on water quality and stability of water levels. Plant species in the Lower Rio Trinidad and Rio Caño Quebrado portions of Gatun Lake could be impacted by fluctuating water levels. Aquatic plant communities could be impacted during project implementation; however, they could re-establish themselves after conditions stabilize.

The severity of impacts from the Upper Rio Indio project will depend on water level fluctuations. Since water levels are anticipated to fluctuate widely, large portions of the shores would be covered with mud, where neither aquatic nor terrestrial plants could thrive.

AQUATIC FAUNA INHABITING AFFECTED AREAS

The proposed project impacts could have some unavoidable, adverse environmental impacts on aquatic fauna in the Lower Rio Trinidad, Rio Caño Quebrado, and associated rivers and tributaries. These impacts should be identified and minimized with appropriate mitigation measures to be discussed in a feasibility level study. Gatun Lake has populations of peacock bass and tilapia, both introduced species that have adapted well. However, several native riverine species that formerly occupied the impoundment have disappeared.

The impacts of the Upper Rio Indio project on aquatic fauna in the Rio Indio and its upstream tributaries could be substantial, since the habitat area would change from riverine to lacustrine. Some aquatic species would continue to inhabit the area; non-native fish species could become dominant in the impoundment area and native riverine species could be pushed upstream or extirpated. Other manmade lakes in the Republic of Panama have been stocked with peacock bass and tilapia, both of which have adapted well. The impoundment area would probably be stocked with these species to promote sport fishing and to provide the local communities with fish for food.

WETLANDS

The impacts to wetlands could be significant. Inundation of wetlands could cause them to become aquatic habitat. The changes in water depth caused by the project may lead to increased or decreased sedimentation and turbidity, which could hamper the biological processes in the wetlands and decrease their productivity. Such impacts could be detrimental to the health and sustainability of the Lower Rio Trinidad and Rio Caño Quebrado areas of

Gatun Lake. Fish and other aquatic species use shallow water areas as spawning grounds, as well as habitat for juvenile aquatic species who survive in the shallows until large enough to venture into deeper water. These wetlands are vital to the sustainability of this portion of Gatun Lake, including the Lower Rio Trinidad and Rio Caño Quebrado areas.

The impacts to wetlands both upstream and downstream from the Upper Rio Indio project area could be significant. Owing to the topography of the project area, a number of wetlands could be impacted. It is possible that although the reservoir level will fluctuate, new wetlands could develop in the littoral zones. Downstream from the dam site, wetlands along the minimal flow zone would survive; wetlands that depend on seasonal flooding for survival may be adversely affected.

AIR QUALITY

During project implementation, emissions from construction equipment, as well as from slash and burn activities could cause deterioration of air quality. After project implementation, the air quality may be impacted by the operation of the power generation facility and the pumping stations.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

The potential impacts on cultural resources and historic properties from the Upper Rio Indio project can be defined and mitigated. In the La Boca de Uracillo area in particular, there are previously identified archaeological sites. The project area is relatively large and is known to contain pre-Columbian sites; therefore, the presence of cultural resources and historic properties is highly probable. Prior to construction, surveys to locate cultural resources and historic artifacts would be conducted, and the important sites would be preserved or salvaged as appropriate.

SOCIO-ECONOMIC IMPACTS

The socio-economic impacts of the project could be substantial. The relocation of the towns and other small communities along the lakeshore would be an important issue. The average monthly income of families in the project area ranges from less than $100 to $200 per month. No indigenous groups are known to reside in the impact area. Land use would be greatly impacted by the inundation of pastures and agricultural lands to expand the impoundment. The relocation of agricultural and ranching activities would be critical, because approximately 10 percent of the land in the impoundment area is used for farming and ranching. After the water level is raised, additional agricultural land could be lost as islands are created from isthmuses. The incremental surface area of the proposed lake is 11,155 ha; another 1,504 ha from the Lower Trinidad and Rio Caño Quebrado project and 634 ha from the Upper Rio Indio project will be occupied by the dam and construction areas, including permanent disposal areas.

During construction, the influx of workers could create a temporary demand for additional housing, resulting in an increase in housing values near the dam site. However, after completion of the project, the workers could leave, the housing demands could drop, and the housing values could return to pre-construction levels. Currently, all residents have access to public schools and health centers. During construction, these services should continue to be available, and additional public and community services may be offered. After construction, these services would return to the normal level.

To construct the dam, some existing roads must be improved and some new roads must be built. However, some paved and unpaved roads within the impoundment area would be eliminated, which could change traffic patterns and could cause some communities to lose overland transportation, communication, cohesion, and commerce with other communities. During construction, the traffic volumes over both new and existing roads systems would increase; however, following completion of construction, the traffic volumes could decline. Noise levels would temporarily increase during construction and could negatively impact noise-sensitive receptors; after construction noise levels may remain elevated as a result of the power generation facility and pump stations.

Communities receiving people displaced by the project could be negatively impacted by overcrowding and by competition for jobs, land, and working areas. Construction of the dams would permanently displace some people and disrupt lives through the division of communities, separation of families, and loss of livelihood. Following completion of the impoundment, the tourism trade in the affected region, including sport fishing and ecotourism, could increase.

Additional Environmental Information Required

This section identifies the subject areas which require additional data to the scope and magnitude of the potential effects of the Lower Rio Trinidad, Rio Caño Quebrado, and Upper Rio Indio alternative. The subject areas are discussed by impact category.

SOCIO-ECONOMIC IMPACTS

Conduct a SIA. The SIA would consist of three tasks: scoping, assessment, mitigation and monitoring. The following information should be developed:

- Business, Industrial, and Agricultural Activities;
- Employment;
- Land Use;
- Property Values;
- Public and Community Facilities and Services (including utilities and schools);
- Transportation;
- Housing;
- Health (vector routes);
- Population;
- Community Cohesion; and,
- Recreational Resources.

TERRESTRIAL AND AQUATIC HABITAT

- Prepare site-specific habitat maps to ensure that the major types of aquatic habitat are identified and quantified.

- Conduct field studies to locate rare and unique habitats, such as wetlands, primary forests, roosting sites, foraging areas, old growth, and migration flyways.
- Determine the present quality and ecosystem value of existing habitats within the Gatun Lake project area.
- Coordinate with local experts to identify and evaluate aquatic and terrestrial habitat areas.
- Prepare species inventory lists for each site area, identifying their status as native or exotic and whether they are threatened and or endangered species.
- Conduct additional research into water currents and estimated turbidity levels to evaluate impacts to the shallow areas along Barro Colorado Island.
- Address cumulative effects caused by natural flow diversions.

ANIMALS ON THE ENDANGERED LIST

- Compile habitat maps to assess the availability and quality of suitable habitats for the animals on the endangered and/or threatened species list.
- Establish field methodology to assess wildlife habitat values.
- Conduct site surveys to determine the presence of selected species or their habitats.
- Develop candidate mitigation measures for the appropriate project alternatives to be considered in the Conceptual Phase.
- Coordinate with local experts on the presence of endangered species.

WATER QUALITY

- Since limited water quality data are available for the Gatun Lake area, compile information on total suspended solids, conductivity, total dissolved solids, dissolved oxygen, nutrients, pH, and coliform bacteria.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

- Information regarding cultural resources and historic properties in the project area is incomplete. Additional evaluation studies should be completed to identify any such resources and/or properties.

Evaluation Matrices

In accordance with evaluation procedures described in Volume One, the following tables reflect the conclusions derived for this alternative. A summary table with ranking is provided in Volume One. Tables 45 - 17 through 45 - 19 present the evaluation of the proposed Lower Rio Trinidad project as related to developmental effects, environmental effects, and socio-economic effects.

Table 45 - 17 Developmental Effects

Evaluation Criteria	Function	Measure 1/	Importance 2/	Composite 3/
Water Contribution (Water Yield)	Meets M&I Demands	10	10	100
	Supplements Existing System	7	10	70
	Satisfies Future Canal Needs/Expansion	0	10	0
	Additional Hydropower Potential	0	5	0
Technical Viability	Design Constraints	2	6	12
	Feasibility of Concept	2	6	12
Operational Issues	Compatibility	8	6	48
	Maintenance Requirements	4	2	8
	Operational Resources Required	4	2	8
Economic Feasibility	Net Benefits	1	9	9
	Total			267

1/ Measure - A numerical from 0 to 10 value representing the degree or level the alternative satisfies the criteria. Value of 10 indicates the most significant beneficial impact and 0 the most significant adverse impact.
2/ Importance - A weighting factor from 0 to 10 to balance the significance of a criteria to the others.
3/ Composite - the product of the measure and importance.

Table 45 - 18 Environmental Effects

Item	Measure 1/	Importance 2/	Composite3/
Terrestrial Habitat	2	8	16
Animals on Extinction List	2	10	20
Water Quantity Impacts – Lake	8	10	80
Water Quantity Impacts -- Downstream	4	7	28
Water Quality	5	10	50
Downstream Aquatic Fauna Habitat	3	8	24
Future Lake Aquatic Plant Community	6	8	48
Aquatic Faunal Inhabiting Affected Area and Upstream Tributaries	4	5	20
Potential for Fishing on Lake	6	6	36
Wetlands	3	4	12
Air Quality	5	3	15
Cultural Resources and Historic Properties	3	10	30
Total			379

1/ Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
2/ Importance - 1 to 10 increasing in importance.
3/ Composite - the product of the measure and importance.

Table 45 - 19 Socio-Economic Effects

Item	Measure 1/	Importance 2/	Composite3/
Land Use	2	7	14
Relocation of People	1	10	10
Relocation of Agricultural/Ranching Activities	1	6	6
Post-Construction Business	6	5	30
Post-Construction on Existing Employment	6	5	30
Property Values During Construction	7	4	28
Property Values Post-Construction	5	5	25
Public/Community Services During Construction	6	4	24
Public/Community Services Post-Construction	5	8	40
Traffic Volumes over Existing Roadway System During Construction	3	5	15
Traffic Volumes over New Roadway System Post-Construction	5	5	25
Noise-Sensitive Resources or Activities	4	4	16
Communities Receiving Displaced People	1	8	8
Community Cohesion	1	8	8
Tourism	6	5	30
Total			309

1/ Measure: 1 to 4 = negative impacts; 5 = neutral; 6 to 10 positive impacts.
2/ Importance - 1 to 10 increasing in importance.
3/ Composite - the product of the measure and importance.

Pertinent Data

Table 45 - 20 presents pertinent data for the proposed Lower Rio Trinidad project.

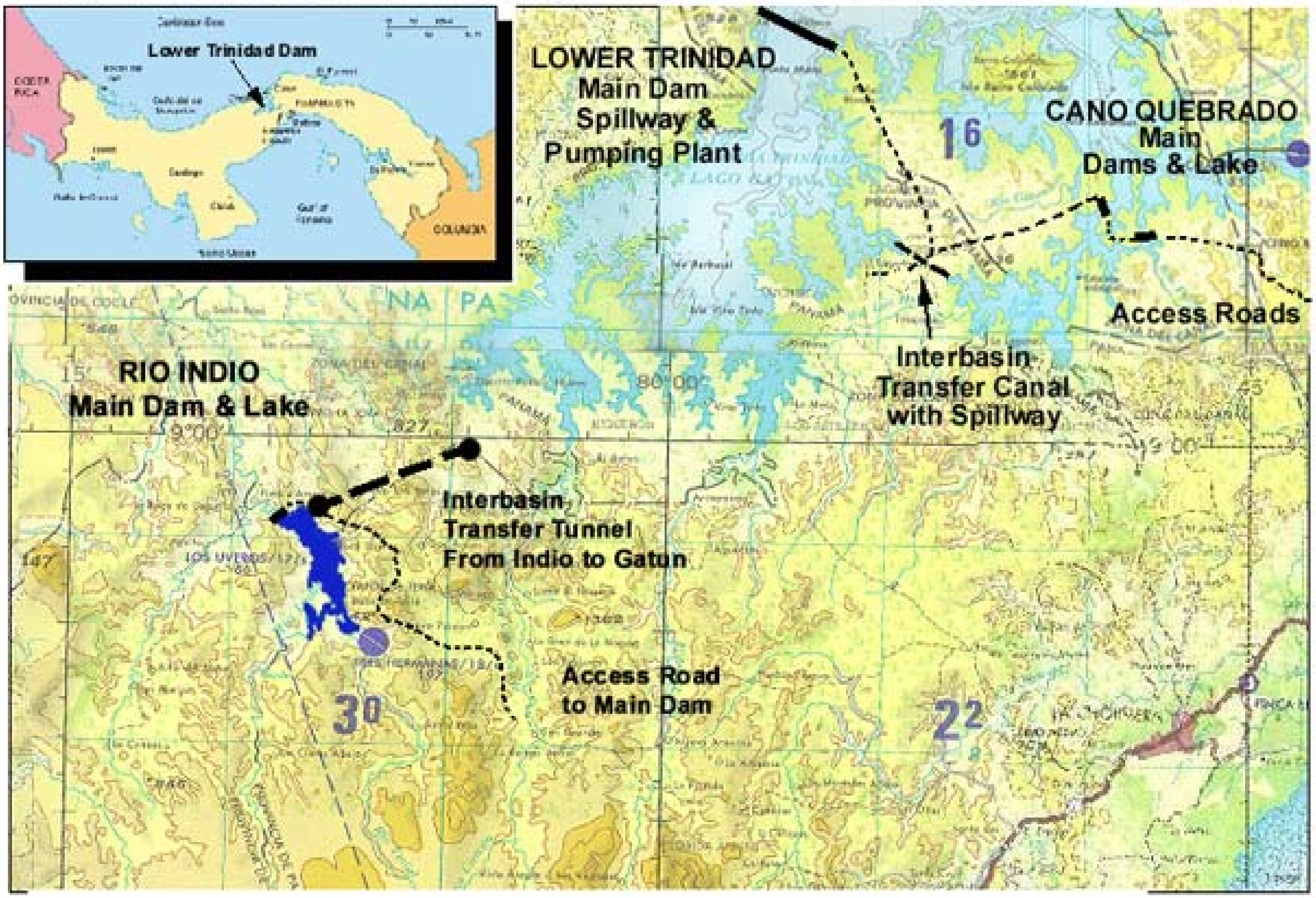
Table 45 - 20 Pertinent Data for Operating Scenario 10

GENERAL	**Gatun**	**Trinidad and Quebrado**	**Rio Indio**
Drainage Area above Dam Site	1,261.5 km^2	1,051.5 km^2	256 km^2
Average Annual Flow at Dam Site	50.4 CMS	39.6 CMS	16.8 CMS
LAKE			
Elevation of Maximum Operating Lake Level	26.67 m MSL	33.53 m MSL	50.0 m MSL
Elevation of Maximum Flood Storage Lake Level	26.74 m MSL	34.14 m MSL	53.0 m MSL
Elevation of Minimum Operating Lake Level	25.91 m MSL	22.86 m MSL	45.5 m MSL
Useable Storage between Max. and Min. levels	200.4 MCM	2052.9 MCM	35.6 MCM
Area at Maximum Operating Lake Level	27,514 ha	25,355 ha	2,134 ha
Area at Maximum Flood Storage Lake Level	27,550 ha	26,459 ha	2,218 ha
Area at Minimum Operating Lake Level	27,321 ha	10,170 ha	732 ha
Top Clearing Elevation	33.5 m MSL	33.53 m MSL	50 m MSL
Lower Clearing Elevation	25 m MSL	25m MSL	45 m MSL
EMBANKMENTS			
Dam – Rock Fill Embankment			
Top Elevation of Dam	34.5 m MSL	34.5 m MSL	53 m MSL
Fixed Crest Width	13 m	13 m	13 m
Height above Lowest Foundation	18 m	28 m	38.5 m
Overall Length of Dam	varies m	4480/422 m	632 m
SPILLWAY			
Type of Spillway	Gated Ogee	Gated Ogee	Uncontrolled Ogee
Number of Gates	14	8	-
Width of Gates	13.72 m	18.33 m	-
Net Length	192.02 m	149.35 m	-
Total Length	246.27 m	238m	113 m
Elevation of Crest	21.03 m MSL	25.91 m MSL	50.0 m MSL
Maximum Discharge	5150 CMS	6038 CMS	618 CMS

INDIO ONLY	
INTER-BASIN TRANSFER TUNNEL	
Tunnel diameter	4.5 m
Tunnel length	7651 m
Inlet invert	45.5 m MSL
Outlet invert	40 m MSL
Tunnel capacity	37.9 CMS
HYDROPOWER PLANTS	
Dam	
Type of hydropower plant construction	Reinforced concrete
Number of units	1
Capacity of each unit	5 MW
Inter-basin Transfer Tunnel	
Type of hydropower plant construction	Reinforced concrete
Number of units	1
Capacity of unit	2 MW
CONSTRUCTION/POWERHOUSE DIVERSION	
Diversion length	800 m
Tunnel diameter	7 m
Inlet invert	12 m
Outlet invert	10 m
MINIMUM FLOW CONDUIT	
Conduit diameter	600 mm
Conduit length	800 m
Inlet invert	12 m
Outlet invert	10 m
Conduit capacity	1.7 CMS
EMBANKMENTS	
Dam	
Type of dam	Rock fill embankment
Top elevation of dam	53 m
Fixed crest width	13 m
Height	38.5 m
Overall length of dam	632m

Plate 45 - 1 Project Location Map

LOWER TRINIDAD / CANO QUEBRADO / UPPER RIO INDIO



Project Location Map

SECTION 46

Comparitive Evaluation of Alternatives

TABLE OF CONTENTS

LIST OF TABLES

Synopsis

The purpose of this study effort was to define the project concepts, determine if a feasible project could be developed for each alternative, develop project costs, and provide an economic analysis. The objective was to present each alternative at the same level of analysis so that the alternatives could be compared and ranked. This section presents the final step of ranking the alternatives previously indicated to be feasible by satisfying the criteria set forth in Volume One, Section 4. Description of project features, detailed analyses, and results for each alternative were presented in Sections 36 through 45.

Evaluations

In the selection of an alternative for implementation, the ability of that alternative to meet wholly or partially the objectives of the planning process must be considered. As part of the reconnaissance study, evaluation matrices have been provided with each alternative that passed the initial screening criteria. These matrices incorporated the five evaluation criteria points presented in Volume One, Section 4. The matrices are found in each section of the alternative analysis and are entitled: Developmental Effects, Environmental Effects, and Socio-Economic Effects. Each matrix provides a means to apply a significance or weight to each analysis criterion, and a measure of how each project satisfies the criterion. The measure column is a numerical value ranging from 0 to 10 representing the degree, or level, to which an alternative was deemed to have satisfied the criteria. A value of 10 indicates the greatest degree of success in satisfying a criterion, and a value of zero indicates the least degree of success in satisfying a criterion. The importance column provides a weighting factor from 1 to 10 to balance the relative significance of a criterion to the other criterion within its respective matrix. Importance values were established for each matrix and remained the same for all projects. The final column, the composite, is the product of the measure and importance. This product provides a balanced assessment of each criterion ranging from 0 to 100.

Table 46-1 presents the maximum possible score for the respective matrices. The total composite scores from each of these matrices were tabulated and normalized by dividing the total by the maximum possible score. Then a composite score was developed by combining the normalized values. The Socio-Economic Effects represented 25 percent of the composite score; Environmental Effects represented 25 percent and Developmental Effects represented 50 percent. The Developmental Effects matrix included water yield, design, technical viability, operational requirements, and economic effects. Each of these were assigned importance levels within the Developmental Effects matrix that resulted in 26.5 percent of the final composite score represented by water yield, 9.1 percent by technical viability, 7.6 percent by operational requirements, and 6.8 percent by economic feasibility. The final step in ranking the alternatives was to list the alternatives sorted by composite score. The alternative with the highest score received the highest ranking.

Table 46 - 1 Maximum Possible Scores

Evaluation Criteria	Function	Importance	Maximum Possible Composite
Developmental Effects			
Water Contribution (Water Yield)	Meets M&I demands	10	100
	Supplements Existing System	10	100
	Satisfies Future Panama Canal needs/expansion	10	100
	Additional Hydropower Potential	5	50
Technical Viability	Design Constraints	6	60
	Feasibility of Concept	6	60
Operational Issues	Compatibility	6	60
	Maintenance Requirements	2	20
	Operational resources required	2	20
Economic feasibility	Net Benefits	9	90
	Maximum Possible		**660**

Item	Importance	Maximum Possible Composite
Envrionmental Effects		
Terrestrial Habitat	8	80
Animals on Extinction List	10	100
Water Quantity Impacts – Lake	10	100
Water Quantity Impacts – Downstream	7	70
Water Quality	10	100
Downstream Aquatic Fauna Habitat	8	80
Future Lake Aquatic Plant Community	8	80
Aquatic Faunal Inhabiting Rio Indio and Upstream Tributaries	5	50
Potential for Fishing on Lake	6	60
Wetlands	4	40
Air Quality	3	30
Cultural Resources and Historic Properties	10	100
Maximum Possible		**890**
Socio-Economic Effects		
Land Use	7	70
Relocation of People	10	100
Relocation of Agricultural/Ranching Activities	6	60
Post-Construction Business	5	50
Post-Construction on Existing Employment	5	50
Property Values During Construction	4	40
Property Values Post-Construction	5	50
Public/Community Services During Construction	4	40
Public/Community Services Post-Construction	8	80
Traffic Volumes over Existing Roadway System During Construction	5	50
Traffic Volumes over New Roadway System Post- Construction	5	50
Noise-Sensitive Resources or Activities	4	40
Communities Receiving Displaced People	8	160
Community Cohesion	8	80
Tourism	5	50
Maximum Possible		**970**

Table 46 - 2 lists the projects that were analyzed and indicates the projects that failed to meet the initial screening parameters. Table 46 - 3 presents the list of projects that were carried forward to the evaluation matrices with the aggregate scores. The projects are sorted by final composite score, with the highest score ranked first.

Table 46 - 2 List of Projects Analyzed

Section Number	Status	Project
36a		Lower Rio Trinidad- 22.9 - 30.5m, Gatun Level 85-87 (25.91m – 30.48m)
36b		Lower Rio Trinidad- 22.9 - 30.5m, Gatun Level 81.0-87 (24.84m – 30.48m)
37		Lower Rio Trinidad- 22.9 - 30.5m; Rio Indio- 50-80m
38		Lower Rio Trinidad- 22.9 - 30.5m; Rio Indio - 50 m
39		Lower Rio Trinidad- 22.9 - 30.5m; Caño Quebrado 22.9 – 30.5 m; Rio Indio - 50-80m
40		Lower Rio Trinidad- 22.9 - 30.5m; Caño Quebrado 22.9 – 30.5 m; Rio Indio - 50m
41		Lower Rio Trinidad- 22.9 - 33.5m; Caño Quebrado 22.9 – 33.5 m;
42		Lower Rio Trinidad- 22.9 - 33.5m; Rio Indio - 50-80m
43		Lower Rio Trinidad- 22.9 - 33.5m; Rio Indio – 50m
44		Lower Rio Trinidad- 22.9 - 33.5m; Caño Quebrado 22.9 – 33.5 m; Rio Indio - 50-80m
45		Lower Rio Trinidad- 22.9 - 33.5m; Caño Quebrado 22.9 – 33.5 m; Rio Indio - 50m

Table 46 - 3 Ranking of Feasible Alternatives

Rank	Section Number	Project	Sum of Composite Developmental Matrix	Sum of Envrionmental Matrix	Sum Socio-Economic Effects Matrix	Developmental divided by Maximum Possible	Environmental divided by Maximum Possible	Socio-Economic divided by Maximum Possible	Final Composite
1	8	Rio Cocle del Norte - Lake at Elevation 100 (Operated in conjunction with Caño Sucio and Indio Lakes)	557	337	302	0.844	0.379	0.339	0.601
2	7	Rio Cocle del Norte - Lake at Elevation 80 (Operated in conjunction with Indio Lake)	539	337	302	0.817	0.379	0.339	0.588
3	9	Rio Toabre and Rio Caño Sucio (Operated in conjunction with Indio Lake)	502	369	315	0.761	0.415	0.354	0.572
4	6	Rio Cocle del Norte - Lake at Elevation 65 - Option 2 (Operated in conjunction with Indio Lake)	496	345	302	0.752	0.388	0.339	0.557
5	22	Rio Caño Sucio - Option 1 (Operated in conjunction with Indio Lake)	398	460	409	0.603	0.517	0.460	0.546
6	44	Trinidad & Quebrado at 110 + Indio 50-80	433	379	309	0.656	0.426	0.319	0.514
7	42	Trinidad 110 + Indio 50 -80	423	391	318	0.641	0.439	0.328	0.512
8	29	Pump Storage From Cocle Del Norte to Rio Toabre (Operated in conjunction with Caño Sucio and Indio Lakes)	421	345	302	0.638	0.388	0.339	0.501
9	39	Trinidad & Quebrado at 100 + Indio 50-80	393	379	309	0.595	0.426	0.319	0.484
10	37	Trinidad at 100+ Indio 50-80	383	391	318	0.580	0.439	0.328	0.482
11	18	Rio Chagres - Option 1	314	381	456	0.476	0.428	0.512	0.473
12	5	Rio Indio - Option 1	342	399	325	0.518	0.448	0.365	0.462
13	24	Deepen Gatun Lake	266	488	367	0.403	0.548	0.412	0.442
14	20	Rio Ciri Grande - Option 1	259	477	380	0.392	0.536	0.427	0.437
15	41	Trinidad & Quebrado at 110	208	489	436	0.315	0.549	0.449	0.407
16									

Note 1

Note 2: Final composite score =
0.5* Developmental / Maximum Possible + 0.25* Environmental / Maximum Possible + 0.25*Socio-Economic / Maximum Possible

For the Developmental Effects matrix, a scale was established that provided a measure the ability of each alternative to meet the water yield objectives of (1) satisfying long-term M&I water supply needs without adversely affecting the operation of the Panama Canal; (2) providing sufficient navigation waters to meet existing Panama Canal transit demands without restricting vessel operation and maintaining historic reliability levels of 99.6 percent; (3) providing sufficient navigation waters to meet future Panama Canal transit demands without restricting vessel operation while maintaining historic reliability levels of 99.6 percent; and, (4) maintaining or increasing the current level of hydroelectric power production as demands for other water uses increase.

The measure for satisfying long-term M&I water supply needs without adversely affecting the operation of the Panama Canal considered the existing and forecast demands for M&I water supply up to the year 2070. The net increase in M&I water supply demand was calculated by subtracting the forecasted demand for the year 2000 from the forecast for each decade. The results were rounded to a whole number and graduated to a scale of 2, 3, 5, 8 and 11, which corresponded to measures of 2, 4, 6, 8 and 10 respectively. If a proposed project would provide 5 lockages of water, it would receive 6 points for this criterion.

A gradation scale for the ability of a project to provide sufficient navigation waters that meet transit demands for the existing Panama Canal system, without restricting vessel operation and maintaining historic reliability levels of 99.6 percent, considered the net increase in forecast lockage demands for existing Panama Canal operations. The net increase in lockages through the year 2070 is approximately 6 lockages, since the existing Panama Canal system is constrained to a sustainable average of 43 transits per day. The measure for each increment (0, 2, 4, 7 and 10) was linearly portioned to the 6 lockages (0, 1, 3, 4, and 6) respectively. M&I requirements were satisfied first. Therefore, any proposed project that provided 15 lockages of water, received 7 measure points for this criterion. (15 lockages of project yield – 11 lockages for M&I requirements = 4 net lockages for navigational increases. The 4 net lockages would correspond to 7 measure points.)

The gradation scale for providing navigation waters to meet future unconstrained Panama Canal transit demands, without restricting vessel operation and maintaining historic reliability levels of 99.6 percent, considered a potential future demand of 32 additional lockages. Since M&I forecasts estimated a net increase up to 11 lockages and the existing Panama Canal system could support increases up to 6 lockages, a total of 17 lockages would be accounted for in the 2 previous criterions. The remaining 15 lockages could only be accommodated through modification of the Panama Canal system. Therefore, the 15 remaining lockages were linearly distributed over the measure range. Thus, the increments are 3, 6, 9, 12 and 15 lockages correspond to measure points of 2, 4, 6, 8 and 10 respectively. If a proposed project provided 20 additional lockages, it would receive two measure points for this criterion. (20 lockages of project yield – 11 lockages for M&I requirements – 6 lockages for existing system = 3 net lockages for Panama Canal expansion.)

The most effective method to consider the measure of additional hydropower effects is to consider the net benefits provided by hydropower when the project is integrated into the system. Several factors influence the contribution that additional hydropower facilities provide. These factors are the capacity of the plant, electrical energy production, transfer of water across basins and the impact of the system on operation of other plants. Net hydropower benefits reflect the composite impact of these factors. The scale for maintaining or increasing the current level of hydroelectric power production as demands for other water uses increase was established by considering the amount of net benefits estimated for power production of the entire system. The scale runs from greater than $5,000,000 to greater than $25,000,000 in average annual benefits by increments of $5,000,000. The measure points assigned to each increment were 1, 3, 5, 7 and 10. If a proposed project had a net increase of average annual hydropower benefits of $17,000,000, it would receive 5 measure points for this criterion.

The technical viability of a project was measured based on two functional areas: design constraints and the feasibility of the concept. Design constraints reflect the difficultly of the engineering and construction technology required to design, construct and operate a proposed project. The feasibility of a concept measures the magnitude of economic and physical resources required to accomplish the design, construction and operation of a proposed project against the ability of the country to implement the project. A scale of 1 to 10 was used to determine the measure of this criterion. These functions cannot be readily represented by a simple numerical value but had to be based on professional judgment. The ranking committee, comprised of representatives from the U.S. Army Corps of Engineers, Mobile District design team and the ACP - Canal Capacity Projects Office, developed these values through consensus, based on their experience and knowledge of the projects and the resources of Panama Canal and the Republic of Panama.

A measure of the operational constraints for a proposed project was based on the compatibility of the project with the existing system, maintenance requirements (including skills and magnitude or frequency), and operational resources. These functions also require the judgment of the professionals with the knowledge and experience of the type of projects considered and the resources of the ACP. The ranking committee developed values from a scale of 1 to 10.

Also, in the Development Effects matrix, a part of the rankings are based upon the economic effects of each alternative project. One of the criterion useful in these rankings is the benefit to cost ratio. This ratio determines whether a project is feasible, that is, it determines whether the benefits attributable to the alternative outweigh the costs of implementing the project. All of the alternatives that were analyzed for economic effects are included in Table 46 - 4. These projects are sorted by their benefit to cost ratio from greatest to least in Table 46 - 4.

Table 46 - 4 Projects Sorted by Benefit-Cost Ratio

Section Number	Project	Average Annual Benefits	Average Annual Costs	Benefit to Cost Ratio	Net Benefits
25	Raise Madden Lake - Option 2	24,901,000	101,000	246.5	24,800,000
25	Raise Madden Lake - Option 1	18,947,000	88,000	215.3	18,859,000
22	Rio Caño Sucio - Option 1 (Operated in conjunction with Indio Lake)	417,544,000	88,590,000	4.7	328,954,000
22	Rio Caño Sucio - Option 2 (Operated in conjunction with Indio Lake)	416,498,000	88,590,000	4.7	327,908,000
20	Rio Ciri Grande - Option 1	68,691,000	15,412,000	4.5	53,279,000
5	Rio Indio - Option 2	189,406,000	46,291,000	4.1	143,115,000
24	Deepen Gatun Lake	121,819,000	36,819,000	3.3	85,000,000
10	Rio Lagarto - Option 2	22,349,000	7,107,000	3.1	15,242,000
5	Rio Indio - Option 1	144,889,000	46,291,000	3.1	98,598,000
18	Rio Chagres - Option 2	177,127,000	59,183,000	3.0	117,944,000
23	Raise Gatun Lake	36,492,000	13,812,000	2.6	22,680,000
9	Rio Toabre and Rio Caño Sucio (Operated in conjunction with Indio Lake)	482,098,000	189,802,000	2.5	292,296,000
11	Rio Salud - Option 2 (Working in conjunction with Lagarto Lake)	70,669,000	27,929,000	2.5	42,740,000
6	Rio Cocle del Norte - Lake at Elevation 65 - Option 1 (Operated in conjunction with Indio Lake)	582,869,000	238,383,000	2.4	344,486,000
6	Rio Cocle del Norte - Lake at Elevation 65 - Option 2 (Operated in conjunction with Indio Lake)	581,505,000	238,383,000	2.4	343,122,000
11	Rio Salud - Option 1 (Working in conjunction with Lagarto Lake)	66,544,000	27,929,000	2.4	38,615,000
34	Recycling Ponds for Lockage Water	84,274,000	35,580,000	2.4	48,694,000
37	Lower Rio Trinidad 22.9m to 30.5m Rio Indio 50m to 80m	535,423,000	356,274,000	2.2	436,788,000
39	Lower Rio Trinidad 22.9m to 30.5m Rio Cano Quebrado 22.9m to 30.5m Rio Indio 50m to 80m	794,318,000	359,636,000	2.2	434,682,000
42	Lower Rio Trinidad 22.9m to 33.5m Rio Indio 50m to 80m	795,653,000	405,437,000	2.0	390,216,000
44	Lower Rio Trinidad 22.9m to 33.5m Rio Cano Quebrado 22.9m to 33.5m Rio Indio 50m to 80m	795,980,000	409,580,000	1.9	386,400,000

Table 46 - 4 Projects Sorted by Benefit-Cost Ratio, Continued

8	Rio Cocle del Norte - Lake at Elevation 100 (Operated in conjunction with Caño Sucio and Indio Lakes)	748,621,000	391,025,000	1.9	357,596,000
7	Rio Cocle del Norte - Lake at Elevation 80 (Operated in conjunction with Indio Lake)	644,748,000	344,093,000	1.9	300,655,000
29	Pump Storage From Cocle Del Norte to Rio Toabre (Operated in conjunction with Caño Sucio and Indio Lakes)	448,683,000	255,724,000	1.8	192,959,000
16	Lower Trinidad - Option 1	89,589,000	63,151,000	1.4	26,438,000
18	Rio Chagres - Option 1	82,149,000	59,183,000	1.4	22,966,000
20	Rio Ciri Grande Option 2	19,890,000	15,412,000	1.3	4,478,000
33	Pump Saltwater into Gatun Lake - 5 Lockages	99,730,000	82,094,000	1.2	17,636,000
45	Lower Rio Trinidad 22.9m to 33.5m Rio Cano Quebrado 22.9m to 33.5m Rio Indio 50mm	403,409,000	377,319,000	1.1	26,090,000
43	Lower Rio Trinidad 22.9m to 33.5m Rio Indio 50m to 80m	395,150,000	373,176,000	1.1	21,974,000
36 B	Lower Rio Trinidad 22.9m to 30.5m Gatun 81' to 87'	188,072,000	178,562,000	1.1	9,510,000
40	Lower Rio Trinidad 22.9m to 30.5m Rio Cano Quebrado 22.9m to 30.5m Rio Indio 50m	339,138,000	327,375,000	1.04	11,763,000

Table 46 - 5 Projects Sorted by Net Benefits

Section Number	Project	Average Annual Benefits	Average Annual Costs	Benefit to Cost Ratio	Net Benefits	Hydropower Benefits ($ Millions)	Year in which Total Demand Exceeds Total Supply	Total Lockages	Net Lockages from 2000
37	Lower Rio Trinidad 22.9m to 30.5m Rio Indio 50m to 80m	535,423,000	356,274,000	2.2	436,788,000	3	2052	55.97	17.29
39	Lower Rio Trinidad 22.9m to 30.5m Rio Cano Quebrado 22.9m to 30.5m Rio Indio 50m to 80m	794,318,000	359,636,000	2.2	434,682,000	3	2058	58.15	19.47
42	Lower Rio Trinidad 22.9m to 33.5m Rio Indio 50m to 80m	795,653,000	405,437,000	2.0	390,216,000	3	2066	61.96	23.27
44	Lower Rio Trinidad 22.9m to 33.5m Rio Cano Quebrado 22.9m to 33.5m Rio Indio 50m to 80m	795,980,000	409,580,000	1.9	386,400,000	3	2068	63.09	24.41
8	Rio Cocle del Norte - Lake at Elevation 100 (Operated in conjunction with Caño Sucio and Indio Lakes)	748,621,000	391,025,000	1.9	357,596,000	17	2070+	63.97	25.29
6	Rio Cocle del Norte - Lake at Elevation 65 - Option 1 (Operated in conjunction with Indio Lake)	582,869,000	238,383,000	2.4	344,486,000	28	2069	63.76	25.08
6	Rio Cocle del Norte - Lake at Elevation 65 - Option 2 (Operated in conjunction with Indio Lake)	581,505,000	238,383,000	2.4	343,122,000	27	2065	61.55	22.87
22	Rio Caño Sucio - Option 1 (Operated in conjunction with Indio Lake)	417,544,000	88,590,000	4.7	328,954,000	0	2041	52.53	13.85
22	Rio Caño Sucio - Option 2 (Operated in conjunction with Indio Lake)	416,498,000	88,590,000	4.7	327,908,000	0	2041	52.37	13.69
7	Rio Cocle del Norte - Lake at Elevation 80 (Operated in conjunction with Indio Lake)	644,748,000	344,093,000	1.9	300,655,000	21	2070+	63.97	25.29
9	Rio Toabre and Rio Caño Sucio (Operated in conjunction with Indio Lake)	482,098,000	189,802,000	2.5	292,296,000	13	2066	62.05	23.37
29	Pump Storage From Cocle Del Norte to Rio Toabre (Operated in conjunction with Caño Sucio and Indio Lakes)	448,683,000	255,724,000	1.8	192,959,000	-1	2070+	63.97	25.29
5	Rio Indio - Option 2	189,406,000	46,291,000	4.1	143,115,000	6	2030	49.55	10.87

Table 46 - 5 Projects Sorted by Net Benefits, Continued

18	Rio Chagres - Option 2	177,127,000	59,183,000	3.0	117,944,000	9	2012	46.59	7.91
5	Rio Indio – Option 1	144,889,000	46,291,000	3.1	98,598,000	5	2010	45.11	6.43
24	Deepen Gatun Lake	121,819,000	36,819,000	3.3	85,000,000	-1	2009	44.30	5.62
20	Rio Ciri Grande - Option 1	68,691,000	15,412,000	4.5	53,279,000	-1	2005	41.78	3.10
34	Recycling Ponds for Lockage Water	84,274,000	35,580,000	2.4	48,694,000	0	2007	42.92	4.24
11	Rio Salud - Option 2 (Working in conjunction with Lagarto Lake)	70,669,000	27,929,000	2.5	42,740,000	0	2003	40.58	1.90
11	Rio Salud - Option 1 (Working in conjunction with Lagarto Lake)	66,544,000	27,929,000	2.4	38,615,000	0	2003	40.38	1.70
16	Lower Trinidad - Option 1	89,589,000	63,151,000	1.4	26,438,000	0	2006	42.74	4.06
45	Lower Rio Trinidad 22.9m to 33.5m Rio Cano Quebrado 22.9m to 33.5m Rio Indio 50mm	403,409,000	377,319,000	1.1	26,090,000	-1	2045	54.1	15.4
25	Raise Madden Lake - Option 2	24,901,000	101,000	246.5	24,800,000	-1	2002	39.92	1.24
18	Rio Chagres - Option 1	82,149,000	59,183,000	1.4	22,966,000	12	2005	41.89	3.21
23	Raise Gatun Lake	36,492,000	13,812,000	2.6	22,680,000	-1	2002	40.33	1.65
43	Lower Rio Trinidad 22.9m to 33.5m Rio Indio 50m to 80m	395,150,000	373,176,000	1.1	21,974,000	-1	2037	51.30	12.62
25	Raise Madden Lake - Option 1	18,947,000	88,000	215.3	18,859,000	-1	2002	39.65	0.97
33	Pump Saltwater into Gatun Lake - 5 Lockages	99,730,000	82,094,000	1.2	17,636,000	0	2008	43.68	5.00
10	Rio Lagarto - Option 2	22,349,000	7,107,000	3.1	15,242,000	0	2002	39.78	1.10
40	Lower Rio Trinidad 22.9m to 30.5m Rio Cano Quebrado 22.9m to 30.5m Rio Indio 50m	339,138,000	327,375,000	1.04	11,763,000	-1	2018	47.00	8.32
36B	Lower Rio Trinidad 22.9m to 30.5m Gatun 81' to 87'	188,072,000	178,562,000	1.1	9,510,000	-2	2020	47.67	8.99
20	Rio Ciri Grande Option 2	19,890,000	15,412,000	1.3	4,478,000	-1	2001	39.50	0.82

APPENDIX A

Selected References

TABLE OF CONTENTS

Published Works, Unnamed Authors

1997 Uniform Building Code, Volume 1, Administrative, Fire- and Life-Safety, and Field Inspection Provisions, International Conference of Building Officials, April 1997.

Climatology and Hydrology of the Panama Canal Watershed, IOCS Memorandum Jax – 50, U.S. Army Corps of Engineers, Jacksonville District, 1968.

Compilation of General Information on the Saddles and Saddle Dams Located Around Gatun Reservoir, PCC, Engineering and Construction Bureau, Engineering Division, Geotechnical Branch, August 5, 1994.

Description of Gatun Dam – Its Construction and Recent Surveillance, PCC, Engineering and Construction Bureau, Engineering Division, Geotechnical Branch, September 1992.

Engineering Services for the Panama Canal, Development of Alternative Operating Plans for Flood Control, Phase VI Study, U.S. Army Corps of Engineers, Mobile District, February 1981.

Engineering Services for the Panama Canal, Development of Probable Maximum Flood & Review of Flood Routing Procedures, Phase III and Phase IV Studies, U.S. Army Corps of Engineers, Mobile District, February 1979.

Engineering Services for the Panama Canal, Probable Maximum Precipitation Estimates for Drainages Above Gatun and Madden Dams, Panama Canal Zone, Phase II Studies, U.S. Army Corps of Engineers, Mobile District, February 1978.

Engineering Services for the Panama Canal, Structural and Hydraulic Adequacy of the Lock Chambers, Phase V Study, U.S. Army Corps of Engineers, Mobile District, February 1980.

Feasibility Studies and Final Designs of Potable Water Projects for Main Urban Centers in the Republic of Panama; Hazen and Sawyer, Louis Berger Int., Tecnipan, Alfa Panama, 1995. Contracted by Instituto de Acueductos y Alcantarillados Nacionales or The National Institute of Water and Sanitation.

Feasibility Studies for Small Scale Hydropower Additions, U.S. Army Corps of Engineers, Hydrologic Engineering Center and Institute For Water Resources, 1979.

Final Report of the Commission for the Study of Alternatives to the Panama Canal, Volume VIII, Engineering and Cost Estimates Phase II (2), Panama, 1993.

Flood Control Manual, PCC, September 1992.

Geologic and Tectonic Development of the Caribbean Plate Boundary in Southern Central America, Special Paper 295, The Geological Society of America, 1995.

Geological Map Republic of Panama, National Geographic Institute, January 1991.

Improvement Program for the Panama Canal, A.T. Kearney & Company, Inc. 1969.

Improvement Program for the Panama Canal, PCC, 1982.

Inspection of Panama Canal Flood Control Facilities, Phase I, Volume I (Summary Report), U.S. Army Corps of Engineers, Mobile District, 1977.

Inspection of Panama Canal Flood Control Facilities, Phase I, Volume II (Miraflores Project), U.S. Army Corps of Engineers, Mobile District, 1977.

Inspection of Panama Canal Flood Control Facilities, Phase I, Volume III (Madden Project), U.S. Army Corps of Engineers, Mobile District, 1977.

Inspection of Panama Canal Flood Control Facilities, Phase I, Volume IV (Gatun Project), U.S. Army Corps of Engineers, Mobile District, 1977.

List of Animals Endangered to Near Extinction, ANAM, published in execution of the authority of Ordinance Law No. 24 dated June 1995, and in declaration of Resolution 002-80 and Executive Order No. 104.

Madden Dam, Sluiceways and Outlets, The Military Engineer, November-December 1936.

Measurement of Pressures Related to Vessel Movement within Miraflores Upper West Lock, Povirk and Rush, for the U.S. Army Corps of Engineers, Pittsburgh District, June 30, 1999.

Panama Canal Water Supply, Panama Canal Company, January 1961.

Project on the Panama Canal Railway, Bridgefarmer Panama, S.A. April 1999.

Report on Preliminary Investigations for Power, Flood Control, and Regulation of Gatun Lake, Panama Canal Company, Department of Operation and Maintenance, Office of Assistant Engineer of Maintenance, March 31, 1946.

Report of the Governor of The Panama Canal, Appendix 8, Geology, 1947.

Report of the Governor of The Panama Canal, Appendix 12, Slopes and Foundations, 1947.

Report on Miraflores Lake, Harza Engineering Company, August 1978.

Seismic Design for Buildings, Departments of the Army, the Navy, and the Air Force, October 1992.

Study and Report on Increasing the Water Supply of the Panama Canal, Tudor Engineering Company, 1962.

The Atlantic-Pacific Interoceanic Canal Study Commission, Annex V, Study of Engineering Feasibility, U.S. Army Corps of Engineers, Atomic Energy Commission, Panama Canal Company, 1970.

Water Resources Assessment for Panama, U.S. Army Corps of Engineers, Mobile District and U.S. Army Topographic Engineering Center, 1997.

Water Supply Handbook, U.S. Army Corps of Engineers, Water Resources Support Center; Institute for Water Resources, December 1998.

Welcome to Panama, Crossroads of World Commerce, Orientation Guide for U.S. Participants in Combined Military Exercises in Panama, United States Southern Command, January 1986.

Published Works, Named Authors

J. Barahona and C. George, *Report on Study Effects of Low Gatun Lake Level*, PCC, October 1997.

E.M. Browder et al., *Water Supply for the Panama Canal*, Proceedings of the American Society of Civil Engineers, Journal of the Power Division, 1962.

Alvaro E. Calvo, *Seismic Performance and Isoacceleration Maps*, Seminar Panamanian Structural Code REP-94, Panamanian Society of Engineers and Architects (SPIA), May 1997.

Pastora Franceschi S., *Geology of the Gatun Dam Site*, Panama Canal Commission Engineering and Construction Bureau, Engineering Division, Geotechnical Branch - Geology Staff, 1992.

W.L. Hersh, *Drum Gates at Madden Dam*, The Military Engineer, March-April 1936.

H.F. Hodges, *General Design of the Locks, Dams and Regulating Works of the Panama Canal, Paper No. 14*, Transactions of the International Engineering Congress, 1915.

H.F. Hodges, *Advisability Of Using Intermediate Gates in the Locks of the Panama Canal, Annual Report of the Isthmian Canal Commission, Appendix B*, U.S. Army Corps of Engineers, Washington, D.C., 1910.

R.L. Klotz, *Foundations for the Madden Dam*, The Military Engineer, November-December, 1935.

Frederick Mears, *The Reconstruction of the Panama Railroad, Paper No. 21*, Transactions of the International Engineering Congress, 1915.

P.S. O'Shaughnessy, *Madden Dam, Sluiceways and Outlets*, The Military Engineer, November-December, 1936.

P.S. O'Shaughnessy, *Discharge of Needle Valves and Sluiceways at Madden Dam*, Civil Engineering, August 1937.

P.S. O'Shaughnessy, *Project on the Panama Canal Railway*, Bridgefarmer Panama, S.A., April 1999.

E.S. Randolph, *The Madden Dam Project*, Panama Section, American Society of Civil Engineers, October 1931.

E.S. Randolph, *Report on Preliminary Office Study on Additional Spillway Capacity from Gatun Lake*, The Panama Canal, March 1945.

R. Rivera, *Compilation of General Information on the Saddles and Saddle Dams located around Gatun Reservoir*, Panama Canal Commission, August 1994.

E.C. Sherman, *The Design of the Spillways of the Panama Canal, Paper No. 15*, Transactions of the International Engineering Congress, 1915.

E.C. Sherman, *The Spillways of the Panama Canal*, Boston Society of Civil Engineers, April 1916.

J.F. Sorzano, *Water Supply for the Lock Canal at Panama*, American Society of Civil Engineers, Transactions, November 1909.

Rafael Spalding, *Elevation of Miraflores Lake Operating Level*, PCC, 1980.

R.H. and J.L. Stewart with the collaboration of W.P. Woodring, *Geologic Map of the Panama Canal and Vicinity, Republic of Panama, Miscellaneous Investigations Series*, United States Geologic Survey, 1980.

Carlos Vargas, *On the Design of a New Spillway for Gatun Lake (Preliminary Study)*, PCC, July 1991.

W. Viessman et al., *Introduction to Hydrology*, Second Edition, Harper & Row Publishers, New York, 1977.

J.F. Widmann, C.M. Heusmann, E. James Davis, *The Effect of a Polymeric Additive on the Evaporation of Aerocolloidal Organic Droplets, Colloid & Polymer Science, Volume 276, N0. 3*, 1998.

F.D. Wilson, *The Climatology and Hydrology of the Panama Canal, Paper No. 9*, Transactions of the International Engineering Congress, 1915.

W.P. Woodring, *Geologic Map of Canal Zone and Adjoining Parts of Panama*, United States Geologic Survey, 1955.

W.P. Woodring, *Geology and Paleontology of Canal Zone and Adjoining Parts of Panama, Geological Survey Professional Paper 306-A*, 1957.

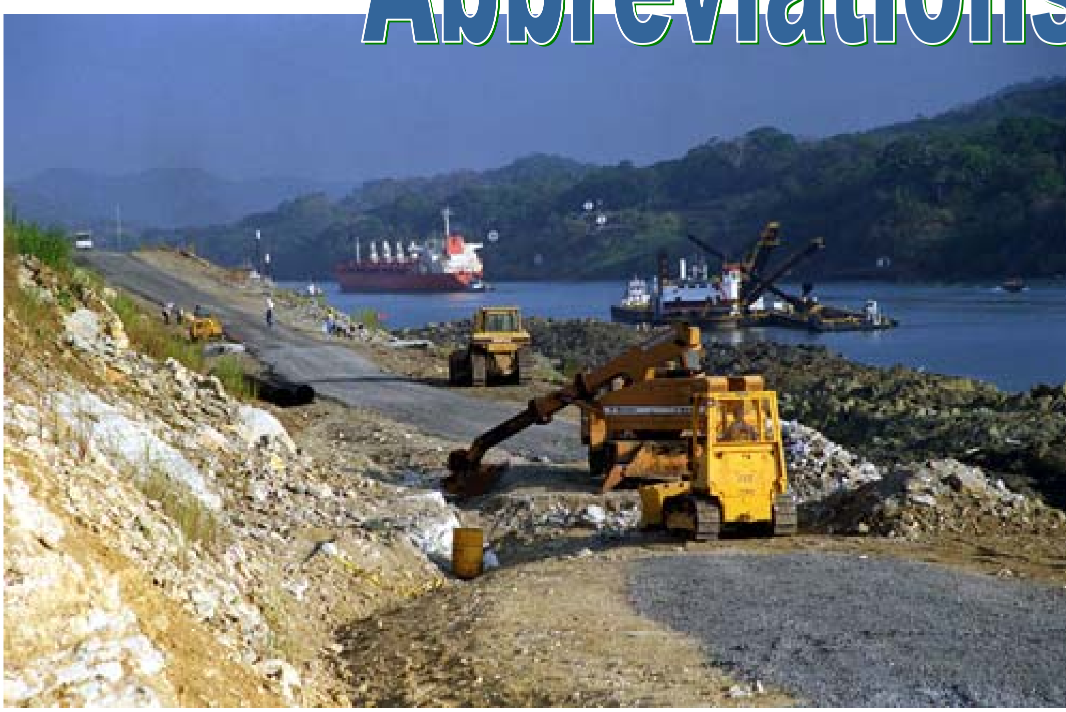
Websites

Background Notes: Panama, March 1998, U.S. Department of State, Released by the Bureau of Inter-American Affairs, [http://www.state.gov/www/background_notes/panama_0398_bgn.html], 1999.

Panama Canal, Panama Canal Commission, [http://www.pancanal.com], 1999.

APPENDIX B

Abbreviations



The following abbreviations are used in this report.

AF	Acre-Feet
ANAM	Autoridad Nacional del Ambiente (National Authority of the Environment)
BCF	Billion Cubic Feet
CFS	Cubic Feet per Second
cm	Centimeter
CMD	Cubic Meters per Day
CMS	Cubic Meter per Second
CWT	Canal Waters Time
CY	Cubic Yard
DWT	Dead Weight Tonnage
E&D	Engineering and Design
ETL	Engineering Technical Letter
ft	Foot, Feet
GPM	Gallons per Minute
ha	Hectare
HP	Horsepower
in	Inch
IRHE	Instituto de Recursos Hidraulicos y Electrificacion (Institute of Hydraulics and Electrical Resources)
kg/m^2	Kilograms per Square Meter
kg/m^3	Kilograms per Cubic Meter
kgps	Kilograms per Second
km	Kilometer
km^2	Square Kilometer
km^3	Cubic Kilometer
kmph	Kilometers per Hour
kV	Kilovolt
kW	Kilowatt
kWh	Kilowatt Hour
l	Liters
LPD	Liters per Day
LPM	Liters per Minute
LPS	Liters per Second
m	Meter
M&I	Municipal and Industrial
M^3	Cubic Meter
MCM	Million Cubic Meters
mg/l	Milligrams per Liter
MGD	Million Gallons per Day
mi	Mile
mi^2	Square Mile
mm	Millimeter
MPH	Miles per Hour
MPS	Meters per Second
MSL	Mean Sea Level
MSM	Million Square Miles
MT	Metric Ton
MW	Megawatt
MWh	Megawatt Hour
NTU	Nephelometric Turbidity Unit
PCC	Panama Canal Commission
PCF	Pounds per Cubic Foot
PMF	Probable Maximum Flood
ppm	Parts per Million
PSF	Pounds per Square Foot
PSI	Pounds per Square Inch
S&A	Supervision and Administration
SIA	Socio-Economic Impact Assessment