US Army Corps
of Engineers
Mobile District

PANAMA CANAL

Reconnaissance Study

Identification, Definition and Evaluation of Water Supply Projects

Volume I

31 December 1999

Environmental evaluations provided under Panama Canal Commission contract by Black & Veatch.

US Army Corps
of Engineers
Mobile District

Volume 1

Panama Canal

Reconnaissance Study

Identification, Definition and Evaluation of Water Supply Projects

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Reconnaissance Study

Identification, Definition and Evaluation of Water Supply Projects

Executive Summary

Executive Summary

Since the opening of the Panama Canal in 1914, the number of ships and the associated tonnage that transit the Panama Canal have increased dramatically. Ship traffic has increased to an average of 36 vessels daily, and increased traffic brings limitations and delays. The transit of ships across the Isthmus of Panama depends on the availability of the freshwater stored within Madden and Gatun Lakes. Water availability for operation of the Panama Canal is limited and even at present traffic levels, is not sufficient to meet traffic demand during prolonged dry periods, as highlighted during the 1998 drought. Inadequate water supply requires the Lakes to be lowered below design levels and thus induces draft restrictions on vessels passing through the Panama Canal. Considering all factors (lockage water, Municipal and Industrial (M&I) withdrawals, hydropower generation, etc.), the current daily average demand on the system is equivalent to 38.68 lockages per day.

The Panama Canal Commission (PCC) began system improvements in the early 1990s, such as the widening of the Gaillard Cut and upgrading the locks. Those improvements are expected to increase capacity to the equivalent of 43 lockages per day by 2002. Continued world economic growth and domestic development within Panama will result in even greater pressure to accommodate more vessels through the Panama Canal system. Without appropriate measures, this increase in demand will result in more frequent occurrences of draft restrictions, limitations, and delays. Concurrently, the system must meet higher M&I water supply needs for Panama.

The PCC, through its Canal Capacity Projects Office, is in the process of developing a long-term plan to address the future needs of the Panama Canal. Through this program, objectives have been set forth to reveal opportunities and provide analyses that will identify the optimum economic and engineering solutions. The new operating agency, the Panama Canal Authority, will continue the effort after control of Panama Canal operations is officially transferred from the United States to the Republic of Panama on December 31, 1999. These objectives include:

1. To satisfy long-term (through the year 2050) M&I water supply needs without adversely affecting the operation of the Panama Canal.

2. To provide sufficient navigation waters to meet existing and future Panama Canal transit demands without restricting vessel operation and to maintain historical reliability levels of 99.6 percent.

3. To take advantage of projects by supplementing hydropower production as demands for other water uses increase. If possible, increase current capacity and energy production as solutions are implemented.

Based on these objectives, the PCC initiated this study to define opportunities to supplement the supply of water to the system, evaluate these opportunities, and identify the most promising alternatives to be carried forward for more detailed analysis and possible implementation.

The PCC and the Department of the Army of the United States of America entered into an Interagency Services Support Agreement (Number 97003) in 1997. In October 1998, the PCC issued Work Order Number GS-16 under the Agreement to the U.S. Army Corps of Engineers, Mobile District for the identification, definition, initial assessment, and screening of potential projects to provide additional sources of water for Panama Canal operations and identify additional hydropower generation opportunities. These projects were strictly focused on water supply or reduction in the use of water for the existing Panama Canal system and sources of water for expanding the capacity of the Panama Canal. No expansion of the navigation facilities of the Panama Canal was considered.

The work order defined the following tasks for the U.S. Army Corps of Engineers, Mobile District in conjunction and coordination with the PCC Canal Capacity Projects Office staff:

- Identify water supply project types and locations,
- Perform water yield calculations,
- Define project concepts and main features,
- Develop criteria and methodology for evaluation,
- Conduct preliminary evaluation of water projects,
- Perform initial screening of projects,
- Prepare a report, and
- Transfer technology.

Investigations included, literature reviews, assembly of existing data, development of data for the project sites, site visits and application of simulation models to determine the water yield for proposed projects. Hydrologic data were derived from existing records with standard hydrologic techniques applied to generate equivalent periods of record. Geotechnical field investigations were not conducted for this reconnaissance study. Geologic conditions were derived from existing publications and site visits. Structural studies included in this report may be categorized as dam and lake projects, existing lake modification projects, and miscellaneous water saving measures. Types and configurations of structures were kept the same as much as possible, allowing for variations based on such things as size and number of water passages required, and dimensions required to fit the features to the proposed project site.

As a starting point, the PCC provided a composite list of approximately 33 projects and measures that could provide additional water for the operation of the Panama Canal. Some of these had been proposed or suggested by previous studies, technical experts, the staff of the Canal Capacity Projects Office of the PCC, or other interested parties during the life of the project. This list reflected the most reasonable and popular measures. After initial review and screening of the list, the U.S. Army Corps of Engineers Mobile District design team eliminated some, modified some, and added others. The final list contained 30 projects that were subjected to a reconnaissance level analysis and evaluation.

For each project, the project site was identified, project features defined, and water yield determined. Once the sufficient project features were defined and the water yield determined, the results were compared to the minimum requirements that were established by the Canal Capacity Projects Office. At a minimum, each project was required to provide the equivalent of one lockage, be implemented with current technologies, not shut down or significantly impact the operation of the Panama Canal during the construction, and be economically feasible (the necessary resources can be obtained). Of the 30 projects, 19 met the minimum objectives and design and construction cost were developed and economic analysis applied for those that met the minimum objectives. These efforts were accomplished with the goal to present each project at an equal level for evaluation. The PCC through a separate contract with Black & Veatch Special Projects Corp, Kansas City, Missouri provided reconnaissance level environmental evaluations of projects that met the minimum objectives including positive cost/benefit analysis. Environmental and socio-economic evaluations at a reconnaissance level do not identify mitigation measures to a sufficient degree that allows determination of expected costs.

Therefore, some added mitigation costs could be expected for alternatives that are subjected to feasibility level studies.

The 19 projects that met the minimum objectives were compared and ranked. The ranking process was based on the water yield, technical viability, operational requirements, economic feasibility, environmental impacts, and socio-economic impacts of each project. The ranking was accomplished by a committee, comprised of representatives from the U.S. Army Corps of Engineers, Mobile District design team, the PCC - Canal Capacity Office staff, and technical personnel from Black & Veatch, Special Project Corp Office. The committee developed the measure of effectiveness for each project through consensus, based on their experience and knowledge of the projects and the resources of the Panama Canal and the Republic of Panama. The relative significance of each of these factors was recognized in the ranking process. The final composite score was scaled by significance in this way: 26.5 percent water yield, 9.1 percent technical viability, 7.6 percent operational requirements, 6.8 percent economic feasibility, 25 percent socio-economic effects and 25 percent environmental effects. The ranking process is explained in more detail in Section 35 of this report. Documentation of the project features and the analysis of each project are presented in the respective sections. Table 1 lists the 19 projects sorted in descending order from the highest ranking to the lowest.

Projects on the Rio Cocle del Norte, Rio Toabre, Rio Caño Sucio and the Rio Indio are located west of the Panama Canal watershed. These western projects consist of combinations of dams, lakes, tunnels, and hydropowerplants. The Rio Cocle del Norte watershed is the greatest distance from the Panama Canal with the Rio Caño Sucio and Rio Indio watersheds lying between the Rio Cocle del Norte and the Panama Canal. The Rio Toabre is a tributary to the Rio Cocle del Norte. The Rio Indio watershed is adjacent to the west side of the Panama Canal watershed. Therefore, the projects on the Cocle del Norte require combinations of the Indio Lake and the Caño Sucio Lake and / or large tunnels through the mountain ridges to transfer the water to the Panama Canal watershed. Lakes on the Cocle del Norte at elevations 65 and 80 m MSL would utilize an 18 km tunnel that would extend under the Rio Caño Sucio watershed to connect the Cocle del Norte Lake to the Indio Lake. Then the Indio Lake would be connected, in turn, to the Panama Canal by another tunnel. The Rio Cocle del Norte project, with a lake at elevation 100 m MSL, and the Rio Toabre projects connect to the Caño Sucio Lake by a channel cut through the ridge that divides the Rio Toabre watershed and the Rio Caño Sucio watershed, then through a tunnel connecting the Caño Sucio Lake to the Indio Lake. The Rio Lagarto and Rio Salud projects are dams and lakes located in small watersheds adjacent to the northwest corner of the Panama Canal watershed, with the Rio Lagarto between the Rio Salud and the Panama Canal. The Rio Charges project is a proposed dam and lake in the mountains above the existing Madden Lake. The Rio Ciri Grande project is a proposed dam and lake in the southwest hills above the Gatun Lake inside the Panama Canal watershed. The Lower Rio Trinidad project places a dam within the Gatun Lake on the Trinidad arm and raises the water level to create additional storage. The Rio Pacora and Rio Caimito projects are small independent watersheds that drain to the Pacific. These projects would provide water to local M&I users to offset the expected future increases in M&I water supply withdrawals from the Panama Canal by these communities. Other projects, such as the raising of Gatun and Madden Lakes, deepening of the navigation channel in Gatun Lake, recycling of lockage water by pumping water from the lowest lock chambers to the upper chambers and the pumping of seawater to Gatun Lake, consider modification of existing structures in the Panama Canal system and / or modification of the operating procedures.

Table 1 Project Ranking

Rank	Section Number	Project	Water Yield (Lockages)	First Cost ($ Millions)	Net Benefits ($ Millons)	Benefit Cost Ratio
1	8	Rio Cocle del Norte - Lake at Elevation 100 (Operated in conjunction with Caño Sucio and Indio Lakes)	25.29	665.81	357.60	1.9
2	7	Rio Cocle del Norte - Lake at Elevation 80 (Operated in conjunction with Indio Lake)	25.29	834.48	300.66	1.9
3	9	Rio Toabre and Rio Caño Sucio (Operated in conjunction with Indio Lake)	23.37	398.07	292.30	2.5
4	6	Rio Cocle del Norte - Lake at Elevation 65 - Option 1 (Operated in conjunction with Indio Lake)	25.08	501.02	344.49	2.4
5	22	Rio Caño Sucio - Option 1 (Operated in conjunction with Indio Lake)	13.85	40.23	328.95	4.7
6	29	Pump Storage From Cocle Del Norte Lake to Rio Toabre Lake (Operated in conjunction with Caño Sucio and Indio Lakes)	25.29	839.19	192.96	1.8
7	18	Rio Chagres - Option 2	7.91	318.98	117.94	3
8	5	Rio Indio - Option 2	10.87	245.87	143.11	4.1
9	24	Deepen Gatun Lake	5.62	200.66	85.00	3.3
10	20	Rio Ciri Grande - Option 1	3.10	71.86	53.28	4.5
11	25	Raise Madden Lake - Option 2	1.24	0.63	24.80	246.5
12	10	Rio Lagarto	1.10	32.04	15.24	3.1
13	16	Lower Rio Trinidad - Option 1	4.06	351.69	26.44	1.4
14	15	Rio Pacora	1.00	291.72	(26.71)	0.4
15	14	Rio Caimito	1.06	277.95	(23.45)	0.5
16	11	Rio Salud (Operated in conjunction with Lagarto Lake)	1.90	66.51	42.74	2.5
17	23	Raise Gatun Lake	1.65	77.24	22.68	2.6
18	34	Recycling Ponds at Gatun Lock	4.24	165.00	48.69	2.4
19	33	Pump Saltwater into Gatun Lake - 1 Lockage	1.00	471.33	(58.64)	0.3

Projects with benefit to cost ratios less than one would clearly not be recommended for further consideration. Also, the recycling ponds at Gatun Locks and Pump Saltwater into Gatun Lake are ranked very low and are not recommended because of the potentially significant environmental impacts. The Lower Rio Trinidad and Raise Gatun Lake elevation projects are also not recommended because of the significant uncertainties of design requirements for the project features. These uncertainties are explained in the respective sections.

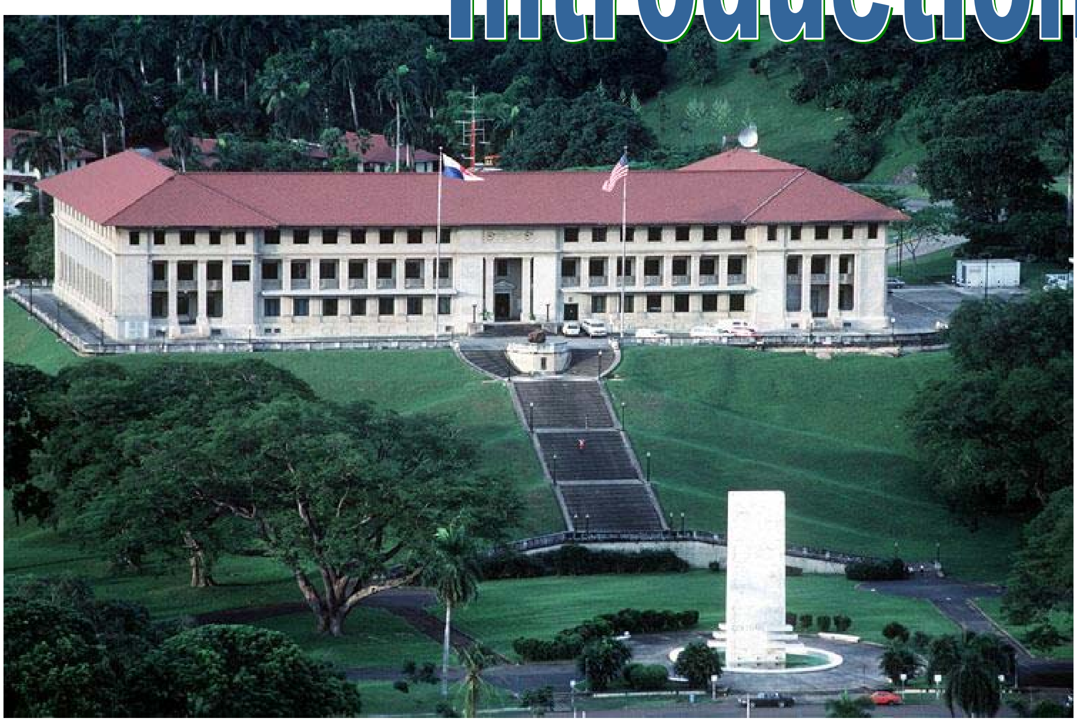
The U.S. Army Corps of Engineers, Mobile District study team worked closely with the technical staff of the Canal Capacity Projects Office during this study and the technical evaluations of the water supply projects that were analyzed. Their extensive, first hand knowledge of the Panama

Canal and its operation, their technical abilities and their dedication and enthusiasm for the work proved invaluable to the success of this study.

Based on the analyses and findings of this study, the first 13 projects ranked in Table 1 are recommended as feasible alternatives for further consideration to develop a long-term plan to meet future needs for M&I water supply, operation of the Panama Canal, and possible modifications or expansion of the Panama Canal.

SECTION 1

Introduction



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Background

The PCC established the Canal Capacity Projects Office in February 1998, to study options for improving Panama Canal operating systems. The study addresses:

- Long-term water supply requirements,
- Added flexibility for providing time to accomplish needed maintenance of major facilities, and
- Project options for meeting projected traffic demand increases.

Evaluation of these elements will allow the Panama Canal to continue providing reliable, efficient and competitive services for the next 50 years and beyond. This action follows several events during 1997 and 1998 that reflected water limitations and the need to improve canal capacity. The drought phenomenon associated with El Niño caused the most severe impact in the history of the Panama Canal. This demonstrated that existing water supplies would not be sufficient to meet future demand and canal capacity. A recent long-term traffic demand forecast indicates that over the next 50 years, the number of transits could grow to almost double the current average number of 13,100 transits per year and that the tonnage passed will increase at an even greater rate.

The Gaillard Cut widening program and ongoing improvements scheduled for completion in the year 2002 will provide short-term relief by increasing capacity and allowing more time for maintenance. It is expected that demand for services will exceed this increased capacity during the second decade of the 21st Century. The study evaluates plans to meet future capacity requirements beyond the year 2002. Advance planning is now underway to prepare for the future. The Canal Capacity Projects Office is preparing a long-term Master Plan that will address capacity limitations and identify viable options. The plan will be a progressive, time-phased program of individual project implementation to parallel traffic growth. The plan will also provide for continuous and expanded service to the customers of the Panama Canal and keep the Panama Canal at the forefront of world trade routes.

It is the vision of the PCC to conceptually develop an enhanced future waterway in terms of facilities, technology, and capability that will provide more efficient services to its customers.

Scope

The PCC and the Department of the Army of the United States of America entered into an Interagency Services Support Agreement (Number 97003) in 1997. In October 1998, the PCC issued Work Order Number GS-16 under the Agreement to the U.S. Army Corps of Engineers, Mobile District for the identification, definition, initial assessment, and screening of potential projects to provide additional sources of water for canal operations and for hydropower generations. These projects were strictly focused on water supply or reduction in use of water for the existing Panama Canal system. They did not consider any expansion of the navigation facilities of the Panama Canal.

The work order defines the following tasks for the Mobile District in conjunction and coordination with the PCC Canal Capacity Projects Office Staff:

- Identify water supply project type and location,
- Perform water yield calculations,
- Define project concept and main features,
- Develop criteria and methodology for evaluation,
- Conduct preliminary evaluation of water projects,
- Perform initial screening of projects,
- Prepare a report, and
- Transfer technology.

Hydrodynamic investigations included, literature reviews, assembly of existing data, development of hydrologic data for the project sites, and application of hydrologic simulation models to determine the water yield for a proposed project. Geotechnical field investigations were not conducted for this reconnaissance study. Geologic conditions were derived from existing publications and site visits. All new dam sites were assumed to have similar foundation conditions. Site visits were made to most sites to verify conditions and assumptions as much as possible. Structural investigations were made using conventional methods, drawing from experience and past similar projects. Economic evaluations were based on comparisons of the outputs of the existing and future conditions without the proposed project, versus the outputs when that project has been added. Cost estimates were unit cost type estimates that reflected direct costs and contractor mark-ups. In most cases the costs were based on historical data escalated to current price levels and tempered with estimator judgement. Environmental evaluations were provided by PCC through a separate contract. This information was provided to the U.S. Army Corps of Engineers, Mobile District, and incorporated into the report.

The PCC, Canal Capacity Projects Office provided an initial list of potential alternatives. This list contained a compilation of projects that would provide additional water or save water. Some of these projects had been proposed over the history of the Panama Canal. The PCC had conceived of others from studies within the agency. Table 1 - 1 contains the initial list of projects as presented by the PCC to the U.S. Army Corps of Engineers, Mobile District. As a part of this scope of work, the U.S. Army Corps of Engineers, Mobile District, was to include additional projects that appeared to have reasonable potential during the course of the study. During the analysis process some projects were modified, some combined and others added in coordination with the PCC. The final listing of the water projects that were evaluated in this study are presented in Table 1 - 2. Plate 1 - 1 is a map showing the locations of these projects.

The study process presented herein is a reconnaissance level effort. The purpose of this effort is to define the project concepts, determine if a feasible project can be developed, and develop project cost and economics as required for this level of study. The objective was to present each alternative at the same level of analysis. Thus the alternatives could be compared and ranked. Projects that are selected for further consideration should be subjected to a feasibility level effort to optimize the design and refine project cost and benefits. General descriptions of the engineering, economic and environmental analysis methodologies are presented in Section 4 of this report. Detailed analysis and results for each alternative are presented in Sections 5 through 34. A comparative analysis of the alternatives is presented in Section 35. Appendix A lists the selected references and Appendix B lists the abbreviations used in the report.

The projects presented in this study are considered to be comprehensive and diverse enough to address the full array of potential alternatives that would allow the Panama Canal to meet future traffic demands and M&I water supply needs for the next 50 years.

Table 1 - 1 Initial List of Projects

<table>
<tr><td rowspan="7">Bring Water from External Watersheds</td><td colspan="2">Rio Indio Dam</td></tr>
<tr><td colspan="2">Coclé del Norte Dam</td></tr>
<tr><td colspan="2">Salud Dam</td></tr>
<tr><td colspan="2">Lagarto Dam</td></tr>
<tr><td colspan="2">Toabre Dam</td></tr>
<tr><td colspan="2">Rio Piedras Diversion</td></tr>
<tr><td colspan="2">Cuango Dam</td></tr>
<tr><td rowspan="16">Control And Management Within the Existing Watershed</td><td colspan="2">Raise Gatun Lake level</td></tr>
<tr><td rowspan="6">Build new dams and storage areas within the watershed</td><td>Trinidad Dam (Escobal)</td></tr>
<tr><td>Upper Trinidad Dam</td></tr>
<tr><td>Trancado Dam (later renamed Upper Rio Chagres Dam)</td></tr>
<tr><td>Pequeni Dam</td></tr>
<tr><td>Ciri Grande Dam</td></tr>
<tr><td>Caño Quebrado Dam</td></tr>
<tr><td colspan="2">Raise Madden Dam and Madden Lake</td></tr>
<tr><td rowspan="2">Deepen Gatun Lake to increase water storage</td><td>Deepening of navigation channel</td></tr>
<tr><td>Deepening of other lake areas</td></tr>
<tr><td colspan="2">Raise Miraflores Lake to save lockage water</td></tr>
<tr><td rowspan="3">Pumped storage of fresh water</td><td>Freshwater from low areas in watershed to upland expanded storage areas within the watershed</td></tr>
<tr><td>Madden Dam</td></tr>
<tr><td>Other sites</td></tr>
<tr><td colspan="2">Groundwater</td></tr>
<tr><td colspan="2">Pumping and generation scheme to bring water from a new Coclé del Norte Lake</td></tr>
<tr><td rowspan="2">Relocate M&I Water Sources to Outside Of Existing Watershed</td><td colspan="2">Pacora Dam</td></tr>
<tr><td colspan="2">Camito Dam</td></tr>
<tr><td rowspan="2">Recycling Ponds for Lockage Water with Pumping Capacity Near the New Locks</td><td colspan="2">Atlantic Locks</td></tr>
<tr><td colspan="2">Pacific Locks</td></tr>
<tr><td colspan="3">Tidal Gates and Terminal Sea Water Pond in the Pacific Side</td></tr>
<tr><td colspan="3">Lower Gatun Lake Elevation 85 to 55 ft (25.9 to 16.8 m) MSL by Eliminating Upper Water (Third) Lift, Dredging to Accommodate Draft of Vessels and Building New Dams</td></tr>
<tr><td colspan="3">Reduce Natural Losses (Evaporation, Seepage, etc.)</td></tr>
<tr><td colspan="3">Pump Salt Water</td></tr>
</table>

Table 1 - 2 List of Projects Evaluated

Number	Project
1	Rio Indio Dam
2	Rio Cocle del Norte Dam - Lake at Elevation 65 m MSL (Operated in conjunction with Indio Lake)
3	Rio Cocle del Norte Dam - Lake at Elevation 80 m MSL (Operated in conjunction with Indio Lake)
4	Rio Cocle del Norte Dam - Lake at Elevation 100 m MSL (Operated in conjunction with Caño Sucio and Indio Lakes)
5	Rio Toabre and Rio Caño Sucio Dams (Operated in conjunction with Rio Indio Lake)
6	Rio Lagarto Dam
7	Rio Salud Dam (Working in conjunction with Rio Lagarto Lake)
8	Rio Piedras Dam
9	Rio Cuango Dam
10	Rio Caimito Dam (M&I Water Supply Project)
11	Rio Pacora Dam (M&I Water Supply Project)
12	Lower Trinidad Dam
13	Upper Rio Trinidad Dam
14	Upper Rio Chagres Dam
15	Rio Pequeni Dam
16	Rio Ciri Grande Dam
17	Caño Quebrado Dam
18	Rio Caño Sucio Dam
19	Raise Gatun Lake to Maximum Operating Level of 89 ft (27.1 m) MSL.
20	Deepen Gatun Lake (Lower Navigation Channel 3 ft (0.9 m) and modify Lock End-sills)
21	Raise Operating Level of Madden Lake 2 and 4 ft (0.6 and 1.2 m)
22	Raise Operating Level of Miraflores Lake to Elevation 55 ft (16.8 m) MSL
23	Pump Storage to Madden Lake
24	Pump Groundwater to the Panama Canal Watershed
25	Pump/Generation From Cocle Del Norte to Toabre (Operating in conjunction with Rio Caño Sucio and Rio Indio Dams.)
26	Tide Gates (At the Pacific Entrance to the Panama Canal)
27	Lower Gatun Lake to Elevation 55 ft (16.8 m) MSL and Eliminate Upper Locks
28	Reduce Seepage and Evaporation Losses From Gatun and Madden Lakes
29	Pump Saltwater into Gatun Lake to Supplement Water Supplies
30	Capture Lockage Water and Recycle for Lockages.

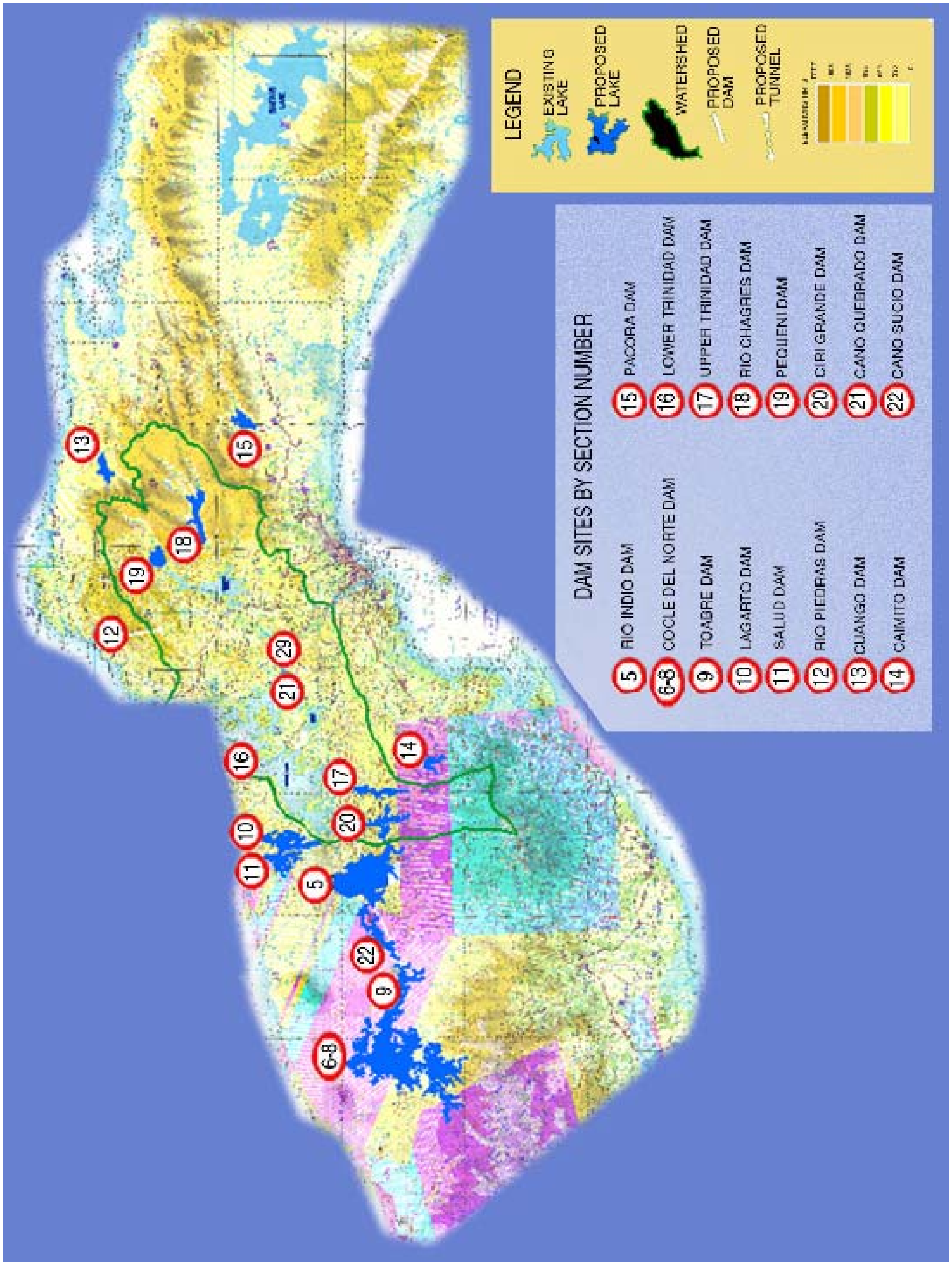

Plate 1 - 1   Project Map

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Existing Conditions

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Geography

Running east and west in an S-shaped curve between Costa Rica and Colombia, Panama forms a link between Central and South America. Panama is an isthmus 772 km in length and between 60 and 177 km in width. The total area of the country is 78,200 km^2 (75,990 km^2 of land and 2,210 km^2 of water). Panama is the fourth largest country in Central America. The two coastlines of Panama are referred to as the Atlantic (or Caribbean) and Pacific, rather than the north and south coasts. The Panama Canal connects the two bodies of water passing from the deep waters of the Atlantic at its northern terminus through Gatun Locks into Gatun Lake, then southward through Gatun Lake and the Gaillard Cut to Pedro Miguel Locks. From Pedro Miguel the Panama Canal continues through Miraflores Lake to Miraflores Locks and from there to the deep waters of the Pacific. A map of the Republic of Panama is shown in Figure 2 - 1.

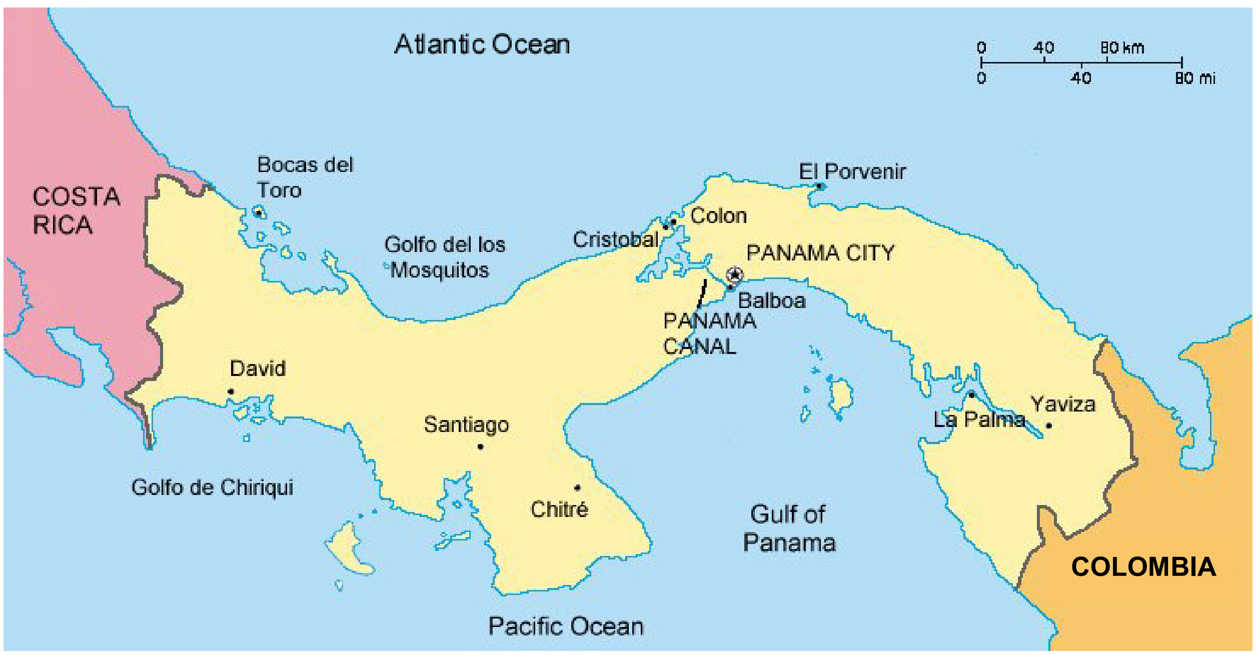

Figure 2 - 1 Map of Panama

The dominant feature of the Panama landform is the central spine of mountains and hills that forms the Continental Divide. The divide does not form part of the great mountain chains of North America, and only near the Colombian border are there highlands that are related to the Andean system of South America. The spine that forms the divide is the highly eroded arch of an uplift from the sea bottom, in which peaks were formed by volcanic intrusions.

The mountain range of the divide is called the Cordillera de Talamanca near the Costa Rican border. Farther east, it becomes the Serranía de Tabasará, and the portion of it closer to the lower saddle of the isthmus, where the Panama Canal is located, is often called the Sierra de Veraguas. As a whole, Panamanian geographers generally refer to the range between Costa Rica and the Panama Canal as the Cordillera Central.

The highest point in the country is the Volcán de Chiriquí, which rises to elevation 3,475 m MSL. Volcán Barú is the apex of a highland that includes the richest soil in the nation, and is still referred to as a volcano, although it has been inactive for millennia.

Although the isthmus is located along the of the Pacific Basin earthquake zone known as the Ring of Fire, major earthquakes have not occurred in the canal area. Minor tremors do occur occasionally.

Land Use

The land use distribution of the Republic of Panama is presented in Table 2 - 1.

Table 2 - 1 Land Use (1993)

Item	Land Use (%)
Arable Land	7
Permanent crops	2
Permanent pastures	20
Forests and woodlands	44
Other	27

Rivers

Panama considers water its most valuable resource. Nearly 500 rivers lace the rugged landscape of Panama. Mostly unnavigable, many originate as swift highland streams, meander in valleys, and form coastal deltas. Outstanding are Río Chiriquí, Río Bayano, and Río Chagres, which are sources of hydroelectric power.

The Rio Chagres is one of the longest and most vital of the approximately 150 rivers that flow into the Atlantic. Parts of this river were dammed to create Gatun and Madden Lakes. Gatun Lake forms a major part of the transit route between the locks near each end of the Panama Canal. Madden Dam was built on the upper middle portion of the Chagres to supplement the water supply into Gatun Lake for lockages. Both Gatun and Madden Lakes provide hydroelectricity for the Panama Canal area.

The Río Bayano and Río Chiriquí, both major sources of hydroelectric power, are two of the more than 300 rivers emptying into the Pacific. These Pacific-oriented rivers are longer and slower running than any river on the Atlantic side. Their basins are also more extensive. One of the longest is the Río Tuira, which flows into the Golfo de San Miguel and is the only river in the country in which large vessels can navigate.

Tides

The Pacific tides at Balboa have a range of about 6 m, while the Atlantic tides at Cristobal have a maximum range of about 0.6 m. A comparison of the tides is presented in Table 2 - 2.

Table 2 - 2 Comparison of Tides

Tidal Ranges (m)	Atlantic (Cristobal)	Pacific (Balboa)
Maximum between successive high and low tides	0.6	6.0
Mean tide elevation	0.3	3.8

Geology

There are two markedly different geological regions in the central area of the Isthmus of Panama west of the Panama Canal. The area from the Pacific Coast to about the middle of the isthmus, including the Continental Divide, is composed of igneous basalt flows, agglomerates, and volcanic tuffs. Sedimentary rocks of the Chagres, Gatun, and Caimito Formations underlie the area from about the middle of the isthmus to the Atlantic coast. On the eastern side of the canal, intrusive and extrusive rocks, ranging from granite to diorite to basalt, commonly cover the north and central portion of the isthmus. Sedimentary rocks are found in relatively minor amounts along the west and south shores of Lago Alajuela (Madden Lake), and along a narrow band adjacent to the Pacific Coast.

The geologic characteristics of these various materials may vary widely. Where basalt and intrusive igneous rocks are encountered they are generally hard and durable. Volcanic rocks, however, can be weaker and have the general characteristics of clay shale. The geologic characteristics of the sedimentary rocks are generally of intermediate nature and may vary from hard to soft and have different degrees of weathering.

Climate

Located approximately 965 km north of the equator, Panama has a tropical climate. The sea level temperatures range from the low 20s to around 30 °C most of the year. On a typical day in Panama City, the early morning minimum may be around 24 °C and the afternoon temperature around 30 °C. Seldom does the temperature exceed 32 °C for more than a short time during the day. Because of the proximity to the Pacific Ocean, the nights are generally cool throughout the year.

Panama has two seasons, a wet season and a dry season. The prolonged rainy season lasts from April to mid-December, usually meaning at least one shower, often cloudbursts, a day with an average daily rainfall of 2.54 cm during the rainy season. Very small amounts of rainfall occur during the short dry season, which lasts from mid-December to March. The prevailing winds and storms travel from the north; therefore, the Atlantic coast receives the greatest rainfall. Annual rainfall decreases inland as the topography rises to the Continental Divide. Rainfall averages 3,300 mm a year on the Atlantic side of the isthmus and 1,800 mm a year on the Pacific side. The annual average rainfall in Panama City (on the Pacific side of the canal) is little more than half of that in Colón (on the Atlantic side of the canal). Seldom does it rain for an entire day. Humidity is high in the rainy season, which makes temperatures more noticeable than in the dry season. During the dry season the trade winds blow steadily.

History

The history of Panama falls into the following periods:

Period	Time Frame
Pre-Hispanic	before 1501
Hispanic	1501-1821, which includes the period of Discovery and Conquest; 1501-1538, and the Colonial, 1538-1821
Union with Colombia	1821-1903
Independence	since 1903

At the beginning of the 16^{th} Century there were more than sixty Indian tribes living on the Isthmus of Panama. Gradually they were reduced to three major ones: the Guaymíes (Ngobe Bugle), Cunas, and Chocos (Emberá and Waunaan). They are ethnically related to the Nahua or Maya from Guatemala and Mexico and to the Chibcha of Colombia.

Rodrigo Galban de Bastidas, one of the captains who accompanied Columbus on his second voyage to America, discovered the Isthmus of Panama in 1501. In 1502, during his last voyage, Columbus dropped anchor in the natural harbor of Portobelo on the Atlantic coast. In 1513, Vasco Nuñez de Balboa discovered the Pacific Ocean from a peak in Darien. In 1519, Pedrarias Davila, the Governor appointed by the Spanish crown to replace Balboa, founded Panama City.

Panama was the center of Spanish exploration and expansion in Central and South America. The Spaniards used Panama City as a way station in the transportation of gold and silver from Peru to Portobelo and then to Spain. Furthermore, Francisco Pizarro organized the conquest of Peru in Panama. The expeditions of Hernando de Soto (discoverer of the Mississippi) and of Sebastian Benalcazar (founder of Quito, Ecuador) were also launched from Panama.

Panama remained a Spanish colony until 1821 when, during the rebellion of the Spanish colonies against Spain, the country proclaimed independence and voluntarily associated with the new independent Colombia.

During the time of the Gold Rush in California land crossings of the isthmus offered a route between the east and west coasts of the United States. A Trans-isthmian railway began operating in 1855. As a vital link between the Atlantic and Pacific Coasts, it was built by a New York consortium over a period of five years and shortened travel time to California.

On November 3, 1903, Panama separated from Colombia. The United States promptly recognized the nation and concluded a treaty for the concession of building the Panama Canal.

The People

Panamanians are a people of diverse origin: direct descendents of Indians, Spaniards who colonized the isthmus, immigrant families of European origin, West Indian Negroes, Chinese, East Indians, North Americans and a mixture of Caucasians and Indians known as Mestizos.

The three Indian tribes that inhabit Panama are the Kuna-Yalas who inhabit the Kuna-Yala Territory and Darién Province, the Emberá-Waunnan of the Darién Province, and the Ngobé Buglé of Chiriquí, Bocas del Toro, and Veraguas Provinces.

The estimated population of the Republic of Panama as of July 1998 was 2,735,943.

Provinces

The country is divided into nine provinces and several territories. The provinces are Bocas del Toro, Chiriquí, Coclé, Colon, Darién, Herrera, Los Santos, Panamá, and Veraguas. The territories are the Kuna Yala, Emberá, Ngobé-Buglé, and Madugandí. For statistical purposes, the Kuna Yala territory is treated as part of the province of Colón in most official documents. The provincial borders have not changed from those determined at independence in 1903. The provinces are divided into districts, which, in turn, are subdivided into sections called corregimientos. Configurations of the corregimientos are changed periodically to accommodate population changes as revealed in the census reports.

Major Cities

The principal cities in the country are Panama City and Colon (both adjacent to the Panama Canal) and David in the Chiriqui Province in the western region of the country. Approximately 46 percent of the population live in urban areas.

Panama City is the capital of the Republic of Panama and the largest city with a population of about 800,000 residents. Panama City is actually three Panamas — Old Panama, Colonial Panama, and Modern Panama.

Colon, on the Atlantic side, is the second largest city in the country with a population of about 117,000 residents. This port city has an atmosphere of its own with its houses on Front Street whose balconies shade the sidewalks. Nearby is Cristobal, one of the busiest ports in Latin America. Roughly 15,000 ships under the flags of 60 or so nations, sail into Cristobal harbor each year. Around two million tons of cargo is handled yearly, much of it to or from the nearby Colon Free Zone.

Natural Resources

Panama is rich in mineral resources although only gold and manganese have been exploited. Limestone is used in the manufacture of Portland cement and native clay supplies the brick, pottery and tile industries. The forests are a source of fine hardwood. The abundance of fish in the surrounding oceans gives Panama her name from an old Indian dialect word meaning an abundance of fish. Current issues are water pollution from agricultural runoff that threatens fishery resources, deforestation of tropical rain forest, and land degradation.

Flora

All of Panama is a garden where the flowering trees are a splendid sight especially from April to June. Among these is the golden shower, lavender lagaestroma, the pink and yellow acacia, the red poinciana and the purple jacaranda. In addition, a great variety of tropical flowers are always in bloom. During the months of December to July, bougainvillea blooms in many shades, while the purple and some reds flower all year round. Hundreds of orchid species abound. Lush leafy plants of many colors are also typical of Panama. Panama is about 44 percent forested, with thick rain forests and evergreens and hardwoods, including mahogany and cedar.

Fauna

With two oceans washing its shores, Panama is rich in marine life. Lobsters, shrimp, clams and the following fish are plentiful: marlin, sailfish, sawfish, porpoises, dolphin, tuna, bonito, wahoo, snook, corvina, mackerel, snapper, bass, trout, tarpon, shark, barracuda, etc. The jungle abounds with monkeys, tapirs, puma, jaguar, peccary, deer, wild pig, ocelots, agouti, paca, armadillos, anteaters, sloths, and other animals native to the American tropics.

There are over 850 native bird species, plus the numerous migrants from the north and south, making Panama a tourist haven for birds and a paradise for birdwatchers.

Industries

Panama manufactures clothing, shoes, leather goods, furniture, matches, candies, crackers, ceramics, tiles, cement, cigarettes, dairy products, beverages (alcoholic and soft drinks), canned juices, flour, refined sugar, refined oil products, aluminum and plastic products. Agricultural industries include poultry, swine, and cattle growing and vegetable, banana, rice, corn, potato, sugarcane, and coconut farming. These are common throughout the Republic. Tourism is considered an important industry. The major exports are bananas, shrimp, sugar, clothing, and coffee.

Economy

For centuries, the economy of Panama has relied heavily on providing services for transit trade and international commerce. Reflecting its historical role as a point of transit between the oceans by trail, river, railroad, and canal, the area adjacent to the canal has developed economically to a much greater extent than the rest of the country. Modern urban service / commerce economy has resulted in the terminal cities of Colon and Panama City. During the past 70 years, the demand for goods and services generated by the Panama Canal, and the U.S. military forces and civilians involved in its defense and operation, has been a major factor in economic development. Rural areas in Panama are not heavily populated; arable regions are characterized by agricultural economies more typical of developing countries in the region.

The economy in Panama grew rapidly in the 1960s and early 1970s. Progress concentrated in the urban areas and made them a magnet for the rural population. Today about half the total population lives in the metropolitan area around the Panama Canal, with one-third residing in Panama City itself.

Since 1968, Panama has developed into a major international financial center, capitalizing on its central location, good communications and transportation facilities, Spanish-speaking environment combined with widespread English proficiency, well-educated labor force, and use of the U.S. dollar on par as currency, thus avoiding monetary exchange controls. In 1970, a new and liberal banking law went into effect that exempted offshore operations from Panamanian taxation and most regulatory scrutiny. It enforced strict confidentiality concerning banking operations.

The Panama Canal

HISTORY

The Panama Canal was opened to commercial ship traffic on August 15, 1914; almost 11 years after the United States had signed a treaty with the Republic of Panama.

The United States had been seriously interested in an isthmian canal for half a century before that time, starting with the Clayton-Bulwer treaty with Great Britain in 1850. Interest in constructing a canal in Panama actually dates back to 1534 when Charles I of Spain ordered the first survey of a proposed canal route across the Isthmus of Panama. More than three centuries passed before the first construction was started. During the intervening years, numerous boards, commissions, and private interest groups urged canal construction at various locations in Central America. The most notable was the effort of a private French company to construct a canal at the Isthmus of Panama beginning in 1880.

That canal construction effort by the French ended after 20 years of work, $280 million in cost and thousands of deaths from yellow fever and other tropical diseases. The leader of the effort was Ferdinand de Lesseps who had been triumphant in constructing the Suez Canal. In fact, his success at Suez was his downfall in Panama because his engineers greatly underestimated the job in Panama, a much more difficult project than the Suez Canal from every point of view. The efforts of the French company failed for several reasons:

a) de Lesseps insistenced on building a sea level canal instead of a locks canal which would have required much less excavation,
b) an inability to solve certain practical engineering problems,
c) a lack of knowledge of the cause of yellow fever and malaria,
d) inadequate attention to housing and feeding a large work force which could not be accommodated by the small Panamanian economy then in existence, and
e) a series of financial scandals.

In 1903, Panama and the United States signed a treaty by which the United States undertook to construct an inter-oceanic ship canal across the Isthmus of Panama. The following year, the United States purchased from the French company rights and properties for $40 million and began construction. The monumental project was completed in ten years at a cost of about

$387 million. Since 1903, the United States has invested about $3 billion in the canal enterprises.

More than 80 years after the first official ocean-to-ocean transit of the canal, the United States and Panama embarked on a partnership for the management and operation of the Panama Canal. Under two new treaties signed on September 7, 1977, the Panama Canal will be operated until the turn of the 21st Century under arrangements designed to strengthen the bonds of friendship and cooperation between the two countries. The treaties were ratified by Panama in a plebiscite on October 23, 1977, and the U.S. Senate gave its advice and consent to their ratification in March and April 1978. The new treaties went into effect October 1, 1979.

CANAL CONSTRUCTION

The work of building the Panama Canal by the United States involved three main problems—sanitation and health, organization, and engineering.

When the United States started construction, health conditions in the area were no better than during the previous centuries. Through the efforts of U.S. Army, Colonel William C. Gorgas, a comprehensive program of drainage, spraying, trash cleanup, and development of water and sewage systems was initiated. By the time canal construction started in earnest in 1907, yellow fever had been eliminated and malaria brought under control.

Another problem was the lack of housing, stores, restaurants, and supporting facilities for construction workers because the canal work force alone, without families, exceeded the entire population of the cities of Panama and Colon (20,000 and 2,000 respectively at that time). Therefore, prior to construction, the United States had to develop adequate facilities to support the work force. Nearly the entire work force had to be imported because Panama had no available labor because of its limited population. Skilled workers came primarily from the United States and unskilled labor came principally from the West Indies and Europe. Less than one percent of the work force of 45,000 was native Panamanian.

The first step in overcoming the third major problem (engineering) was realized through the actions of President Theodore Roosevelt. On the advice of American engineers and rejecting the unanimous recommendations of European engineers who favored a sea level canal, he convinced Congress by a narrow margin that the United States should build a lock-type canal. The wisdom of this decision became apparent during the canal construction period. The construction scheme was relatively simple in concept:

1. Dam the Rio Chagres to create a man-made lake through which it would be relatively easy to dredge a channel following the old river bed,
2. Construct a harbor on the Atlantic side and dredge a sea level channel from the harbor to the dam,
3. Build a set of locks in the dam to raise and lower ships from sea level to the lake at elevation 26 m MSL,
4. Excavate in the dry a big ditch at the other end of the lake for 12.9 km through the mountains of the Continental Divide,
5. Build locks to lower ships to a dredged channel and harbor on the Pacific side,
6. Dispose of the material from the big ditch by building new land areas on the Pacific mud flats and a causeway to the islands in the Pacific, and
7. Relocate the Panama Railroad around the new lake and ditch.

Although the concepts were simple, the magnitude was without precedent. Gatun Dam, 2.4 km long and 0.8 km wide at its base and containing a raging torrent, would be the largest man-made earthen dam in the world. Gatun Lake was the largest man-made lake at the time. The big ditch (later known as Gaillard Cut) was the largest excavation in history, and the locks (with the biggest gates ever swung) were far larger than other locks in the world. The engineers were pushing the state of the art in electric generators and motors because the world had just barely reached the electric age. Every single feature of the project was a major triumph; the combination was an extraordinary engineering achievement that has so been recognized by engineers throughout the world.

The successful completion of the Panama Canal was due principally to the engineering genius and administrative skill of such men as John F. Stevens and U.S. Army, Colonel George W. Goethals, and to the solution of monumental public health problems by Colonel Gorgas.

PRINCIPAL CANAL FEATURES

The Panama Canal runs from northwest to southeast and is 80 km long from deep water in the Atlantic to deep water in the Pacific. It was cut through one of the narrowest and lowest saddles of the long, mountainous isthmus that joins the North and South American continents. The original elevation was 95 m MSL where it crosses the Continental Divide in the rugged mountain range. The principal features of the Panama Canal are the two terminal ports (Balboa and Cristobal), short sections of the channel at each end at sea level, the three sets of twin locks (Gatun, Pedro Miguel, and Miraflores), Gatun Dam and Lake, Gaillard Cut, and Madden Dam and Lake. An average ship takes about eight to ten hours to transit the Panama Canal. Plate 2 – 1 shows the existing profile of the Panama Canal.

The Panama Canal operates a series of twin-lane locks continuously on a 24-hour, 365 days a year basis to pass vessels between the Atlantic and the Pacific Oceans. Ships transiting from the Atlantic to the Pacific enter the channel from Limon Bay at Cristobal breakwater. This sea level section of the canal channel on the Atlantic side is 10.5 km long and 152.4 m wide and runs through a mangrove swamp that is only barely above sea level at most points. A ship is raised or lowered 26 m in a continual flight of three equal steps at Gatun Locks to Gatun Lake. The length of Gatun Locks, including two approach walls, is 1.9 km.

The ships travel 37.6 km across Gatun Lake and then 13.7 km through Gaillard Cut. The Gaillard Cut channel was carved through rock and shale for most of its length. The channel was originally a minimum 91.5 m wide along its entire length. In the 1930s, a cut-widening project was started to increase the channel width to a minimum 152 m in some of the more slide prone areas. The objective was to have a catch basin for slide debris in such areas. In the 1950s and 1960s, the widening extended into other areas in order to improve navigation. By the early 1970s, the entire Gaillard Cut channel had a minimum width of 152 m. This permitted unrestricted two-way traffic for the vast majority of the ships using the Panama Canal at that time.

A Pacific-bound ship enters Pedro Miguel Locks at the south end of Gaillard Cut. Here it is lowered 9.4 m in one step to Miraflores Lake. The length of Pedro Miguel Locks is 1.27 km. Miraflores Lake is a small lake located between the Pedro Miguel and Miraflores Locks. A passing vessel to reach the next lock must navigate approximately 1 mi (1.6 km) of channel in Miraflores Lake. The lake surface elevation varies between 53.5 and 54.4 ft

(16.3 to 16.6 m) MSL. A transiting ship is lowered the remaining two steps to sea level at Miraflores Locks, which is slightly over 1.6 km in length. The 82 ft (24.99 m) high lower lock gates at Miraflores are the tallest of any in the system because of the extreme tidal variation in the Pacific Ocean. The Miraflores Locks are about 9.6 km inland.

The operating chambers in all locks are a nominal 110 ft (33.5 m) wide by 1,000 ft (306 m) long. Maximum allowable draft is 39.5 ft (12.04 m). Minimum depth is 41 ft (12.50 m) over the lock sills and 45 ft (13.72 m) in the navigation channel. An 18 ft (5.49 m) diameter culvert in each outside wall and a shared center wall culvert of the same cross-sectional area feed the lock chambers. Water from the main culverts is fed to the chamber by 10 lateral culverts with 5 openings each, evenly distributed along the lock chamber floors.

There are two dams within the Panama Canal proper, and one on the Rio Chagres above Gatun Lake by which the canal water levels are controlled. Gatun Dam, an earthen embankment dam with a concrete gravity spillway with 14 gates and earthen embankments at the west side of Gatun Locks forms the closure that creates Gatun Lake. The two wings of the dam and the spillway have an aggregate length of about 2.4 km. The dam is nearly 0.8 km wide at the base, tapering to a width of 30.5 m at the crest, which is 32 m MSL, or 6.1 m above the normal level of Gatun Lake. At the downstream end of Miraflores Lake an earthen dam and concrete spillway with eight gates controls the level of Miraflores Lake. This dam and spillway are located on either side, and at the upstream end, of Miraflores Locks. Madden Dam is a high-gated concrete dam on the Rio Chagres about 19.3 km to the east of the canal. It provides water storage for navigation, flood control, and M&I water supply. Water for M&I use is also taken from Gatun Lake and Miraflores Lake.

Gatun Dam forms a lake of 418.25 km^2, while the overall watershed controlled by Gatun Dam is 3,340 km^2. Of this, Madden Dam on the Rio Chagres controls 1,025 km^2. Both dams have hydroelectric facilities that supply the demands of PCC customers and the canal operating facilities and supporting structures.

Sometimes called the 8th Wonder of the World, this path between the seas, the Panama Canal, has earned its title as one of the greatest engineering feats of all time.

FUTURE WITHOUT PROJECT CONDITION

Statistics on the history of the fleet of ships currently using the Panama Canal were not collected nor displayed in these analyses. Rather, historic data provided by the PCC were used in the analyses. It is assumed that such historic statistics were used in their analyses. For example, a forecast of the number of commercial ocean-going transits was provided. That forecast included the total tonnage, the average load per laden vessel, and the average dead weight tons per vessel. While the average load per vessel is the simple average of total tonnage divided by total number of vessels, the average dead weight tons per vessel is a measure of the size of the vessels transiting the Panama Canal. The forecast showed that the percent of total vessels represented by these large vessels is expected to increase in the future. The benefits for navigation were based upon the growth of the average dead weight tons per vessel since the toll structure is based upon the carrying capacity of vessels and not on the actual load. It was assumed that the average carrying capacity of vessels would become constant after the year 2015. A thorough examination of the future demands on the Panama Canal was not undertaken. Thus, no estimate of changes in current shipping patterns was made. That is, no estimate of changes in the origin or destination of cargoes, no estimate of changes in types of cargo, and no estimate in changes in foreign port facilities were made. It seems clear, however, that the trend of using larger vessels will continue into the near future. This assumption also considers the unknowns associated with changes in the structure of toll revenue or in the rates charged laden vessels or vessels in ballast.

The PCC is currently undertaking several steps to improve the efficiency of the Panama Canal. They are purchasing new locomotives and tug boats, installing a traffic management system, improving the lock chamber door operating machinery, and widening the Gaillard Cut. These steps will shorten the time needed to move vessels through the locks as well as allow two-way traffic of the larger vessels through the Gaillard Cut. The result of these improvements will increase the through-put capacity of the Panama Canal. The improvements are scheduled for completion in the year 2002. The PCC estimated that the sustainable transit capacity after all of these improvements have been effected would be 43 vessels per day. While the forecast of the demand for navigation services increases throughout the planning period, the capacity to accommodate the demand is constrained to 43 vessels per day.

OTHER USERS

The PCC provides raw and finished water for domestic use. Approximately 121 MGD of raw water is withdrawn from Madden Lake and provided to a utility that treats and then distributes the finished water, primarily to the Panama City area. The PCC consumes much of the water they treat, but they also provide treated water to areas west of the canal. The locations of the withdrawal sites for these waters are near Gamboa and Parisio in Gatun Lake. These intakes supply raw water to the Miraflores Water Filtration Plant through several kilometers of pipeline. The system has the ability to deliver treated water at a rate of 48 MGD and averaged 46.4 MGD during 1997 and 1998. At the Atlantic end of the Panama Canal, two raw water intakes are located in the northeast backwater areas of the lake near Colon. They supply water to the nearby Mount Hope Water Filtration Plant. This system has the ability to deliver up to 27 MGD and averaged 26 MGD during 1997 and 1998.

In the future, water will be withdrawn from the Panama Canal in ever increasing amounts. The amount of increase is estimated to mirror the increase in the population surrounding the Panama Canal Zone. The forecast of the increase in water withdrawals for M&I use also considers the addition of the demands of a burgeoning tourist industry. After December 31, 1999, the PCC will be replaced with the Panama Canal Authority. In the future, the Panama Canal Authority will continue providing raw water and will be allowed to sell any treated water that is excess to their needs at the cost to produce such water.

The PCC also produces electrical energy for its own use. They have two hydroelectric facilities, one at Gatun Dam (24 MW) and the other at Madden Dam (36 MW). Currently, there is not enough water in the system for the hydroelectric plants to generate all of the electrical energy needed for the operation of the canal. In order to be self-sufficient, the PCC also has a steam generation plant. The PCC generates more energy with the combination of the hydropower plants and the steam generator than is needed for the operation of the canal. The Panama Canal Authority will be permitted to sell any energy that is excess to their needs at the cost to produce that energy.

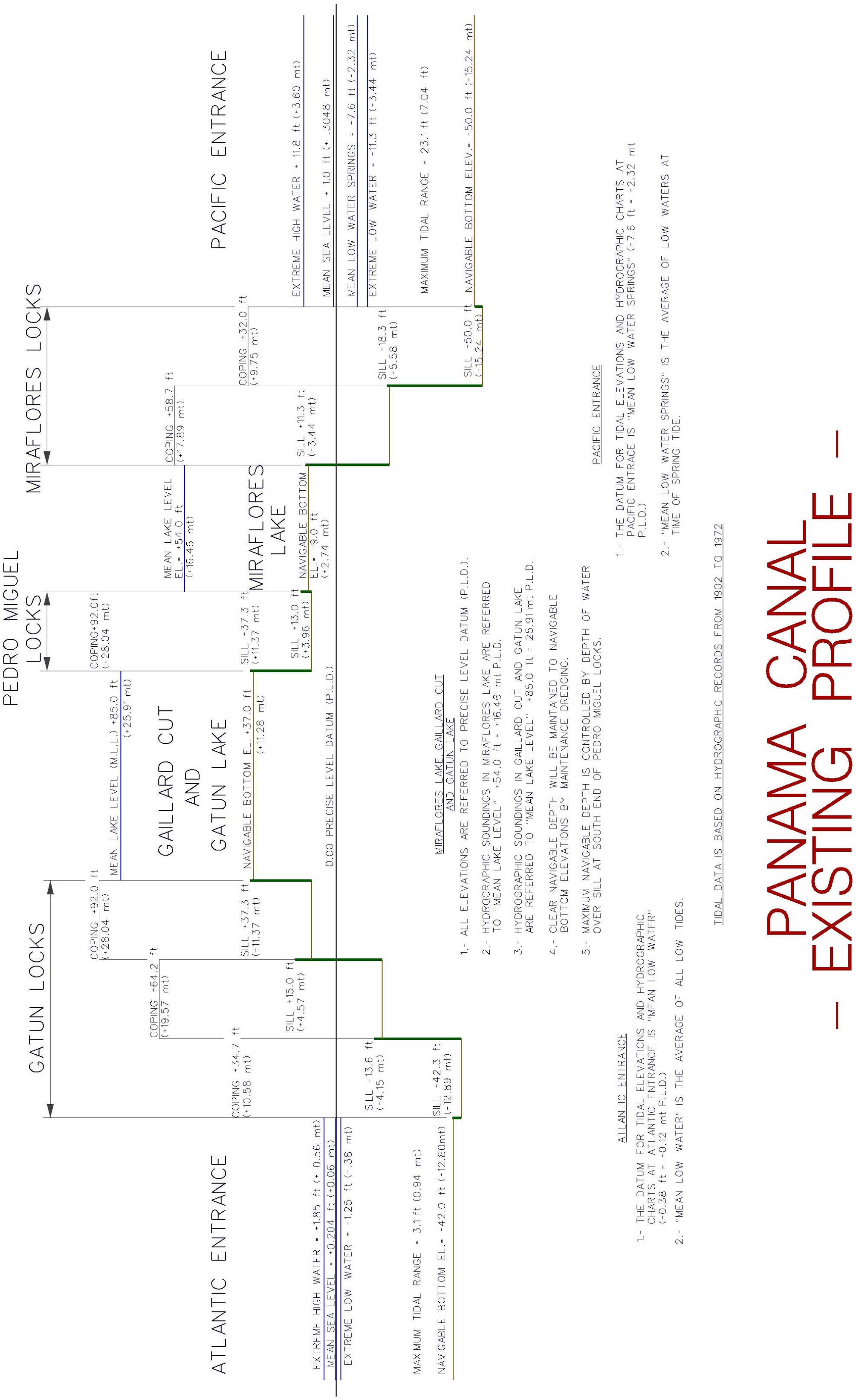

Plate 2 - 1   Panama Canal Existing Profile

SECTION 3

Problems and Opportunities

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Ship Traffic Capacity

Since the opening of the Panama Canal in 1914, the number of ships and the associated tonnage that transit the Panama Canal have increased dramatically. Ship traffic has increased to an average of 36 vessels daily, and increased traffic brings limitations and delays. The average transit time for a vessel from ocean to ocean is 8 to 10 hours. Considering all factors, the current daily average capacity is 38 ships but it will be increased to 43 ships after ongoing improvements are completed in 2002. The horizontal lock dimensions and depths over the lock end sills limit the maximum vessel size to 294 m length, beam width of 32.3 m, and maximum draft of 12.04 m. This is generally considered a 65,000 dead weight tonnage (DWT) vessel. Many modern ships in the current world fleet exceed these limits. The lock structures are 84 years old and require vigilant maintenance.

The PCC is currently widening and straightening Gaillard Cut to a width varying from 192 to 223 m to allow two-way traffic of large vessels and to increase efficiency of lock operations. This work is scheduled for completion in the year 2002. To make full use of the cut widening, the PCC is procuring additional tugs, towing locomotives, hydraulic miter gates and valve operators, centralized lock control systems, and modern vessel positioning equipment. Panama Canal throughput will increase from a daily average of 38 vessels to a sustainable daily average capacity of 43 vessels.

Widening of the cut will increase the operational capacity of the Panama Canal; hence, the locks sizes, lockage time, and water availability will become the principal, limiting parameters that prevent future growth of the Panama Canal.

Even with the above modernization program, market studies indicate that between the years 2010 and 2020, world shipping needs will exceed the capacity of the Panama Canal. Average Canal Waters Times (CWT), a measure of efficiency, will exceed 24-hours and customer service will deteriorate. Restrictions during lock outages for maintenance and upgrading will further increase transit times.

Water Availability

The transit of ships across the Isthmus of Panama depends on the availability of the freshwater stored within Madden and Gatun Lakes. This storage is the result of rainfall in the watershed that is captured by the two lakes. Water availability at the Panama Canal is limited and, even at present traffic levels, is not sufficient to meet traffic demand during prolonged dry periods, as highlighted during the 1998 drought. Inadequate water supplies require the Lakes to be lowered below design levels and thus induces draft restrictions on vessels passing through the Panama Canal. Accordingly, water resources for canal operations must be managed more efficiently and additional sources of water supply must be developed to meet the growing requirements of the Panama Canal. New sources of water supply therefore need to be identified, defined and evaluated to determine additional water contributions into the existing watershed system and their effectiveness in meeting increased demand for Panama Canal services.

In addition to supplying water for navigation, the Gatun and Madden Lakes also provide M&I water for developed areas adjacent to the Panama Canal. M&I daily water use currently withdraws a volume of water equal that required for four transits through the Panama Canal. Based on a projection of population growth over a period of 30 years, demand for M&I water will double for the cities adjacent to the Panama Canal. Recent development programs underway in Panama suggest that increased industrial and tourism development will impose an added 10 percent on that increased demand. These demands cannot be supplied by the existing watershed without adversely affecting canal operations.

The storage capacity of the present watershed of the Panama Canal is being used to its maximum, especially during prolonged dry spells. Additional water supply and added storage is required if the Panama Canal is to continue providing an efficient service to world maritime trade and meet M&I increased demands.

Projections predict a considerable increase in traffic and cargo through the Panama Canal over the next 50 years. To meet future traffic demands plus M&I water supply needs, the Panama Canal must develop new water sources and improved management of its resources.

Objectives

The PCC has developed a long-term plan to address the future needs of the Panama Canal. Through this program, they have set forth objectives that will reveal opportunities and provide analysis that will suggest the optimum economic and engineering solutions. The PCC has set forth the following objectives for this study.

1. To satisfy long-term (through the year 2050) M&I water supply needs without adversely affecting the operation of the Panama Canal.

2. To provide sufficient navigation waters to meet existing and future canal transit demands without restricting vessel operation and maintain historical reliability levels of 99.6 percent.

3. To maintain the current level of hydropower production as demands for other water use increases. If possible, increase current capacity and energy production as solutions are implemented.

Based on these problems and objectives, the PCC initiated this study as a first step to define possible opportunities, evaluate them, and identify the most promising alternatives to be carried forward for more detailed analysis and eventual implementation.

SECTION 4

GENERAL DESCRIPTION OF ENGINEERING, ECONOMIC, AND ENVIRONMENTAL INVESTIGATION METHODOLOGIES

Methodologies

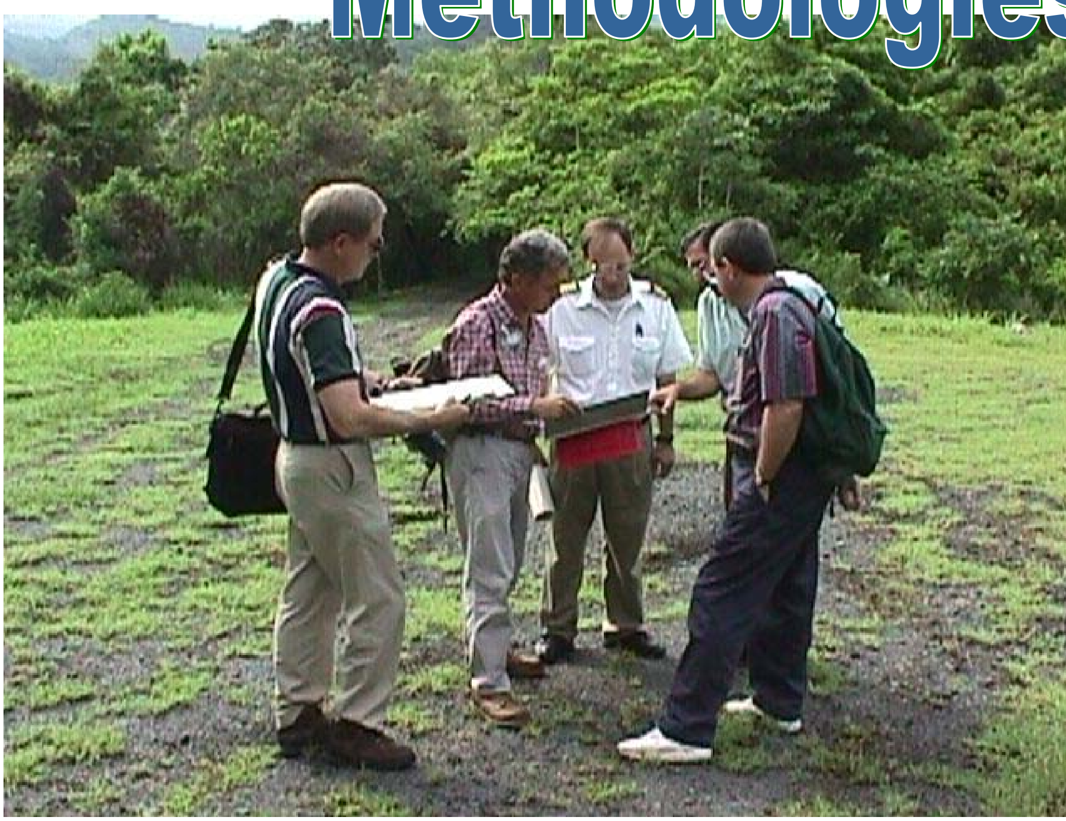

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Table 4 - 3 Total Demand Expressed in Equivalent Lockages 4-20

Synopsis

This section presents a general explanation of the level and degree of analysis applied to produce the results of the evaluations in the following sections. The basic purpose of this study was to identify and conduct a reconnaissance level evaluation of possible projects that would help the Panama Canal meet future M&I, and navigation needs. The objective of a reconnaissance level study is to identify possible measures, combine the measures in alternatives and demonstrate if the alternative projects would be feasible. The 30 projects listed in Table 1 – 2 in Section 1 reflect the final list of possible alternatives. This list was derived by considering projects that had been suggested in other studies, projects proposed by others or projects devised in technical sessions with experts and interested parties. The initial list of projects was developed from a full review by the PCC of all past studies, drawings from the most potential study information, and the development of additional project concepts by the Canal Capacity Projects Office of the PCC study team. The Canal Capacity Projects Office study team investigated all possible additions of new water supply projects with the existing Panama Canal watershed and adjacent watersheds from which water could be transferred. The concepts also included water saving project features and water management techniques. The developed list was considered to be the full range of techniques and projects available that would provide new sources of water and/or extend existing water supplies.

For this reconnaissance study, designs were performed only to the extent necessary to establish, with reasonable accuracy, the major features, the principal dimensions, the water yield, the benefits and costs of the proposed projects. Assumptions, analysis and calculations were based on existing data. Site specific data were developed only from existing data and brief field inspections of most sites by a technical team. Separate documentation was provided to the PCC that contained assumptions and design calculations for the investigations. Proposed projects that are carried into the planning studies should be further developed with more specific site data. Optimization of the project features and improvements must be accomplished to insure that all developmental requirements are satisfied.

Initial Assessment Criteria

It was recognized that some alternatives would not be feasible and some would not have sufficient information to be developed to the level of detail of others. Therefore, each alternative was initially tested for five major factors. These factors are listed below. If an alternative did not meet all five requirements, then it was sufficiently documented as such and excluded from the final comparison and ranking of the feasible alternatives. Cost estimates, economic evaluations and environmental evaluations were not developed for alternatives that did not satisfy the first three requirements. Project descriptions, costs, environmental and economic impacts were only presented to the extent necessary to demonstrate the project had been appropriately considered and that it failed to meet the requirements. Projects that lacked sufficient information to be developed and evaluated at the same level of the others was described to the extent possible and recommended for further studies if they demonstrated potential.

The initial assessment criteria were:

1. Volume of water provided. (Water Yield) – A project was required to provide the equivalent of at least one lockage (55 million gallons) to be listed for further consideration.

2. Technical Viability – The proposed project must be developed using existing engineering design and constructions methods. Appropriate materials must be obtainable at reasonable costs and within practical time frames.

3. Operational Impacts – Construction or development of any project can not result in an extended shut down of the Panama Canal. Operation of the project must be practical and not significantly impact the operation of the Panama Canal.

4. Economic Feasibility. – If an initial rough order of magnitude (ROM) cost estimate demonstrates that the project can not be developed such that it is obvious that the benefit to cost ration would be much less than 1, the project would not be considered further. Traditional economic analysis would be conducted if the project goes to further study.

5. Environmental Consequences - Failure with respect to environmental effects during initial screening would only occur if the alternative results in impacts judged unacceptable by the PCC. All other projects would be subjected to appropriate environmental procedures. The PCC provided environmental assessments through a separate contract with Black & Veatch Special Projects Corp, Kansas City, Missouri. These assessments were integrated into this report and are found in respective sections under the paragraph topics Socio-Economic Impacts, Environmental Settings, and Environmental Impacts.

Once a proposed project passed all five criteria, the evaluation process was carried through to completion. Those projects that demonstrated feasible engineering, operational and economic potential to meet the future needs of the Panama Canal are listed and ranked in Section 35 of this report. Sections 5 through 34 present the features and analysis of the projects considered.

Engineering Investigations

GEOLOGY

The geology in the areas where many of the water supply projects are proposed is, at best, only generally known. Geologic maps and published reports are more available for areas within the Panama Canal Basin. For areas outside the basin, the only information often available is that which can be obtained from large-scale geologic maps. Site visits were made to several of the proposed dam locations during preparation of this report, however, only rock outcrops in the streambeds could be examined during these visits; the abutment areas were typically covered by dense vegetation. Therefore, core borings and geophysical investigations must be conducted early for projects carried into the feasibility phase. The cores and other information obtained from these investigations should be analyzed to determine the general suitability of the foundation and abutment materials. Specifics that need to be considered include; depth to sound rock, rock strength, presence of joints or faults, and suitability of excavation material for use as construction materials.

SEISMIC

The Panama Canal and vicinity is located in a relative quiet seismic area, compared to surrounding areas, but is zoned as 3 in the *1997 Uniform Building Code*. This high-risk zone is justified due to the occurrence of relatively large seismic events associated with the North Panama Deformed Belt (approximately 75 km north of Colon), the South Panama Deformed Belt (approximately 150 km south of Panama City), and possible closer smaller events associated with faulting near the Panama Canal (such as along the Rio Gatun Fault Zone). Therefore, subsequent to this report, detailed site explorations, site-specific ground motion studies, and dynamic structural analyses would be required for each alternative project that is recommended for further detailed investigations. This comprehensive seismic investigation should be developed in phases in conjunction with the individual detailed investigations. At the feasibility stage, which is to follow this study, the magnitude of seismic motions should be estimated. Initial evaluation of essential project features should be included in sufficient detail to determine the extent to which seismic loads would control the designs.

GEOTECHNICAL INVESTIGATONS

No geotechnical investigations were conducted for this reconnaissance study. All new dam sites were assumed to have similar foundation conditions. The foundations for the dams were placed 5 to 10 m below the thalwag of the existing rivers to be contained. The excavated soils and rock were assumed to be of sufficient quality to be used in the construction of earth and rock fill embankments and concrete features of each dam. The quality of these materials produced a dam configuration using a crest width of 42.65 ft (13 m) and side slopes of 2 horizontal to 1 vertical. Foundation grouting for seepage control was assumed similar for all sites with several lines of grout injection forming a continuous curtain for a depth of 65.62 ft (20 m).

Early in the investigations the possibility of using concrete gravity dams at certain of the sites was discussed. General parameters were set to guide this choice based on achieving economy of construction. These parameters included having a relatively narrow gorge in which to place the dam, and having relatively low dam height. While several of the sites might have met these criteria, the concrete gravity dam alternative was investigated only at the Cocle del Norte dam with top elevation at 70 m MSL. The apparent economy of first cost achieved at this site might be also achieved at other sites. However, considering the high cost of the projects under consideration, and the small percentage that the margin between the earth and concrete dam options would contribute in each case, it was concluded that this refinement could best be made during the feasibility stage of project development. The concrete dam was included in the Cocle Del Norte Lake At Elevation 65 alternative as an example of the potential that this type of construction might have during these future studies.

The design of the diversion and inter-basin transfer tunnels were assumed to have similar geotechnical characteristics. The excavations were assumed to use conventional techniques of drilling, blasting and shoring. Rock bolting would be required for all ceilings and sidewalls and the tunnel interior surface would be concrete lined. The excavation quantities assumed a 3.28 ft (1 m) increase in diameter for rock removal and a percentage of overbreak was added to each site for areas of instability immediately outside the excavation template. Vent shafts spaced periodically were added to the excavated quantities as well.

Excavations within the existing channel assumed that slopes underwater would be stable on 5 horizontal to 1 vertical for soils and soft rock and 1 horizontal to 5 vertical for hard rock. Excavations within rock would be achieved by drilling and blasting to break up the rock materials into sizes capable of being lifted to the surface by mechanical means and transported by barge to existing disposal areas within the lakes.

HYDROLOGY

Hydrologic data for this reconnaissance study were developed from available flow records of rivers inside and immediately adjacent to the Panama Canal watershed. This work was accomplished jointly by the PCC and the U.S. Army Corps of Engineers, Mobile District. For this study, the area extended from the Rio Coclé del Norte watershed, west of the Panama Canal, to the Rio Mamoní, east of the Panama Canal. The existing hydrologic records of rivers of interest were extended by means of correlation, using standard hydrologic methods. Statistical correlation parameters for average monthly flows were developed between similar or adjacent stations. In some cases, relationships were developed separately for wet and dry seasons. These relationships were verified with double mass curves and coefficients of correlation. These relationships were then used to help fill data gaps and extend records.

Data were obtained from data records of the Panama Canal hydrologic stations within the Panama Canal watershed. Some of this data spanned the full 85 years that the Panama Canal has been in operation. Data for rivers outside the Panama Canal watershed were mostly provided by the Instituto de Recursos Hidraulicos y Electrificacion, Departamento de Hidrometeorologia, Seccion de Hidrologia (IRHE). Most of the data from IRHE only spanned a 50 plus year period of record. Correlation parameters were developed first for rivers that had the longest periods of record.

For example: Initial efforts began with hydrologic records on the Rio Indio. The daily flows of the Rio Indio at Limon and at Boca de Uracillo were obtained from the Engineering Group of IRHE and a correlation developed. The Rio Indio at Limon has records from 1958 up to 1980 but was a staff gage station that was discontinued. The station in Boca de Uracillo, a continuos recording station, has records from 1979 to present. The following correlation was made between both stations. Initial investigations found that these two stations did not correlate as well as hoped. Therefore, correlations with gages in adjacent basins, the Rio Trinidad and the Rio Ciri Grande, were developed with the station at Boca de Uracillo. The coefficient of correlation between both rivers was 0.95, which was considered very satisfactory. Using these relationships, the record at Boca de Uracillo was extended and data gaps filled. Then the hydrologic flow data for the proposed dam site were developed using a basin area ratio.

This process was continued until hydrologic records were developed for all proposed project sites. The maximum period of record that could be developed for stations outside of the Panama Canal watershed was 50.5 years. The final data were assimilated and placed in a database designed to interface with HEC-5 models.

Spillways were designed to pass a flow with a return frequency of approximately 1 in 1,000. For sites where there was not sufficient daily peak flow data to develop a flow-frequency curve the 1 in 1,000 flow was based on regional equations in the report Analisis Regional de Crecidas Maximas, Instituto de Recursos Hidraulicos y Electriicacion, Departamento de Hidrometeorologia, Seccion de Hidrologia, Panama, junio de 1986. This report was provided to the U.S. Army Corps of Engineers, Mobile District by the PCC.

The minimum required flow released at each of the proposed dam sites is estimated as 10 percent of the computed average annual flow. This requirement was determined by the PCC. A minimum flow is released from each dam site for environmental considerations and will be released through a powerhouse or through a minimum flow conduit.

Electrical energy produced by hydropower plants in the country of Panama normally supplements the base load and are not used to meet peak loads. Therefore, hydropower plants in the proposed projects were sized with a plant factor of 0.5. Hydropower potential at proposed projects was based on flows at the dam after water was diverted to satisfy M&I needs and operational needs of the Panama Canal.

SIMULATION MODELS

Introduction

A reservoir simulation tool is required to evaluate the most promising reservoir alternatives to meet the objectives stated in Section 3. The U.S. Army Corps of Engineers, Hydrologic Engineering Center (HEC) developed HEC-5, Simulation of Flood Control and Water Conservation Systems Computer Program that performs sequential simulation of reservoir operations given a time-series of flow.

HEC-5 was used to evaluate alternatives that bring water from external watersheds, revise control and management of projects within the existing watershed, and relocate M&I water sources to projects outside of the Panama Canal watershed. This model was applied to appropriate project listed in Table 1 - 2 in Section 1.

Data Requirements

The basic input requirements consist of three types of data: (1) Physical data including: storage-discharge capacity curves, linkage defining the system structure, hydrologic routing criteria; (2) Operational data including: allocation of reservoir storage volumes to project purposes (rule curves), forecast ability, maximum allowable flow goals (channel capacities), minimum flow goals; and (3) Hydrologic time-series data consisting primarily of flow data.

Program Capabilities

The HEC-5 program conducts sequential simulations of reservoir operations given a time-series of flow. The reservoirs are defined by their storage and outflow capability. In addition, the reservoir storage is allocated to operational zones (levels) that define their usage. In the simplest form, the flood control zone is used to store excess inflow. The conservation zone is used to store water to meet water supply requirements, and water in the inactive zone (dead storage) is not used. Water demands in the model are represented as minimum flow goals, diversions, and hydroelectric power generation. Reservoirs are linked to other reservoirs and control points (non-reservoir locations) using routing reaches. A combination of reservoirs, control points and connection routing reaches then define a reservoir system model. Normally HEC-5 is used to evaluate flood control operations. The program user can change the prioritization of release selection to favor hydropower or water supply operation over flood control.

HEC-5 is a generalized program operational on PC-DOS and UNIX computers. The data defining the reservoir system, operation goals, and flow are assembled in an input data file. The file is processed by the program to determine the reservoir releases and resulting flow and storage throughout the system. The results are written to an ASCII file and to a data storage system adapted by HEC. This system uses the HEC-DSS random access file based input specifications. Data written to a DSS file can be tabulated, graphically displayed, and processed using utility programs to develop summary statistics or to perform data manipulations. The HEC-DSS package of programs is documented in the HEC-DSS Users Guide and Utility Manuals.

HEC-5 is capable of simulating the operation of simple or complex systems of reservoirs of almost any configuration. Analyses of a system may be made in a planning mode, or coupled with HEC runoff forecast programs through the data storage system (HEC-DSS).

Hydrologic time-series data may be specified in a variety of time intervals including minutes, hours, days, weeks, 10-days, half months and months. Flow data may be specified as end of time interval or averaged over the time interval. Analyses may be made for single events, multiple events or period-of-record. General capabilities of the modeling system are summarized below.

English or Metric (SI) Units
Up to 40 Reservoirs
Up to 80 Control Points
Up to 40 Diversions
Up to 35 Powerplants
7 Hydrologic Routing Methods
Linked to HEC-DSS
Single Event or Period-of-Record Simulation
Flood Control, Water Supply, and Hydropower

Base Model Description

The U.S. Army Corps of Engineers, Hydrologic Engineering Center, developed a base model of the existing Panama Canal system under separate contract. The base model represents the existing Panama Canal water supply system with Madden and Gatun Lakes as the primary elements of the system. The multiple demands for M&I water supply and lockages to the Atlantic and Pacific Oceans were summed as diversions out the system. Average monthly values for the 5-year period 1993 to 1997 were used, assuming that the recent average best represents the current demand. HEC-5 can only process one diversion for each lake; therefore, diversions from Gatun Lake represented a composite of the lockages and M&I withdrawals.

The model was established in English units. The simulation time-interval was set at one month. Given the monthly time-step, the seasonally varying data are all defined over the 12 months. River-reach routing is not required for a model that employs a monthly time step.

The average-monthly flow data are input to Madden and Gatun Lakes. The inflow data in the HEC-DSS database was assigned as incremental-local inflow, which means that the total inflow to Gatun Lake included the outflow from Madden Lake and the local inflow. The flow data was read from the HEC-DSS file with appropriate DSS records assigned by their pathname.

The model began with Madden Lake, which received basin inflow, provided M&I water supply, and released flow to Gatun Lake. Releases from the lakes were assumed to pass through the hydroelectric facility and energy generation was computed up to limits of power capacity. The outflow from Madden Lake was passed to Gatun Lake. The channel capacity below Madden Dam to Gatun Lake was set to the limit specified in the operations manual, 15,240 CMS. When flows from Madden exceed this amount cross currents in the navigation channel at the confluence with the Chagres River impede safe passage of vessels. Therefore, the limit was only exceeded when necessary to keep Madden Lake from exceeding its maximum allowable lake level.

Gatun Lake is the next location below Madden Lake and receives local basin inflow and the Madden Lake releases. Gatun Lake provides M&I water supply and lockages for Pedro Miguel and Gatun Locks. Lake evaporation was subtracted from the reservoir inflow. The inflow to Gatun Lake was negative each month that the evaporation was greater than the inflow. Flows released from Gatun Lake generated electrical energy and were passed to the Atlantic Ocean. Flows out of Gatun Lake and Pedro Miguel Locks were modeled as diversions.

The only data that changes in the physical system data are the starting storages. The inflow data was read from a DSS file with the starting record defining the number of simulation periods, the starting date, and the time interval in hours. A time interval of 720 hours was used to define monthly data. Then the essential pathname parts for each DSS record were read. For the base model simulation, these data represent the incremental inflow to Madden and Gatun Lakes.

HEC-5 Modeling of Alternatives

Alternatives are categorized as within the Panama Canal basin or outside the Panama Canal basin. Two of the external projects are water supply projects that relocate M&I water sources to outside the existing watershed.

The area-volume tables were derived from available topographic maps or previous studies to define the required physical data. Development of inflow data for each project site is described above in the paragraphs under the heading of HYDROLOGY in the respective sections. There were two configurations for the rule curves for external water supply reservoirs. The top of conservation pool for each project varied seasonally similar to the storage distribution at Madden Lake or remained constant throughout the year.

Physical and operational data for each proposed project outside the watershed were linked to the existing system model. The models were coded to balance the storages between the reservoirs, with the upper reservoirs operating to optimize storage in Gatun Lake to meet water demands. Water diverted from Gatun Lake was set as the highest priority; therefore, water for canal operation and M&I demands were satisfied before hydropower generation. For proposed projects located above Madden Lake, a tandem operation scheme was specified to meet the Gatun Lake diversion requirements. Any combination of alternatives outside the watershed also required a tandem operation. Evaporation rates for Madden Lake were used for projects in the east of the Panama Canal. Evaporation rates for Gatun Lake were used for projects west of the Panama Canal.

Proposed projects within Gatun Lake required special attention. Incremental inflow to Gatun Lake or Madden Lake was reduced by the amount equal to the inflow above the proposed site. If the proposed project included part of the existing lake, the storage and area table requires similar adjustments.

The HEC-5 model also has the capability to assign intermediate zones in the conservation storage to help the model balance the storage between two or more reservoirs. The intermediate operational zones allow flexibility in the distribution of the conservation pool. For the models developed for this study, levels 3 and 4 define the conservation storage distribution (note level 3 is below level 4). When an upstream reservoir operates for the downstream reservoir, a greater percent of the conservation storage can be assigned to the upper level. This allows storage from the upstream reservoir to be used first to meet demands in Gatun Lake. For example, Upper Chagres Lake was specified to operate for Madden Lake and, in turn, Madden Lake was specified to operate for Gatun Lake. In order to use water from Upper Chagres Lake first, Upper Chagres Lake has a greater percent of the conservation storage between levels 3 and 4. Figure 4 - 1 compares the storage distribution between the levels for Upper Chagres and Madden Lakes.

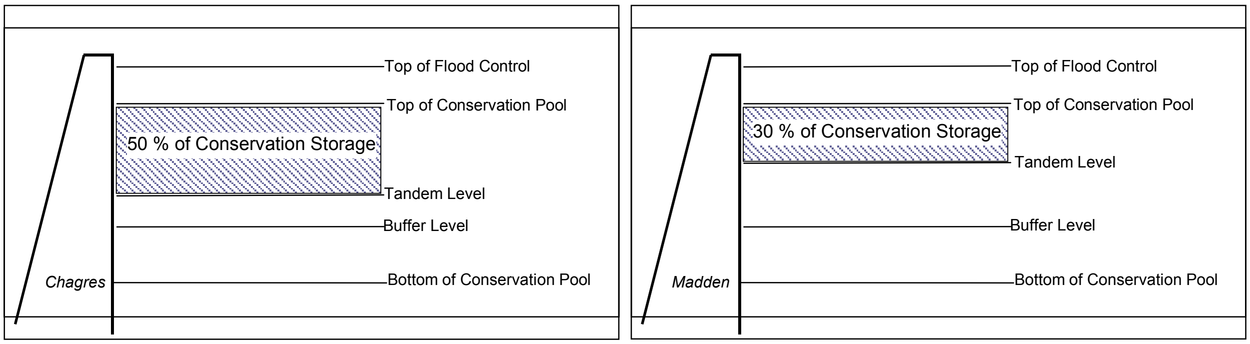

Figure 4 - 1 Conservation Storage

Two of the proposed projects would be new lakes within Gatun Lake watershed that enveloped part of Gatun Lake. These projects would operate as run-of-the-river with essentially no flood control storage. A tandem configuration was used to control when a proposed project would provide additional water to Gatun Lake for water supply demands. To minimize spillage at Gatun the stored waters were held back until 20 to 40 percent of storage in Gatun Lake had been consumed. The tandem level was set approximately 1 ft (0.3 m) below the top of conservation. This operation allowed new projects within Gatun Lake to act as reserve storage. This storage was only used after a portion of Gatun Lake storage had been depleted.

Alternatives with a proposed dam containing hydropower and an inter-basin diversion tunnel were modeled as two reservoirs. The first reservoir represented the diversion tunnel operation; the second represented the spillway and powerplant. The tunnel diversion operation passed water from the new lake to Gatun Lake and all floodwaters were diverted to the spillway-powerplant reservoir. Minimum flow requirements from all proposed dams are estimated as 10 percent of the annual mean flow. Minimum flows would also be diverted to the spillway-powerplant reservoir and released down the river. This diversion occurs by putting a negative diversion at the spillway-powerplant reservoir. The Figure 4 - 2 shows the model schematic for the proposed Rio Indio Dam.

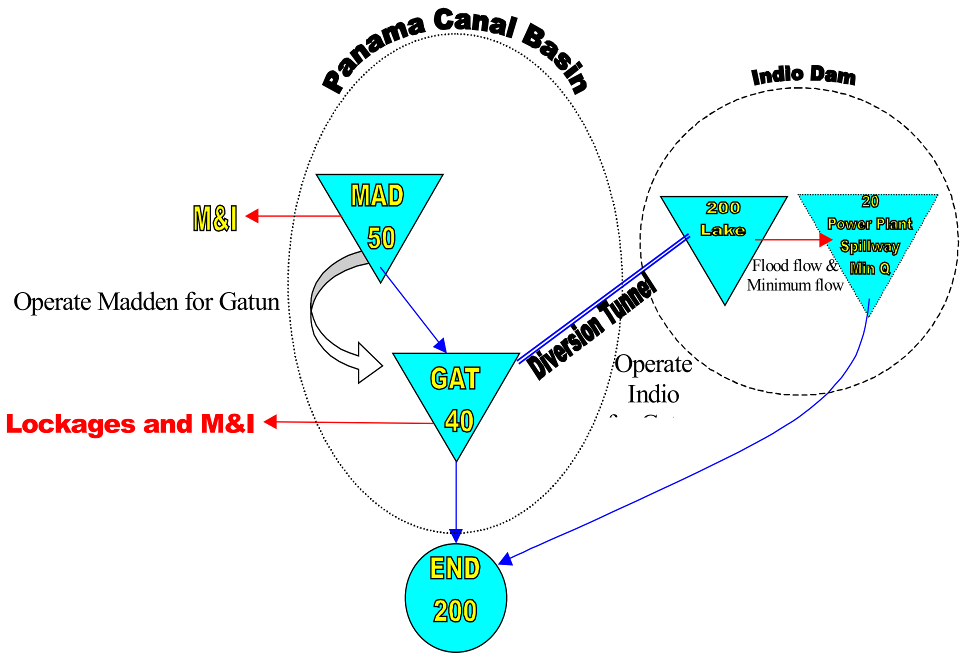

Figure 4 - 2 Model Schematic

The period of hydrologic record considered for simulation was determined to be 50.5 years (January 1948 through July 1998). The first task in the study was to compute the potential water yield available from each alternative. An economic forecast of demands was not performed at this stage. In order to compute the water yield, it was necessary to estimate the total likely growth in demands. From data provided by the PCC, it appeared that total growth in water demands to the year 2050 would not exceed 180 percent of existing demands. Therefore, model simulations were conducted considering proportionally increasing demands up to 180 percent of current demand levels.

HYROLOGIC RELIABILITY

The Panama Canal has historically been very reliable with respect to the availability of water. It has experienced only occasional periods of limited service because of water shortages over the past 85 years of operation. There have been some occasions of limited service because of scheduled maintenance or emergency repairs. One delay was experienced because of political and military actions in the country. The recent El Niño phenomenon experienced in 1997 and 1998 caused significant water shortages that resulted in draft limitations for large vessels passing through the Panama Canal. This experience highlighted the need to identify viable options that would allow the Panama Canal to maintain the existing high level of reliability as demands for water increase on the system.

Hydrologic reliability was defined as the ability of the Panama Canal system to provide sufficient water for unrestricted operation. Unrestricted operation for the Panama Canal would be its ability to pass all requested navigation without draft restrictions and to meet all M&I water supply needs during the designated period. The hydrologic reliability is represented by a ratio of the volume of water provided to the volume of water demanded for canal operations during the designated period with no draft restrictions.

$$\text{Reliability} = \left[\frac{\sum Vol\_Provided}{\sum Vol\_Demanded} \right] x100\%$$

In the past, when water shortages have been experienced, the Panama Canal has continued to provide passage to all requesting vessels. This generally resulted in the lake elevation becoming so low that draft restrictions had to be imposed on large vessels. Draft restrictions obviously reduce the capacity of the vessels, and thus, results in a significant economic impact on world shipping. As future demands for both navigation and M&I water increase, the frequency of shortages will increase.

Current conditions in the Panama Canal permit vessels to load to a maximum draft of 39.5 ft (12.0 m) when Gatun Lake is equal or above elevation 81.5 ft (24.8 m) MSL. Figure 4 – 3 reflects the simulated Gatun Lake elevations throughout the 79.5-year historical hydrologic record with current demands for navigation water and M&I water supply withdrawals imposed on the system for the entire period. Current demands were represented by averaging monthly records for the last five years (1993-1997) of lockage and M&I water withdrawals. This method of operation allowed the system to meet all demands but allowed Gatun Lake to drop to levels below elevation 81.5 ft (24.8 m) MSL. Each time Gatun Lake dropped below elevation 81.5 ft (24.8 m) MSL indicates a period that draft restrictions would be required. This serves as a good indicator of the systems current reliability.

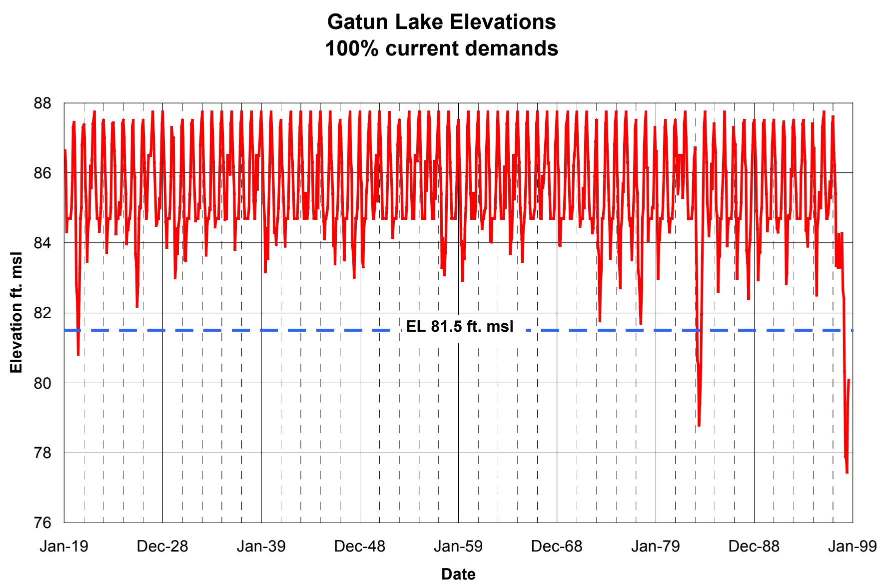

Figure 4 - 3 Current Demands

If demands for navigation water and potable water increase and actions are not taken to increase the supply of water to the system, the frequency of draft restrictions will increase. The next chart (Figure 4 - 4) presents simulated Gatun Lake elevations for the historical hydrologic record with the total water demand (navigation plus M&I) increased by 20 percent. This level of demand indicates a significant increase in the frequency of draft restrictions.

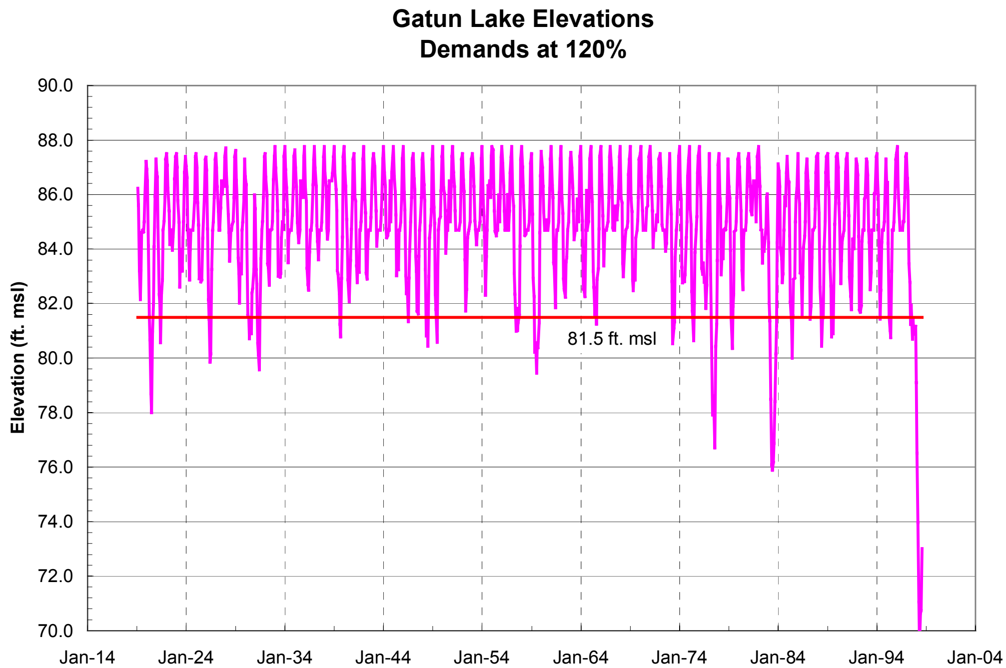

Figure 4 - 4   120 percent of Current Demands

Instead of draft restrictions, the PCC could have limited the number of vessels passing through the system when water shortages were experienced and not imposed draft restrictions. This would have resulted in a reduced number of lockages and identified the actual volume of water the system would be short. This shortage can be used to compute the hydrologic reliability. As demands increase the reliability would decrease. Figure 4 - 5 presents a comparison of the hydrologic reliability of the system to incrementally increasing water demands. The horizontal axis along the bottom of the chart reflects demands as a ratio of the last five-year average (1993-1997) and the axis along the top reflects demands in lockages (assuming 55 million gallons per lockage). These values are also provided in Table 4 - 1. The current level of hydrologic reliability for the 50.5 year period of record is approximately 99.6 percent. This includes the 1998 drought year. The 50.5 year record is shown here since this is the period of record used to evaluate the alternatives presented in the following sections.

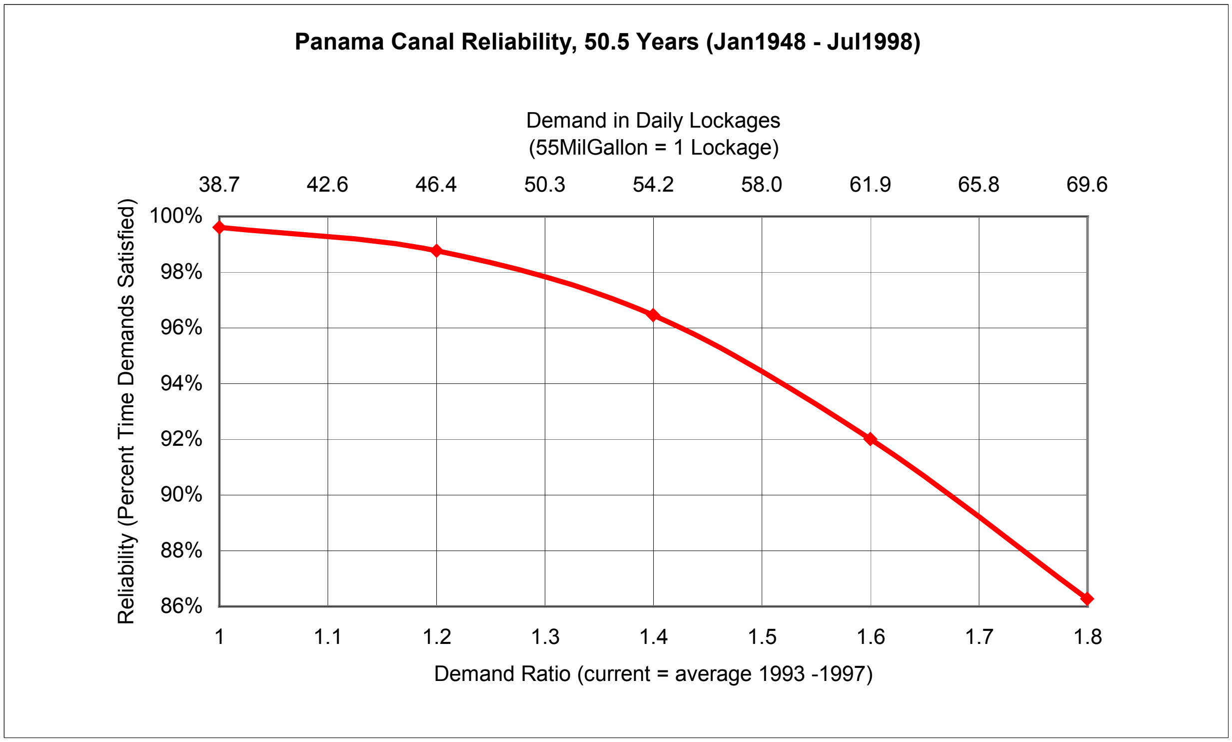

Figure 4 - 5 Hydrologic Reliability

Table 4 - 1 Reliability

Demand Ratio	Demand in Daily Lockages	Gatun Reliability 1948 – 1998 (%)
1	38.68	99.60
1.2	46.42	98.74
1.4	54.15	96.38
1.6	61.89	91.97
1.8	69.63	86.24

As demand for additional water increases, the ability of the Panama Canal to reliably transit vessels through the system will decrease. The current high reliability that the Panama Canal enjoys can only be maintained if water saving methods are developed or facilities are constructed that provide additional water supply and storage.

STRUCTURAL INVESTIGATIONS

General

For structural considerations, the studies included in this report may be categorized as dam and reservoir projects, existing reservoir modification projects, and miscellaneous water savings measures. Types and configurations of structures were kept the same as much as possible, allowing for variations in sizes based on such things as size and number of water passages required, and differences in dimensions required to fit the features to the proposed project site. The following is a description of the basis for development of the structural features in each of the various types of projects.

Cofferdams

For the dam and reservoir projects employing rock fill dams, intake structures, outlet structures, and powerplants this would include sufficient cofferdams to protect each structure site and cofferdams upstream and downstream of the rock fill dam to protect the dam up to and including the 10 percent frequency flood at the site. These cofferdams would be constructed to allow their incorporation into the dam as construction progressed, thus avoiding the cost to remove the cofferdams.

A concrete dam would require a slightly different cofferdam treatment. The dam would be constructed in two stages, and would require a cofferdam for each stage to provide protection to the 10 percent flood frequency for either side of the valley floor. These would have to be at least partially constructed of steel coffercells because of the narrowness of the valley floor. Other features of this alternative would require protection during construction as described for those associated with the rock fill dams.

For those alternatives involving modification of existing reservoirs and including installation of major civil structures similar measures would be required to those outlined for the dam and reservoir projects, i.e. protection to the 10 percent frequency flood level.

Dam and Reservoir Projects

The proposed projects were generally configured with an earth and rock fill dam, outlet works consisting of an intake structure, an outlet tunnel with a downstream headwall structure, and a hydropower plant which would receive its flow from a Y off of the main tunnel. Projects outside the Panama Canal watershed also included inter-basin transfer tunnels. These tunnels were designed to convey water between basins. The structural features for these tunnels were in every case similar to those for the outlet works, except that these tunnels required a gate structure at their downstream and upstream ends.

The intake structures were tower structures varying from a few meters to over 100 m in height. Given this variation and considering the need to allow for some moderate seismic activity in the project areas, these structures were generally configured similar to those used by the U.S. Army Corps of Engineers, Jacksonville District in 1980 for the Cerrillos Dam Project in Puerto Rico. This intake structure was configured as a leaning structure built into a slot excavated into the hillside adjacent to the abutment of the dam. This configuration allows for maximum lateral support over the full height of the structure and should negate the stability problems inherent in freestanding tower structures. These intake structures were configured to provide flow for diversion during construction, and minimum flow, hydropower flow, and reservoir evacuation after construction is complete. Estimates of construction quantities were derived from the intake tower configured for each reservoir site.

The tunnels were configured as concrete lined horseshoe shapes with lengths determined from rough site layouts and horizontal and vertical opening dimensions hydraulically determined from required flows.

Structural components of the proposed powerplant structures were accounted for using the publication, Feasibility Studies For Small Scale Hydropower Additions, A Guide Manual, prepared by the Hydrologic Engineering Center, U.S. Army Corps of Engineers, 1979. Physical dimensions that were developed for some of the power house structures were used only as rough guides for laying out the graphic presentations. The estimated construction cost figures were taken from the provisions in the document noted above.

One exception to the dam and intake arrangement described above is the proposed Cocle del Norte Dam constructed with lake elevation 213.3 ft (65 m) MSL. The dam included in the proposed project is a mass concrete dam with gated spillway and power intakes. This was done to demonstrate that, in a relatively narrow gorge and with moderate dam height, a concrete dam configuration might successfully compete with an earth and rock fill dam.

Design stability computations were made using the following generalized data:

Phi angle for sliding at Foundation, 40º
Cohesion at foundation, 2,000 PSF (9,760 kg/m^2)
Unit weight soft rock, 125 PCF (2,000 kg/m^3), Moist
135 PCF (2,160 kg/m^3), Saturated
Phi angle soft rock, 38º
K at rest, soft rock, 0.38
Unit weight silt, 120 PCF (1,920 kg/m^3), Saturated
Phi angle silt, 5º
K at rest silt, 0.9

The dam and spillway depicted in the report were checked using the above constants and applying current U.S. Army Corps of Engineers guidance as contained in Engineering Circular EC 1110-2-291 and found to be stable (base of structure fully in compression, foundation pressures in acceptable range, and minimum sliding factor of safety greater than or equal to 1.5) under normal loading with water to top of spillway gates upstream and no water downstream. Full headwater to tailwater uplift gradient was assumed beneath the structures.

The concrete monoliths were stepped up the side of the abutment slopes and proportioned for concrete quantity maintaining the same structure slopes as the largest blocks.

Should a design be carried forward for feasibility analysis, the structures presented in this report must be addressed in more detail, using site-specific foundation and backfill / silt figures (unit weights, etc.). A full array of design conditions including varied water levels up to maximum flood, and seismic loading conditions should also be addressed.

Existing Reservoir Modification Projects

The proposed alternatives involving modification of existing structures to accommodate changed water surface elevations, etc. were assessed in parametric terms. These were based on the experience of the design and cost estimating staff personnel and using information provided by the PCC.

Where major components were to be added to the existing facilities, quantities for these features are estimated based on other past projects and designer experience, and were included in the project for estimating purposes. For instance, where a gated spillway was required, an idealized gravity spillway block using vertically operating tainter gates was used with no actual numerical analysis or structural design performed. The actual configuration for this structure may be substantially different in type and configuration from that used in the study, but the cost included should be representative of the effort and materials required for the project.

Miscellaneous Water Saving Measures

These alternatives include specific features including the installation of tide gates in the Pacific canal inlet to regulate the tide variations at Miraflores Locks and for pumping water from various sources into the canal for navigation. The structures associated with these alternatives can be very large and costly. It is very important to assess the total project cost, as indicated in the CASS Report for the tide gate structure. The structure can be considered as incidental to the operation involved and included in the overall plant cost, as is the case in the pumping plant assessments included in these reports.

It should be noted that in the case of the Tide Gate Alternative as well as others in this series, the hydraulic analysis of reliability dictated the effort to be expended in determining structure quantities and costs. Those alternatives returning less than the equivalent of one lockage (defined as 55 million gallons) were deemed by the PCC as unworthy of further consideration. Therefore, the tide gate alternative, for example, contains no details or configurations for the structural components, and no cost estimate in this report.

COST ESTIMATES

The first cost estimates are unit cost type estimates, which reflect all direct costs and contractor mark-ups. In most cases the basis for the unit costs are historical data escalated to current (1998) price levels and tempered with estimator judgement. The quantities estimated for each proposed project were derived from the layouts of each proposal. Much of the costs for dam construction were based on similar work at the Richard Russell Dam and Powerhouse located on the Georgia-South Carolina border, circa 1978. These costs were escalated to current cost by using Engineer News-Record Construction Cost Index History (1908-1999). Cost for other items, such as structural steel, were taken from R.S. Means Building Construction Cost Data and adjusted to Dothan, Alabama rates. Historically, costs for this area were found to be comparable with bid results from the Republic of Panama.

The project cost estimates also included a factor of 12 percent for Engineering and Design, a factor of 6 percent Supervision and Administration, and a factor of 2 percent for field overhead (construction camps, contractor facilities, etc.). These factors were all applied to the first costs and referred to as indirect costs.

A 25 percent contingency factor, which is typical for civil works at the reconnaissance stage of design, was applied to the sum of the first costs and the indirect costs. The 25 percent contingency was applied in all cases except for the Deepen Gatun Lake alternative. In this case, a 15 percent contingency was applied. One of the overall objectives of the study was to place all of the alternatives on an equal basis in order to make meaningful comparisons among them. Since current unit costs and very good quantity estimates were available from the in-progress channel widening, it was assumed that a 25 percent contingency would be too conservative and would penalize the Deepen Gatun Lake alternative in relationship to all other alternatives.

For items that require major replacement during the project life, experience with similar kinds of equipment was used to estimate the useful life or replacement cycle of these items. Generally, the major components of a hydropower facility (turbines and generators) need to be replaced every 30 to 35 years. Many small parts are replaced far more frequently. To account for this, ordinary annual maintenance was used. Other items that would be subject to wear and tear were assumed to be replaced on a 50-year cycle, which essentially lengthens the total useful project life to 100 years. With a project discount rate of 12 percent, inclusion of these items on a 50-year cycle did not add significantly to the total average annual costs of any proposed project.

The PCC provided data on the number of employees and the burdened wage rates that would generally be needed at any of the proposed projects. Consideration of benefits and other overhead items are assumed to constitute the burden on hourly wages. The total staff for each proposed project was adjusted depending upon the size of the proposal and / or the inclusion of hydropower facilities.

For some alternatives, two operating schemes were investigated. While there may be small differences in the construction of some project features, these differences would be small and would not impact total project costs at this level of investigation. Therefore, only one cost estimate was made for those alternatives.

Reconnaissance level environmental and socio-economic evaluations do not identify mitigation measures to a sufficient degree that allows determination of expected costs. Therefore, some added mitigation costs could be expected for alternatives that are subjected to feasibility level studies.

Development Sequence

The logical and orderly development of each proposed alternative carried forward for further study and possible implementation would proceed with planning studies, which would be accomplished to evaluate the alternative features. Each potentially viable project would be evaluated to assure that the plan presented would provide all of the features required to make it functional. Each would also be assessed as to its effectiveness in meeting the project goal of providing M&I water supply in relief of current or future planned withdrawals from the Panama Canal, with due recognition of any secondary benefits. Environmental assessments of the proposed projects would also be made to assure environmental acceptability of the project features. These environmental assessments would begin during the planning studies phase and would continue during the final design, advertising, and award phase. The final design would be accomplished for the recommended project. After completion of the final design, plans and specifications would be prepared for the advertising and award phase.

Economics Investigations

The economic evaluation of proposed projects is based on a comparison of the outputs of the existing and future conditions without the proposal and the outputs of the future conditions when that proposal has been added. These two conditions are frequently referred to as the with and without project conditions. Since large construction projects typically are meant to last for long periods, an economic planning period of 50 years is usually selected. This 50-year period starts at project construction completion or when benefits start to accrue to the project. The planning period does not infer that the project will only physically last for 50 years or that there is no useful life left to the project after the 50-year period. It is simply a means to measure the flow of benefits, costs, and other impacts that can reasonably be attributed to the proposed project.

In these analyses, we considered two types of benefits for the provision of additional volumes of water; the actual provision of additional volumes of water, and the increase in the reliability of providing those additional volumes of water. For convenience, these two types of benefits are referred to as water supply benefits and reliability benefits. To determine the amount of additional water supplied by a proposed project, the system simulation model was run using an 85-year period of record for the existing system. The model demonstrated that the current system could supply the current amount of water demanded for both navigation and M&I uses at a 99.7 percent level of reliability. The PCC has stated that one of their primary goals and objectives is to maintain that level of service.

For the watersheds outside of the Panama Canal area, a period of record of only 50.5 years is available. To compare one proposed project to another, the same period of record must be used. Using the 50.5-year period of record for the Panama Canal watershed, the simulation model determined that the level of reliability for the existing conditions is 99.6 percent. This decrease is due to the drought conditions in 1997 and 1998. These conditions have a greater influence in the shorter period of record. Since the same assumptions are being used in the analyses of the each proposal, this small difference is relative and does not alter the comparison of the proposed projects.

The price level for benefits attributable to navigation, M&I water supply, and hydropower generation is in constant 1998 dollars. Likewise, the unit cost values provided by the PCC are also in constant 1998 dollars.

The general concepts used in the benefit evaluations are that any proposed project can provide additional volumes of water and that the reliability of providing those volumes of water will be increased. Thus, the measure of the volumetric benefits is the difference between the volumes of water supplied at a very high level of reliability. For these analyses, that level is the 99.6 percent level of reliability. Currently, the existing system can provide 38.68 lockages per day at a 99.6 percent level of reliability. If some proposed project can provide 45.68 lockages per day at the same 99.6 percent level of reliability, then the proposed project can provide 7 additional lockages per day. In time, the amount of water demanded would exceed the amount of water that can be supplied and shortages would occur. Since the demand for M&I water use is met first, any shortages would accrue to navigation. Likewise, all shortages provided are then valued as navigational use.

The measure of the reliability benefits is the difference between the reliability of the existing system to provide 100 percent of the total amount of water demanded, and the reliability of the system with the addition of a proposed project to provide the same amount of water demanded. For example, the existing system can provide 100 percent of current total demands 99.6 percent of the time. The existing system can provide 120 percent of current total demands 98.74 percent of the time. The reliability of meeting all of the total demand decreases as total demand increases, (see Table 4 - 1). If some proposed project can provide 100 percent of total current demands 99.8 percent of the time and 120 percent of total demands 99.54 percent of the time, then the proposed project can claim benefits for that increase in reliability. Since the total amount of water demanded is comprised of demands for M&I water use and demands for navigational water use, the estimated value of the increase in reliability reflects both uses. The portion of total demand represented by M&I demand reflects the value of water used for M&I purposes. The portion of total demand represented by navigational demand reflects the value of water used for navigational purposes. The simulation model for the existing condition as well as for any proposed project is configured to estimate the reliability of providing total amounts of water demanded. The model is then modified to estimate the reliability of providing 120 percent of current demands. Additional modifications are made to estimate 140 percent, 160 percent and 180 percent of total current demands.

The first item of work in evaluating the benefits of a project is to construct a demand schedule for the project outputs. For all of the proposals presented here, the two major outputs will be water supply for navigation and water supply for M&I uses. Many of the proposals will also produce hydroelectric energy. In those cases, the value of the generation is also evaluated as a benefit.

The demand schedule for navigation water usage is based on the forecast of the total number of ocean-going commercial vessels. These data were provided by the PCC. The forecast of total number of vessels includes both laden vessels and vessels in ballast as well as consideration for the change in the average size of vessels. This forecast was made in 1997 by the Economic Research and Forecasting Branch of the PCC and is entitled the Panama Canal Commission Long Term Transportation Forecast. In 1998, 13,025 ocean-going vessels transited the Panama Canal. This forecast envisions 13,413 vessels in 2000, 15,477 vessels by 2010 and 24,971 vessels by 2040, the terminal year of the forecast. The U.S. Army Corps of Engineers, Mobile District extended the forecast to 2070 in order to have complete data for any selected planning period. The data provided by the PCC suggested a growth trend that increases at a decreasing rate. This growth trend was used to extend the forecast. The amount of decrease between the last two periods of the forecast was used to successively reduce the growth per period in the extension. Table 4 - 2 displays the historic number of vessels that transited the Panama Canal, the total tonnage carried by those vessels, and an estimate of the total toll revenue collected.

Table 4 - 2 Historic Transit Statistical Information

FY Ending September 30	Total Vessels	Total Cargo (tons)	Toll Revenue (US dollars) [1/]
1983	11,707	145,590,759	287,791,023
1984	11,230	140,470,818	289,155,035
1985	11,515	138,643,243	300,807,914
1986	11,926	139,810,493	322,734,202
1987	12,230	148,690,380	329,858,775
1988	12,234	156,482,641	339,319,326
1989	11,989	151,636,113	329,696,838
1990	11,941	157,072,978	355,557,957
1991	12,572	162,695,886	374,624,737
1992	12,454	159,272,618	368,662,504
1993	12,086	157,703,910	400,884,033
1994	12,337	170,538,437	419,218,757
1995	13,459	190,303,065	462,754,053
1996	13,536	198,067,990	486,688,265

[1/] All annual toll figures have been revised to show total tolls collected instead of ocean-going commercial tolls.

The capacity of the Panama Canal to pass ships was next considered. This study is only concerned with the provision of additional water supplies and not with any other means of increasing the capacity of the Panama Canal. Toward that end, the capacity of the Panama

Canal will constrain the number of ships that can be passed to a sustainable average of 43 ships per day. For short periods, a larger number of ships could be passed, but that amount of throughput could not be sustained for an entire year. The conditions that will allow an average of 43 ocean-going vessels per day include completion of the current widening of the Gaillard Cut, provision of programmed additional tugboats and locomotives (mules), and the current programmed improvements in the traffic management system.

Finally, the average number of ships per day is converted to an average number of lockages per day. The number of ships and the number of lockages per day are not equal since two or more small ships can be accommodated in a single lockage. The historic number of lockages from 1983 through 1998 were examined and compared to the historic number of ocean-going vessels. The ratio of vessels to lockages for the period 1983 to 1997 ranges from a low of 1.05 in 1984 to a high of 1.093 in 1996. The average ratio is 1.077. In 1998 the ratio was 1.137. If this value is included, the historic average becomes 1.081. It is presumed that the 1998 average is considerably larger than other years due to imposed draft restrictions during that year. This would tend to dampen the number of large vessels, which in turn would increase the ratio of number of vessels to number of lockages. The 1998 value was not included in the factor used to convert number of vessels to number of lockages because of the obvious bias that such an anomalous year would have on the forecast and hence the benefits of any proposed project. Additionally, it can be argued that this ratio will decline over time as the average size of vessels increases. A thorough analysis of these trends should be made in any future studies. Using the 1.077 conversion factor, the 43 average number of daily ocean-going vessels would be constrained at 40 lockages per day. The forecast number of equivalent daily lockages is displayed in Table 4 - 3 below. Note that the capacity of 40 lockages per day is reached in 2012.

The other major category of water demand is for M&I purposes. To estimate the demand for this water use, a forecast of population of the Districts of Panama, San Miguelito, Arraijan, La Chorrera and Colon was obtained from the Proyecciones de Poblacion performed by the Oficina de Planificacion. This forecast shows the total population for this area doubling in thirty-year cycles from 1,345,375 in 1998 to 2,688,000 in 2030. The U.S. Army Corps of Engineers, Mobile District extended the forecast to 5,360,000 in 2060 and 6,746,000 in 2070 by holding the growth rate between 2025 and 2030 (1.122) constant over the remainder of the forecast period.

The amount of water demanded for M&I purposes was likewise converted to an equivalent number of lockages. The PCC provided historical data on water withdrawal from both Gatun Lake and Madden Lake that totals nearly four lockages per day. The PCC also estimated the amount of water used in a lockage that includes consideration of water used to balance pools, hydraulic assistance and other needs in operating the canal for navigation at 55 million gallons per lockage. The forecast of equivalent number of lockages for M&I uses the growth rates established for population, starting with four lockages in 1998.

Of major concern in the forecast of water use for M&I purposes is the amount of water that will be demanded by the burgeoning tourist industry. There are current plans to greatly expand this trade. The extent of the water use for the tourist industry can be quite large. Thus, an extra equivalent lockage for tourism was added to the forecast for 2010. This new total number of equivalent lockages was then extended using the growth rate in the overall population. The forecast number of equivalent lockages for M&I uses, including provisions for tourism, is displayed in Table 4 - 3 below. Note that the increase in demand beyond the year 2012 is due to the growth in the demand for M&I water supply.

Table 4 - 3 Total Demand Expressed in Equivalent Lockages

Year	M&I	Unconstrained Navigation	Constrained Navigation	Total Demand	Hydrologic Reliability (%)
1998	4.00	33.14	33.14	37.14	N/A
2000	4.17	34.51	34.51	38.68	99.60
2005	4.62	37.13	37.13	41.74	99.27
2010	6.13	38.98	38.98	45.11	98.91
2011	6.27	39.73	39.73	45.99	98.81
2012	6.40	40.47	40.00	46.40	98.76
2015	6.82	42.70	40.00	46.82	98.64
2020	7.61	46.41	40.00	47.61	98.41
2030	9.55	54.76	40.00	49.55	97.83
2040	12.02	63.12	40.00	52.02	97.09
2050	15.13	70.77	40.00	55.13	95.89
2060	19.05	75.96	40.00	59.05	93.65
2070	23.97	78.47	40.00	63.97	90.47

For those proposals where the addition of hydropower is contemplated, it was assumed that the amount of power produced would be used either for the operation of the canal or on the national grid. This implies that the Republic of Panama can always use additional amounts of power, regardless of the source of that generation and that conjunctive use of additional supplies of water will always be considered. The water for the production of hydropower energy is excess to the operational needs of the Panama Canal since the computer models for the operation of the system are configured to provide the hydropower output over the planning period after withdrawals from the system for navigation and M&I purposes. Thus, the initial amounts of hydropower energy production decrease as the withdrawals for navigation and M&I increase. Since the design of each project would not be appreciably altered for the addition of hydropower generation, a benefit to cost ratio for hydropower only will be estimated. The benefits for hydropower are estimated as the product of net generation times the current (1998) cost to the PCC of producing power of $0.070 / kWh. Net hydropower generation is estimated as the power output from Gatun and Madden Lakes plus a proposed project less Gatun and Madden Lakes without a proposed project. Since the simulation models tend to provide water to the Panama Canal in anticipation of the demand, it is possible that there is a small increase in the generation at Gatun Lake or Madden Lake with the proposed project.

The next major step in evaluating the benefits of additional supplies of water is to assign a dollar value to the amount of water demanded for each of the various purposes. For navigation, the toll revenue per vessel is used.

The revenue per vessel was allowed to increase according to the average dead weight tonnage (DWT) per laden vessels, as indicated in the above referenced forecast of commercial transits. This is a measure of change in the average size of vessels that are expected to demand transit through the Panama Canal. To a large extent, the rate structure is based upon the carrying capacity of the vessel and not on the actual load. Thus, the change in the average carrying capacity of laden vessels is integral to the total revenue expected. Since the benefits for the supply of lockage water for navigation are quite sensitive to the revenue per vessel and because there is the possibility of significant change in this value over time, the value was allowed to grow through the year 2015 and then held constant over the remainder of the planning period. This analysis does not consider any changes in the rate structure for toll revenue or any increases in the rate per Panama Canal / Universal Measurement System net tonnage. In 1998, the total revenue from all ocean-going vessels was reported to be $545,700,000 and the number of commercial transits was 13,025. In 1998 price levels, the current average toll per ocean-going vessel is $41,875.

In 1995, laden transits averaged 26,377 DWT. This average is forecast to increase to 29,210 DWT in 2000, 31,179 DWT in 2005, 33,222 DWT in 2010 and 35,076 in 2015. Thus, the toll per vessel is forecast to grow from $41,875 to $43,675 in 2000, $49,675 in 2010 and $54,445 in 2015. The toll revenue per vessel is then converted to toll revenue per lockage in the same manner as the number of vessels per day is converted into number of lockages per day. This results in toll revenue per lockage of $47,050 in 2000, $53,515 in 2010, $54,112 in 2011, $54,709 in 2012, $55,306 in 2013, $55,903 in 2014, and $56,500 in 2015. The value of $56,500 per lockage is held constant over the remainder of the planning period.

For both M&I and hydropower, it was assumed that the Panama Canal Authority would be permitted to sell water or electricity that is excess to the needs of the operation of the Panama Canal. The values used for these purposes are the current cost of producing finished M&I water or $0.69 per 1,000 gallons, and the current cost to the PCC for producing power of $0.070 / kWh. In neither case is the cost of additional equipment nor the cost of operating and maintaining that equipment included in the cost of producing finished water or hydroelectric power. These values represent the cost to the PCC for the production of these commodities and not the true economic value of the commodities. It is believed that the values used significantly underestimate the true economic value for finished M&I water supplies or hydroelectric power. In any future study of the feasibility of proposed projects, effort should be expended to determine the full economic value of M&I water as well as hydropower.

The analysis of volumetric benefits is to compare the amount of equivalent daily lockages provided at the 99.6 percent level of reliability for both the existing condition and the conditions with the proposed project in place. For each proposal, therefore, the amount of water supplied at the 99.6 percent level of reliability represents the amount of additional water supply to which benefits can be attributed. For example, at the 99.6 percent level of reliability the existing conditions can supply a total of 38.68 equivalent lockages. With a proposed project in place, let us assume that at the 99.6 percent level of reliability, the system can provide 46.82 equivalent lockages. With the proposed project, the system can meet all of the total demand for water through the year 2015.

In the absence of any explicit policy, it was assumed that all of the M&I water demand would be met first and that any subsequent shortages would be attributed to navigation. Accordingly, as the demand for M&I water increases, the amount of water available for navigation decreases. Increasing the amount of water available to meet all of the demands means that more water is available to meet the demands for navigation. The benefits for 2015 are thus the additional number of equivalent daily lockages provided (46.82 less 38.68 = 8.14 in our example above) times the value of daily navigation lockages times 365 (8.14 x $56,500 x 365 = $167,867,000). These values change over time as either the number of navigation lockages supplied increases or the value of a navigation lockage increases up to the year 2015.

The other type of benefit for each proposed project is the ability of the system to meet the entire amount of water demanded – the reliability benefits. Since the economic evaluation compares the output of the without project condition to the output of the with project condition, the hydraulic reliability of providing those conditions must be considered. The assumptions used in the simulation models are presented in the Engineering Investigations above, but they are to operate the system to meet the monthly demands of both navigation, and M&I water supply. The economic evaluation does not consider imposing draft restriction on the operation of the Panama Canal since the focus of this study is upon the provision of additional supplies of water. The same assumptions for simulation models and economic evaluation are the same for both the without project and with project conditions in order to provide a true comparison of the outputs and hence the benefits of any proposed project. The benefits for this category are thus the difference in reliability (ability of the system to provide 100 percent of total demands) times the number of equivalent lockages demanded by either navigation or M&I purposes times the value of each equivalent daily lockage. For example, let us assume that the existing system can supply the 47.61 total daily number of lockages demanded in 2020 with a level of reliability of 97.25 percent and that some proposed project can supply the same total number of daily lockages demanded with a level of reliability of 98.35 percent. The number of equivalent lockages for M&I purposes is taken from the demand data presented in Table 4 - 3 above. The value of an equivalent lockage for M&I water supply is equal to $0.69 / 1,000 gallons times 55,000,000 gallons. The 2020 benefits for M&I water supply would be .9835 - .9725 x 7.61 x $37,950 x 365 = $1,159,500. The benefits for navigation in 2020 would be .9835 - .9725 x 40 x $56,500 x 365 = $9,073,900. The number of lockages for navigation is restricted to 40 lockages per day from 2012 through the remainder of the planning period.

The benefits for hydropower are estimated as the difference between the generation of the exiting system of Gatun Lake and Madden Lake versus the generation of these two plants plus the addition of any proposed project. The PCC current producing power cost was used for the value of any additional megawatts of power produced or lost. It was assumed that there would be sufficient demand for any electricity produced and that it could be marketed. Since the PCC has both thermal and hydroelectric capability, and that the thermal capacity is adequate for operation of the Panama Canal, any losses in hydropower would not affect the operation of the canal. These analyses did not consider the needs for peak power versus base load power needs, or the difference in value between dependable capacity and energy. It is recognized that these analyses are simplistic and do not begin to cover the complexities involved in the economic evaluation of a hydropower station. It is recommended that any further study of these proposals include the more rigorous studies required to demonstrate the demand for additional power production, the uses to which such additional power would be out, the timing of the use of additional power production and ultimately the feasibility of including additional hydropower plants at any of these proposals.

The costs and benefits of any proposed project will occur over time. The comparison of the benefits and costs are made on an average annual equivalent basis using a discount rate. This rate should reflect, to some extent, the long-term cost of capital to the PCC and some assessment of the risk involved in the ability of the PCC to recover the cost of large construction endeavors. The PCC provided a discount rate of 12 percent.

In the analysis of average annual costs, the total construction costs are disaggregated into annual construction costs using a set of generalized curves that have been developed for various lengths of time. These curves represent typical contractor earnings for large-scale heavy construction jobs. Compound interest on the annual construction costs is then estimated from mid-year through project completion. The timing of future replacement costs for large components is estimated and then the present worth of those future amounts is estimated at the time of project completion and added to the total of the construction cost and the interest during the construction period. A capital recovery factor (interest and amortization) of 0.120417 for the planning period (50 years) is then applied to this sum. Finally, an amount for the annual operation and maintenance of the proposed project is added to develop total average annual costs.

The analysis of the benefits follows much the same kind of pattern. The present worth of the stream of future benefits is estimated using the project discount rate of 12 percent. The sum of the present worth of the annual benefits is then computed. The same capital recovery factor is applied to the sum of the present worth to finally estimate total average annual benefits.

Once average annual benefits and costs have been computed, it is possible to compute the ratio of benefits to costs and to estimate the amount of net benefits - average annual benefits less average annual costs. For a project to be considered feasible, the benefit to cost ratio must exceed 1.0. The proposed project that produces the most net benefits is the proposal that best meets the objective of supplying additional water for canal operations.

In addition to computing annual costs and benefits, an internal rate of return analysis is also made. By trial and error, an interest rate is found that will discount all of the values so that the present worth of all of the costs is equal to the present worth of all of the benefits. To perform this analysis, the annual construction costs were arrayed as the investment with amounts for annual operation and maintenance, and major replacements included. The stream of benefits was arrayed as a series of cash flows over the planning period. The benefits for the years between the decades are estimated using straight-line interpolation. This analysis was made for information purposes only at the request of the PCC.

Environmental Setting

The PCC provided the descriptions of the environmental setting through a separate contract with Black & Veatch Special Projects Corp, Kansas City, Missouri. The description of the environmental setting is based on field observations (April and October, 1999) made while walking and traveling by boat and helicopter, as well as on interviews with of the PCC, Autoridad Nacional del Ambiente (ANAM), Asociacion Nacional para la Conservacion de la Naturaleza, Electrical Transmission Agency, Smithsonian Tropical Research Institute, and Directorate of Mineral Resources to identify site characteristics and activities that could affect the project. In addition, data from the 1990 Panama census, with extrapolations for the site area, and a review of the Informe de Cobertura Boscosa 1992 were used to determine extent of forest cover.

The following terms were defined to assist in the understanding of the environmental descriptions and concerns of each alternative within this report.

Benthic: Organisms located on the bottom of a body of water or in the bottom sediments.

Biodiversity: Biodiversity is the variety of species, their genetic make-up, and the natural communities in which they occur.

Domestic Waste: Liquid or solid waste associated with residential homes within each area.

Dry Season: The time of year when precipitation is less frequent than during the rest of the year. In the Panama the dry season is mid-December through March.

Ecotone: Juncture of two or more different kinds of ecosystems.

Emergent Vegetation: Plant life standing in water and growing above the surface under normal conditions.

Fauna: Animals inhabiting a region, period, or special environment.

Floating Mats: A dense growth of living plant species that grow along the surface of the water under normal conditions

Hydric Soils: Soils that are formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part of the soil profile.

Hydrophilic: Organisms having an affinity for water.

Lentic: Organisms living in still waters of lakes or ponds.

Lotic: Organisms that live in flowing waters.

Photosynthesis: The biological process that captures light energy and transforms it into the chemical energy of organic molecules (such as glucose), which are manufactured from carbon dioxide and water.

Piscivorous: Any organism that consumes fish as its prey.

Submergent Vegetation: Plant life growing beneath the surface of the water under normal conditions.

Terrestrial Habitat: Land areas where organisms live.

Socio-Economic and Environmental Impacts

The PCC provided the evaluation of socio-economic and environmental impacts through a separate contract with Black & Veatch Special Projects Corp, Kansas City, Missouri.
Each of the projects with socio-economic and environmental impacts was evaluated and assigned a numerical score based on Measure and Importance. These impacts are summarized in tables titled Environmental Effects and Socioeconomic Effects within each applicable section of the report. The measure category relates the degree of impact of the construction of the dam to the impact categories listed in each table. The measure numbers range from 1 to 10, with 1 to 4 representing a continuum of negative impacts, 5 indicating neutral, and 6 to 10 representing an increasing continuum of positive impacts. The importance category represents the degree of significance of each item. The importance numbers range from 1 to 10, with 1 representing low importance and 10 being significant. The importance numbers are consistent on each table.

The projects were ranked relative to each other by considering all elements presented within each Socio-Economic and Environmental Impacts section of this report. The final numbers obtained for both the measure and importance ranking categories were based on an inter-disciplinary team of professionals from Black & Veatch, U.S. Army Corps of Engineers, Mobile District, and the PCC.

SECTION 5

Rio Indio

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Synopsis

The development plan presented herein would include a dam and lake on the Rio Indio connected by tunnel to the Panama Canal watershed above Gatun Lake. Transfers of water impounded in Indio Lake to the Panama Canal watershed would support canal operations as needed. See Figure 5 - 1.

The Rio Indio watershed is located adjacent to the western side of the Panama Canal watershed. The proposed Rio Indio dam site would be approximately 25 km inland from the Atlantic Ocean and would be near the mountain named Cerro Tres Hermanas. Plate 5 - 1 shows the location of the proposed Rio Indio project. The structures for this proposed project would 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 would transfer water from Indio Lake to the Panama Canal watershed as needed for canal operations. The total project first costs of the proposed Rio Indio project are estimated to be $245,868,000.

The proposed Rio Indio project would contribute measurably to the hydrologic reliability of the Panama Canal to provide water for M&I needs and canal operation. It would greatly 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 (46.42 lockages) of current level would be 98.8 percent. Table 4 - 3 displays the hydrologic reliability associated with the entire total demand schedule. Construction of the proposed Rio Indio project would continue the existing high hydrologic reliability as demand for water increases up to 17 percent (6.43 lockages) for Option 1 and 28 percent (10.87 lockages) for Option 2 above current demand levels.

The amount of hydropower energy that could be produced by the hydropower plants in the system of Gatun Lake and Madden Lake would decline over time as the demands for navigation and M&I water increase. With the inclusion of the hydropower plants at the proposed Rio Indio project, the system could produce additional megawatt hours of hydropower.

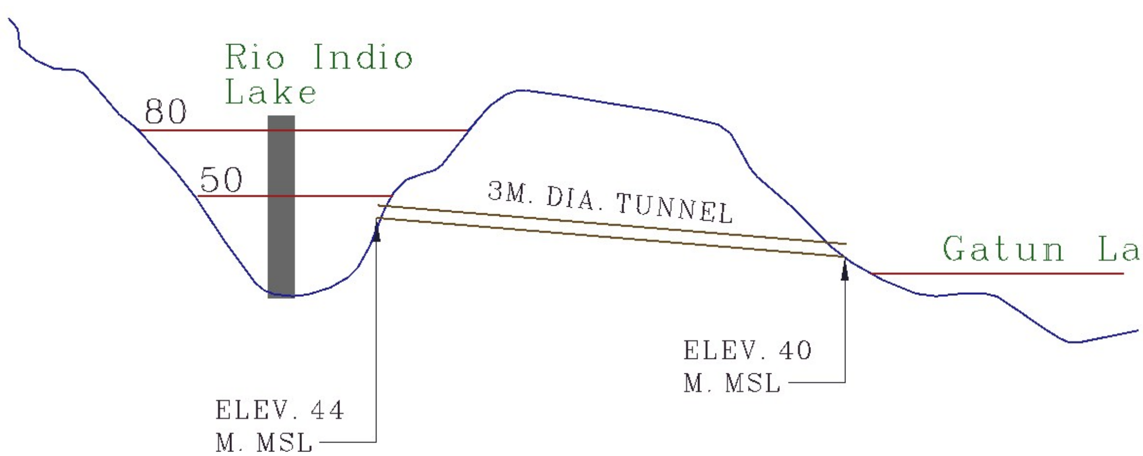


Figure 5 - 1 System Profile

Site Selection

The proposed 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 and minimizing the number of saddle dams required to contain the lake. To maximize the water impounded, it was desirable to locate the dam as far downstream in the Rio Indio watershed as possible. In choosing a site for the dam, the ideal location was where the surrounding hillsides were relatively steep and high, and the valley was 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 would be approximately 25 km inland from the Atlantic Ocean and would be near the mountain named Cerro Tres Hermanas. This site would accommodate construction of a dam with a normal operating lake level at elevation 80 m MSL and a maximum flood lake level at elevation 82.5 m MSL.

Hydrologic Considerations

The Rio Indio flows northward from the Continental Divide to the Atlantic Ocean. The headwaters of the watershed begin at elevation 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 would 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 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 were considered appropriate for the evaporation rates of Indio Lake.

Geologic Considerations

The proposed 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, 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. The lower member weathers deeply. 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 would 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 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 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 underlie the dam foundation.

The proposed inter-basin transfer tunnel connecting the 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 was necessary. Available general geologic mapping and general data were the basis of predictions that rock, at the proposed Rio Indio dam site, 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: that the required excavation would make available sufficient rock for fill, and that the immediate area contains available impervious materials and concrete aggregate for use in the construction of the proposed project.

Lake Operation

This study considered two operating options for periods that require water transferal from Indio Lake to the Panama Canal watershed for canal operations. Operating Option 1 consists of the water surface of the lake fluctuating from the normal operating lake level at elevation 80 m MSL down to the minimum operating lake level at elevation 70 m MSL with 359,000,000 M^3 of useable storage. Operating Option 2 consists of the water surface of the lake fluctuating from the normal operating lake level at elevation 80 m MSL down to the minimum operating lake level at elevation 50 m MSL with 993,000,000 M^3 of usable storage. The maximum flood lake level would be at elevation 82.5 m MSL. The volume between the maximum flood lake level and the normal operating lake level would store flood waters and reduce peak flood flows. Areas along the Rio Indio downstream of the dam would realize some reduction in flooding. Table 5 - 1 shows the lake levels for the two operating options.

Table 5 - 1 Lake Operating Options

Lake Level (m MSL)	Operating Option 1	Operating Option 2
Normal Operating Lake Level	80	80
Minimum Operating Lake Level	70	50
Maximum Flood Lake Level	82.5	82.5

Project Features

GENERAL

The structures for this proposed project would consist of a rock fill dam, two saddle dams, an uncontrolled ogee spillway, inter-basin transfer facilities, two hydropower plants, and outlet works. The following paragraphs provide a description of the proposed structures and improvements for the Indio Lake project. Operating Option 2 is the basis of the configuration for the major structural components indicated here. In some instances, the proposed structures and improvements for Operating Option 1 and Operating Option 2 would be slightly different. Plate 5 - 2 depicts the site plan.

Performance of the design was only to the extent necessary to establish, with reasonable accuracy, the principal dimensions, elevations, and costs of the proposed project. The PCC received separate documentation that contained assumptions and design calculations for the reconnaissance level investigations of these structures. Further development of this project into the planning studies requires the accomplishment of optimization of the project features and improvements.

EMBANKMENTS

Dam

The dam would be an embankment with the top at elevation 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 would be approximately 73.5 m high, and the overall length would be 891 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 5 - 3 presents a typical section of the embankment at the dam, incorporating upstream and downstream cofferdams within the section.

Foundation grouting will 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 could provide seepage cutoff in the embankment foundations. A concrete or bentonite cutoff wall could also provide seepage cutoff.

Saddle Dams

Two saddle dams would be required to complete the lake impoundment. For this study, both saddle dams were 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 elevation 83.5 m MSL, and they would have a crest width of 13 m. The length of the north saddle dam would be 255 m, while the length of the south saddle dam would be 272 m. Further study would determine the actual side slopes and crest widths 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 5 - 3 shows a typical section of the embankment at the main dam and the saddle dams are configured similar.

SPILLWAY

An uncontrolled ogee spillway with a length of 120 m and a crest at elevation 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 elevation 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 5 - 2 for the location of the spillway and Plate 5 - 4 for a typical section at the spillway.

IMPOUNDMENT

The lake formed by the proposed Rio Indio Dam would have a normal operating lake level at elevation 80 m MSL. The surface area at the normal operating lake level would be approximately 4,280 ha. At the maximum flood lake level, elevation 82.5 m MSL, the surface area would be approximately 4,440 ha. With the minimum operating lake level at elevation 70 m MSL (Operating Option 1), the surface area would be approximately 3,630 ha. With the minimum operating lake level at elevation 50 m MSL (Operating Option 2), the surface area would be approximately 2,360 ha.

CLEARING AND / OR GRUBBING

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 require clearing and grubbing. Under Operating Option 1, only the 650 ha in the lake area between the normal operating lake level at elevation 80 m MSL and the minimum operating lake level at elevation 70 m MSL require clearing. Under Operating Option 2, only the 1,920 ha in the lake area between the normal operating lake level at elevation 80 m MSL and the minimum operating lake level at elevation 50 m MSL require clearing. The transmission lines also require clearing under both options.

INTER-BASIN TRANSFER FACILITIES

The project would include excavation of a tunnel beneath the common watershed divide to connect the proposed Indio Lake to the Panama Canal watershed. The finished tunnel would be concrete lined, 3 m in diameter, and approximately 5.2 km in length. This tunnel would have an inlet invert at elevation 44 m MSL and an outlet invert at elevation 40 m MSL. The maximum capacity of the tunnel would be 37.1 CMS. Assumptions were that rock stabilization requires rock bolting over much of the tunnel length. The tunnel outlet would be on the Rio Ciricito approximately 5 km upstream from Gatun Lake. A gate structure located at the tunnel outlet would control flow through the tunnel. The channel of Rio Circito downstream of the outlet would likely require enlargement to provide sufficient flow capacity to the Lake and some surface armoring to prevent erosion. The tunnel discharge will 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 could occur which calls for the construction of a series of surge protection shafts. These shafts would require relatively minor surface structures for safety purposes. Plate 5 - 1 shows the location of the tunnel outlet, and Plate 5 - 5 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 would 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 would receive flow from an Y off the main tunnel. The 25 MW hydropower plant would have two 12.5 MW units. These facilities would be designed and configured to function as part of the national power grid. A 115 kV transmission line would be required to carry the energy to a connection with the grid near La Chorrera. Plate 5 - 6 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 would be required to provide for 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 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 was no longer needed for construction, the structure would be used to control the flows for hydropower and emergency drawdown. It would 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 as minimum flow. The hydropower intake would also be elevated to prevent silt from entering the power units.

This system would 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 5 - 8 and 5 - 9. The diversion tunnel would be 1,500 m in length; it would have an inlet invert at elevation 10 m MSL and an outlet invert at elevation 7 m MSL. The diversion tunnel would serve in combination with the cofferdam to protect the construction area from floods up to a 10 percent frequency. A

10 percent frequency flood would 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 in length; it would have an inlet invert at elevation 8 m MSL and an outlet invert at elevation 5 m MSL. The capacity of the minimum flow conduit would be 2.5 CMS. A bulkhead structure would be 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 could be removed in the event that the Indio Lake had to be drawn down.

ACCESS ROUTE

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

The route from Colon would be westward across the Panama Canal and then generally southwestward along existing roads to the village of Pueblo Viejo and then southward by new roads along the Rio Indio to the dam site and the other construction sites. The route westward from Colon 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. The road from Gatun westward would also require refurbishment to be reliable for this effort. The route southward up the Rio Indio watershed would require a new road with numerous stream crossings.

A route requiring a ferry across Gatun Lake to a point on the extreme western shore of the Lake was also considered. This route would require that offloading dock facilities be constructed and would require extensive refurbishment of existing roads to accommodate the passage of construction materials and equipment.

A route from Panama City would travel 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. A new road generally to the northwest would be required from Ciri Grande to the construction sites. This route too would require extensive refurbishment of existing roads and several kilometers of new road construction.

It was concluded that the route from Panama City would be best since there would be fewer stream crossings, and it would not involve the restrictions and delays to vehicles crossing the Panama Canal that the route from Colon would. This route would not require construction of port facilities and the off-loading of materials and equipment that the ferry route would. The new route from Panama City (Ciri Grande) would also be somewhat shorter than the new route from Colon, though the road between Panama City and Ciri Grande would have to be upgraded over much of its length and the route west of Ciri Grande would 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. Plate 5 - 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 of benefit to those living in that region, providing ready access to the main centers of commerce in the southern part of the country. It would 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

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

Cement would be available within the Republic of Panama. Rock, obtained from the construction site or from the lake area, would be used for onsite manufacture of aggregates for the concrete. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) would 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 Rio Indio project would be located in the Cocle, Colon, and Panama Provinces. Construction of this proposed project would require acquisition of approximately 5,600 ha. Table 5 - 2 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 5 - 2 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 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 elevation 85 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 five towns in the lake area (El Limon, Los Uveros, La Boca de Urcelillo, Aguila, and Tres Hermanas), approximately 30 other small settlements (just a few structures), and numerous isolated structures. The five towns all have elementary schools, churches, electricity, and limited telephone coverage.

Development Sequence

Planning studies would be accomplished to evaluate the alternative features of each proposed project. Each potentially viable project would be evaluated to assure that the plan presented would provide all of the features required to make it functional. Each would also be assessed for its effectiveness in meeting the project goal of providing navigation water to the Panama Canal, with due recognition of any secondary benefits. Environmental assessments of the proposed projects would also be made to assure environmental acceptability of the project features. These environmental assessments would begin during the planning studies phase and would continue during the final design, advertising and award phase, and on through construction of the project. The final design would be accomplished for the recommended project. After completion of the final design, plans and specifications would be prepared for the advertising and award phase.

Project implementation would begin with land acquisition, rights of way 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, transmission lines and lake would then be acquired.

Access roads would be constructed to the dam site and the inter-basin transfer tunnel inlet and outlet sites. Once highway access to the sites has been established, a camp would be built to house workers during construction.

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

Construction of the dam would begin with the clearing and grubbing of the construction sites and the clearing of the lake area. Excavation for the inter-basin transfer tunnel and the intake structure and construction of the diversion tunnel at the dam site and the spillway would follow with work being done simultaneously. Where possible, materials removed from the nearest of these sites would be placed directly into the earth and rock fill portions of the dam. Once the intake structure and diversion tunnel were completed, the dam construction site would be isolated using upstream and downstream cofferdams, which would eventually become part of the main dam, and the stream would be diverted through the tunnel. The dam foundation would then be excavated and grouted, and the dam constructed. Concurrently with construction of the dam, the hydropower plant site downstream of the dam would be excavated, and the powerhouse construction would be started. The power transmission lines would be constructed during this period also. Upon completion of the dam and the inter-basin transfer tunnel and appurtenant structures, the diversion would be stopped by closure of the intake structure gates, and lake filling would begin. Simultaneously with this operation, the downstream gate and flow separation structure would be constructed to provide for closure of the diversion tunnel and diversion of the tunnel flows to the hydropower penstock(s). The minimum flow conduit would also be installed through the diversion tunnel at this time. At the completion of the project, all facilities would undergo trial operations followed by commissioning for service.

Considering the climatic conditions and the obstacles posed by the remote location of the construction sites and the nature of the work, it is estimated that development of this project could be completed in approximately 10 years, from initial planning to lake filling. Figure 5 - 2 depicts the development sequence of the various project features.

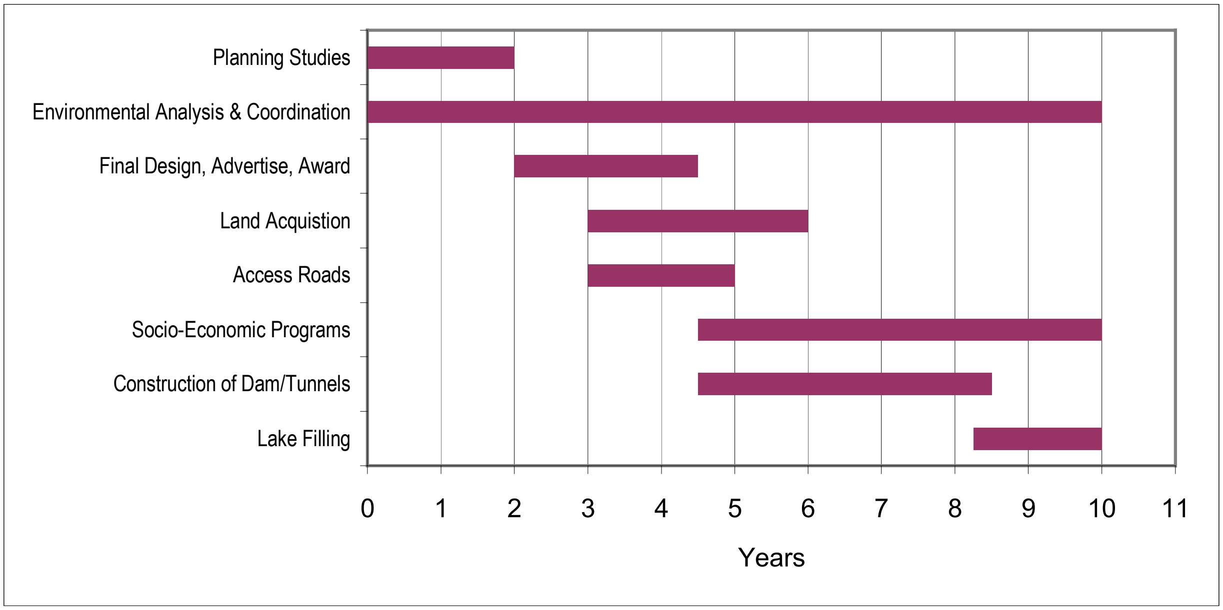


Figure 5 - 2 Development Sequence

Hydrologic Reliability

In order to determine the effect of the proposed Indio Lake on the hydrologic reliability of the Panama Canal, the lake was evaluated as linked with the Panama Canal watershed. A HEC-5 model was constructed that linked the Indio Lake to the Gatun Lake through the inter-basin transfer tunnel. Water stored in Indio Lake was provided, as needed, to Gatun Lake when shortages were expected. Excess flows were still released down the Rio Indio, taking advantage of the hydropower generation when possible. Minimum flow requirements were deducted from the waters made available to the Panama Canal watershed and released down the Rio Indio.

HEC-5 model simulations were conducted for both the existing Panama Canal system and the system operating with the proposed Indio Lake providing water to the Panama Canal watershed. The simulations considered proportionally increasing demands up to 180 percent of current demand levels. The period of simulation considered 50.5 years (January 1948 through July 1998) of hydrologic record. Figure 5 - 3 presents the resulting hydrologic reliability for three configurations with demands increasing up to 180 percent of current demands. These configurations were:

- Existing system,
- Operating Option 1 (Indio Lake fluctuating between the normal operating lake level at elevation 80 m MSL and the minimum operating lake level at elevation 70 m MSL), and
- Operating Option 2 (Indio Lake fluctuating between the normal operating lake level at elevation 80 m MSL and the minimum operating lake level at elevation 50 m MSL).

The horizontal axis along the bottom of Figure 5 - 3 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 5 - 3, the existing hydrologic reliability of the Panama Canal, based on the period of record of 50.5 years, is approximately 99.6 percent, while the hydrologic reliability with a demand ratio of 1.8 would be 86.3 percent. This period of record includes the first six months of the 1998 drought year. The hydrologic reliability with a demand ratio of 1.0 would be 99.9 percent for Operating Option 1, and the hydrologic reliability with a demand ratio of 1.8 would be 93.7 percent. With Operating Option 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 94.7 percent. Table 5 - 6 displays the number of lockages associated with various levels of reliability.

Without additional water supplies, the hydrologic reliability of the Panama Canal system would decrease. With the construction of the proposed Rio Indio Project Option 1 the existing high hydrologic reliability could be continued as demand for lockages increases up to 17 percent (6.43 lockages) above current demand levels. Option 2 would allow increases up to 28 percent (10.87 lockages) above current demand levels.

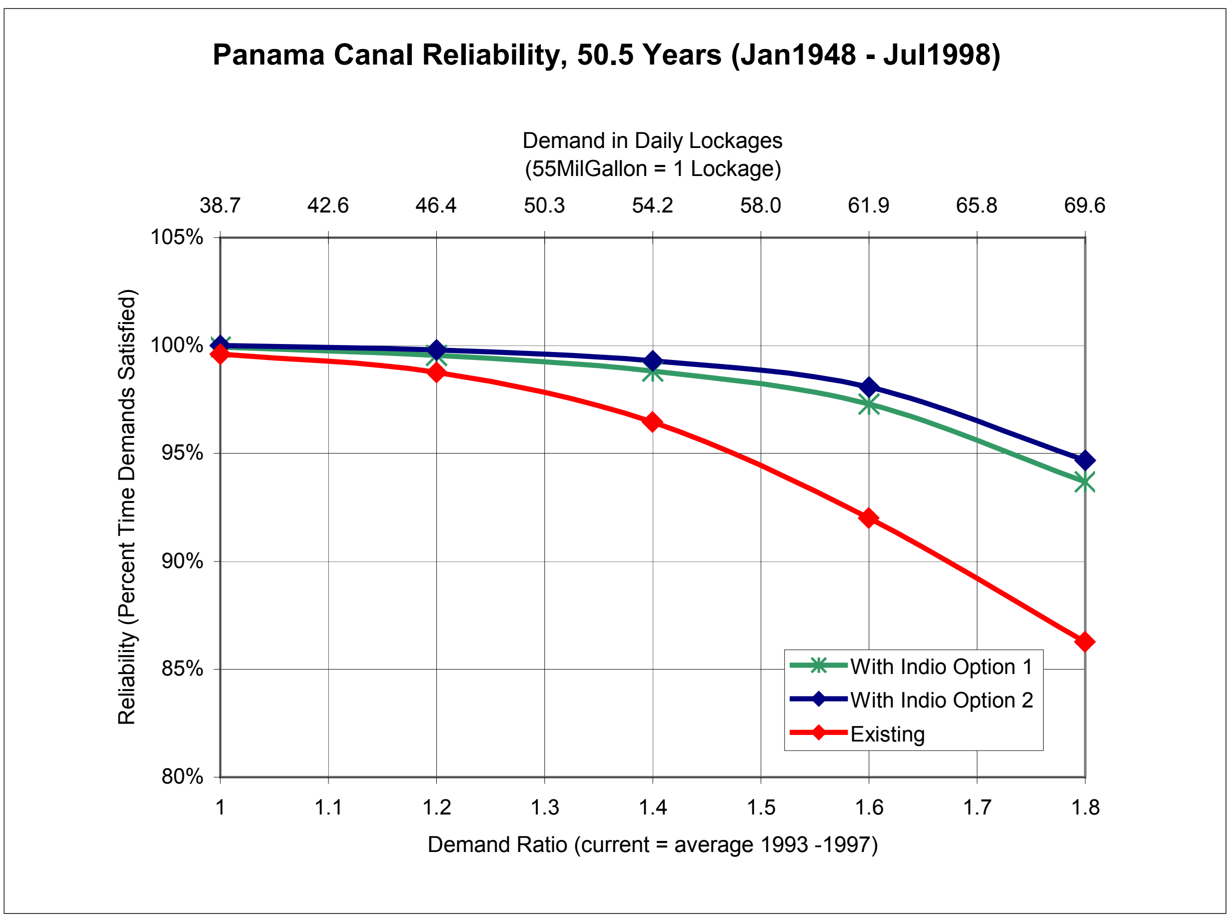


Figure 5 - 3 Panama Canal Hydrologic Reliability

Project Costs

GENERAL

The quantities estimated for the principal features required in the construction of this proposed project were derived from the layouts shown on Plates 5 - 3 through 5 - 9. The unit prices applied to these quantities were 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, information gathered from Mobile District Construction Division personnel in the Republic of Panama, and the publication, Feasibility Studies For Small Scale Hydropower Additions, A Guide Manual, prepared by the Hydrologic Engineering Center, U.S. Army Corps of Engineers, 1979.

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

FIRST COSTS

The total project first costs are estimated to be $245,868,000. Table 5 - 3 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 5 - 3 Summary of Project First Costs

Principal Feature	Costs ($)
Lands and Relocations	14,000,000
Access Roads	8,030,000
Clearing and / or Grubbing	3,566,250
Diversion Tunnel	14,732,944
Inter-basin Transfer Tunnel	11,595,800
Intake for Inter-basin Transfer Tunnel	365,258
Cofferdam	4,850,665
Dam	22,723,329
Spillway	43,387,450
Intake	7,701,295
Hydropower Plants	22,118,125
Transmission Lines	6,600,000
North Saddle Dam	3,179,260
South Saddle Dam	1,061,883
Subtotal	163,912,258
E&D, S&A, Field Overhead	32,782,452
Contingencies	49,173,677
Total Project First Costs	245,868,387 **approximately** 245,868,000

OPERATION AND MAINTENANCE

Staff

A staff would operate and maintain the proposed Rio Indio project during the day and then run the facility remotely. The full-time staff would ultimately consist of a total force of 11 who would include a station manager, a multi-skilled supervisor, 3 leaders (Electronics / Instrumentation, Electrical and Mechanical), 5 craftsmen, and one 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 $500,000.

Ordinary Maintenance

Ordinary maintenance and care would be required and would include minor repair materials, lubricants and other supplies needed by the project staff. It is estimated that the costs of ordinary maintenance would be $20,000 per year for the access road and $300,000 per year for the main project facilities.

Major Replacements

The average service life of gates, electrical equipment, turbines, trash racks and other features would be less than the total useful life of the proposed project, which would be 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 would cost the same as at present. No allowance was made for salvageable fixed parts. Table 5 - 4 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 $759,000 and the average annual replacement costs would be $91,000.

Table 5 - 4 Major Replacement Costs

Component	Service Life (years)	Number of Times Replaced During Planning Period	Future Costs ($)	Present Worth of Replacement Costs ($)
Roads	50	1	8,580,000	29,700
Bridges	50	1	3,375,000	11,700
Intake				
Head Gates	50	1	801,900	2,800
Minimum Flow Gates	50	1	90,000	300
Stoplogs	50	1	378,300	1,300
Trashracks	50	1	121,500	400
Access Stairs	50	1	66,750	200
Hydropower Plant				
Turbines and Generators	33	1	21,375,000	507,800
Station Electrical Equipment	33	1	3,000,000	71,300
Switchyard Equipment	33	1	2,559,375	60,800
Miscellaneous Plant Equipment	33	1	1,593,750	37,900
Transmission Lines	50	1	9,900,000	34,300
Total			51,842,000	759,000
Average Annual Replacement Costs				91,000

Annual Costs

The total project first costs are estimated to be $245,868,000. 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 total project first costs was computed from mid-year throughout the 10-year period from initiation of the Planning Studies until the lake was filled. The interest during construction at 12 percent would be $130,992,000 and it was added to the total project first costs for total project investment costs of $376,860,000. A capital recovery factor for the 50-year planning period was applied to get the annual average investment costs of $45,380,000. Annual operation and maintenance costs were added. Major replacement costs are estimated and were converted to an annual cost by discounting the future replacement costs of major components of the project back to the present worth as of completion of reservoir filling. Table 5 - 5 contains a summary of the annual costs.

Table 5 - 5 Summary of Annual Costs

Item	Costs ($)
Total Project First Costs	245,868,000
Interest During Construction	130,992,000
Total Project Investment Costs	376,860,000
Annual Average Investment Costs	45,380,000
Operation and Maintenance Costs	
Staff Costs	500,000
Ordinary Maintenance Costs	320,000
Major Replacement Costs	91,000
Total Average Annual Costs	46,291,000

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 Rio Indio project. The 50-year planning period for this proposal is 2010 to 2060.

The proposed Rio Indio project would increase the reliability of providing water to accommodate the total daily number of lockages demanded. Table 5 - 6 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 were obtained from the data used to develop Figure 5 - 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 5 - 6 Panama Canal Hydrologic Reliability

Current Demand Ratio	Year	Demand in Daily Average Number of Lockages (Navigation and M&I)	Hydrologic Reliability		
			Existing System (%)	Operating Option 1[1/] (%)	Operating Option 2 [2/] (%)
1	2000	38.68 [3/]	99.60	99.90	100.0
	2010	45.11	98.91	99.60	99.83
1.2		46.42	98.76	99.54	99.79
	2020	47.61	98.41	99.43	99.72
	2030	49.55	97.83	99.25	99.59
	2040	52.02	97.09	99.02	99.43
1.4		54.15	96.45	98.82	99.30
	2050	55.13	95.89	98.62	99.14
	2060	59.05	93.65	97.85	98.53
1.6		61.89	92.02	97.28	98.08
	2070	63.97	90.47	96.37	97.16
1.8		69.63	86.27	93.67	94.67

[1/] Operating Option 1 (Indio Lake fluctuating between the normal operating lake level at elevations 80 m MSL and the minimum operating lake level at elevation 70 m MSL).

[2/] Operating Option 2 (Indio Lake fluctuating between the normal operating lake level at elevations 80 m MSL and the minimum operating lake level at elevation 50 m MSL).

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

Regardless of the operating option, water supply shortages for navigation would continue. The demand for the M&I purposes will always be met first. As these demands grow, the amount of water available to meet the demands for navigation will decrease. Thus, the benefits for the additional water supply are estimated at the value for navigation. With the addition of the proposed Rio Indio project, these shortages would be less than they would be under the existing system. With a hydrologic reliability of 99.6 percent, Operating Option 1 would increase the amount of water supplied for navigation by approximately 6.43 equivalent lockages, and Operating Option 2 would increase that amount by 10.87 equivalent lockages. For Operating Option 1, the 99.6 percent hydrologic reliability would occur in the year 2010 with an equivalent daily average number of lockages set to 45.11. For Operating Option 2, the 99.6 percent hydrologic reliability level would occur in the year 2030 with an equivalent daily average number of lockages of 49.55. 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 would be attributable to navigation. The benefits are estimated using the toll revenue per lockage and the increased daily average number of lockages provided by each option. The average annual benefits for water supply would be $130,654,000 for Operating Option 1 and $172,671,000 for Operating Option 2. Table 5 - 7 provides the estimate of daily shortages under the existing system, the remaining daily shortages with the proposed Rio Indio project in operation, the annual benefits for meeting shortages and the average annual benefits for both options.

Table 5 - 7 Benefits for Additional Water Supply for Navigation

Year	Daily Shortages In Lockages Under Existing System	Remaining Daily Shortages With Operating Option 1	Remaining Daily Shortages With Operating Option 2	Annual Benefits for Operating Option 1 ($)	Annual Benefits For Operating Option 2 ($)
2010	6.43	0	0	125,598,000	125,639,000
2020	8.93	2.50	0	132,602,000	184,141,000
2030	10.87	4.44	0	132,602,000	224,232,000
2040	13.34	6.91	2.47	132,602,000	224,232,000
2050	16.45	10.02	5.58	132,602,000	224,232,000
2060	20.37	13.94	9.49	132,602,000	224,232,000
Average Annual Benefits				130,654,000	172,671,000
With Option 1, the system will provide a total of 45.11 equivalent lockages at the 99.6 percent level of reliability or 6.43 more lockages than the existing system. With Option 2, the system will provide a total of 49.55 equivalent lockages at the 99.6 percent level of reliability or 10.87 more lockages than the existing system.					

With either operating option, 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 Rio Indio project would be $8,086,000 for Operating Option 1 and $10,345,000 for Operating Option 2. Table 5 - 8 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 for each operating option.

Table 5 - 8 Average Annual Reliability Benefits for Navigation

Year	Daily Average Number of Lockages	Value Per Daily Lockage ($)	Annual Navigation Benefits For Operating Option 1 ($)	Annual Navigation Benefits For Operating Option 2 ($)
2010	39.0	2,086,000	5,288,000	7,019,000
2020	40.0	2,260,000	8,408,000	10,789,000
2030	40.0	2,260,000	11,700,000	14,552,000
2040	40.0	2,260,000	15,885,000	19,333,000
2050	40.0	2,260,000	22,524,000	26,814,000
2060	40.0	2,260,000	34,641,000	40,240,000
Average Annual Benefits			8,086,000	10,345,000

M&I WATER SUPPLY

The future demand for water supply for M&I purposes was 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 was 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 Rio Indio 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 would be $1,125,000 for Operating Option 1 and $1,427,000 for Operating Option 2. Table 5 - 9 displays the population forecast, the resulting number of equivalent lockages demanded per day, the annual benefits for increased reliability, and the average annual benefits for M&I water supply.

Table 5 - 9 Average Annual Reliability Benefits for M&I Water Supply

Year	Population	Equivalent Lockages per Day	Annual M&I Water Supply Benefits for Operating Option 1 ($)	Annual M&I Water Supply Benefits for Operating Option 2 ($)
2010	1,724,000	6.1	591,000	784,000
2020	2,141,000	7.6	1,075,000	1,380,000
2030	2,688,000	9.6	1,879,000	2,337,000
2040	3,384,000	12.0	3,205,000	3,901,000
2050	4,259,000	15.1	5,721,000	6,810,000
2060	5,360,000	19.0	11,082,000	12,873,000
Average Annual Benefits			1,125,000	1,427,000
The value of a daily lockage for M&I is $0.69 X 55,000 = $37,950				

HYDROPOWER

The amount of hydropower energy that could be produced by the system of Gatun Lake and Madden Lake would decline over time as the demands for navigation and M&I water supply increase. With the inclusion of the proposed Rio Indio project, the system could produce net additional megawatt hours of hydropower. The value for hydropower energy used in this analysis was $0.070 / kWh. On an average annual basis, Operating Option 1 would have benefits of $5,024,000 and Operating Option 2 would have benefits of $4,963,000. Table 5 - 10 provides the net additional megawatt hours of hydropower generation and the resulting annual and average annual benefits for each option.

Table 5 - 10 Average Annual Benefits for Hydropower Generation

Year	Net Generation for Operating Option 1 [1/] (MWh)	Net Generation for Operating Option 2 [1/] (MWh)	Annual Hydropower Benefits for Operating Option 1 ($)	Annual Hydropower Benefits for Operating Option 2 ($)
2010	73,457	72,653	5,142,000	5,086,000
2020	71,401	70,470	4,998,000	4,933,000
2030	69,439	68,534	4,861,000	4,797,000
2040	66,970	66,098	4,688,000	4,627,000
2050	64,584	63,462	4,521,000	4,442,000
2060	58,844	56,674	4,119,000	3,967,000
Average Annual Benefits			5,024,000	4,963,000

[1/] Net generation of Gatun, Madden, and Indio hydropower plants above generation of Gatun and Madden hydropower plants.

SUMMARY OF ANNUAL BENEFITS

As shown in Table 5 - 11, total average annual benefits for Operating Option 1 and Operating Option 2 of the proposed Rio Indio project would be $144,889,000 and $189,406,000, respectively.

Table 5 - 11 Summary of Annual Benefits

Benefit Category	Average Annual Benefits	
	Operating Option 1 ($)	Operating Option 2 ($)
Navigation – Water Supply	130,654,000	172,671,000
Navigation – Reliability	8,086,000	10,345,000
M&I - Reliability	1,125,000	1,427,000
Hydropower	5,024,000	4,963,000
Total	144,889,000	189,406,000

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 determines which proposal among several provides the greatest value for the investment dollars. While there would be small differences in some project features between Operating Option 1 and Operating Option 2, the differences would not have any impact on total project first costs at this level of investigation. The same facilities would be constructed for each operating option. Table 5 - 12 provides the benefit to cost ratios for Operating Option 1 and Operating Option 2 and the net benefits for both.

Table 5 - 12 Economic Evaluation

Item	Operating Option 1 ($)	Operating Option 2 ($)
Average Annual Benefits	144,889,000	189,406,000
Average Annual Costs	46,291,000	46,291,000
Benefit to Cost Ratio	3.1	4.1
Net Benefits	98,598,000	143,115,000

Internal Rate of Return

An internal rate of return analysis for each operating option was performed. To accomplish this analysis, the annual construction costs were used as the investment, and the undiscounted benefits were used as return cash flows. For Operating Option 1, the internal rate of return would be 29.3 percent, and for Operating Option 2, the internal rate of return would be 31.7 percent.

Incremental Evaluation of Hydropower

Since the generation of hydropower energy would be provided through the conjunctive use of storage, an analysis of the incremental benefits and costs for this purpose was accomplished. The first costs of the Lands and Relocations and the Clearing and / or Grubbing, which were associated with hydropower, as well as the costs of the Hydropower Plants and the Transmission Lines were taken from Table 5 - 3. The portion of annual operation and maintenance costs associated with hydropower generation were derived from the data included in Table 5 - 4. The construction costs are estimated to be approximately $31,016,250. Interest during a two-year construction period is estimated to be $3,777,750 for a total hydropower investment costs of $34,794,000. The portion of annual operation and maintenance costs for hydropower were assumed to be $350,000 for staff, $250,000 for ordinary maintenance and $86,000 for major replacement. The total average annual costs for hydropower would be $4,876,000. The average annual benefits are estimated to range between $5,024,000 and $4,963,000. The average annual benefits based on this approach exceed the average annual costs; therefore, the addition of hydropower at the proposed Rio Indio project would appear to be feasible. It should be noted, however, that hydropower was valued at the current costs of production of the PCC. This value might underestimate the economic value of any additional hydropower generating capacity. Additional effort should be expended in any future planning studies to determine the economic value of added hydroelectric power generation. If the proposed Rio Indio project is operated differently, the amount of net generation could be increased. The simulation model for Option 2 was modified in an attempt to produce additional net generation without reducing the hydrologic reliability achieved by the previous operating scheme. The results of this model run are an increase in net generation of 12,700 MWh in 2010 down to an increase of 8,200 MWh in 2060. There was no change in the hydrologic reliability. Under this operating scheme, the benefits, valued at $0.070 / kWh, would be $5,796,000. This would produce a benefit to cost ratio of 1.2. If the proposed Rio Indio project is carried forward into more detailed study, it is recommended that further study be performed to optimize the operation of the project.

Socio-Economic Impacts

The socio-economic impacts of the project could be substantial. The relocation of the towns of Tres Hermanas, Los Cedros, El Coquillo, El Limon, Los Uveros, and La Boca de Uracillo and their approximately 2,300 residents would be an important issue. The average monthly income of families in the project area is $100 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 create the Indio Lake. The relocation of agricultural and ranching activities would be a substantial issue, because approximately 60 percent of the impoundment area is used for farming and ranching. The surface area of the proposed lake will encompass 4,600 ha with another 600 ha for the dam and construction areas including permanent disposal areas.

Post-construction revenues generated for the nation would be greater, because the project will create electric power generating potential. On a per hectare basis, the revenues from power generation would be greater than those produced by the current agricultural activity. It is estimated that after construction, 11 persons would be employed to operate and maintain the new facilities. During construction, the housing values in the areas adjacent to the dam site would increase, because there should be a higher demand by workers for livable homes. However, after project completion, as the workers leave the area and housing demands drop, the housing values could decrease 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 more public and community services may be offered to the local residents. After construction, these services should remain at the normal level.

To construct the dam, some existing roads would be improved and some new roads would be built. However, some dirt roads within the impoundment area would be eliminated, which would change the 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 road systems during construction would increase; however, following cessation of construction; the traffic volumes would decline. Noise levels would increase during construction and could negatively impact noise-sensitive receptors, however, after construction; noise levels should return to pre-construction levels.

The communities that will receive the displaced people 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 through the division of communities, separation of families, and loss of livelihood. Following completion of the impoundment, tourism trade in the affected region, including fishing and ecotourism, could increase.

Environmental Setting

The Rio Indio project will produce hydroelectric power and provide for 6.43 additional lockages per day on a continual basis. The structures for this proposed project would 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 area encompasses the area to be flooded as well as the area downstream from the dam site. This area is sparsely populated and has steep hills as well as low coastal regions. The Rio Indio is located west of the Panama Canal, is used for navigation, and flows northward from the Continental Divide into the Atlantic Ocean. The Rio

Indio watershed above the dam is approximately 381 km^2. The impoundment area covers approximately 4,600 ha and consists of approximately 25 percent of forested land, 30 percent of pasture land (used by ranchers), 30 percent of cropland, and 15 percent of newly slashed and burned land. The lake water elevation would fluctuate from elevation 50 to 82.5 m MSL. The transmission lines, tunnel portals, and roads associated with the project could also have environmental impacts and should be sited to minimize those impacts.

LAND USE

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

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

INFRASTRUCTURE

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 coverage. No treatment of community waste is provided. Wastewater from showers and washing is discharged into the environment; some of it might eventually reach the Rio Indio and its tributaries. Disposal of domestic waste is the responsibility of individual homeowners: each home has an outdoor latrine (a deep hole in the ground). There are some known health problems, such as hepatitis, dysentery, dermatitis, intestinal parasites and respiratory illnesses associated with the present waste disposal methods. No major industries or poultry or beef processing plants are located in the project area. The only roads in the project area are poorly maintained dirt roads that are usable only in the dry season (mid-December through March). The roads are rarely graded and receive little attention by 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

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 upper mountainous areas above the Rio Indio impoundment area. As a result of slash and burn activities, there are no large contiguous tracts of forests at lower elevations in the impoundment area.

ANIMALS ON ENDANGERED LIST

The Autoridad Nacional del Ambiente (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 it has not been determined, some of the listed species might be found in the project area.

AQUATIC HABITAT

The Rio Indio in the project area displays traits characteristic of streams in mountainous regions. Its water is clear and cool, and the river bottom ranges from sand to boulders, with numerous riffles, runs, and pools. The Rio Indio has four major tributaries: Rio El Torno, Rio Uracillo, Rio Teria, and Rio Riacito. Approximately 20 smaller creeks also flow into the Rio Indio. The river is approximately 16 km long, its width ranges from 3 m (in the dry season) to 30 m at its mouth, and its depth ranges from less than 1 m to 15 m. The Rio Indio and its tributaries appear to support some fish communities; however, information about the fish communities in the project area is limited.

WETLANDS

Areas that contain hydric soils and hydrophytic plant communities, and that are subject to hydrologic conditions are termed wetlands. The wetlands consist of forested riparian habitat, and are limited by the relatively steep topography of the project area to the immediate vicinity of the stream banks. The width of the riparian habitat within the impoundment area varies from approximately 5 m to 50 m. Approximately 90 percent of the streams 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, sizable areas of established forests and secondary growth are burned and cleared to prepare the land for agricultural use. Based on observations in the Rio Indio project area, approximately 10 percent (or 400 ha) of forested land is burned annually.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

No parks or other government-protected lands are known to be located in the Rio Indio impoundment area. In the pre-Columbian period, the Rio Indio constituted 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; therefore, the project area has a high potential to be rich in archaeological and historical remains. 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 impoundment area would be scattered, since patches of forest cover approximately 1,000 ha, or 25 percent of the impoundment area. The forested area constitutes a relatively high quality terrestrial habitat. With the creation of the lake, the migratory routes of some species could be adversely affected. The only forests that would remain near the Rio Indio reservoir and its drainage basin would be confined to the higher elevations.

ANIMALS ON ENDANGERED LIST

The extent of potential effects cannot be determined at this time, because it is not known which of the listed species occur within the proposed project area. Furthermore, the significance of the forested riparian corridor along area streams may increase if animals on the endangered list are found in the region. The Mesoamerican Biological Corridor is also promoting biodiversity conservation throughout the Atlantic basin, which could impose restrictions on the use of the project area.

WATER QUANTITY

The impacts of the project on water quantity could be positive, because construction of the dam will result in an increase in the volume of stored fresh water in surrounding areas during the dry season. The impacts downstream from the dam site should be minimal, although water should be released at lower rates, and seasonal flooding could be significantly reduced. Further, measures could be taken to release water at appropriate periods and amounts to avoid problems with water quality and temperature downstream. The cumulative impacts downstream of the dam site over time should also be minor.

WATER QUALITY

The impacts downstream from the dam site could be positive. The water should contain less silt due to minimum normal flow and should provide people downstream a higher quality supply. The proposed Indio Lake should also provide high quality water for people living around the lake.

DOWNSTREAM AQUATIC FAUNAL HABITAT

The impacts on downstream aquatic faunal communities should be minimal, because the dam would be designed to allow multi-level releases of water to avoid problems with water quality and temperature downstream. The Rio Indio Dam should act as a large sediment trap, which should cause the released water to have low turbidity; therefore, siltation could not be a problem. The impacts of interference with the migratory movements of natural stream fishes are unknown. Streambed degradation below the dam should be minimal.

FUTURE LAKE AQUATIC PLANT COMMUNITY

The impacts of the project on future aquatic plant communities in the proposed lake will depend on water level fluctuations, which are anticipated to range from 50 to more than 80 m over a 3-month period. Since the water levels would fluctuate widely, much of the shores would be covered with mud, where neither aquatic nor terrestrial plant communities could thrive. Rooted aquatic plants tend to grow as deep as light penetration allows.

AQUATIC FAUNA INHABITING AFFECTED AREAS

The impacts of the project on aquatic fauna inhabiting the Rio Indio and its upstream tributaries could be important. If aquatic fauna were able to thrive in the new reservoir, they would be beneficially affected by having their habitat enlarged. Some unavoidable, adverse environmental impacts could occur and these impacts should be identified and appropriate mitigation measures addressed in feasibility level studies, should the alternative be recommended for further consideration. The new reservoir could provide good opportunities for recreational and subsistence fishing if it is responsibly managed and stocked with game fish by the Aquaculture Department. An increase in fish population could cause an increase in piscivorous predators, such as crocodiles, caimans, otters, and herons, etc. Other manmade lakes in the Republic of Panama have been stocked with peacock bass and tilapia, both of which have adapted well, but several riverine native species that formerly occupied the impoundments have disappeared.

WETLANDS

The impacts to upstream and downstream wetlands could be significant. Owing to the topography of the project area, a number of wetlands could be impacted by the project. It is possible that new wetlands could develop in the littoral zones, although the reservoir water levels will fluctuate. Due to minimum normal flow, the cumulative effects downstream of the dam site are expected to be minor.

AIR QUALITY

During construction of the dam, dust and emissions from equipment could impact the air quality in the project area. After construction, the air quality could improve because slash and burn activities are currently discouraged by the Panamanian government.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

The potential impacts on cultural resources and historic properties 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.

Additional Environmental Information Required

This section identifies the subject areas for which additional data are required to evaluate the scope and magnitude of the potential effects in further detail of the Rio Indio alternative. The subject areas 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).
    - Community and Regional Growth.
    - Transportation.
    - Housing.
    - Health (vector routes).
    - Population.
    - Community Cohesion.
    - Recreational Resources.
    - Mineral Resources.

TERRESTRIAL AND AQUATIC HABITAT

- Prepare site-specific habitat maps to ensure that all major terrestrial and aquatic habitat types are identified and quantified.
- Conduct field studies to locate special habitat features such as wetlands, roosting sites, reproductive sites, and the relative quality of forested areas.
- Determine the present quality and ecosystem value of existing habitats within the Rio Indio project area.

ANIMALS ON THE ENDANGERED LIST

- Compile habitat maps to assess the availability and quality of suitable habitats for the animals on the endangered list.
- Conduct site surveys to determine the presence of selected species.
- Develop candidate mitigation measures for the appropriate project alternatives to be considered in the Conceptual Phase.

WATER QUALITY

- As there are no water quality data available for the Rio Indio 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 is incomplete. Additional evaluation studies need to be completed to identify the cultural resources and historic 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 Section 35. Tables 5 - 13 through 5 - 15 present the evaluation of the proposed Rio Indio project as related to developmental effects, environmental effects, and socio-economic effects.

Table 5 - 13 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	0	10	0
	Satisfies Future Canal needs/expansion	0	10	0
	Additional Hydropower Potential	1	5	5
Technical Viability	Design Constraints	8	6	48
	Feasibility of Concept	8	6	48
Operational Issues	Compatibility	10	6	60
	Maintenance Requirements	10	2	20
	Operational resources required	8	2	16
Economic feasibility	Net Benefits	5	9	45
	Total			342

[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 5 - 14 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	4	8	32
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			399

[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 5 - 15 Socio-Economic Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Land Use	2	7	14
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			325

[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 5 - 16 presents pertinent data for Operating Option 1 of the proposed Rio Indio project.

Table 5 - 16 Pertinent Data for Operating Option 1

GENERAL		
Dam site, above mouth of Rio Indio	25 km	
Drainage area above dam site	381 km^2	
Average annual flow at dam site	25 CMS	
LAKE	**Option 1**	**Option 2**
Elevation of normal operating lake level	80 m MSL	80 m MSL
Elevation of maximum flood lake level	82.5 m MSL	82.5 m MSL
Elevation of minimum operating lake level	70 m MSL	50 m MSL
Area at normal operating lake level	4,280 ha	4,280 ha
Area at maximum flood lake level	4,440 ha	4,440 ha
Area at minimum operating lake level	3,630 ha	2,360 ha
Useable Storage between Max. & Min. levels	359 MCM	993 MCM
Top clearing elevation	80 m MSL	80 m MSL
Lower clearing elevation	70 m MSL	50 m MSL
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	
SPILLWAY		
Type of Spillway	Uncontrolled ogee	
Total length	120 m	
Elevation of spillway	80.0 m MSL	
Maximum discharge	920 CMS	

Table 5 - 17 Pertinent Data for Operating Option 1 (continued)

INTER-BASIN TRANSFER TUNNEL		
Tunnel diameter	3 m	
Tunnel length	5.2 km	
	Option 1	**Option 2**
Inlet invert	60 m MSL	44 m MSL
Outlet invert	40 m MSL	40 m MSL
Tunnel capacity	42.5 CMS	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	

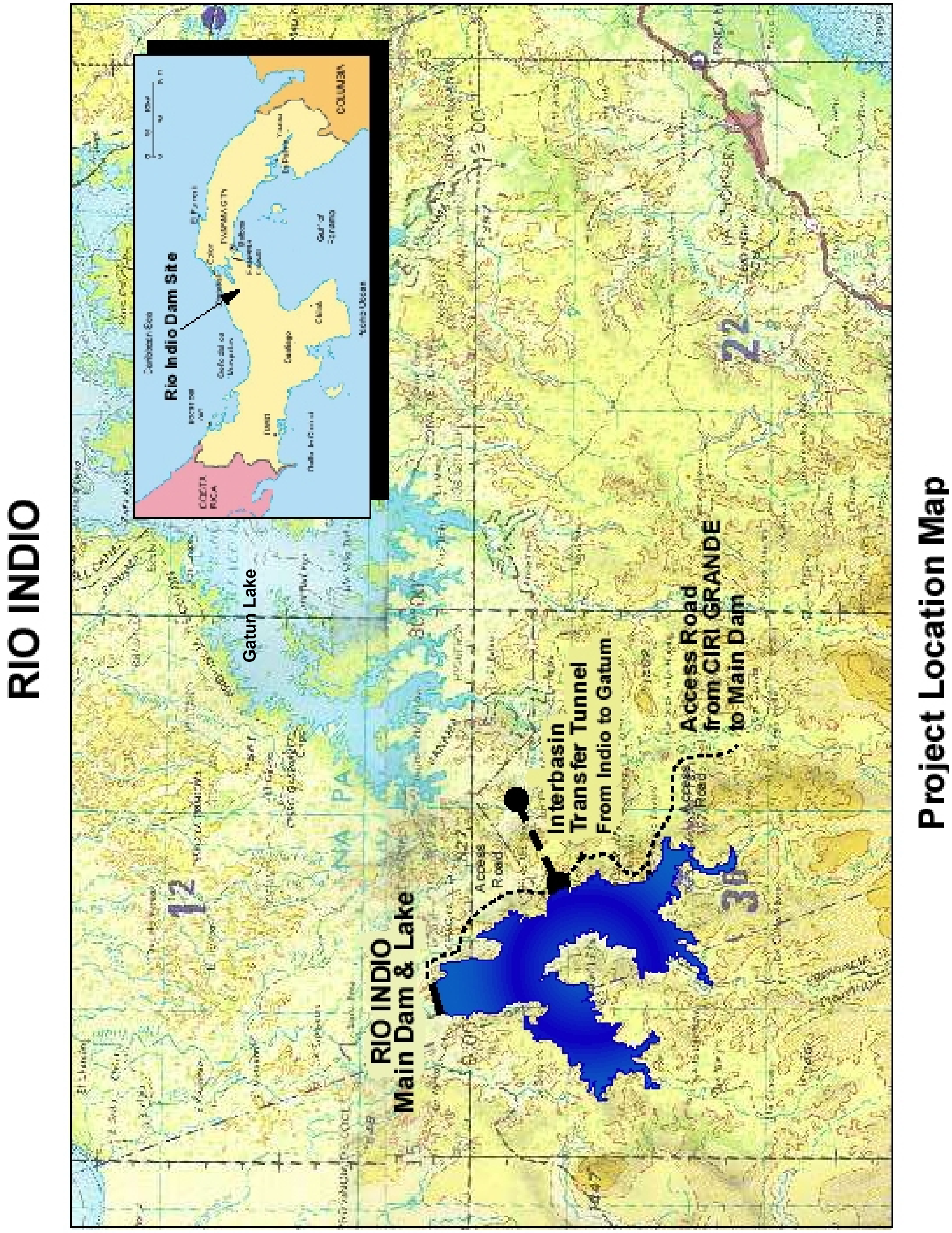
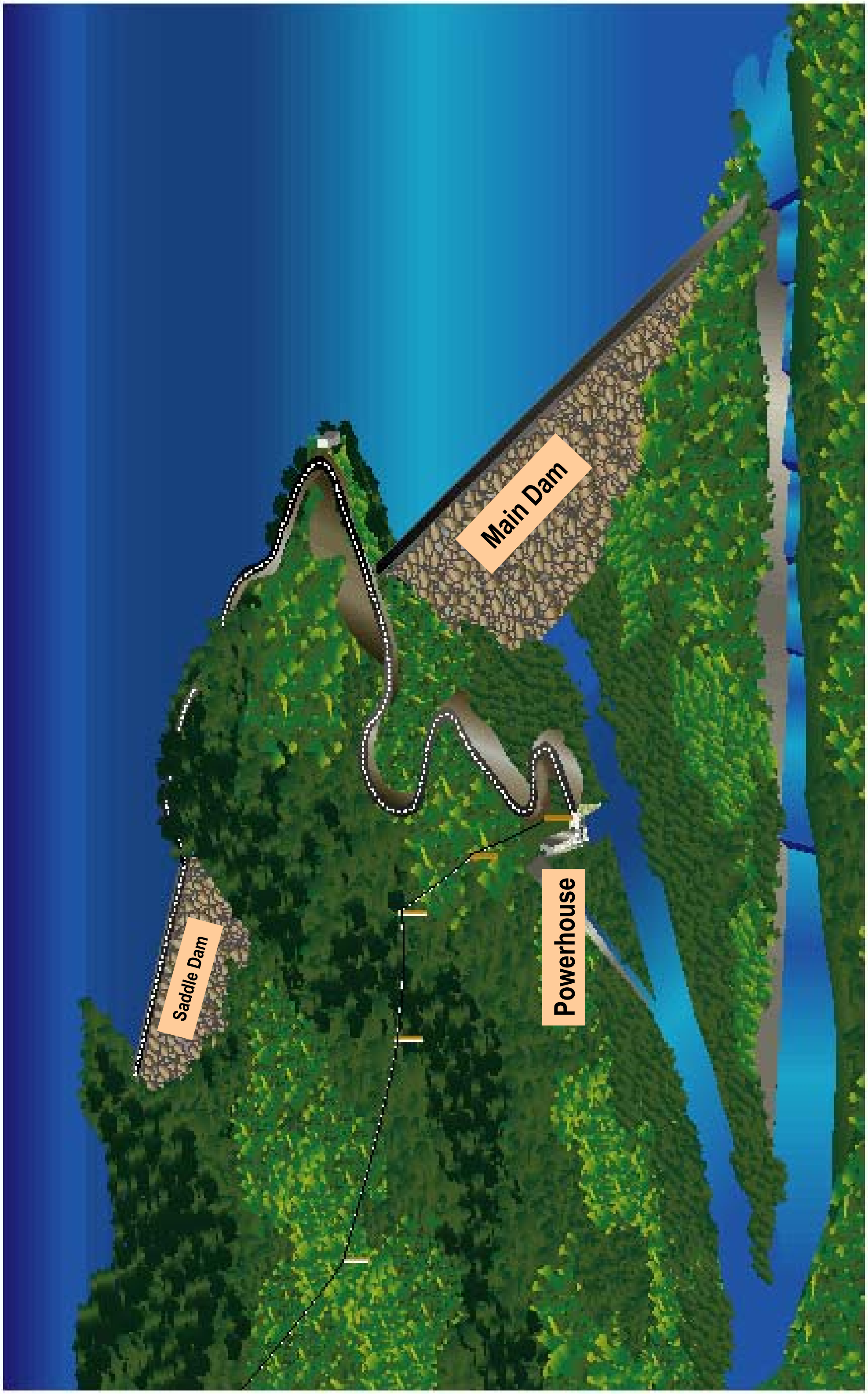


Plate 5 - 1 Project Location Map

RIO INDIO



Site Plan

Plate 5 - 2 Site Plan

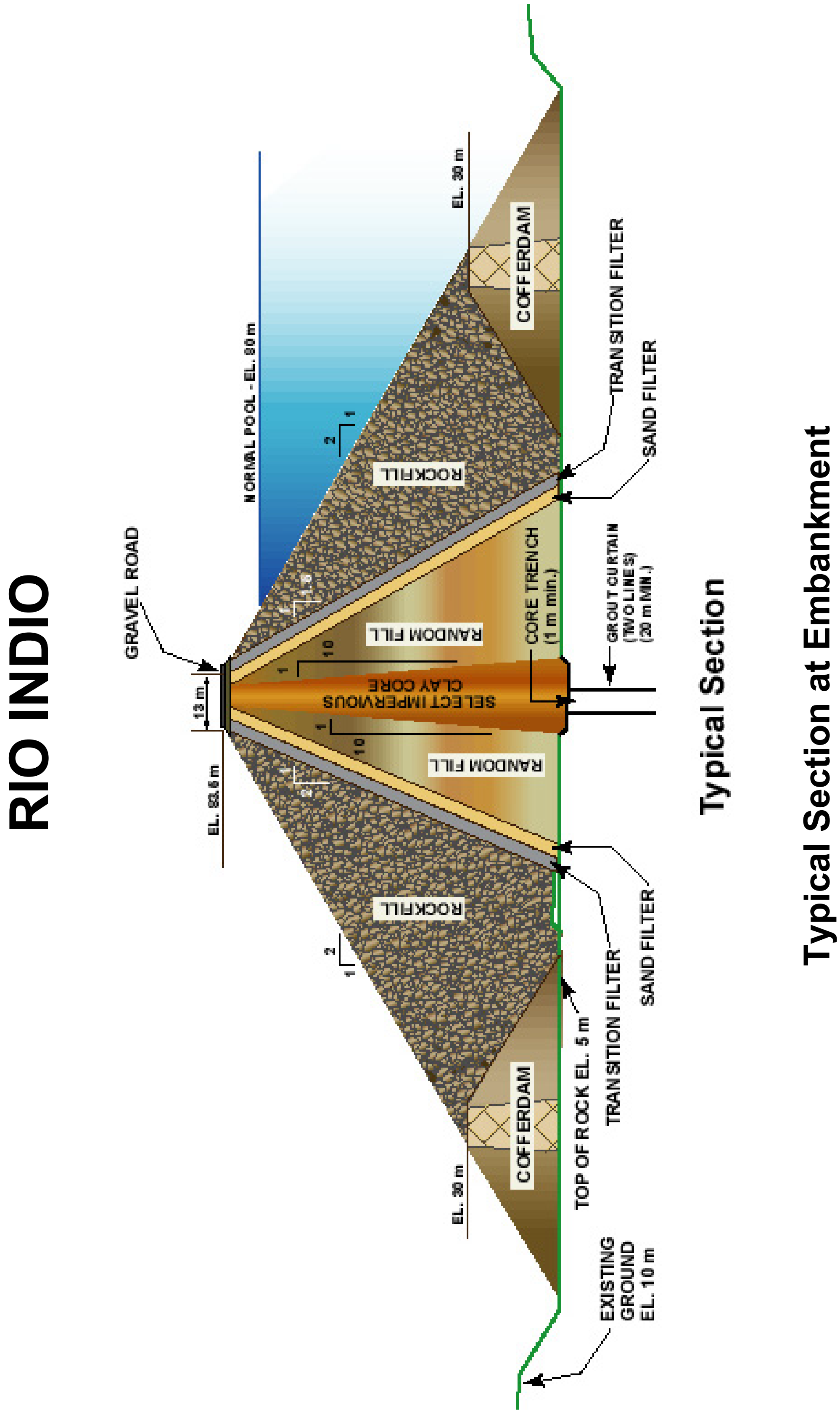


Plate 5 - 3 Typical Section at Embankment

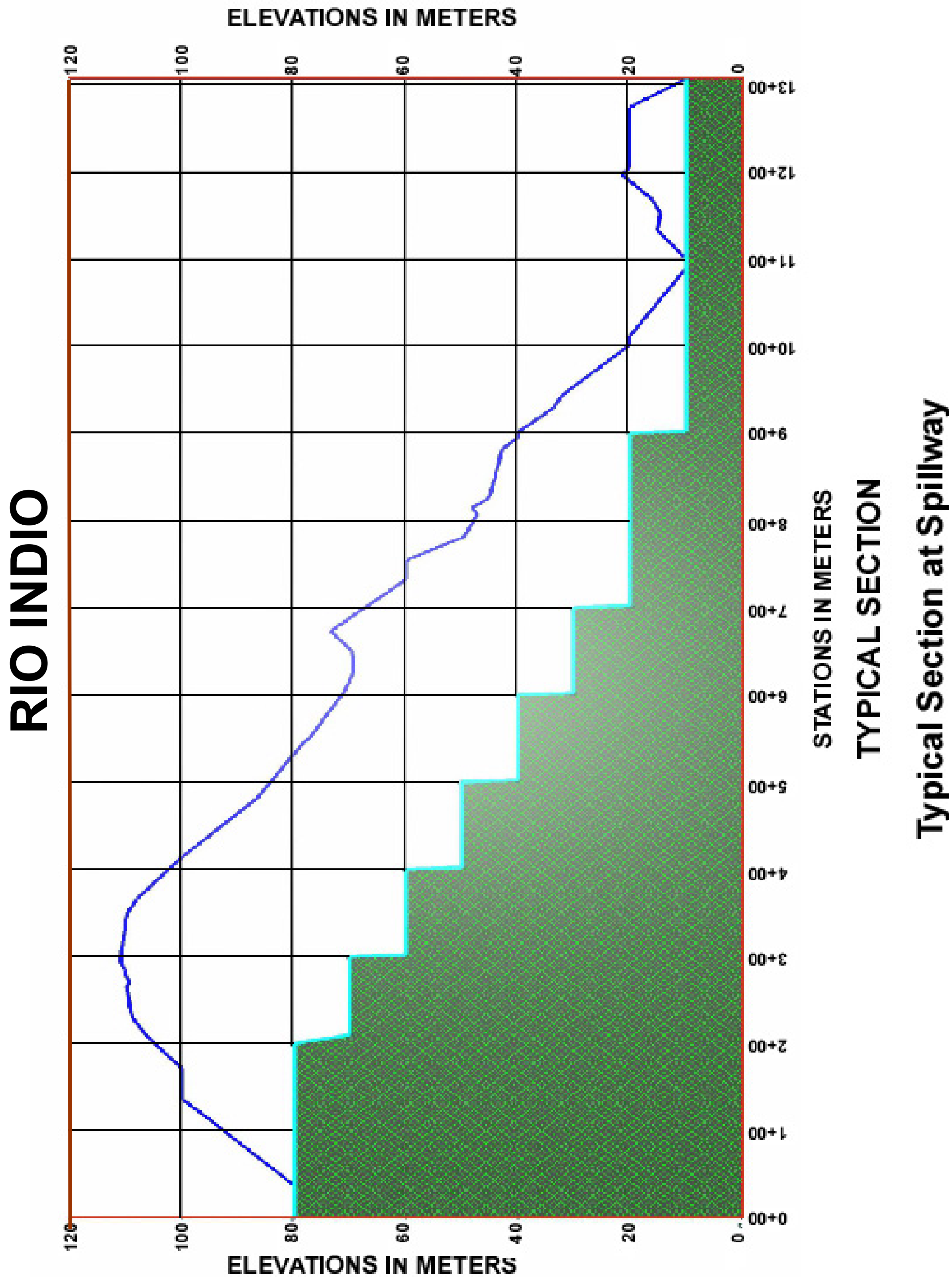


Plate 5 - 4 Typical Section at Spillway

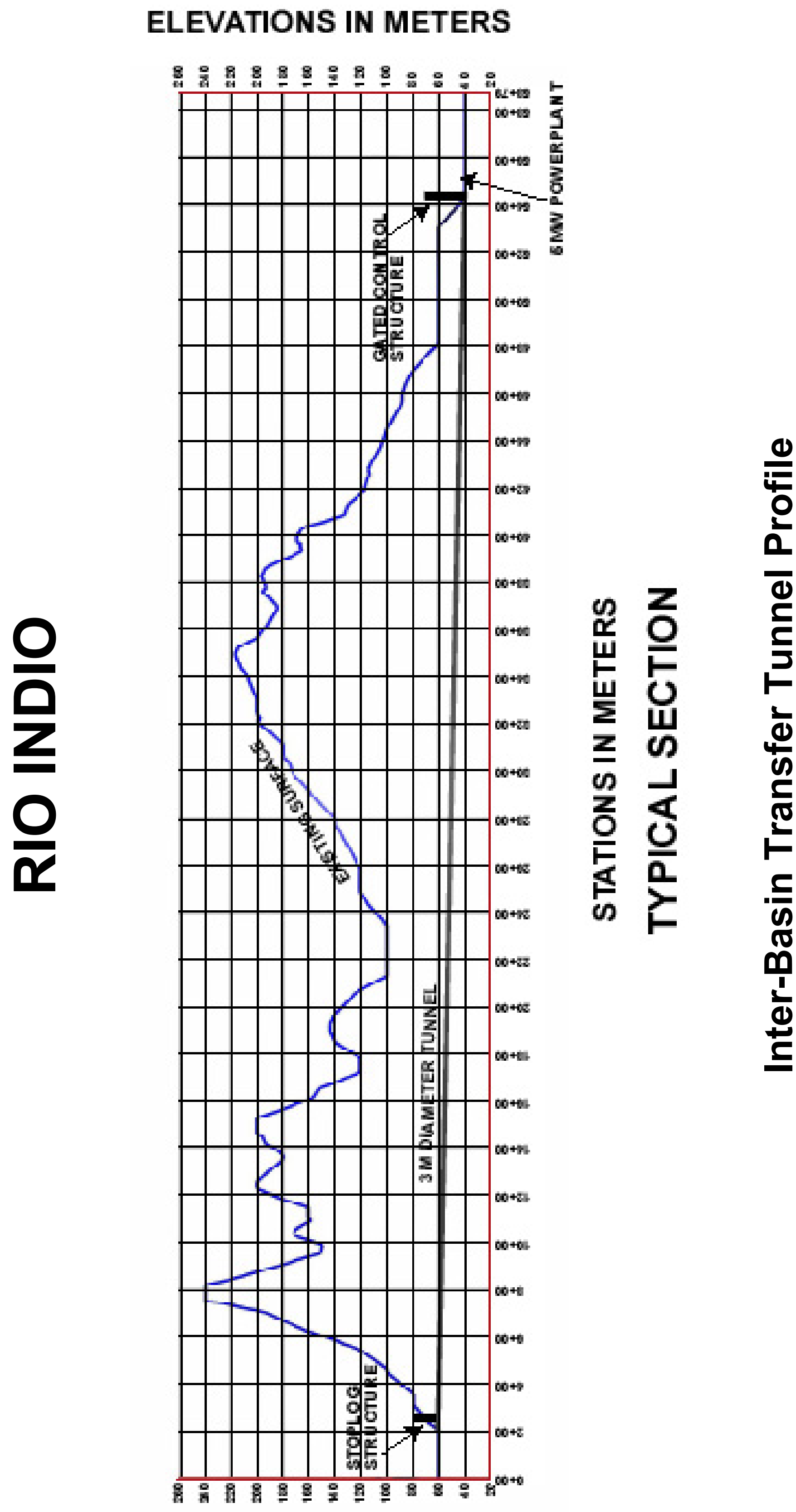


Plate 5 - 5 Inter-Basin Transfer Tunnel Profile

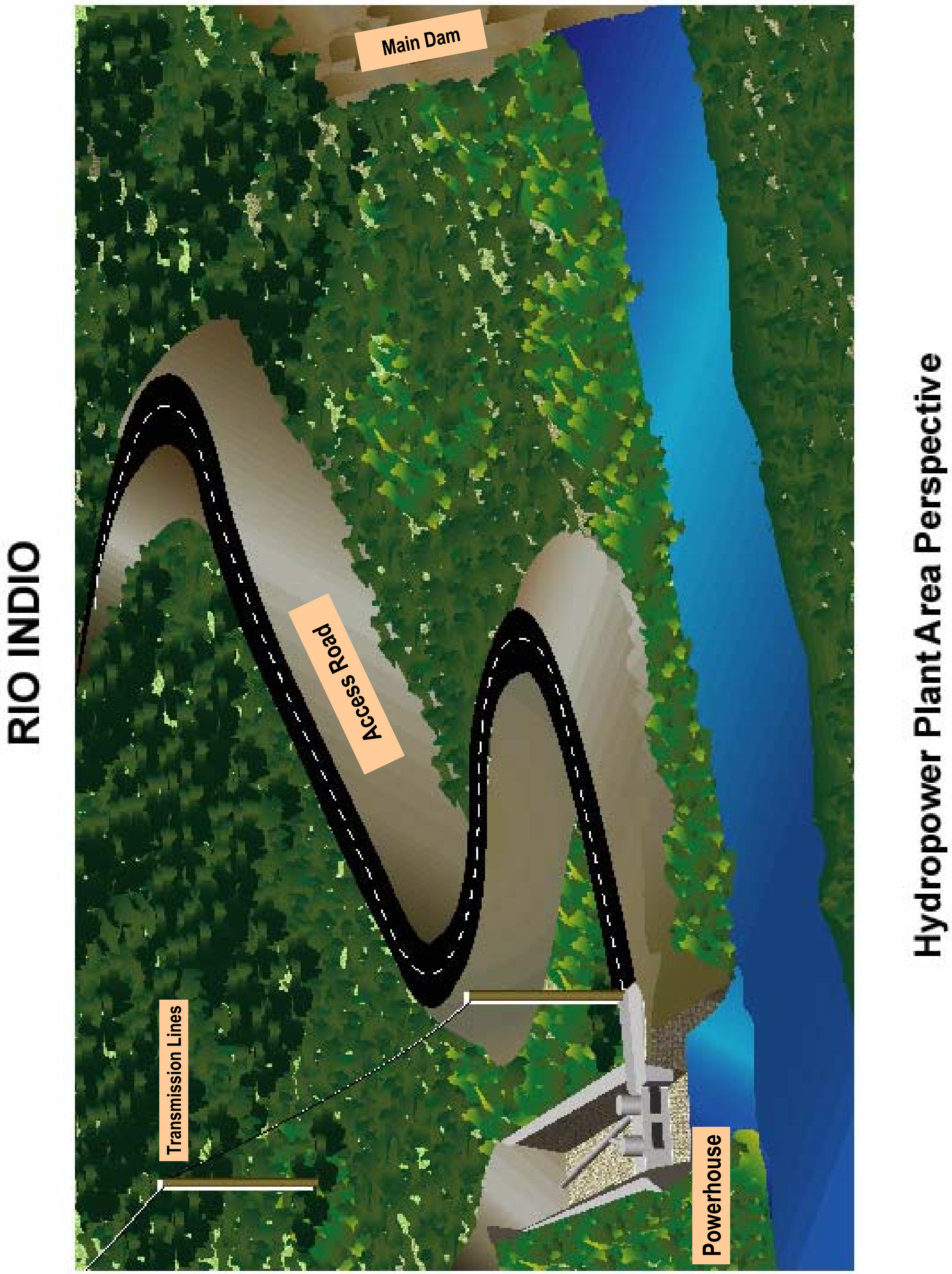
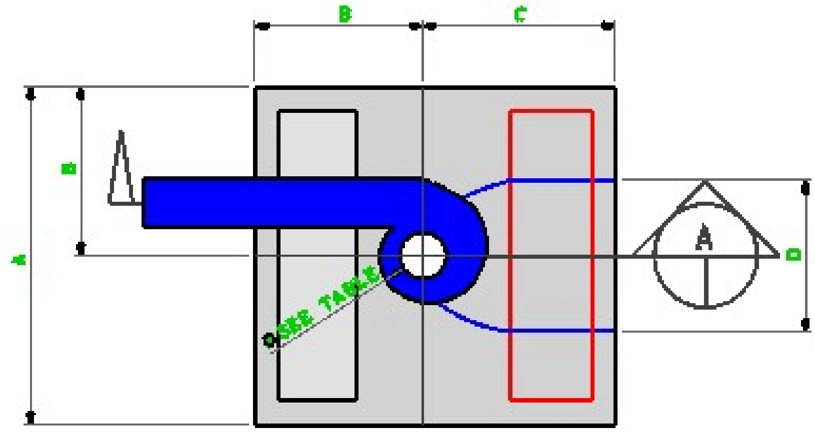
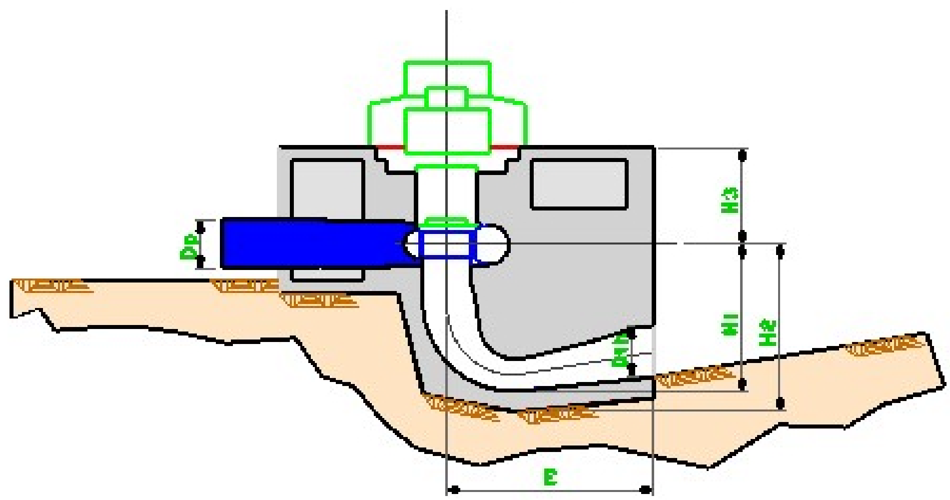


Plate 5 - 6 Hydropower Plant Area Perspective

RIO INDIO



PLAN
NOT TO SCALE
A



SECTION
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RIO INDIO DAM POWER FACILITIES									
UNIT	A	B	C	G	E	Dp	H1	H2	H3
D1h					(Meters)				
BASIN TRANSFER UNIT									
1.04	11.70	4.08	4.15	3.32	4.15	1.55	2.9	3.51	2.44
UNITS 1 AND 2									
1.60	12.34	4.72	6.71	5.36	6.71	2.53	4.60	5.30	2.44

Plate 5 - 7 Hydropower Plant Details

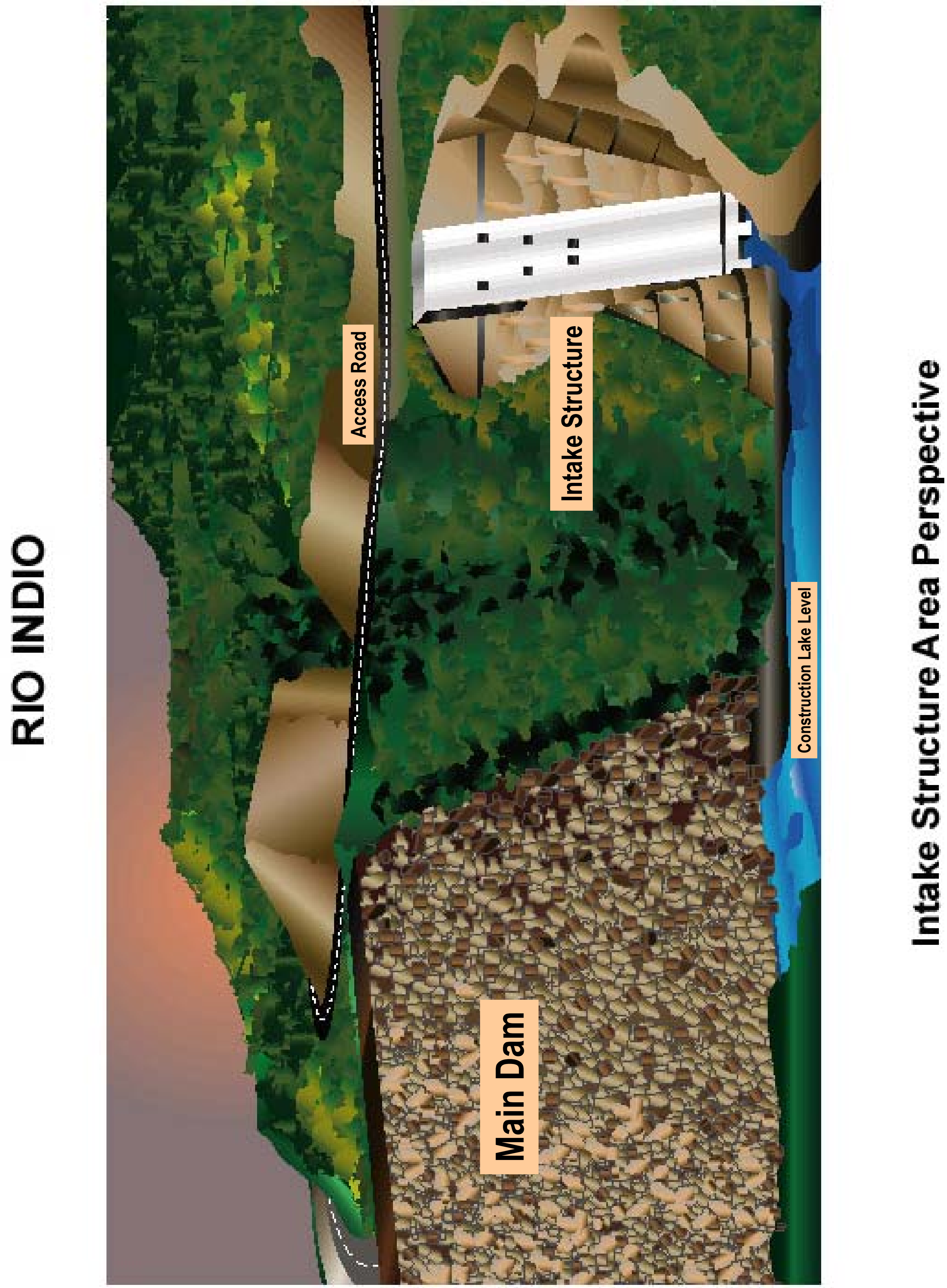
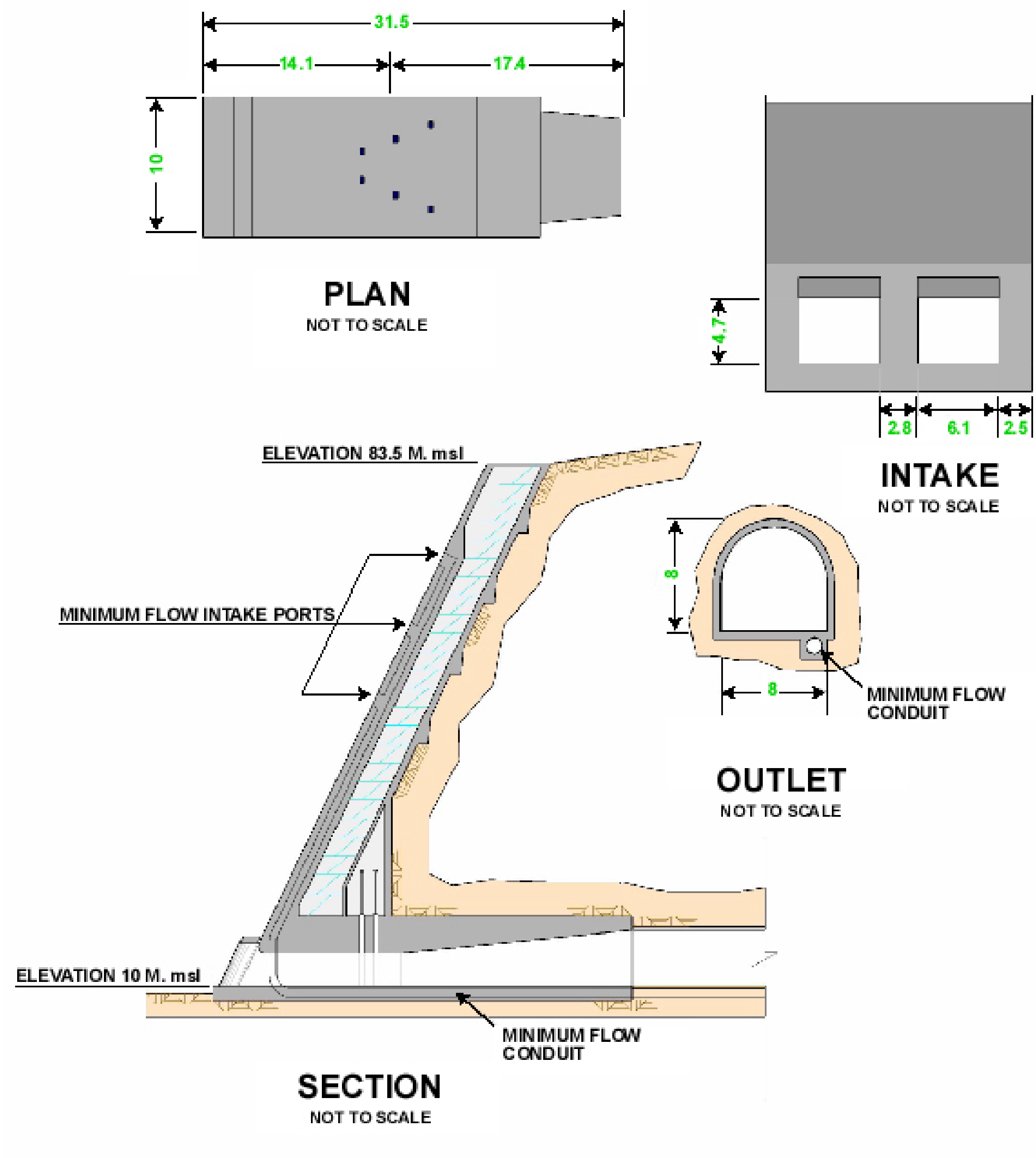


Plate 5 - 8   Intake Structure Area Perspective

RIO INDIO



Intake Structure Details

Plate 5 - 9   Intake Structure Details

SECTION 6

LAKE AT ELEVATION 65
(Operated in conjunction with Indio Lake)

Rio Cocle del Norte

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Synopsis

The development plan presented herein would include a dam and lake on the Rio Cocle del Norte with a normal lake level at 65 m MSL connected by a large tunnel to Indio Lake. Indio Lake would be connected to the Panama Canal watershed at Gatun Lake via a second tunnel (see section 5 of this report for details of the Rio Indio development). Water impounded in these two lakes would be transferred to the Panama Canal watershed as needed to support navigation.

The Rio Cocle del Norte watershed is located to the west of the Panama Canal watershed. The proposed Rio Cocle del Norte dam site would be approximately 15 km inland from the Atlantic Ocean, and approximately 7 km downstream of the confluence of Rio Cocle del Norte and Rio Toabre. The structures for this proposed project would consist of a mass concrete gravity dam with a gated spillway, an inter-basin transfer facility connecting the Cocle del Norte Lake with Indio Lake, an enlarged inter-basin transfer facility connecting Indio Lake with the Panama Canal watershed, and a hydropower plant. The total project first costs of the proposed Rio Cocle del Norte project are estimated to be $501,018,000.

The proposed Rio Cocle del Norte project would contribute measurably to the hydrologic reliability of the Panama Canal to serve its customers. It would greatly 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, is approximately 99.60 percent, while the hydrologic reliability with a demand ratio of 1.6 (61.89 lockages) would be 92.02 percent. Construction of the proposed Rio Cocle del Norte and Rio Indio projects would continue the existing high hydrologic reliability as demand for lockages increases up to 65 percent (25.07 lockages) above current demand levels.

The amount of hydropower that could be produced by the hydropower plants in the existing Panama Canal watershed system (Gatun Lake and Madden Lake) would decline over time as the demands for navigation and M&I water increase. With the inclusion of the hydropower plant at the proposed Rio Cocle del Norte project, the system could produce net additional megawatt hours of hydropower.

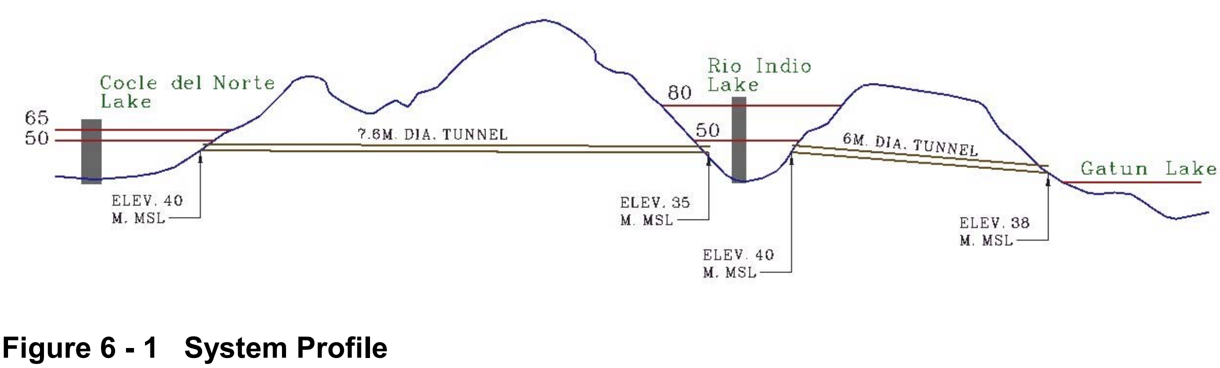


Figure 6 - 1 System Profile

Site Selection Considerations

The proposed Rio Cocle del Norte dam site was chosen 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. To maximize the water impounded, it was desirable to locate the dam as far downstream in the Rio Cocle del Norte watershed as possible. In choosing a site for the dam, a location was sought where the surrounding hillsides were relatively steep and high, and the valley was relatively narrow. The downstream portion of the Rio Cocle del Norte watershed contains several sites that meet these criteria.

The site chosen for the proposed Rio Cocle del Norte Dam would be approximately 15 km inland from the Atlantic Ocean and approximately 7 km downstream from the confluence of Rio Cocle del Norte and Rio Toabre. This site would accommodate construction of a dam with a normal operating lake level at elevation 65 m MSL and a maximum flood storage lake level at elevation 69 m MSL.

Hydrologic Considerations

The Rio Cocle del Norte flows northward from the Continental Divide to the Atlantic Ocean. The headwaters of the watershed begin at elevation 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 Cocle del Norte watershed varies from a high of 4,000 mm at the coast to a low of 2,500 mm in the middle watershed area and increases again to over 3,000 mm in the Continental Divide. The proposed Cocle del Norte Lake would receive runoff from approximately 1,600 km^2 of the upper portion of the watershed. Rainfall runoff produces an average annual flow of 109 CMS at the proposed dam site.

The discharge at the Rio Cocle del Norte dam site was obtained by extrapolating the recorded and correlated streamflow data of the Canoas hydrologic station, and adding to this, the recorded and correlated streamflow of the Rio Toabre at Batatilla. There were two hydrologic data stations located in the Rio Cocle del Norte basin. One station was a staff gage at El Torno and the second gage was a continuous recorder located at Canoas, approximately 6 km due south of the staff gage. The El Torno staff gage was read twice daily from 1958 through 1986 and the continuous recorder at Canoas began operating in 1983. The flows at El Torno, were extended by statistical correlation with the Rio Toabre gage data at Batatilla. These flows at El Torno were then used to fill in missing data and extend the recorded flows at Canoas, again using statistical correlation. The consistency of the data measured and correlated was verified using the double mass curve method. It is recommended that a stream gage be installed near the dam site if this river is going to be subjected to additional studies.

Because of the absence of site specific information, the monthly evaporation rates established for Gatun Lake were considered appropriate for the evaporation rates of Cocle del Norte Lake.

Geologic Considerations

The proposed Rio Cocle del Norte project is located in an area of the Isthmus of Panama where volcanic or intrusive igneous rocks are encountered at the surface. The volcanic rocks consist of lava flows, breccias, tuffs and plugs of the Tucue Formation, which are andesitic or basaltic in nature. The intrusive igneous rocks consist of granodiorites, quartzmonzonites, gabrodiorites, diorites, or dacites. Little has been found concerning the engineering characteristics of the rocks of these formations. It is anticipated, however, that they may show a wide variation in quality, from high quality of the intrusive rocks and the extrusive lava flows, to possibly weathered and lesser quality volcanic tuffs.

Hard, high quality igneous rock (diabase or fine-grained gabbro) outcrops along the riverbank at the proposed dam site. This rock should be excellent for use as either rock fill or concrete aggregate. It is not known for certain what type of rock underlies the abutment slopes, since they are completely covered with vegetation, but there is no reason to believe that it differs from that exposed at the rivers edge.

In the absence of detailed geologic mapping for the proposed Rio Cocle del Norte dam site, a degree of extrapolation was necessary. It was predicted that rock, at the proposed Rio Cocle del Norte dam site, would be encountered at a shallow depth and would be of sufficient quality to serve as foundation material for the dam and appurtenant structures. This prediction was based on available general geologic mapping and general data. Furthermore, it was assumed that sufficient rock for fill and concrete aggregate would be available from the required excavation and that impervious materials would be available within the immediate area for use in the construction of the project.

Alternative Dam Comparative Analysis

The valley at the proposed Rio Cocle del Norte dam site is relatively narrow. Because of the relatively low height and short length, it was believed that a concrete gravity dam might prove feasible for this site. Thus, a rock fill dam alternative and concrete gravity dam alternative were developed to the extent necessary to arrive at a comparative estimate of construction costs. Pertinent details of each alternative are described in the following paragraphs.

ROCK FILL DAM ALTERNATIVE

The rock fill dam would be an embankment with the top at elevation 70 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 993618 north and 550113 east. The right abutment would be 993594 north and 550621 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 would be approximately 65 m high, and the overall length would be approximately 391 m. The actual side slopes and crest width 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.

This alternative would require construction of an uncontrolled ogee spillway and a tailrace channel to return flow to the existing stream. An outlet works system would be required to provide for diversion of the Rio Cocle del Norte 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. A gate structure (gates mounted in a reinforced concrete intake structure) would be required at the inlet to control flow through the tunnel and the minimum flow conduit in the outlet works system. Separate documentation was provided to the PCC that contained assumptions and design calculations for this analysis.

CONCRETE GRAVITY DAM ALTERNATIVE

The dam would be a mass concrete gravity structure with a gated ogee crest spillway containing two gate bays. It was assumed that the base of the dam would be recessed approximately 10 m into the foundation across the full length of the dam. The dam would be stepped up the valley walls at the abutments.

The two gated spillway bays would be designed to pass the entire design flood for the lake. The spillway bays would be located near the center of the existing channel. The spillway crest would be at elevation 50 m MSL. Each spillway bay would be fitted with mechanically operated gates measuring 17 m wide by 15.5 m high. Tainter gates with torque tube and wire rope gate lifting devices, operated by electric motors mounted on the top of the spillway piers, were used for this study. For periodic maintenance of the gates, a bridge would be placed across the top of the spillway to facilitate the placement of stoplogs between the spillway piers.

The hydropower plant penstocks would be constructed in the mass concrete gravity structure adjacent to the spillway. A series of low-level sluiceways would be constructed in the spillway to provide for diversion of the Rio Cocle del Norte flows during construction and to allow for emergency drawdown of the lake. Minimum flows would be released through the gated spillway; however, multilevel intakes with outlets into the spillway tailrace channel could be incorporated for water quality releases.

The concrete structure shapes used in deriving costs for this analysis were obtained from two-dimensional mechanical analysis of the dam and spillway sections at the highest point of the dam. For these analyses, relatively conservative soils values and basic structure constants were used in keeping with current U.S. Army Corps of Engineers guidance (see Section 4). Separate documentation was provided to the PCC that contained assumptions and design calculations for this comparative analysis.

PRELIMINARY COST ANALYSIS

The rock fill dam and the concrete dam were each evaluated on their gross features. It was assumed that all other features of the proposed Rio Cocle del Norte project would be the same for either dam. It was further assumed that the channel excavation and stabilization work required downstream of either dam would be approximately the same. Table 6 - 1 contains rough-order-magnitude cost estimates for the main features of both dams.

Table 6 - 1 Comparative Cost ROM Estimate for Alternative Dam Structures

Feature	Total Costs ($)
Rock fill Dam Excavation and Fill, Tunnel Excavation, Intake Structure, Closure Structure	76,968,596
Concrete Gravity Dam Excavation, Concrete, Spillway Gates and Machinery	59,635,500

RECOMMENDED DAM TYPE

From the comparative cost estimates in Table 6 - 1, it appears that the concrete gravity dam alternative would be the most feasible alternative for initial construction. Incorporation of this alternative into the proposed project would avoid the need for diversion tunneling and a lengthy fixed crest spillway. No attempt was made at determining the relative operation and maintenance costs; however, it was assumed that the costs would not vary greatly between the two alternatives. Based on this comparison, the concrete gravity dam with a gated ogee crest spillway was included as a principal feature in the evaluation of the proposed Rio Cocle del Norte project. Plate 6 - 2 shows a site plan in perspective view with the concrete gravity dam and pertinent features noted.

If this alternative is carried forward for further development and design substantial study and refinement must be done to optimize the type and configuration of the dam and appurtenant structures to be incorporated. Although the data used in developing the physical dimensions of the concrete dam described herein were considered conservative, it is possible that later site specific data could require that these facilities be substantially larger than indicated here. Should this occur, the comparative analysis of dam types should be revisited and the site features optimized using designs based on the site specific data.

Lake Operation

Two operating options were considered in this study for periods when water would be transferred from Cocle del Norte Lake to the Panama Canal watershed for canal operations. Operating Option 1 consists of the water surface of the lake fluctuating from the normal operating lake level at elevation 65 m MSL down to the minimum operating lake level at elevation 50 m MSL, with 2,093,600,000 M^3 of useable storage. The maximum flood storage lake level for Option 1 would be at elevation 69 m MSL. Operating Option 2 consists of the water surface of the lake fluctuating from the normal operating lake level at elevation 60 m MSL down to the minimum operating lake level at elevation 50 m MSL, with 1,054,900,00 M^3 of useable storage. The maximum flood storage lake level for Option 2 would be at elevation 64 m MSL.

The volume between the maximum flood storage lake level and the normal operating lake level would be used to store flood waters and reduce peak flood flows. Some reduction in flooding would be realized in areas along the Rio Cocle del Norte downstream of the dam.

Water would be transferred from Cocle del Norte Lake to Indio Lake and then to the Panama Canal watershed for use in canal operations. The normal operating lake level at Indio Lake ranges from elevation 50 m MSL to elevation 80 m MSL and, at times, would be higher than at the Cocle del Norte Lake which only ranges from 50 to 65 m MSL. Thus, operation of the linked system of lakes, Cocle del Norte Lake, Indio Lake, and Panama Canal watershed, would require a unique approach. The water in storage at the Indio Lake would have to be transferred to the Panama Canal watershed initially until the Indio Lake level is below the Cocle del Norte Lake level. The Indio Lake elevation would have to remain lower than the Cocle del Norte Lake elevation so water could be transferred to Indio Lake. The rate of transfer of water from Cocle del Norte Lake to Indio Lake would be a function of the difference in lake levels. Table 6 - 2 shows the lake levels for the two operating options.

Table 6 - 2 Lake Operating Options

Lake Level	Operating Option 1 (m MSL)	Operating Option 2 (m MSL)
Normal Operating Lake Level at Cocle del Norte Lake	65	60
Minimum Operating Lake Level at Cocle del Norte Lake	50	50
Maximum Flood Storage Lake Level at Cocle del Norte Lake	69	64
Normal Operating Lake Level at Indio Lake	80	80
Minimum Operating Lake Level at Indio Lake	50	50

Project Features

GENERAL

The structures for this proposed project would consist of a mass concrete gravity dam with a gated spillway, inter-basin transfer facilities, and a hydropower plant. Since the higher lake elevation would be more productive in providing water for navigation to the Panama Canal watershed and would better facilitate flow between Cocle del Norte Lake and Indio Lake, the following paragraphs provide a description of the proposed structures and improvements for Operating Option 1 only. Plates 6 - 3 and 6 - 4 provide upstream and downstream perspective views of the proposed structures at the dam 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 PCC that contained assumptions and design calculations for the reconnaissance level investigations of these structures. If this proposed project is carried into the planning studies, optimization of the project features and improvements must be accomplished.

DAM AND SPILLWAY

The dam would be a mass concrete gravity structure with a gated ogee crest spillway containing two gate bays. It was assumed that the base of the dam would be recessed approximately 10 m into the foundation across the full length of the dam. The dam would be stepped up the valley walls at the abutments. Foundation grouting will 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 could provide seepage cutoff in the embankment foundations. A concrete or bentonite cutoff wall could also provide seepage cutoff.

The two gated spillway bays would be designed to pass the entire design flood for the lake. The spillway bays would be located near the center of the existing channel. The spillway crest would be at elevation 50 m MSL. Each spillway bay would be fitted with mechanically operated gates measuring 17 by 15.5 m. Tainter gates with torque tube and wire rope gate lifting devices, operated by electric motors mounted on the top of the spillway piers, would be used. For periodic maintenance of the gates, a bridge would be placed across the top of the spillway to facilitate the placement of stoplogs between the spillway piers. Typical sections of the concrete dam and spillway are presented on Plates 6 - 5 and 6 - 6. The stoplog / gate structure is shown on Plate 6 - 8.

The hydropower plant penstocks would be constructed in the mass concrete gravity structure adjacent to the spillway. A series of low-level sluiceways would be constructed in the spillway to provide for diversion of the Rio Cocle del Norte flows during construction and to allow for emergency drawdown of the lake. Minimum flows were assumed to be released through the gated spillway; however, multilevel intakes with outlets into the spillway tailrace channel could be incorporated for water quality releases.

A limited stability analysis was performed on the full height dam monolith and the interior spillway monolith to confirm the size of the structure required. The analyses only evaluated the condition with the lake at the top of the spillway gates. Additional analyses must be performed during further planning studies to include all reasonable operating scenarios and seismic loading conditions as well.

IMPOUNDMENT

The lake formed by the proposed Rio Cocle del Norte Dam would have a normal operating lake level at elevation 65 m MSL. The surface area at the normal operating lake level would be approximately 17,940 ha. With the minimum operating lake level at elevation 50 m MSL, the surface area would be approximately 10,730 ha. At the maximum flood storage lake level at elevation 69 m MSL, the surface area would be approximately 20,090 ha. At the top of dam at elevation 70 m MSL, the surface area would be approximately 20,640 ha.

CLEARING AND / OR GRUBBING

Clearing and grubbing would be required for all areas required for construction of the dam and associated structures, inter-basin transfer facilities, hydropower plant, access roads, and disposal and staging areas. Clearing only would be required for the 7,210 ha in the lake area between normal operating lake level at elevation 65 m MSL and the minimum operating lake level at elevation 50 m MSL, and for the transmission lines.

INTER-BASIN TRANSFER FACILITIES

A tunnel would be excavated beneath several watersheds to connect the proposed Cocle del Norte Lake to the Indio Lake. The finished tunnel would be concrete lined, 7.6 m in diameter, and approximately 18 km in length. This tunnel would have an inlet invert at elevation 40 m MSL and an outlet invert at elevation 35 m MSL. The maximum capacity of the tunnel would be 134 CMS. It was assumed that rock bolting would be required over much of the tunnel length to stabilize the rock. The tunnel outlet would be on the Rio Uracillo arm of Indio Lake approximately 5 km upstream from the confluence of Rio Uracillo and Rio Indio. A gate structure located at the tunnel outlet would control flow through the tunnel. The tunnel would be under pressure continually since the elevation of the tunnel would be lower than the minimum operating lake level at both lakes. To allow for maintenance of the tunnel and to provide for rapid emergency closure of the tunnel, a stoplog / gate structure would be constructed at the upstream end. In the process of stopping flow through the tunnel, a water hammer effect could be generated. Therefore, a series of surge protection shafts would be constructed. These shafts would require relatively minor surface structures for safety purposes. Plate 6 - 1 shows the location of the tunnel outlet, and Plate 6 - 9 depicts a profile of the tunnel.

The 3 m finished diameter inter-basin transfer tunnel included in the proposed Rio Indio project between Indio Lake and the Panama Canal watershed would need to be enlarged to a 6 m finished diameter to pass the combined flows from Indio Lake and Cocle del Norte Lake at elevation 80 m MSL. The maximum capacity of this tunnel would be 216 CMS, and it would have invert elevations at its inlet and outlet ends of 40 m and 38 m MSL respectively. This would result in a slight lengthening of the tunnel over that indicated in the Rio Indio evaluation (See Section 5). The additional cost of this tunnel resulting from changes in diameter and length would be directly attributable to the Rio Cocle del Norte project and are included in the accompanying construction cost estimate for the Rio Cocle del Norte facilities.

The location and assumed alignment of these features are shown on Plate 6 - 1 and a profile of the entire transfer system is shown in Figure 6 - 1. The tunnels would be under pressure continually since flow through the tunnels would be controlled at the downstream end of each. This control would be in the form of a gate control structure and / or a hydropower plant. To allow for maintenance of the tunnel and to provide for rapid emergency closure of the tunnel, a gate / stoplog structure would be constructed at the upstream end of each. In the process of stopping flow through the tunnel, a water hammer effect could be generated. Therefore, sufficient surge protection shafts would be constructed. These shafts would require relatively minor surface structures to protect the openings and to provide for personnel safety.

It was assumed that the tunnels would be concrete lined and that rock bolting would be required over much of the length of the tunnel to stabilize the rock.

HYDROPOWER PLANTS

The flows, excess to the needs of the Panama Canal operation, at the proposed Rio Cocle del Norte Dam would support installation of a 68 MW hydropower plant at the dam. This plant would have four 17 MW units. The hydropower plant penstocks would be constructed in the concrete dam. For this study, vertical Francis type turbines were included in the design. These facilities would be designed and configured to function as part of the national power grid. A 115 kV transmission line would be required to carry the energy to the hydropower plant at the Rio Indio project and ultimately to a connection with the grid near La Chorrera. Plate 6 - 2 shows the location of the hydropower plant at the dam and Plate 6 - 7 shows general configuration and dimensional data for the individual power generation units.

In analyzing the flow characteristics of the inter-basin transfer tunnel between Cocle de Norte Lake and Indio Lake, it was determined that sufficient energy would only be available to maintain flow between the two lakes. Therefore, no hydropower capability could be provided at this location.

As noted previously, in order to transfer water from the Cocle del Norte Lake to Indio Lake and then to the Panama Canal watershed, the Indio Lake elevation would have to remain lower than the Cocle del Norte Lake elevation. This would substantially reduce the energy available between Indio Lake and the Panama Canal watershed. It is estimated that sufficient energy would be available to pass the water through the inter-basin transfer tunnel between Indio Lake and the Panama Canal watershed; however, sufficient energy would not be available for additional hydropower at this tunnel outlet.

ACCESS ROUTE

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

The route from Colon could be westward across the Panama Canal and then generally southwestward along existing roads to the village of Salud. From this point new or vastly improved roadways would be constructed along the north coast to the village of Cocle del Norte and then along the Rio Cocle del Norte to the dam site and the other construction sites.

Alternately, this route could be by barge southwestward along the Atlantic Ocean to the village of Cocle del Norte and then by new roads along the Rio Cocle del Norte to the dam site and the other construction sites. This route would also require docking facilities at the village of Cocle del Norte. Approximately 100 m of dock facilities and minimal dredging for barge access would be required at the village of Cocle del Norte for offloading of construction materials and equipment. The proposed access road from the Cocle del Norte village to the dam site would be approximately 13 km in length. An additional 30 km of roads would be required to provide access to the inlet and outlet of the inter-basin transfer tunnel.

The above two scenarios would also require that access to the tunnel outlet at Indio Lake be established, possibly by a new road from the existing roads at the Rio Indio project.

The route from Panama City would be by roads previously constructed in conjunction with the Rio Indio project and then generally westward by new roads to the Inter-basin transfer tunnel entry and exit points and the Rio Cocle del Norte dam site and the other construction areas. Note that this route, as well as the secondary access to the inter-basin tunnel outlet noted above, assumes that the Rio Indio project would be in place prior to construction of the Rio Cocle del Norte project.

It was concluded that the land route from the Rio Indio project would be the best alternative since the new road construction would benefit the general population. In addition to providing construction access, this new corridor, into the interior of the country west of the Panama Canal, will be of benefit to those living in that region. This route would also provide continuous access to the new power transmission lines constructed from the dam site to their connection with the Rio Indio transmission lines. Bridges and / or culverts would be required at five streams. Plate 6 - 1 shows the proposed route.

Sources of Construction Material

Cement would be available within the Republic of Panama. Rock, obtained from the construction site or from the lake area, would be used for onsite manufacture of aggregates for the concrete. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) would be fabricated outside the Republic of Panama and imported for final assembly and installation at the proposed dam site.

Real Estate Requirements

The proposed Rio Cocle del Norte project would be located in the Cocle and Colon Provinces. Construction of this proposed project would require approximately 21,640 ha. Table 6 - 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 6 - 3 Real Estate Requirements

Project Feature	Land Required (ha)
Lake	20,640
Dam Site	200
Staging Area	200
Housing and Facilities	200
Disposal Area	400
Total	21,640

Relocations

The town of Coclecito, located within the lake area, would be inundated. This town has a population between 800 to 1,000 and will require significant relocation efforts. The remainder of the Lake would be located in a sparsely settled region with few roads and utilities. This area is devoted primarily to subsistence farming, pineapple growing, and ranching. Structures and individuals located in the lake area below elevation 70 m MSL would require relocation because of the normal lake inundation and the need to secure the lake perimeter for flood considerations. Other relocations associated with the proposed project would be minimal.

Development Sequence

For the economic evaluation of this project, it was assumed that the planning for the Rio Cocle del Norte project would begin during the construction of the Rio Indio project. Construction would be started immediately following completion of the Rio Indio project.

Planning studies would be accomplished to evaluate the alternative features of each proposed project. Each potentially viable project would be evaluated to assure that the plan presented would provide all of the features required to make it functional. Each would also be assessed for its effectiveness in meeting the project goal of providing navigation water to the Panama Canal, with due recognition of any secondary benefits. Environmental assessments of the proposed projects would also be made to assure environmental acceptability of the project features. These environmental assessments would begin during the planning studies phase and would continue during the final design, advertising and award phase, and on through construction of the project. The final design would be accomplished for the recommended project. After completion of the final design, plans and specifications would be prepared for the advertising and award phase.

Project implementation would begin 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 would then be acquired.

Access roads would be constructed to the dam site and the inter-basin transfer tunnel inlet and outlet sites. Once highway access to the sites has been established, a camp would be built to house workers during construction.

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

Construction of the dam would begin with the clearing and grubbing of the construction sites and the clearing of the lake area. Excavation for the inter-basin transfer tunnel would follow and would run concurrently with construction of the dam and appurtenant structures. The concrete gravity dam would be constructed in two stages. The first stage construction would begin with stream flows being routed around the construction area in an excavated, open channel and construction of the first stage cofferdam. The dam foundation would then be excavated and grouted, and the portion of the dam within the first stage cofferdam would be constructed. Concurrently with construction of the dam, the hydropower plant site downstream of the dam would be excavated and the powerhouse construction would be started. Work on clearing and construction for the electric power transmission lines would also begin at this time. With completion of the first stage dam and hydropower plant construction, the cofferdam would be removed and stream flows would be diverted through the low level sluice. A cofferdam would then be constructed to protect the second stage construction area. The remaining gravity dam foundation work and dam construction would be completed. The spillway gates, operating machinery, and the hydropower units, would be installed concurrently with the second stage dam construction. Upon completion of the dam and the inter-basin transfer tunnel and appurtenant structures, the diversion would be stopped and reservoir filling would begin. At the completion of the project, all facilities would undergo trial operations followed by commissioning for service.

Considering the climatic conditions and the obstacles posed by the remote location of the construction sites and the nature of the work, it is estimated that development of this project could be completed in approximately 12 years from initial planning to lake filling. Figure 6 - 2 depicts the development sequence of the various project features.

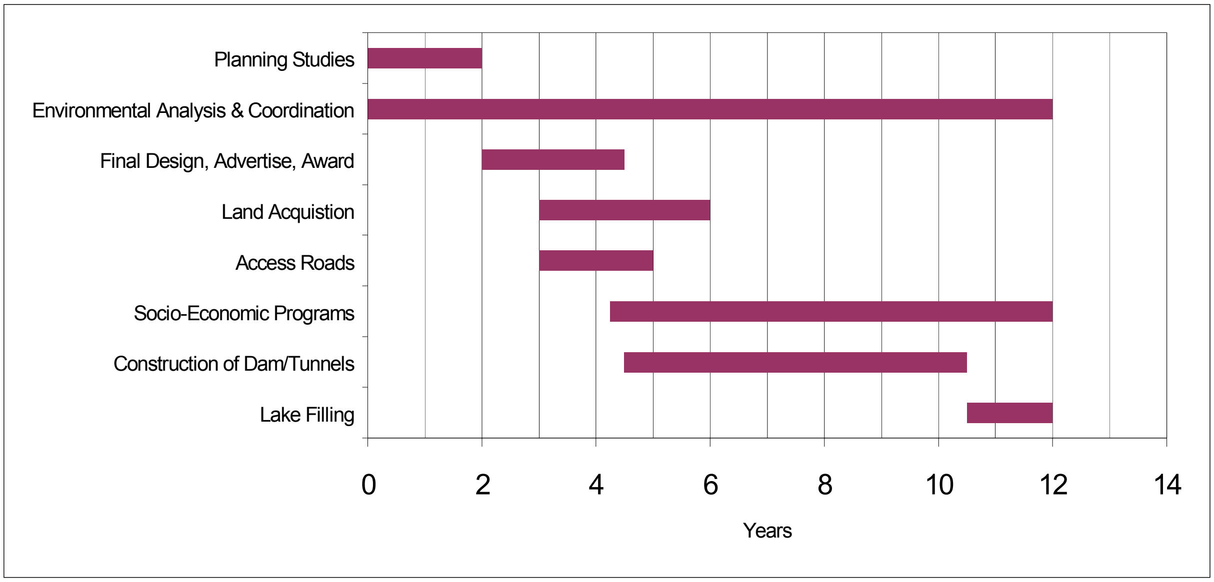


Figure 6 - 2 Development Sequence

Hydrologic Reliability

In order to determine the effect of the proposed Cocle del Norte Lake on the hydrologic reliability of the Panama Canal, the Lake was evaluated as linked with the Indio Lake and the Panama Canal watershed. A HEC-5 model was constructed that linked the Cocle del Norte Lake to the Indio Lake through the inter-basin transfer tunnel and Indio Lake was linked to the Panama Canal watershed. Water stored in Cocle del Norte Lake was provided, as needed, to Gatun Lake when shortages were expected using the Indio Lake as a conduit. Excess flows in the Rio Cocle del Norte were still released down the Rio Cocle del Norte, taking advantage of the hydropower generation when possible. Minimum flow requirements were deducted from the waters made available to the Panama Canal watershed and released down the Rio Cocle del Norte.

HEC-5 model simulations were conducted for both the existing canal system and the system operating with the proposed Cocle del Norte Lake linked by an inter-basin transfer tunnel to the proposed Indio Lake, which was linked by another inter-basin transfer tunnel to the Panama Canal watershed. The simulations considered proportionally increasing demands up to 180 percent of current demand levels. The period of simulation considered 50 years (1948 through 1998) of hydrologic records at Rio Cocle del Norte. Since the normal operating lake level at Indio Lake (80 m MSL) is higher than the normal operating lake level at Cocle del Norte Lake (65 m MSL), water could only be transferred from Cocle del Norte Lake to Indio Lake when the Indio Lake level was lower than the Cocle del Norte Lake level. Cocle del Norte Lake would fluctuate between the normal operating lake level at elevation 65 (Operating Option 1) or 60 (Operating Option 2) m MSL and the minimum operating lake level at elevation 50 m MSL. Indio Lake would fluctuate between the normal operating lake level at elevation 80 m MSL and the minimum operating lake level at elevation 50 m MSL for both options. Separate documentation was provided to the PCC containing the model code and simulation output for these investigations. Figure 6 - 3 below is a schematic of the proposed linked lake system.

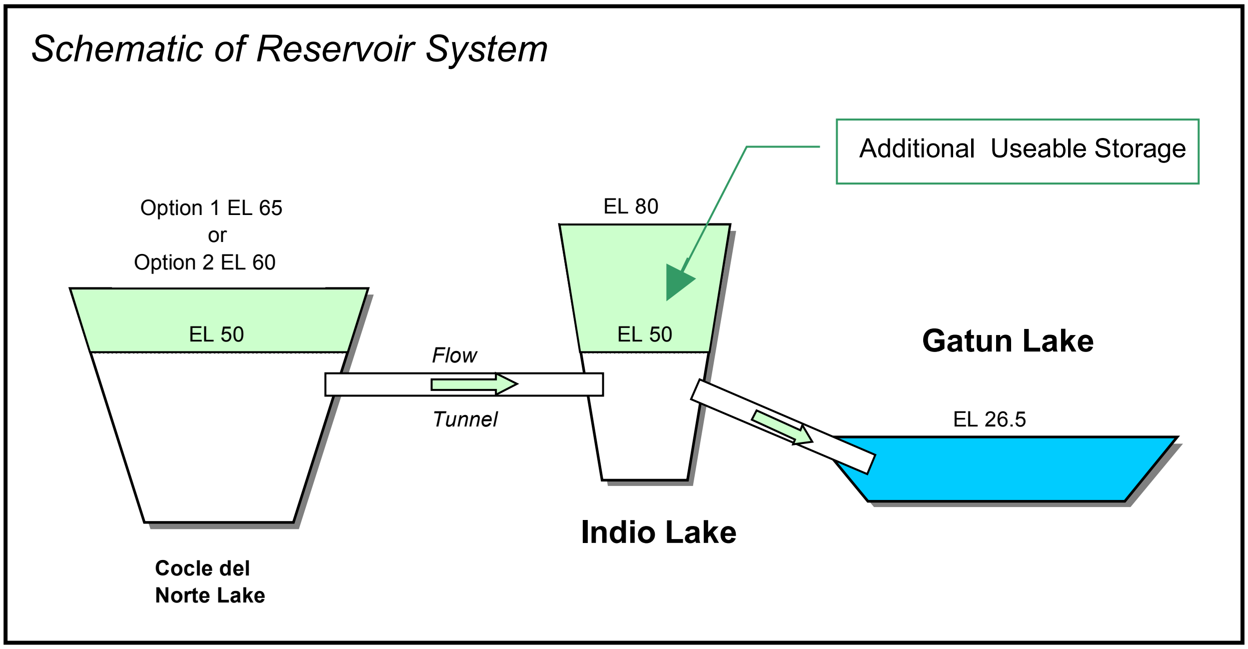


Figure 6 - 3 Schematic of Linked Lake System

Figure 6 - 4 compares the resulting hydrologic reliability for the two operating options to the reliability of the existing system. The horizontal axis along the bottom of Figure 6 - 4 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 6 - 4, the existing hydrologic reliability of the Panama Canal, based on the 50 year period of record, is approximately 99.6 percent while the hydrologic reliability with a demand ratio of 1.8 would be 86.3 percent. This period of record does not include the first six months of the 1998 drought year. The hydrologic reliability, with the Cocle del Norte Lake and Indio Lake transferring water to the Panama Canal watershed, would be 100 percent with a demand ratio of 1.0 and 99.1 percent with a demand ratio of 1.8. Table 6 - 7 displays the number of lockages associated with various levels of reliability.

Without additional water supplies, the hydrologic reliability of the Panama Canal system would decrease. With the construction of the proposed Rio Cocle del Norte project and Rio Indio project, the existing high hydrologic reliability could be continued as demand for lockages increases up to 65 percent (25.07 lockages) above current demands for Option 1 and 59 percent (22.87 lockages) above current demands for Option 2.

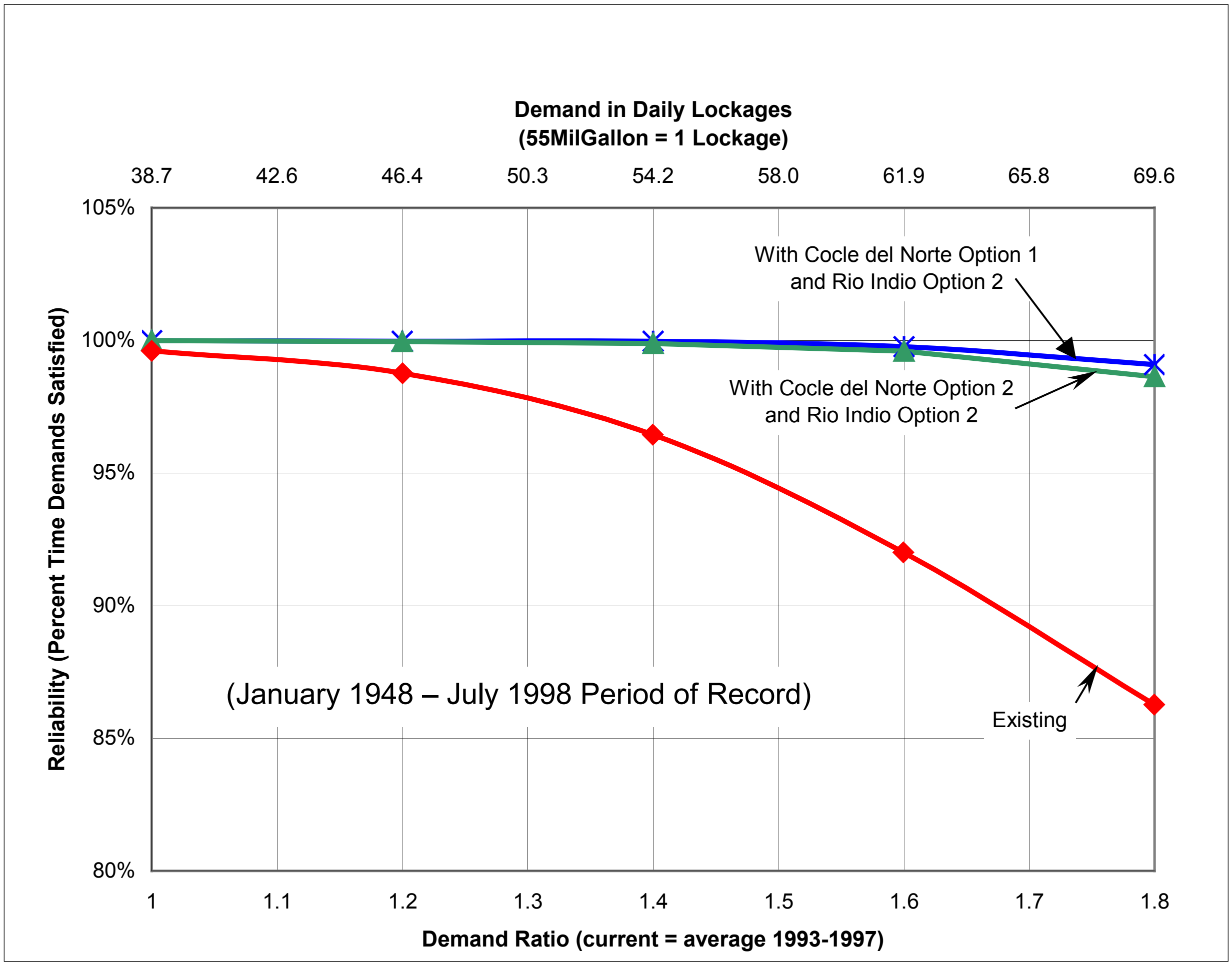


Figure 6 - 4   Panama Canal Hydrologic Reliability

Project Costs

GENERAL

The quantities estimated for the principal features required in the construction of this proposed project were derived from the layouts described previously. The unit prices applied to these quantities were 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, information gathered from Mobile District Construction Division personnel in the Republic of Panama, and the publication, Feasibility Studies For Small Scale Hydropower Additions, A Guide Manual, prepared by the Hydrologic Engineering Center, U.S. Army Corps of Engineers, 1979.

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

FIRST COSTS

The project first costs are estimated to be $501,018,000. Table 6 - 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 6 - 4 Summary of Project First Costs

Principal Feature	Costs ($)
Lands and Relocations	54,100,000
Access Roads	10,930,000
Clearing and / or Grubbing	6,816,250
Inter-basin Transfer Tunnels [1/]	164,477,573
Cofferdam	3,524,000
Concrete Dam	59,149,000
Channel	415,000
Spillway Gates and Operating Machinery	2,380,000
Hydropower Plants	24,514,205
Transmission Lines	7,700,000
Switchyard	5,825
Subtotal	334,011,853
E&D, S&A, Field Overhead	66,802,371
Contingencies	100,203,556
Project First Costs	501,017,780 **APPROXIMATELY** 501,018,000

[1/] The difference in costs to enlarge the inter-basin transfer tunnel connecting Indio Lake and the Panama Canal watershed from a 3 m finished diameter tunnel to a 6 m finished diameter tunnel are included.

OPERATION AND MAINTENANCE

Staff

A staff would operate and maintain the proposed Rio Cocle del Norte project during the day and then run the facility remotely. The full-time staff would ultimately consist of a total force of 11 who would include a station manager, a multi-skilled supervisor, 3 leaders (Electronics / Instrumentation, Electrical and Mechanical), 5 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 $500,000.

Ordinary Maintenance

Ordinary maintenance and care would be required and would include minor repair materials, lubricants and other supplies needed by the project staff. It is estimated that the costs of ordinary maintenance would be $20,000 per year for the access road and $300,000 per year for the main project facilities.

Major Replacements

The average service life of gates, electrical equipment, turbines, trash racks and other features would be less than the total useful life of the proposed project, which would be 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 would cost the same as at present. No allowance was made for salvageable fixed parts. Table 6 - 5 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 $861,000 and the average annual replacement costs would be $104,000.

Table 6 - 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	14,190,000	49,000
Bridges	50	1	1,125,000	3,900
Spillway Gates and Machinery				
Tainter Gates and Machinery	50	1	2,070,000	7,200
Sluice Gates and Machinery	50	1	1,500,000	5,200
Intakes				
Head Gates	50	1	464,100	1,606
Stoplogs	50	1	418,200	1,447
Trashracks	50	1	133,500	462
Access Stairs	50	1	18,750	65
Hydropower Plant				
Turbines and Generators	33	1	24,750,000	588,000
Trashracks	50	1	100,988	349
Slide Gates	50	1	75,000	260
Stoplogs	50	1	314,070	1,087
Station Electrical Equipment	33	1	3,225,000	76,619
Switchyard Equipment	33	1	2,625,000	62,364
Miscellaneous Plant Equipment	33	1	975,000	23,164
Transmission Lines	50	1	11,550,000	39,965
Total			63,534,608	861,000
Average Annual Replacement Costs				104,000

Annual Costs

The project first costs for the proposed Rio Cocle del Norte project are estimated to be $501,018,000, and it includes $58,396,000 to enlarge the inter-basin transfer tunnel between Indio Lake and the Panama Canal watershed from a 3 m finished diameter tunnel to a 6 m finished diameter tunnel. The total project first costs including the $245,868,000 costs for the Rio Indio project (see Section 5) are estimated to be $746,886,000. These total project first costs were distributed across the development period using generalized curves for contractor earnings for large, heavy construction jobs. It was assumed that the 6 m finished diameter inter-basin transfer tunnel from Indio Lake to the Panama Canal watershed would be constructed at the Rio Indio project instead of the 3 m finished diameter inter-basin transfer tunnel. Interest on the total project first costs of $442,622,000 ($501,018,000 - $58,396,000) was computed from mid-year throughout the 12-year development period from initiation of Planning and Design until the lake was filled. Interest during construction for the Rio Indio project including the enlarged inter-basin transfer tunnel at the Rio Indio project was computed from mid-year throughout its 18-year development period until lake filling was complete at the Rio Cocle del Norte project. The interest during construction at 12 percent would be $374,340,000 for Rio Cocle del Norte, and $841,388,000 for Rio Indio for a total interest during construction of $1,215,728,000. These costs were added to the total project first costs for total project investment costs of $1,962,614,000. A capital recovery factor for the 50-year planning period was applied to get the annual average investment costs of $236,331,000. Annual operation and maintenance costs were added. Major replacement costs are estimated and were 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 6 - 6 contains a summary of the $238,382,000 total annual costs.

Table 6 - 6 Summary of Annual Costs

Item	Costs ($)
Total Project First Costs – Rio Cocle del Norte	442,622,000
Total Project First Costs – Rio Indio	245,868,000
Enlarged Tunnel at Rio Indio project	58,396,400
Interest During Construction – Rio Cocle del Norte	374,340,000
Interest During Construction – Rio Indio	841,388,000
Total Project Investment Costs	1,962,614,000
Annual Average Investment Costs	236,331,000
Operation and Maintenance Costs	
Staff Costs – Rio Cocle del Norte	500,000
Staff Costs – Rio Indio	500,000
Ordinary Maintenance Costs – Rio Cocle del Norte	320,000
Ordinary Maintenance Costs – Rio Indio	320,000
Major Replacement Costs – Rio Cocle del Norte	104,000
Major Replacement Costs – Rio Indio	307,000
Total Average Annual Costs	238,382,000

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 Rio Cocle del Norte project. The 50-year planning period for this proposal is 2019 to 2069.

The proposed Rio Cocle del Norte project would increase the reliability of providing water to accommodate the total daily number of lockages demanded. Table 6 - 7 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 were obtained from the data used to develop Figure 6 - 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 6 - 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 Rio Cocle del Norte Operating Option 1 [1/] (%)	With Rio Cocle del Norte Operating Option 2 [2/] (%)
1	2000	38.68 [3/]	99.60	100.00	100.00
	2010	45.11	98.91	99.98	99.97
1.2		46.42	98.76	99.97	99.96
	2015	46.82	98.64	99.97	99.96
	2020	47.61	98.41	99.97	99.95
	2025	48.52	98.14	99.97	99.94
	2030	49.55	97.83	99.97	99.93
	2035	50.72	97.48	99.97	99.92
	2040	52.02	97.10	99.97	99.90
	2045	53.49	96.65	99.97	99.89
1.4		54.15	96.45	99.97	99.88
	2050	55.13	95.89	99.94	99.85
	2055	56.98	94.83	99.89	99.78
	2060	59.05	93.65	99.84	99.70
	2065	61.37	92.32	99.78	99.62
1.6		61.89	92.02	99.76	99.60
	2070	63.97	90.47	99.58	99.34
1.8		69.63	86.27	99.09	98.64

[1/] Includes Rio Cocle del Norte Operating Option 1 (the lake fluctuates from the normal operating lake level at elevation 65 m MSL down to the minimum operating lake level at elevation 50 m MSL) and Rio Indio Operating Option 2 (the lake fluctuates from the normal operating lake level at elevation 80 m MSL down to the minimum operating lake level at elevation 50 m MSL).

[2/] Includes Rio Cocle del Norte Operating Option 2 (the lake fluctuates from the normal operating lake level at elevation 60 m MSL down to the minimum operating lake level at elevation 50 m MSL) and Rio Indio Operating Option 2 (the lake fluctuates from the normal operating lake level at elevation 80 m MSL down to the minimum operating lake level at elevation 50 m MSL).

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

Regardless of the operating option, water supply shortages for navigation would continue. The demand for the M&I purposes will always be met first. As these demands grow, the amount of water available to meet the demands for navigation will decrease. Thus, the benefits for the additional water supply are estimated at the value for navigation. With Operating Option 1, there would be no water supply shortages for navigation. With the addition of the proposed Rio

Cocle del Norte project, all demands for water supply for navigation would be met over the planning period. With Operating Option 2, there would be a small shortage beginning at approximately year 2065. With a hydrologic reliability of 99.6 percent, Operating Option 1 would increase the amount of water supplied by approximately 25.07 equivalent lockages and Operating Option 2 would increase the amount by approximately 22.87 equivalent lockages. For Operating Option 1, the 99.6 percent hydrologic reliability would occur about the year 2070 with an equivalent daily average number of lockages of 63.76. For Operating Option 2, the 99.6 percent hydrologic reliability would occur about the year 2065 with an equivalent daily average number of lockages of 61.55. 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 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 $215,877,000 for Operating Option 1 and $215,852,000 for Operating Option 2. Table 6 - 8 provides the estimate of daily shortages under the existing system, the remaining daily shortages with the proposed Rio Cocle del Norte project in operation, the annual benefits for meeting shortages, and the average annual benefits for each option.

Table 6 - 8 Benefits for Additional Water Supply for Navigation

Year	Daily Shortages In Lockages Under Existing System	Remaining Daily Shortages WithOperating Option 1	Remaining Daily Shortages WithOperating Option 2	Annual Benefits for Operating Option 1 ($)	Annual Benefits For Operating Option 2 ($)
2019	8.77	0	0	180,856,000	180,856,000
2030	10.87	0	0	224,201,000	224,201,000
2040	13.34	0	0	275,147,000	275,147,000
2050	16.45	0	0	339,266,000	339,266,000
2060	20.37	0	0	419,966,000	419,966,000
2069	24.77	0.00	1.90	510,794,000	471,602,000
Average Annual Benefits				215,877,000	215,852,000
Option 1 will provide a total of 63.76 equivalent lockages at the 99.6 percent level of reliability or 25.07 more lockages than the existing system. Option 2 will provide a total of 61.55 equivalent lockages at the 99.6 percent level of reliability or 22.87 more lockages than the existing system.					

With either operating option, 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 Rio Cocle del Norte project would be $16,754,000 for Operating Option 1 and $16,439,000 for Operating Option 2. Table 6 - 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 for each operating option.

Table 6 - 9 Average Annual Reliability Benefits for Navigation

Year	Daily Average Number of Lockages	Value Per Lockage ($)	Annual Benefits For Navigation Operating Option 1 ($)	Annual Benefits For Navigation Operating Option 2 ($)
2019	40.0	2,260,000	11,350,000	11,192,000
2030	40.0	2,260,000	17,673,000	17,327,000
2040	40.0	2,260,000	23,739,000	23,212,000
2050	40.0	2,260,000	33,392,000	32,623,000
2060	40.0	2,260,000	51,072,000	49,960,000
	40.0	2,260,000	72,455,000	70,583,000
Average Annual Benefits			16,754,000	16,439,000

M&I WATER SUPPLY

The future demand for water supply for M&I purposes was 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 was 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 Rio Cocle del Norte 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 would be $2,794,000 for Operating Option 1 and $2,739,000 for Operating Option 2. Table 6 - 10 displays the population forecast, the resulting number of equivalent lockages per day, the annual benefits for increased reliability, and the average annual benefits for M&I water supply.

Table 6 - 10 Average Annual Reliability Benefits for M&I Water Supply

Year	Population	Equivalent Lockages per Day	Annual M&I Water Supply Benefits for Operating Option 1 ($)	Annual M&I Water Supply Benefits for Operating Option 2 ($)
2019	2,096,600	7. 5	1,421,000	1,401,000
2030	2,688,000	9.6	2,839,000	2,783,000
2040	3,384,000	12.0	4,790,000	4,683,000
2050	4,259,000	15.1	8,481,000	8,286,000
2060	5,360,000	19.0	16,338,000	15,983,000
2069	6,599,400	23. 5	28,533,000	27,796,000
Average Annual Benefits			2,794,000	2,739,000

HYDROPOWER

The amount of hydropower energy that could be produced by the system of Gatun Lake and Madden Lake would decline over time as the demands for navigation and M&I water supply increase. With the inclusion of the proposed Rio Cocle del Norte project, the system could produce net additional megawatt hours of hydropower. The value for hydropower energy used in this analysis was $0.070 / kWh. On an average annual basis, Operating Option 1 would have benefits of $27,896,000 and Operating Option 2 would have benefits of $26,927,000. Table 6 - 11 provides the net additional megawatt hours of hydropower generation and the resulting benefits.

Table 6 - 11 Average Annual Benefits for Hydropower Generation

Year	Net Generation for Operating Option 1 [1/] (MWh)	Net Generation for Operating Option 2 [1/] (MWh)	Annual Hydropower Benefits for Operating Option 1 ($)	Annual Hydropower Benefits for Operating Option 2 ($)
2019	401,914	387,886	28,134,000	27,152,000
2030	398,002	384,116	27,860,000	26,888,000
2040	393,398	379,686	27,538,000	26,578,000
2050	386,403	373,582	27,048,000	26,151,000
2060	374,313	364,446	26,202,000	25,511,000
2069	359,243	350,686	25,147,000	24,548,000
Average Annual Benefits			27,896,000	26,927,000

[1/] Net generation of Gatun, Madden, Indio, and Cocle del Norte hydropower plants above generation of Gatun and Madden hydropower plants.

SUMMARY OF ANNUAL BENEFITS

As shown in Table 6 - 12, total average annual benefits for Operating Option 1 and Operating Option 2 of the proposed Rio Cocle del Norte project would be $268,489,000 and $267,083,000, respectively.

Table 6 - 12 Summary of Annual Benefits

Benefit Category	Average Annual Benefits	
	Operating Option 1 ($)	Operating Option 2 ($)
Navigation – Water Supply	215,877,000	215,852,000
Navigation – Reliability	16,754,000	16,439,000
M&I - Reliability	2,794,000	2,739,000
Hydropower	27,896,000	26,927,000
Total	263,321,000	261,957,000

To perform an analysis of benefits versus costs, a common point in time was selected. This common point was at the completion of the filling of the proposed Rio Cocle del Norte project, the end of the year 2018. In these analyses, it was important to note that the average annual benefits or average annual costs were 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 Rio Cocle del Norte would be to develop the Rio Indio project first (2001 – 2010) and then the Rio Cocle del Norte project second (2007 – 2018).

The benefits attributable to the proposed Rio Indio project would begin to accrue in 2010 when that reservoir is filled. Thus, the Rio Indio project benefits for the period 2010 to 2018 were escalated by the project discount rate, 12 percent, in order to estimate their total present worth of $2,653,688,000 in the year 2019. The average annual benefits for the proposed Rio Indio project that accrue during the construction of the proposed Rio Cocle del Norte project are estimated to be $319,548,000. The benefits for the proposed Rio Cocle del Norte project are estimated with the assumption that the Rio Indio project would use its Operating Option 2. Although the discharge tunnel would be larger, the proposed Rio Indio project would be operated for the period 2010 through 2018 just as if the proposed Rio Cocle del Norte project was not to be constructed.

To estimate the interest during construction, similar calculations were made for the costs of each proposed project. For the proposed Rio Indio project, interest during construction was taken from year 2001 to year 2018 and the interest during construction for the proposed Rio Cocle del Norte project was taken from the year 2007 to the year 2018. Additionally, there would be added costs for the larger inter-basin transfer tunnel between Indio Lake and the Panama Canal watershed that would only be required if the proposed Rio Cocle del Norte project were to be constructed. Those amounts were subtracted from the cost estimate for the proposed Rio Cocle del Norte project and added to the cost estimate for the proposed Rio Indio project. The revised estimated average annual costs for the Rio Indio portion of the overall project would be $139,083,000.

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) were computed. In the first instance, the analysis determines the feasibility of the proposal. The net benefits determines which proposal among several provides the greatest value for the investment dollars. While there would be some differences in project features between Operating Option 1 and Operating Option 2 for the Rio Cocle del Norte project, the differences would only have minimal impact on total project first costs at this level of investigation. Table 6 - 13 provides the benefit to cost ratios for Operating Option 1 and Operating Option 2 and the net benefits for both.

Table 6 - 13 Economic Evaluation

Item	Operating Option 1 ($)	Operating Option 2 ($)
Average Annual Benefits		
Rio Indio	319,548,000	319,548,000
Rio Cocle del Norte	215,877,000	215,852,000
Sum	582,869,000	581,505,000
Average Annual Costs		
Rio Indio	139,083,000	139,083,000
Rio Cocle del Norte	99,300,000	99,300,000
Sum	238,383,000	238,383,000
Benefit to Cost Ratio	2.4	2.4
Net Benefits	344,486,000	343,122,000

Internal Rate of Return

An internal rate of return analysis for each operating Option was performed. To accomplish this analysis, the annual construction costs were used as the investment, and the undiscounted benefits were used as return cash flows. For Operating Option 1, the internal rate of return would be 21.5 percent. For Operating Option 2, the internal rate of return would be 21.5 percent.

Incremental Evaluation of Hydropower

Since the generation of hydropower would be provided through the conjunctive use of storage, an analysis of the incremental benefits and costs for this purpose was accomplished. The first costs of the Lands and Relocations and the Clearing and / or Grubbing, which were associated with hydropower, as well as the costs of the Hydropower Plants and the Transmission Lines were taken from Table 6 - 4. The portion of annual operation and maintenance costs associated with hydropower generation were derived from the data included in Table 6 - 6. The construction costs are estimated to be approximately $48,433,000. Interest during a two-year construction period is estimated to be $5,899,000 for a total hydropower investment costs of $54,332,000. The portion of annual operation and maintenance costs for hydropower were assumed to be $350,000 for staff, $250,000 for ordinary maintenance, and $95,000 for major replacement. The total average annual costs for hydropower would be $7,238,000. The average annual benefits are estimated to range between $27,896,000 and $26,927,000. The average annual benefits exceed the average annual costs for both Operating Option 1 and Operating Option 2 yielding benefit to cost ratios of 3.9 and 3.7, respectively. Operating Option 1 has greater net benefits and would thus be preferred to Operating Option 2. It should be noted, however, that hydropower was valued at the current costs of production of the PCC. This value might underestimate the economic value of any additional hydropower generating capacity. Additional effort should be expended in any future planning studies to determine the economic value of added hydroelectric power generation.

Socio-Economic Impacts

The socio-economic impacts of the project could be substantial. The relocation of the towns of Coclesito, Cutevilla, Boca de La Encantada, El Calabazo, Platanal, Molejon, and La Boca del Guasimo and their approximately 5,600 residents would be an important issue. The average monthly income of families in the project area is $100 per month. No indigenous groups of peoples are known to reside in the impact area. Land use would be greatly impacted by the inundation of pastures and agricultural lands to create the Cocle del Norte Lake. The relocation of agricultural and ranching activities would be a substantial issue, because approximately 40 percent of the impoundment area is used for farming and ranching. The impoundment area would substantially impact the mineral and ore resources. The surface area of the proposed lake will encompass 20,900 ha with another 800 ha for the dam and construction areas including permanent disposal areas.

Post-construction revenues generated for the nation would be greater, because the project will create electric power generating potential. On a per hectare basis, revenues from the power generation would be greater than those produced by the current agricultural activity. It is estimated that after construction, 11 persons would be employed to operate and maintain the new facilities. During construction, the housing values in the areas adjacent to the dam site would increase, because there could be a higher demand by workers for livable homes. However, after project completion as the workers leave the area and housing demands decline, the housing values would drop 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 more public and community services may be offered to the local communities. After construction, these services should remain at the normal level.

To construct the dam, some existing roads would be improved and some new roads would be built. However, the dirt roads within the impoundment would be eliminated, which would change the 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 road systems would increase; however following cessation of construction, the traffic volumes would decline. Noise levels would increase during construction and could negatively impact noise-sensitive receptors, however, after construction, noise levels should return to pre-construction levels.

The communities that will receive the displaced people 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 through the division of communities, separation of families, and loss of livelihood. Following completion of the impoundment, tourism trade in the affected area, including fishing and ecotourism, could increase.

Environmental Setting

The Rio Cocle del Norte project will produce hydroelectric power and provide for 25.07 additional lockages per day on a continual basis. The structures for this proposed project would consist of a mass concrete gravity dam with a gated spillway, inter-basin transfer facilities, and a hydropower plant. The project encompasses the area to be flooded as well as the area downstream from the dam site. This area is sparsely populated. It is mountainous, has low coastal regions, and has primary forests. The Rio Cocle del Norte is located west of the Panama Canal, is used for navigation, and flows northward from the Continental Divide into the Atlantic Ocean. The Rio Cocle del Norte watershed above the dam is approximately 1,600 km^2. The impoundment area covers approximately 20,900 ha and consists of approximately 30 percent of forested land, 20 percent of pasture land (used by ranchers), 20 percent of cropland, 25 percent of newly slashed and burned land, and 5 percent of mining land. The lake water elevation will fluctuate from elevation 50 to 69 m MSL. The transmission lines, tunnel portals, and roads associated with the project could also have environmental impacts and should be sited to minimize those impacts.

LAND USE

The Rio Cocle del Norte project area encompasses the area to be flooded as well as the area downstream from the dam site. It is inhabited by about 5,600 people, dispersed throughout the area, with concentrations in the towns of Coclesito (population – 1,150), Cutevilla (population – 300), Boca de La Encantada (population – 250), El Calabazo (population – 250), Platanal (population – 230), Molejon (population –220) and La Boca del Guasimo (population – 220) and approximately 50 smaller settlements. Approximately 800 people live in eight communities downstream from the dam site at Cerro Pelado. The largest of these is Cocle del Norte with more than 300 people. San Lucas and Cocle del Norte are downstream towns, which should not be flooded.

Approximately 40 percent of the land in the project area is occupied by farms and ranches of various sizes. Farm crops include mandioc, maize, rice, beans, sugar, coffee, and tobacco. Ranchers raise cows, horses, chickens, and hogs. Some of the farmers and ranchers run small commercial enterprises, and there is also some cash crop and subsistence farming. There are also mineral and ore resources in the impoundment area.

INFRASTRUCTURE

The towns of El Calabazo and Platanal have 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 the Rio Cocle del Norte and its tributaries. Disposal of domestic waste is the responsibility of individual homeowners: each home has an outdoor latrine (a deep hole in the ground). There are some known health problems, such as hepatitis, dysentery, dermatitis, intestinal parasites, and respiratory illnesses associated with the present waste disposal methods. No major industries or poultry or beef processing plants are located in the project area. The roads in the project area are poorly maintained dirt roads that are usable only in the dry season (mid-December through March). The roads are rarely graded and receive little attention by either the Ministry of Public Works or the local government. There are a limited number of paved roads around Coclesito. 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. People living in the Cocle del Norte project area use the river as their primary means of transportation. The town of Cocle del Norte can only be reached by river from Coclesito or by sea from Colon.

The town of Coclesito supplies valuable services to many surrounding communities. Coclesito possesses schools, a hospital (with two resident doctors), a small diesel generating facility, and a museum honoring the late General Omar Torrijos, who is considered a national folk hero.

Coclesito has two elementary schools and one junior high school. The students of Coclesito and / or hospital patients come from Cocle del Norte, San Lucas, and other neighboring communities. The junior high school students stay in school dormitories during the week and return home for the weekend. The main road through Coclesito heads east to west and is gravel-packed. This road heads west to the Coclesito Bridge River that divides the town of Coclesito into northern and southern halves. Coclesito is connected by a gravel/dirt road to Llano Grande and from Llano Grande to La Pintada and Penonome by a paved road.

TERRESTRIAL HABITAT

Forests along the river that could support a diverse wildlife population cover about 90 percent of the area along the Rio Cocle del Norte and its tributaries. The forests extend to the upper mountainous areas above the Rio Cocle del Norte impoundment area. There are also some contiguous forests in the lowlands west of Coclesito within the Rio Cocle del Norte impoundment area.

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 it has not been determined, some of the listed species of the above list might be found in the project area.

AQUATIC HABITAT

The Rio Cocle del Norte in the project area displays traits characteristic of streams in mountainous regions. Its water is clear and cool, and the river bed ranges from sand to boulders, with numerous riffles, runs, and pools. The Rio Cocle del Norte has six major tributaries: Caño Rey, Rio San Lucas, Rio Toabre, Rio Cuatro Calles, Rio Don Juan, and Rio Cascajal; approximately 32 smaller creeks also flow into the Rio Cocle del Norte. The river is approximately 32 km long; its width ranges from 10 m (in the dry season) to 50 m at its mouth, and its depth ranges from less than 1 m to 25 m. The Rio Cocle del Norte and its tributaries appear to support some fish communities; however, information about fish communities that occur in the project area is limited.

WETLANDS

Areas that contain hydric soils and hydrophytic plant communities, and that are subject to hydrologic conditions are termed wetlands. The wetlands consist of forested riparian habitat along the immediate stream bank area. The width of the riparian habitat within the impoundment area varies from approximately 10 to 75 m. In the west portion of the impoundment area, the wetlands become part of the dense forest. Approximately 90 percent of the streams above and below the dam site are bordered by forested riparian habitat along the Rio Cocle del Norte and its tributaries.

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 and early April, sizable areas of established forests and secondary growth are cleared and burned to prepare the land for agricultural use. Based on observations in the Rio Cocle del Norte project area, the amount of land burned varies annually.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

The El Cope National Park covers over 25,000 ha in the highlands of the Rio Cocle del Norte impoundment area and is important for its avifauna. The late General Omar Torrijos owned a home in Coclesito, which is now a museum. There are also Pre-Columbian cultural resources that have been identified by archaeological surveys located in the Rio Cocle del Norte impoundment area. 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 impoundment area would be substantial, since the forest covers approximately 6,300 ha, or 30 percent of the impoundment area. The forested area constitutes a relatively high quality terrestrial habitat. With the creation of the lake, migratory routes of some species could be adversely affected. The only forests that would remain near the Cocle del Norte Lake and its drainage basin would be confined to the higher elevations.

ANIMALS ON ENDANGERED LIST

Potential impacts on species on the endangered list could have a significant effect on the Rio Cocle del Norte project. The extent of potential effects cannot be determined at this time, because it is not known which of the listed species occur within the proposed project area. Furthermore, the significance of the forested riparian corridor along the area streams may increase if animals on the endangered list are found in the region. The Mesoamerican Biological Corridor is also promoting biodiversity conservation throughout the Atlantic basin, which could impose restrictions on the use of the project area.

WATER QUANTITY

The impacts of the project on water quantity should be positive, because construction of the dam should result in a significant increase in the volume of fresh water in surrounding areas during the dry season. The impacts downstream from the dam site could be important, because water rates would be reduced. Further, measures should be taken to release water at appropriate periods and amounts to avoid problems with water quality and temperature downstream. The cumulative impacts downstream of the dam site over time should also be minor.

WATER QUALITY

The impacts of the project on water quality are unknown. The impacts downstream from the dam site could be positive. The water should contain less silt due to minimum normal flow and should provide people downstream higher quality water. It is unclear whether the proposed Cocle del Norte Lake will provide high quality water.

DOWNSTREAM AQUATIC FAUNAL HABITAT

The impacts on downstream aquatic fauna communities could be substantial, even though facilities would be included in the design of the dam to allow multi-level releases of water to avoid problems with water quality and temperature downstream. The Rio Cocle del Norte dam should act as a large sediment trap, which should cause the released water to have low turbidity; therefore, siltation should not be a problem. The impacts of interference with migratory movements of natural stream fishes are unknown. Streambed degradation below the dam should be minimal.

FUTURE LAKE AQUATIC PLANT COMMUNITY

The impacts of the project on future aquatic plant communities in the proposed lake will depend on water level fluctuations, which are anticipated to range from 50 to 100 m over a 3-month period. Since the water levels would fluctuate widely, much of the shore would be covered with mud, where neither aquatic nor terrestrial plant communities could thrive. Rooted aquatic plants tend to grow as deep as light penetration allows.

AQUATIC FAUNA INHABITING AFFECTED AREAS

The impacts of the project on aquatic fauna inhabiting the Rio Cocle del Norte and its upstream tributaries could be important. If aquatic fauna is able to thrive in the new reservoir, they would be beneficially affected by having their habitat enlarged. Some unavoidable, adverse environmental impacts could occur and these impacts should be identified and appropriate mitigation measures addressed in feasibility level studies, should the alternative be recommended for further consideration. The new reservoir could provide excellent opportunities for recreational and subsistence fishing if it is responsibly managed and stocked with game fish by the Aquaculture Department. An increase in fish population could cause an increase in piscivorous predators, such as crocodiles, caimans, otters, and herons, etc. Other manmade lakes in the Republic of Panama have been stocked with peacock bass and tilapia, both of which have adapted well, but several riverine native species that formerly occupied the impoundments have disappeared. Loss of native species may affect their predator populations (otter, birds, and fish eating mammals).

WETLANDS

The impacts to upstream and downstream wetlands could be significant. Owing to the topography of the project area, a number of wetlands could be impacted by the project. It is possible that although the reservoir water levels will fluctuate, new wetlands could develop in the littoral zones. Due to minimum normal flow, the cumulative effects downstream of the dam site are expected to be minor.

AIR QUALITY

During construction of the dam, dust and emissions from equipment could impact the air quality in the project area. After construction, the air quality could improve because the Panamanian government currently discourages slash and burn activities.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

The impacts on cultural resources and historic properties could be substantial. The project area is large and is known to contain cultural resources and historic properties; therefore, the presence of cultural resources and historic properties is high. 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.

Additional Environmental Information Required

This section identifies the subject areas for which additional data are required to evaluate the scope and magnitude of the potential effects in further detail of the Rio Cocle del Norte alternative. The subject areas are discussed by impact category. This section identifies the subject areas for which insufficient data are available to fully evaluate the scope and magnitude of the potential effects of the Rio Cocle del Norte alternative. The data gaps 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).
  - Community and Regional Growth.
  - Transportation.
  - Housing.
  - Health (vector routes).
  - Population.
  - Community Cohesion.
  - Recreational Resources.
  - Mineral Resources.

TERRESTRIAL AND AQUATIC HABITAT

- Prepare site-specific habitat maps to ensure that all major terrestrial and aquatic habitat types are identified and quantified.
- Conduct field studies to locate special habitat features such as wetlands, roosting sites, reproductive sites, and the relative quality of forested areas.

- Determine the present quality and ecosystem value of existing habitats within the Rio Cocle del Norte project area.

ANIMALS ON THE ENDANGERED LIST

- Compile habitat maps to assess the availability and quality of suitable habitats for the animals on the endangered list.
- Conduct site surveys to determine the presence of selected species.
- Develop candidate mitigation measures for the appropriate project alternatives to be considered in the Conceptual Phase.
- Obtain other wildlife reports produced for the Rio Cocle del Norte project area.

WATER QUALITY

- As there are no water quality data available for the Rio Cocle del Norte 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 is incomplete. Additional evaluation studies need to be completed to identify cultural resources and historic 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 Section 35. Tables 6 - 14 through 6 - 16 present the evaluation of the proposed Rio Cocle del Norte project as related to developmental effects, environmental effects, and socio-economic effects.

Table 6 - 14 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	6	10	60
	Additional Hydropower Potential	10	5	50
Technical Viability	Design Constraints	3	6	18
	Feasibility of Concept	5	6	30
Operational Issues	Compatibility	4	6	24
	Maintenance Requirements	6	2	12
	Operational resources required	6	2	12
Economic feasibility	Net Benefits	10	9	90
	Total			496

[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 6 - 15 Environmental Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Terrestrial Habitat	2	8	16
Animals on Extinction List	1	10	10
Water Quantity Impacts – Lake	6	10	60
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			345

[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 6 - 16 Socio-Economic Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Land Use	1	7	7
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			302

[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 6 - 17 presents pertinent data for proposed Rio Cocle del Norte dam.

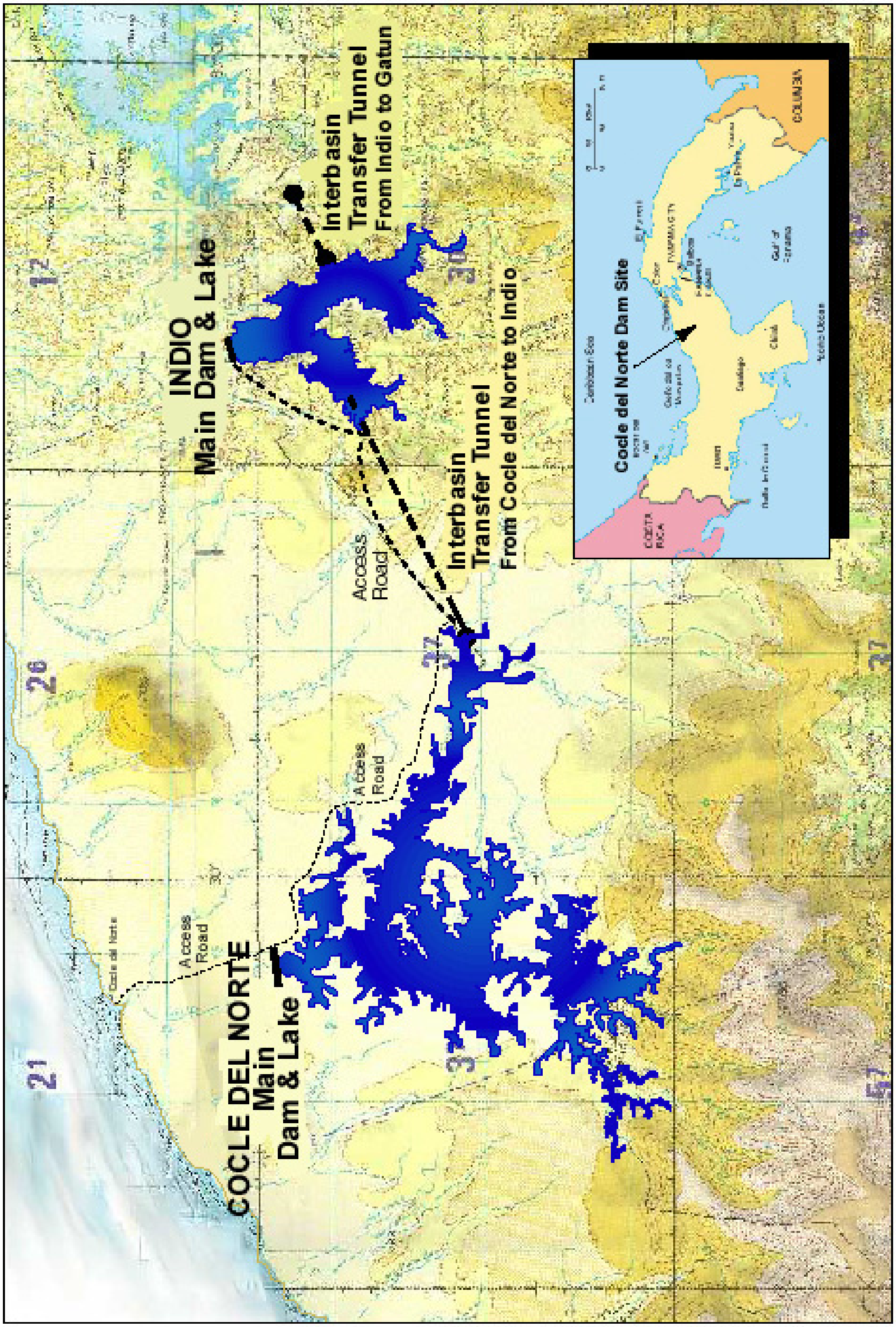
Table 6 - 17 Pertinent Data for Operating Option 1

GENERAL	
Dam site, above mouth of Rio Cocle del Norte	15 km
Drainage area above dam site	1,600 km^2
RESERVOIR	
Elevation, top of flood storage lake	69 m MSL
Area at top of flood storage lake	20,090 ha
Top clearing elevation	70 m MSL
Lower clearing elevation	50 m MSL
Elevation of normal operating lake	65 m MSL
Elevation of minimum operating lake	50 m MSL
Useable Storage between Max. and Min. levels	2,093 MCM
Area at normal operating lake	17,940 ha
Area at minimum operating lake	10,730 ha

Table 6 - 17 Pertinent Data for Operating Option 1 (continued)

DAM AND APPURTENANT STRUCTURES	
Dam	
Type of dam	Concrete Gravity
Top elevation of dam (nominal)	70 m
Overall length of dam	391 m
Height above lowest foundation	65.0 m
Crest width (nominal)	9 m
Volume of concrete dam (including spillway)	638,300 M^3
SPILLWAY	
Type of Spillway	Gated ogee with flip bucket
No. / Type Spillway gates	2 / vertical operating Tainter
Spillway gate dimensions	17 m wide x 15.5 m high
Total length at flow surface	34 m
Elevation of crest	50 m MSL
Maximum discharge	5,346 CMS
Width of piers	4 m
INTER-BASIN TRANSFER TUNNEL	
Rio Cocle del Norte to Rio Indio:	
Tunnel length	18.1 km
Tunnel diameter	7.6 m
Tunnel capacity at maximum head	134 CMS
Inlet invert	40 m MSL
Outlet invert	35 m MSL
Rio Indio to Gatun Lake:	
Tunnel length	5.5 km (+/-)
Tunnel diameter	5 m
Tunnel capacity at maximum head	216 CMS
Inlet invert	40 m MSL
Outlet invert	38 m MSL
HYDROPOWER PLANT	
Type of hydropower plant construction	Reinforced concrete, outdoor
Number of units	4
Capacity of each unit	17 MW
Type hydraulic turbine	Vertical Francis

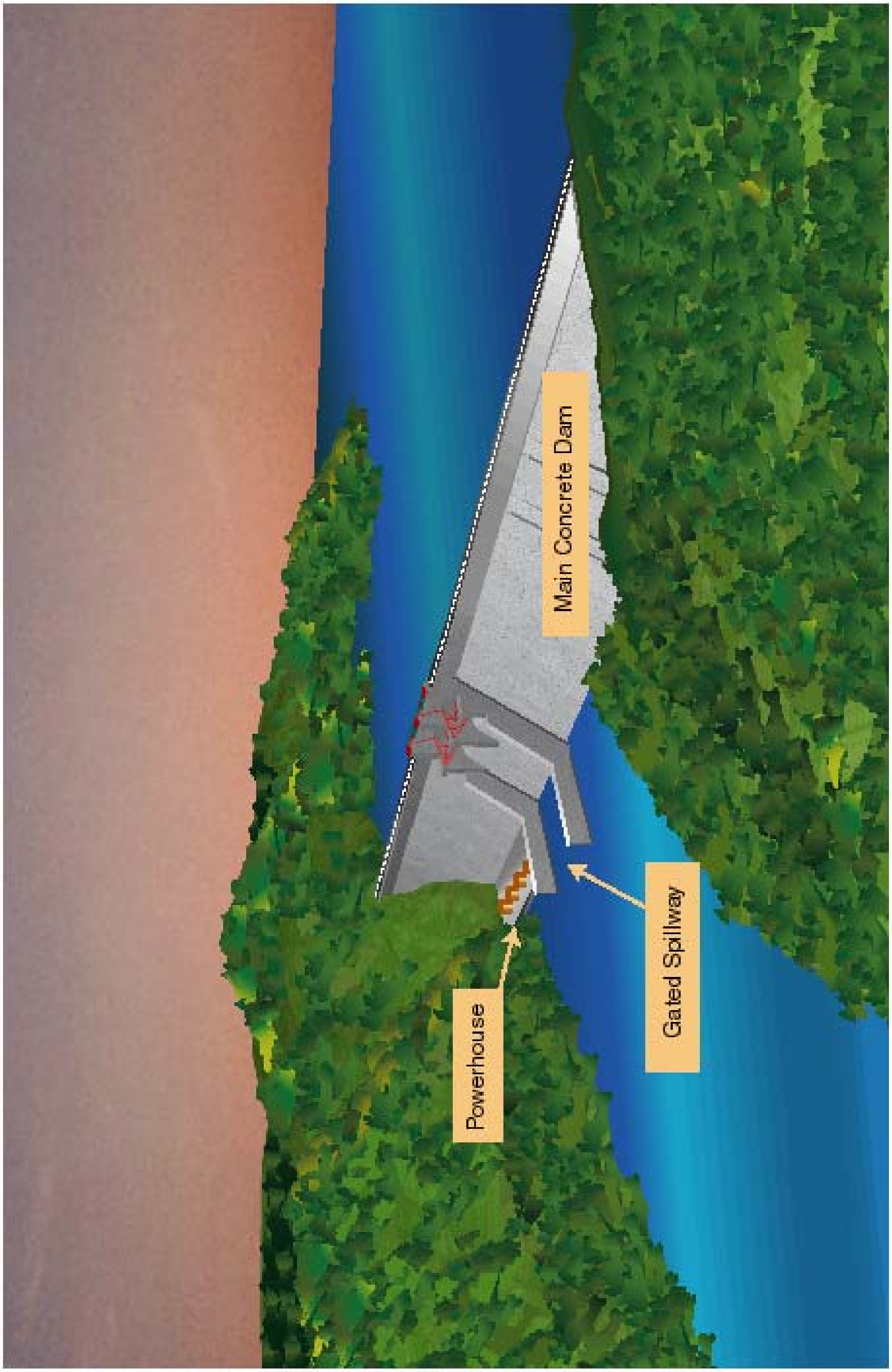
COCLE DEL NORTE (Lake - 65 m)



Project Location Map

Plate 6 - 1 Project Location Map

COCLE DEL NORTE (Lake - 65m)



Site Plan

Plate 6 - 2 Site Plan

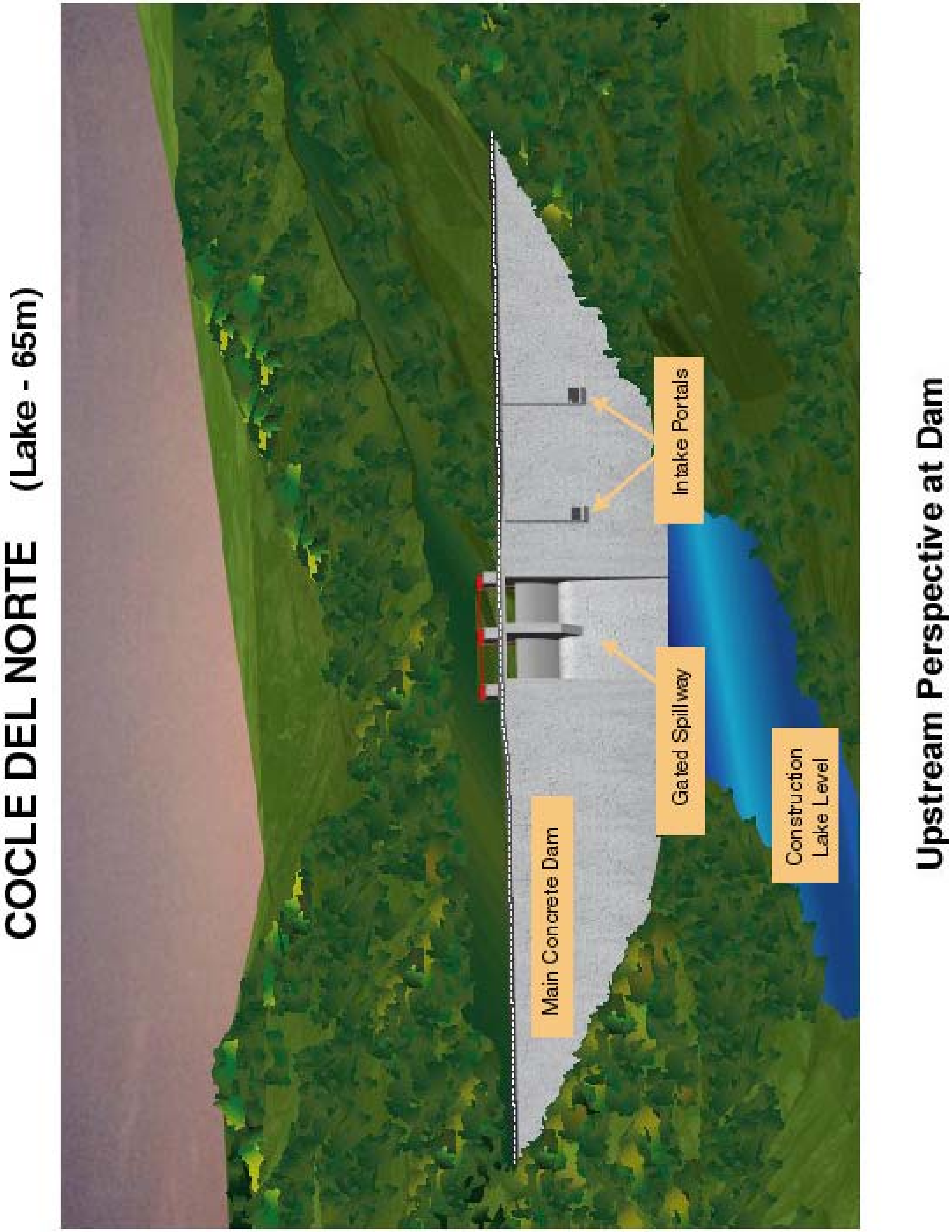


Plate 6 - 3 Upstream Perspective at Dam

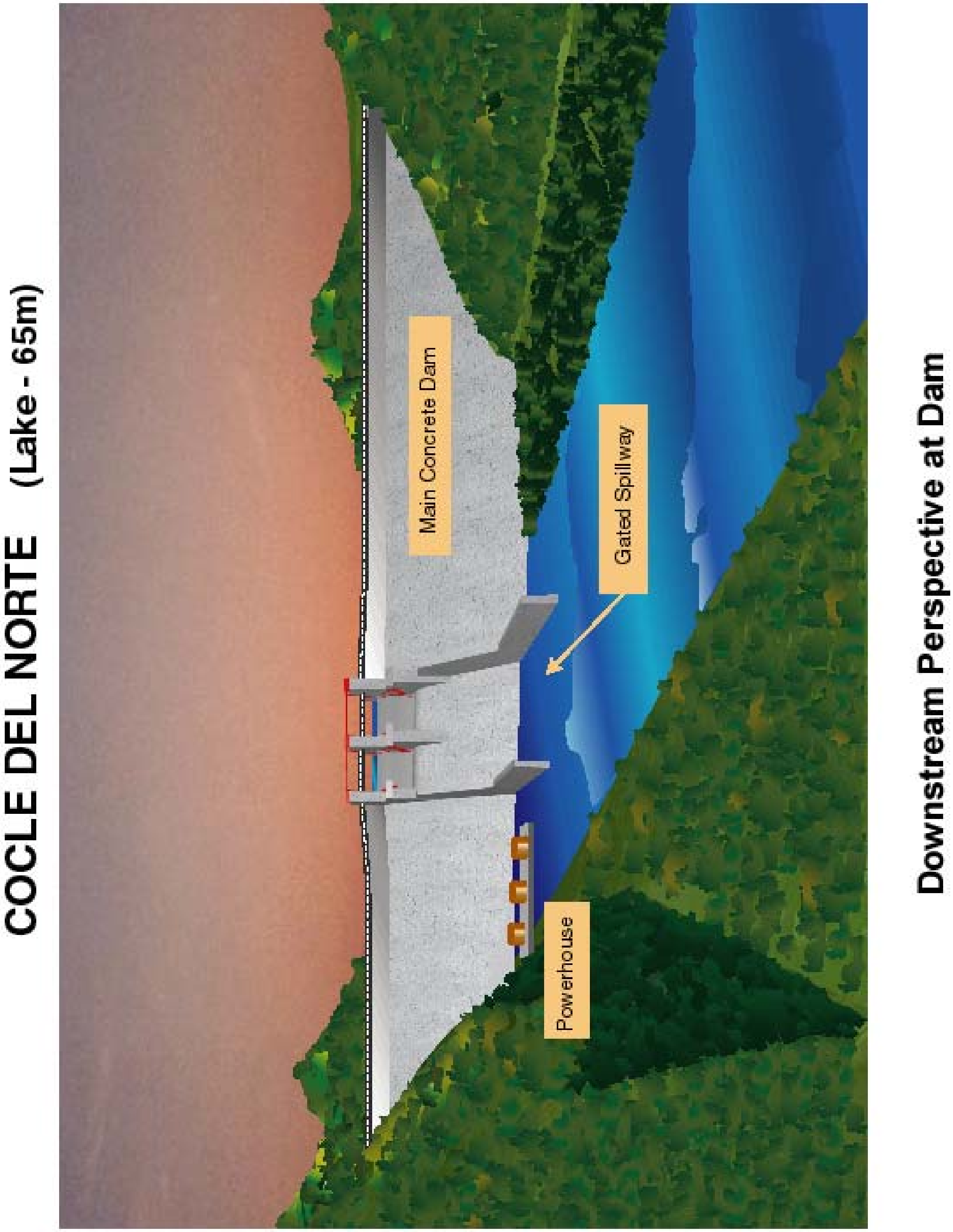


Plate 6 - 4 Downstream Perspective at Dam

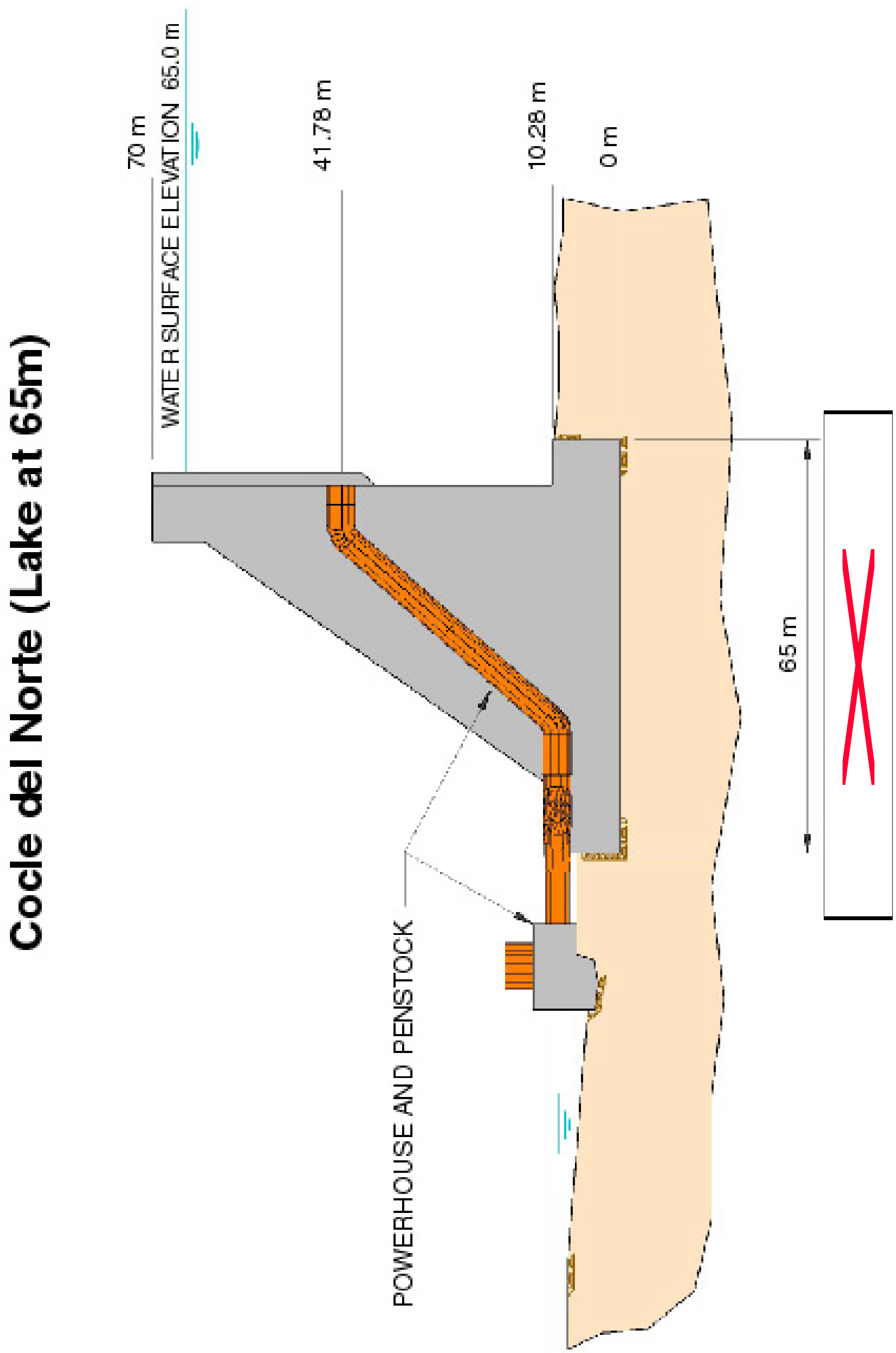


Plate 6 - 5 Typical Section at Powerhouse

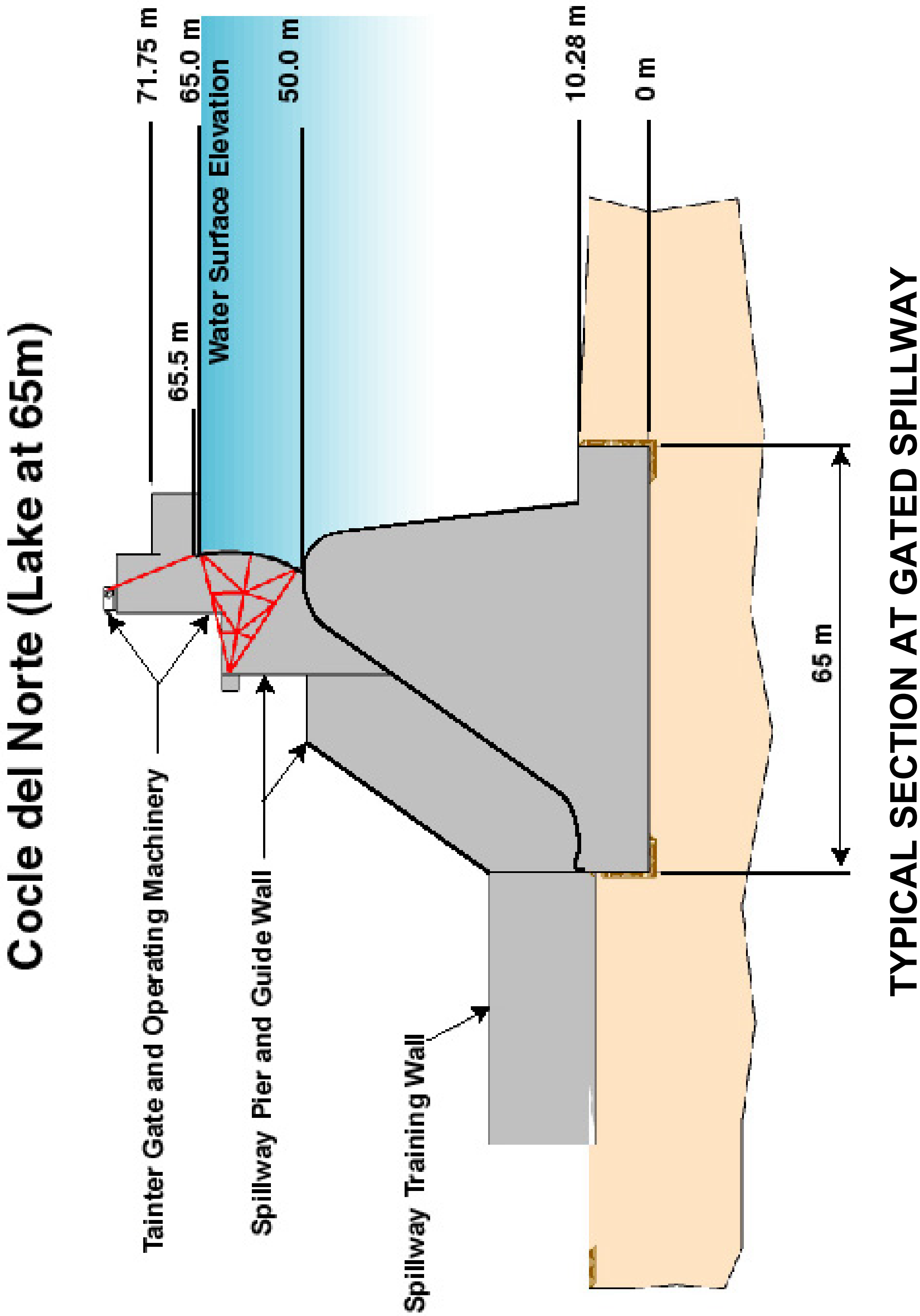
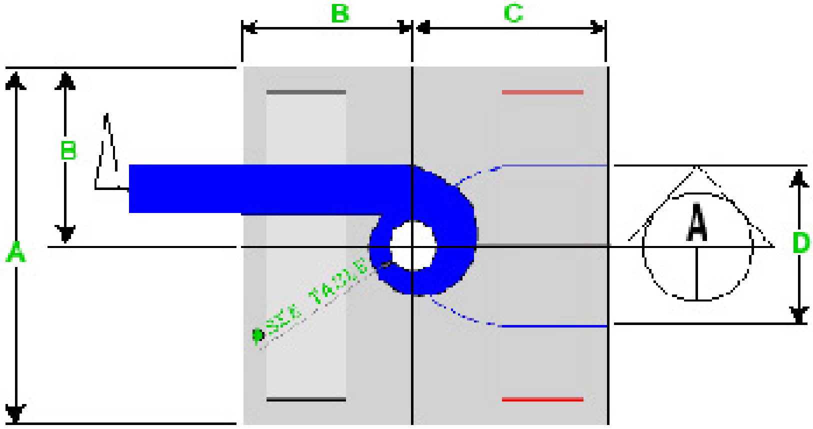
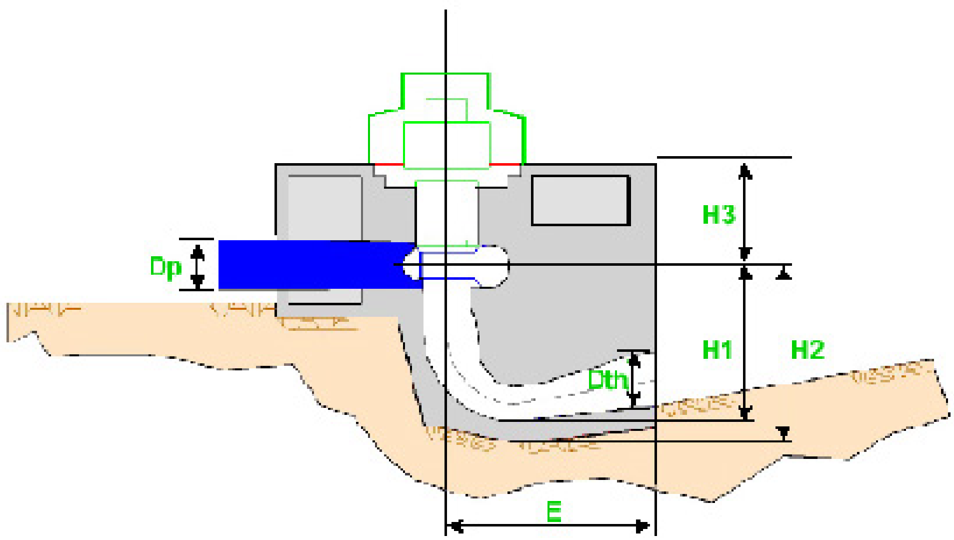


Plate 6 - 6 Typical Section at Gated Spillway

Cocle del Norte (Lake at 65m)



PLAN
NOT TO SCALE



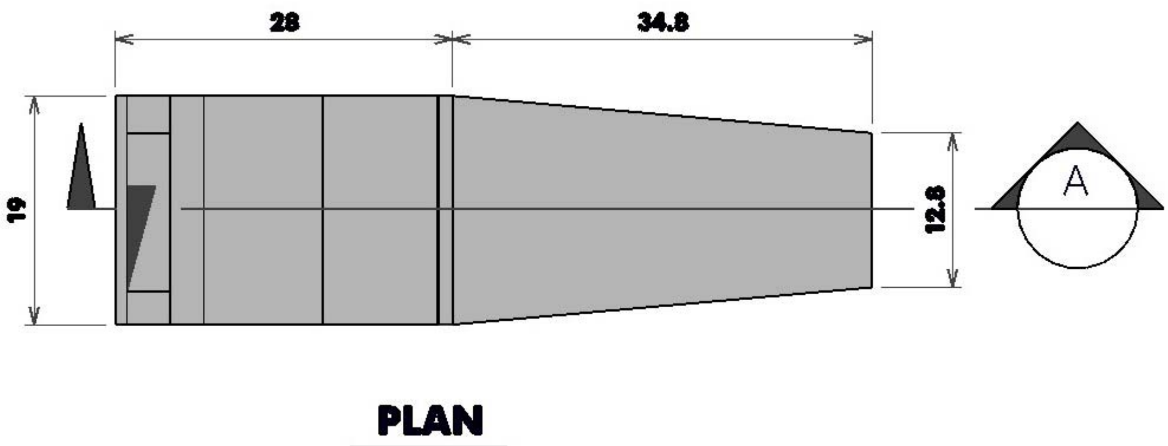
SECTION
NOT TO SCALE

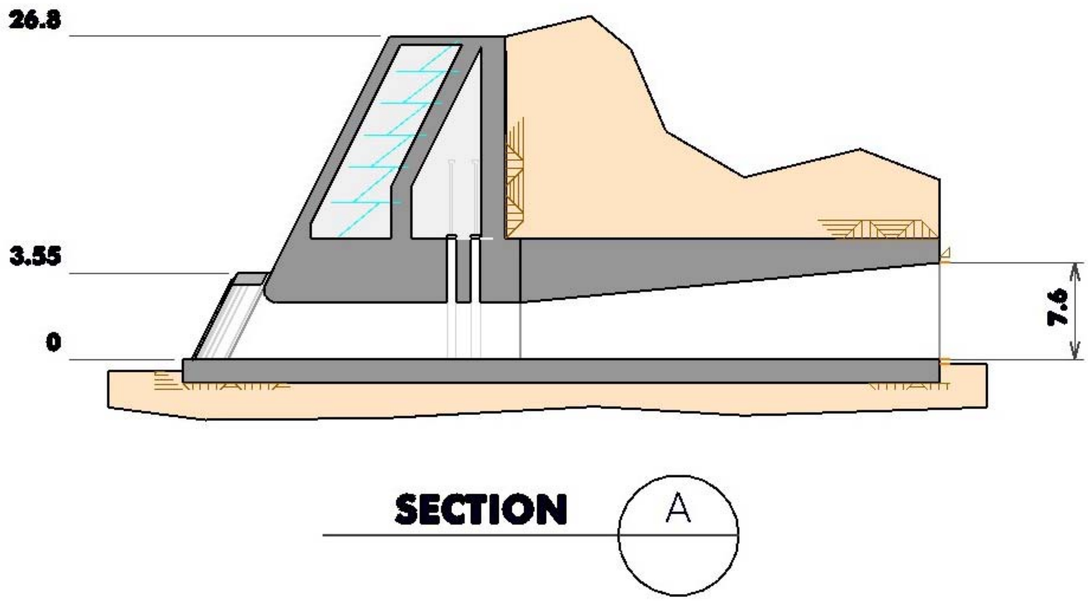
COCLE DEL NORTE DAM POWER FACILITIES

UNIT	Dth	A	B	C	D	E	Dp	H1	H2	H3
1	2.29	12.95	5.33	9.14	7.32	9.14	3.44	6.4	7.01	2.44
2	2.29	12.95	5.33	9.14	7.32	9.14	3.44	6.4	7.01	2.44
3	2.29	12.95	5.33	9.14	7.32	9.14	3.44	6.4	7.01	2.44
4	2.29	12.95	5.33	9.14	7.32	9.14	3.44	6.4	7.01	2.44

Plate 6 - 7 Hydropower Plant Details

RIO COCLE DEL NORTE (Lake at 65 m)





Stoplog / Gate Structure

Plate 6 - 8 Stoplog / Gate Structure

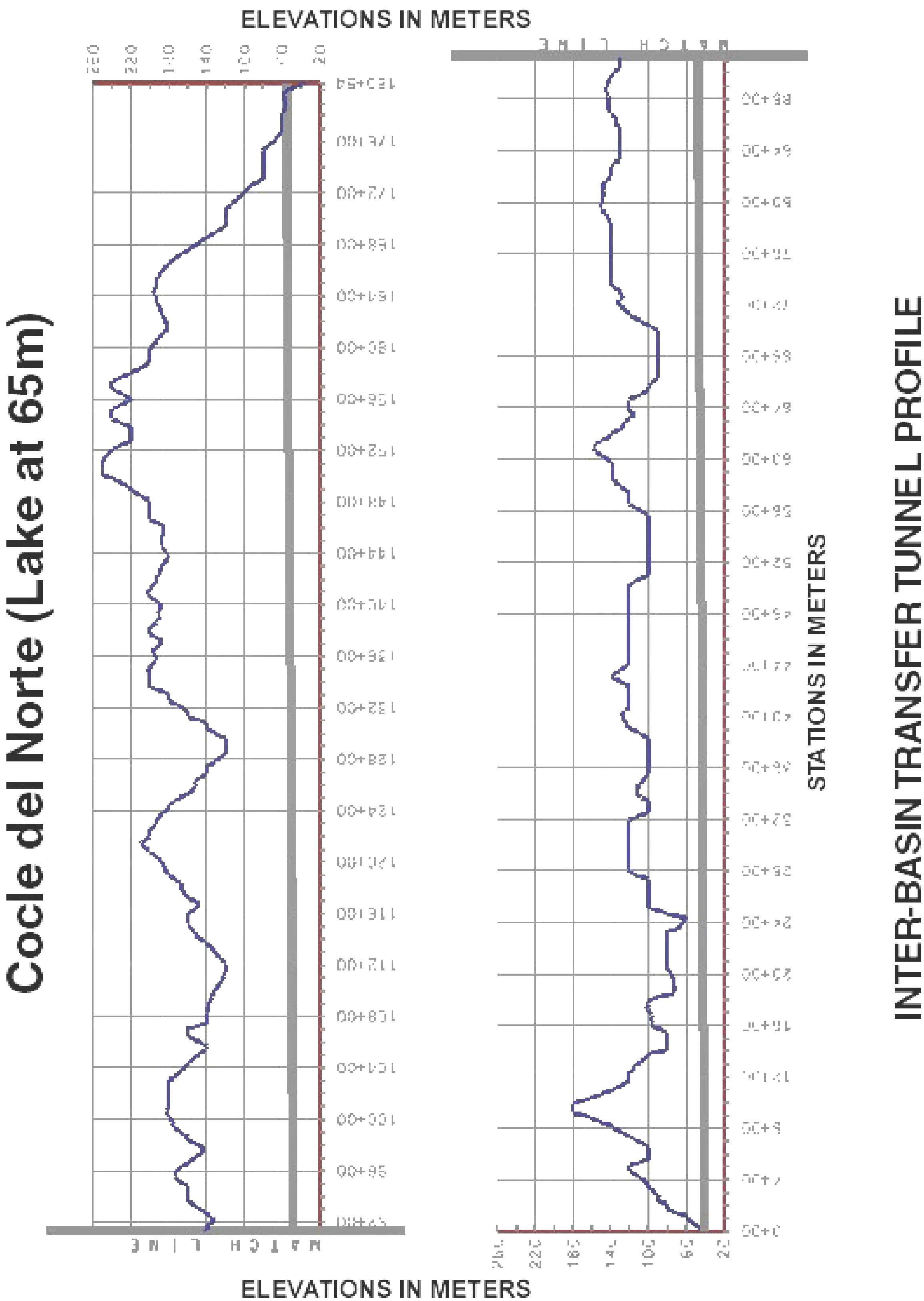


Plate 6 - 9 Inter-Basin Transfer Tunnel Profile

SECTION 7

LAKE AT ELEVATION 80
(Operated in conjunction with Indio Lake)

Rio Cocle del Norte

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Synopsis

The development plan presented herein would include a dam and lake on the Rio Cocle del Norte with a normal lake level at 80 m MSL connected by a large tunnel to Indio Lake. Indio Lake would be connected to the Panama Canal watershed at Gatun Lake via a second tunnel (see Section 5 of this report for details of the Rio Indio development). Water impounded in these two lakes would be transferred to the Panama Canal watershed as needed to support canal operations.

The Rio Cocle del Norte watershed is located to the west of the Panama Canal watershed. The proposed Rio Cocle del Norte dam site would be approximately 15 km inland from the Atlantic Ocean, and approximately 7 km downstream of the confluence of Rio Cocle del Norte and Rio Toabre. The structures for this proposed project would consist of a rock fill dam, an 18 km inter-basin transfer tunnel connecting the Cocle del Norte Lake with Indio Lake, an enlarged inter-basin transfer tunnel connecting Indio Lake with the Panama Canal watershed, and a hydropower plant. The total costs of the Rio Cocle del Norte project are estimated to be $834,484,000.

The Rio Cocle del Norte project would provide additional water, equivalent to approximately twenty five (25.29) lockages per day, for canal operations up to the year 2070. The Rio Cocle del Norte project would provide this amount of water at a 100 percent level of reliability. This would contribute measurably to the reliability of the Panama Canal to serve its customers as future demands increase and it would greatly reduce the need for imposing draft restrictions that results in light loading of vessels during periods of low water availability. Additional benefits would be realized in the form of increased hydropower. This number of additional lockages far exceeds the maximum capacity of the existing lock systems and could be used to accommodate any canal expansion that might take place in the future. Construction of this proposed project would continue the existing high hydrologic reliability as demand for lockages increases above 180 percent of current demand levels. Additional benefits would also be realized in the form of increased hydropower. The net increase in average annual energy produced by the hydropower plants, including the power generated from the Rio Cocle del Norte project and the existing plants, would be 284,000 MWh after sufficient water is used for canal operations.

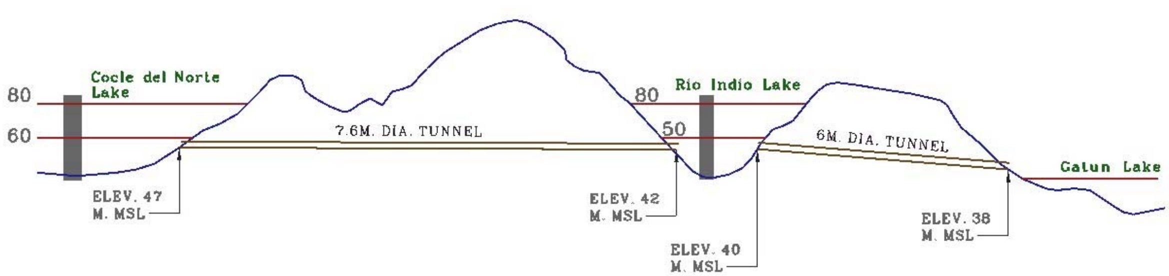


Figure 7 - 1 System Profile

Site Selection

The proposed Rio Cocle del Norte dam site was chosen 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. To maximize the water impounded, it was desirable to locate the dam as far downstream in the Rio Cocle del Norte watershed as possible. In choosing a site for the dam, a location was sought where the surrounding hillsides were relatively steep and high, and the valley was relatively narrow. The downstream portion of the Rio Cocle del Norte watershed contains several sites that meet these criteria.

The site chosen for the proposed Rio Cocle del Norte Dam would be approximately 15 km inland from the Atlantic Ocean and approximately 7 km downstream from the confluence of Rio Cocle del Norte and Rio Toabre. This site would accommodate construction of a dam with a normal operating lake level at elevation 80 m MSL and a maximum flood storage lake level at elevation 84 m MSL. Plate 7 - 1 shows the location of the proposed Rio Cocle del Norte project.

Hydrologic Considerations

The Rio Cocle del Norte flows northward from the Continental Divide to the Atlantic Ocean. The headwaters of the watershed begin at elevation 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 Cocle del Norte watershed varies from a high of 4,000 mm at the coast to a low of 2,500 mm in the middle watershed area and increases again to over 3,000 mm in the Continental Divide. The proposed Cocle del Norte Lake would receive runoff from approximately 1,600 km^2 of the upper portion of the watershed. Rainfall runoff produces an average annual flow of 109 CMS at the proposed dam site.

The discharge at the Rio Cocle del Norte dam site was obtained by extrapolating the recorded and correlated stream flow data of the Canoas hydrologic station, and adding the recorded and correlated flows of the Rio Toabre at Batatilla.

Two hydrologic stations have gauged the Rio Cocle del Norte. A staff gage, read twice daily, located at El Torno, operated from 1958 to 1986. A continuous recorder located at Canoas started operating in 1983. The recorder gage is located 6 km due south of where the staff gage was located. The flow records from the staff gage at El Torno were extended by statistical correlation with the flows from the Rio Toabre gage at Batatilla. These flows at El Torno were then used as a transfer point to fill in missing data and extend the recorded flows at Canoas utilizing further statistical correlations. The consistencies of the measured and correlated data were verified using the double mass curve method with satisfactory results. However, it is recommended that a stream gage be installed near the dam site to further extend and verify the hydrology of the site, if this river is going to be subjected to additional studies.

Because of the proximity and in the absence of additional information, the monthly evaporation rates recorded at Gatun Lake were used to establish the evaporation of Cocle del Norte Lake.

Geologic Considerations

The proposed Rio Cocle del Norte project is located in an area of the Isthmus of Panama where volcanic or intrusive igneous rocks are encountered at the surface. The volcanic rocks consist of lava flows, breccias, tuffs and plugs of the Tucue Formation, which are andesitic or basaltic in nature. The intrusive igneous rocks consist of granodiorites, quartzmonzonites, gabrodiorites, diorites, or dacites. Little has been found concerning the engineering characteristics of the rocks of these formations. It is anticipated, however, that they may show a wide variation in quality, from high quality of the intrusive rocks and the extrusive lava flows, to possibly weathered and lesser quality volcanic tuffs.

Hard, high quality igneous rock (diabase or fine grained gabbro) outcrops occur along the river bank at the proposed dam site. This rock should be excellent for use as either rock fill or concrete aggregate. It is not known for certain what type of rock underlies the abutment slopes, since they are completely covered with vegetation, but there is no reason to believe that it differs from that exposed at the rivers edge.

In the absence of detailed geologic mapping for the proposed Rio Cocle del Norte dam site, a degree of extrapolation was necessary. It was predicted that rock, at the proposed Rio Cocle del Norte dam site, would be encountered at a shallow depth and would be of sufficient quality to serve as foundation for the dam and appurtenant structures. This prediction was based on available general geologic mapping and general data. Furthermore, it was assumed that sufficient rock for fill and concrete aggregate would be available from the required excavation and that impervious materials would be available within the immediate area for use in the construction of the project.

Lake Operation

Waters stored between lake level at elevation 80 m MSL down to the lake level at elevation 60 m MSL was considered in this study to be available for transfer to the Panama Canal watershed for canal operations. This would provide 4,155,000,000 M^3 of useable storage. Maximum flood level of the Cocle del Norte Lake would be at elevation 84 m MSL. The volume between the maximum flood lake level and the normal operating lake level would be used to store flood waters and reduce peak flood flows. Some reduction in flooding would be realized in areas along the Rio Cocle del Norte downstream of the dam.

Water would be transferred from Cocle del Norte Lake to Indio Lake and then to the Panama Canal watershed for use in canal operations. The Indio Lake would operate between elevations 80 m and 50 m MSL. Thus, operation of the linked system of lakes, Cocle del Norte Lake, Indio Lake, and Panama Canal watershed, would allow some flexibility in operational use of stored water. The water in storage at the Indio Lake could be transferred to the Panama Canal watershed initially with that in the Cocle del Norte Lake held at a higher level, or both lake levels could be allowed to fluctuate simultaneously. Once the lake levels reached elevation 60 m MSL the water surface in Indio Lake could be lowered further, down to elevation 50 m MSL, the lower limit of its operating range.

Project Features

GENERAL

The structures for this proposed project would consist of a rock fill dam with an uncontrolled ogee spillway, inter-basin transfer facilities, and a hydropower plant. The following paragraphs provide a description of the proposed structures and improvements. 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 proposed project is carried into the planning studies, optimization of the project features and improvements must be accomplished.

EMBANKMENT

The proposed Rio Cocle del Norte Dam would be an embankment with the top at elevation 85 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 993641 north and 549816 east. The right abutment would be 993471 north and 550655 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 would be approximately 85 m high, and the overall length would be 848 m. Foundation grouting will 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 could provide seepage cutoff in the embankment foundations. A concrete or bentonite cutoff wall could also provide seepage cutoff.

The actual side slopes and crest width 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. The embankment cross section would be similar to that shown for the Rio Indio project, Section 5 of this report.

No saddle dams would be required to complete the lake impoundment for this alternative.

SPILLWAY

At the proposed Rio Cocle del Norte Dam, an uncontrolled ogee spillway with a length of 346 m and a crest at elevation 80 m MSL would be required. The spillway crest would be 5 m below the elevation of the top of the dam. The maximum discharge from the spillway would be 5,346 CMS with a maximum flood storage lake level at elevation 84 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 right 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. A stilling basin would be excavated into the rock adjacent to the natural channel at the downstream end of the tailrace channel for energy dissipation. See Plate 7 - 2 for the location of the spillway The spillway construction would be similar to that shown for the Rio Indio project, Section 5 of this report.

IMPOUNDMENT

The lake formed by the proposed Rio Cocle del Norte Dam would have a normal operating lake level at elevation 80 m MSL. The surface area at the normal operating lake level would be approximately 26,520 ha. With the minimum operating lake level at elevation 60 m MSL, the surface area would be approximately 15,520 ha. At the maximum flood storage lake level at elevation 84 m MSL, the surface area would be approximately 28,830 ha. At the top of dam, elevation 85 m MSL, the surface area would be approximately 29,450 ha.

CLEARING AND / OR GRUBBING

Clearing and grubbing would be required for all areas required for construction of the dam and associated structures, inter-basin transfer facilities, hydropower plants, access roads, disposal areas and staging areas. Clearing only would be required for the 11,000 ha in the lake area between normal operating lake level at elevation 80 m MSL and the minimum operating lake level at elevation 60 m MSL, and for the transmission lines.

INTER-BASIN TRANSFER FACILITIES

A tunnel would be excavated beneath several watersheds to connect the proposed Cocle del Norte Lake with the Indio Lake. The finished tunnel would be concrete lined, 7.6 m in diameter, and approximately 18 km in length. This tunnel would have an inlet invert at elevation 47 m MSL and an outlet invert at elevation 42 m MSL. The maximum capacity of the tunnel would be 188.4 CMS when a maximum possible difference of 30 m occurs between Cocle del Norte Lake and Indio Lake. It was assumed that rock bolting would be required over much of the tunnel length to stabilize the rock. The tunnel outlet would be on the Rio Uracillo arm of Indio Lake approximately 5 km upstream from the confluence of Rio Uracillo and Rio Indio. A gate structure located at the tunnel outlet would control flow through the tunnel. The tunnel would be under pressure continually since the elevation of the tunnel would be lower than the minimum operating lake level at both lakes. To allow for tunnel maintenance and to provide for rapid emergency closure of the tunnel, a gate / stoplog structure would be constructed at the inlet also. In the process of stopping flow through the tunnel, a water hammer effect could be generated. Therefore, a series of surge protection shafts would be constructed. These shafts would require relatively minor surface structures for safety purposes. Plate 7 - 1 shows the location of the tunnel outlet.

The 3 m finished diameter inter-basin transfer tunnel included in the proposed Rio Indio project between Indio Lake and the Panama Canal watershed would not be large enough to pass the additional flows from the Cocle del Norte Lake. This tunnel would need to be enlarged to a 6 m finished diameter to pass the combined flows from Indio Lake and Cocle del Norte Lake at elevation 80 m MSL. The maximum capacity of this tunnel would be 216 CMS, and it would have invert elevations at its inlet and outlet ends of 40 m and 38 m MSL respectively. This would result in a slight lengthening of the tunnel over that indicated in the Indio Lake alternative described in Section 5. The additional cost of this tunnel resulting from changes in diameter and length would be directly attributable to the Rio Cocle del Norte project.

The location and assumed alignment of these features are shown on Plate 7 - 1 and a profile of the entire transfer system is shown in Figure 7 - 1. The tunnels would be under pressure continually since flow through the tunnels would be controlled at the downstream end of each. This control would be in the form of a gate control structure and / or a hydropower plant. To allow for maintenance of the tunnel and to provide for rapid emergency closure of the tunnel, a gate / stoplog structure would be constructed at the upstream end of each. In the process of stopping flow through the tunnel, a water hammer effect could be generated. Therefore, sufficient surge protection shafts would be constructed. These shafts would require relatively minor surface structures to protect the openings and to provide for personnel safety.

It was assumed that the tunnels would be concrete lined and that rock bolting would be required over much of the length of the tunnel to stabilize the rock.

HYDROPOWER PLANTS

The flows, excess to the needs of the Panama Canal operation, at the proposed Rio Cocle del Norte Dam would support the installation of an 18 MW hydropower plant at the dam. This plant would have two 9 MW units. For this study, vertical Francis type turbines were included in the design. These facilities would be designed and configured to function as part of the national power grid. A transmission line would be required to carry the energy to the hydropower plant at the Rio Indio project and ultimately to a connection with the grid near La Chorrera. Plate 7 - 2 shows the location of the hydropower plant at the dam.

In analyzing the flow characteristics of the inter-basin transfer tunnel between Cocle de Norte Lake and Indio Lake, it was determined that sufficient energy would only be available to maintain flow between the two lakes. Therefore, no hydropower capability could be provided at this location.

Whenever the Indio Lake elevation is lower than Cocle del Norte Lake elevation inter-basin water transfer is possible. The Cocle del Norte Lake at elevation 65 alternative only allowed inter-basin transfer when the Indio Lake elevation dropped below elevation 65 m MSL. Therefore raising Cocle del Norte Lake to elevation 80 m MSL allows more water to be diverted to Indio Lake. The increase in flow passing between Indio Lake and the Panama Canal watershed would allow the hydropower plant at the tunnel outlet (determined to be a 5 MW plant in the Rio Indio evaluations, Section 5) to be increased in capacity. The increased plant rating would be approximately 10 MW. Table 7 - 1 lists the powerplant parameters for the installations at the two plants. Design head for the powerplants at the dams are based on the average lake elevation above the expected tailwater elevation. Design head for the plant at the Indio to Gatun Tunnel is based on the average Indio Lake elevation above the tunnel outlet.

Table 7 - 1 Powerplant Parameters

Project	Capacity (MW)	Head (m)	Flow (CMS)
Rio Cocle del Norte Dam	18.0	50	42.7
Indio to Gatun Tunnel	10.0	30	98.8
Rio Indio Dam	25	60	49.4

OUTLET WORKS

At the Rio Cocle del Norte Dam, an outlet works system would be required. This system would provide for diversion of the Rio Cocle del Norte during construction, supply water for production of hydropower, allow for emergency drawdown of the lake after it is raised and placed in service, and allow minimum flow to pass by the dam.

These water handling facilities would consist of two 7.5 by 7.5 m horseshoe shaped tunnels passing through the dam abutment, an intake structure located in the lake, an outlet channel downstream, and various gate structures and water conduits. The diversion tunnels would be approximately 400 m in length; they would have an inlet invert elevation at 10 m MSL and an outlet invert elevation at 9 m MSL. The diversion tunnels would serve in combination with the cofferdam to protect the construction area from floods up to a 10 percent frequency. A 10 percent frequency flood would deliver a peak flow of approximately 2820 CMS at the site without regulation from the dam. The cofferdam would measure 35 m above the upstream invert of the tunnel.

A separate 1.5 m diameter conduit, required for minimum flow, would be installed beneath the floor of this tunnel. The minimum flow conduit would be approximately 400 m in length and it would have an invert elevation of 8 m MSL. Intake for minimum flow would be through individually gated water quality intake ports located at various levels in the intake structure. The elevations of these intakes would be established during environmental water quality investigations made during subsequent phases of study. The capacity of the minimum flow conduit would be 10.9 CMS.

The hydropower intake would be raised above the intake structure floor also, to prevent silt from entering and damaging the turbines. The elevation and configuration of this intake would be incorporated into the design as the details are developed.

At the downstream end of the tunnel, a bulkhead structure would be installed to close the construction diversion and to divert reservoir water into the hydropower penstock. The closure would be configured so that it could be removed in the event that the Cocle del Norte Lake had to be drawn down. The intake structure would be similar to that shown for the Rio Indio project, though much larger.

ACCESS ROUTE

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

The route from Colon could be by barge southwestward along the Atlantic Ocean to the village of Cocle del Norte. Then by new roads along the Rio Cocle del Norte to the dam site and the other construction sites with one exception. Access to the tunnel outlet at Indio Lake would be by a new road from the roads built as part of the proposed Rio Indio project. This route would also require docking facilities at the village of Cocle del Norte. Approximately 100 m of dock facilities and minimal dredging for barge access would be required at the village of Cocle del Norte for offloading of construction materials and equipment.

The route from Panama City would be by proposed roads to the Rio Indio project and then generally westward by newly constructed roads to the dam site and the other construction sites.

The conclusion was that the land route from the Rio Indio project would be best since the new road construction would benefit the local population and the water access would be subject to coastal storms. The proposed access road from the Cocle del Norte Village to the dam site would be approximately 13 km in length. An additional 30 km of roads would be required to provide access to the inlet and outlet of the inter-basin transfer tunnel. Bridges and / or culverts would be required at five streams. Plate 7 - 1 shows the proposed routes.

Sources of Construction Material

Cement would be available within the Republic of Panama. Rock, obtained from the construction site or from the lake area, would be used for onsite manufacture of aggregates for the concrete. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) would be fabricated outside the Republic of Panama and imported for final assembly and installation at the proposed dam site.

Real Estate Requirements

The proposed Rio Cocle del Norte project would be located in the Cocle and Colon Provinces. Construction of this proposed project would require approximately 30,450 ha. Table 7 - 2 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 7 - 2 Real Estate Requirements

Project Feature	Land Required (ha)
Lake	29,450
Dam Site	200
Staging Area	200
Housing and Facilities	200
Disposal Area	400
Total	30,450

Relocations

Much of the lake area would be located in sparsely populated regions with few roads and utilities. These areas are devoted primarily to subsistence farming, pineapple growing, and ranching. Some areas are densely forested. Structures and individuals located in the lake area below elevation 85 m MSL would require relocation because of the normal lake inundation and the need to secure the lake perimeter for flood considerations. The relocation of the towns of Coclesito, Cutevilla, Boca de La Encantada, El Calabazo, Platanal, Molejon, and La Boca del Guasimo and their approximately 5,600 residents would be an important issue. The town of

Coclesito supplies valuable services to many surrounding communities. Coclesito possesses schools, a hospital (with two resident doctors), a small diesel generating facility, and a museum honoring the late General Omar Torrijos, who is considered a national folk hero.

Development Sequence

For the economic evaluation of this project, it was assumed that the planning for the Rio Cocle del Norte project would begin during the construction of the Rio Indio project and that construction would be started immediately following completion of the Rio Indio project.

Planning studies would be accomplished to evaluate the alternative features of the proposed project. The viable project would be evaluated to assure that the plan presented would provide all of the features required to make it functional. It would also be assessed as to its effectiveness in meeting the project goal of providing M & I water supply in relief of current or future planned withdrawals from the Panama Canal, with due recognition of any secondary benefits. Environmental assessments of the proposed project would begin during the planning studies phase and would continue during the final design, advertising and award phase and would continue through construction of the project. The final design would be accomplished for the recommended project. After completion of the final design, plans and specifications would be prepared for the advertising and award phase.

Project implementation would begin 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 would then be acquired.

Access roads would be constructed to the dam site and the inter-basin transfer tunnel inlet and outlet sites. Once highway access to the sites has been established, a camp would be built to house workers during construction.

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

Construction of the dam would begin with the clearing and grubbing of the construction sites and the clearing of the lake area. Excavation for the inter-basin transfer tunnel and the intake structure and construction of the diversion tunnel(s) at the dam site and the spillway would follow with work being done simultaneously. To the extent possible, materials removed from these sites would be placed directly into the embankment portions of the work. The remainder would be stockpiled for future use in the completion of the earth and rock fill portions of the dam. Once the intake structure and diversion tunnel(s) were completed, the dam construction site would be isolated using upstream and downstream cofferdams, which would eventually become part of the main dam, and the stream would be diverted through the tunnel. The dam foundation would then be excavated and grouted, and the dam constructed. Concurrently with construction of the dam, the hydropower plant site downstream of the dam would be excavated, and the powerhouse construction would be started. Upon completion of the dam and the inter-basin transfer tunnel and appurtenant structures, the diversion would be stopped by closing the gates on the intake structure, and lake filling would begin. Simultaneously with this operation, the downstream gate and flow separation structure would be constructed to provide for closure of the diversion tunnel(s) and diversion of the tunnel flows to the hydropower penstock(s). The minimum flow conduit would also be installed through the diversion tunnel at this time. Upon completion of the project, all facilities would undergo trial operations followed by commissioning for service.

Considering the climatic conditions and the obstacles posed by the remote location of the construction sites and the nature of the work, it is estimated that development of this project could be completed in approximately 12.5 years, from initial planning to lake filling. Figure 7 - 2 depicts the development sequence of the various project features.

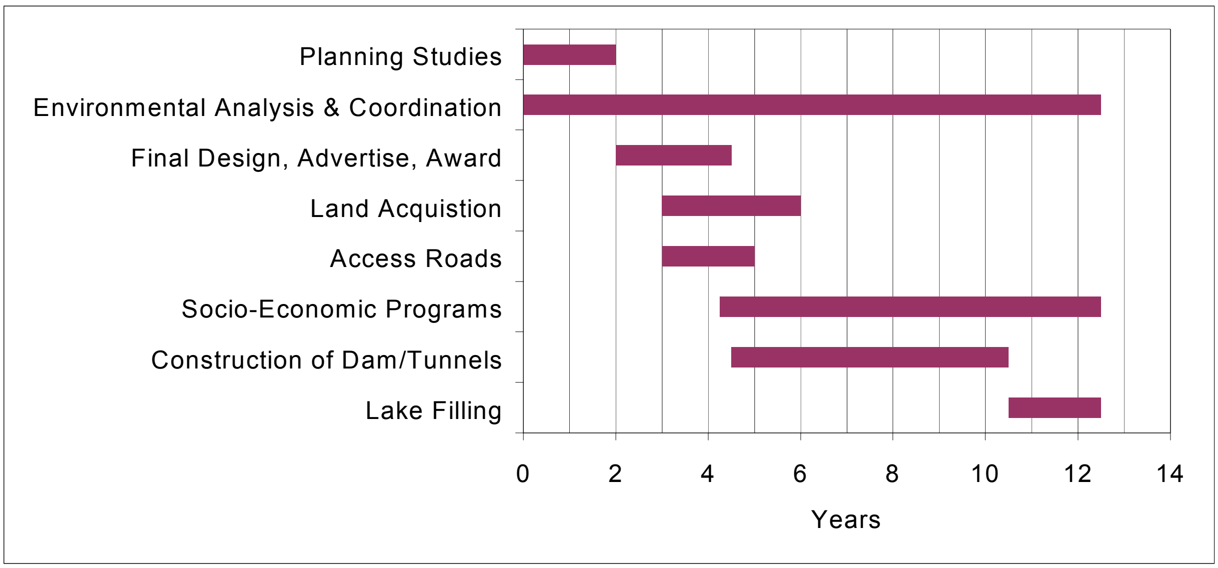


Figure 7 - 2   Development Sequence

Hydrologic Reliability

In order to determine the effect of the proposed Cocle del Norte Lake on the hydrologic reliability of the Panama Canal, the Lake was evaluated as linked with the Indio Lake and the Panama Canal watershed. A HEC-5 model was constructed that linked the Cocle del Norte Lake to the Indio Lake through the inter-basin transfer tunnel and Indio Lake was linked to the Panama Canal watershed. Water stored in Cocle del Norte Lake was provided, as needed, to Gatun Lake when shortages were expected using the Indio Lake as a conduit. Excess flows in the Rio Cocle del Norte were still released down the Rio Cocle del Norte, taking advantage of the hydropower generation when possible. Minimum flow requirements were deducted from the waters made available to the Panama Canal watershed and released down the Rio Cocle del Norte.

HEC-5 model simulations were conducted for both the existing canal system and the system operating with the proposed Cocle del Norte Lake linked by an inter-basin transfer tunnel to the proposed Indio Lake, which was, in turn, linked by another inter-basin transfer tunnel to the Panama Canal watershed. The simulations considered proportionally increasing demands up to 180 percent of current demand levels. The period of simulation considered 50.5 years (January 1948 through July 1998) of hydrologic records at Rio Cocle del Norte. Since the normal operating lake level for both Cocle del Norte and Indio Lakes is 80 m MSL, water can only be transferred from Cocle del Norte Lake to Indio Lake when the Indio Lake level is lower than the Cocle del Norte Lake level. Lake operating scenarios are described above in the section titled Lake Operation. Separate documentation was provided to the PCC that contained the model code and simulation output for these investigations. Figure 7 - 1 is a profile schematic of the proposed linked lake system.

Figure 7 - 3 compares the resulting hydrologic reliability for the alternative to the reliability of the existing system. The horizontal axis along the bottom of Figure 7 - 3 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).

The existing hydrologic reliability of the Panama Canal, based on the 50.5 year period of record, is 99.6 percent while the hydrologic reliability with a demand ratio of 1.8 would be 86.3 percent. With the Cocle del Norte Lake and Indio Lake transferring water to the Panama Canal watershed, the hydrologic reliability increased to 100 percent even up to a demand ratio of 1.8. A 100 percent reliability implies that all demands were met and no shortages were realized. Furthermore, under the operating scheme, the minimum pool elevation only drops to 74.97 m MSL with demands at 180 percent of current levels. This means that there is storage available for beneficial uses such as domestic water supply, water supply for canal operations or for the production of hydroelectric power. Since all demands were met at the 100 percent level of reliability, the number of lockages represented by this storage was not estimated. Benefits for the storage between 74.97 and 60 m MSL were likewise not estimated.

Without additional water supplies, the hydrologic reliability of the Panama Canal system would decrease. With the construction of the proposed Rio Cocle del Norte project and Rio Indio project, a hydrologic reliability near 100 percent could be realized as demand for lockages increases beyond 180 percent of current demand levels. This equates to at least 30.95 additional lockages per day. This study only addressed demand levels that would be required to meet the needs of the Panama Canal system through the year 2070, which approximated 25.29 additional lockages above the year 2000 demand levels. This project is capable of providing even more than required before the reliability drops below 99.6 percent. The unused storage could be used for increased forecast demands of navigation or M&I water uses.

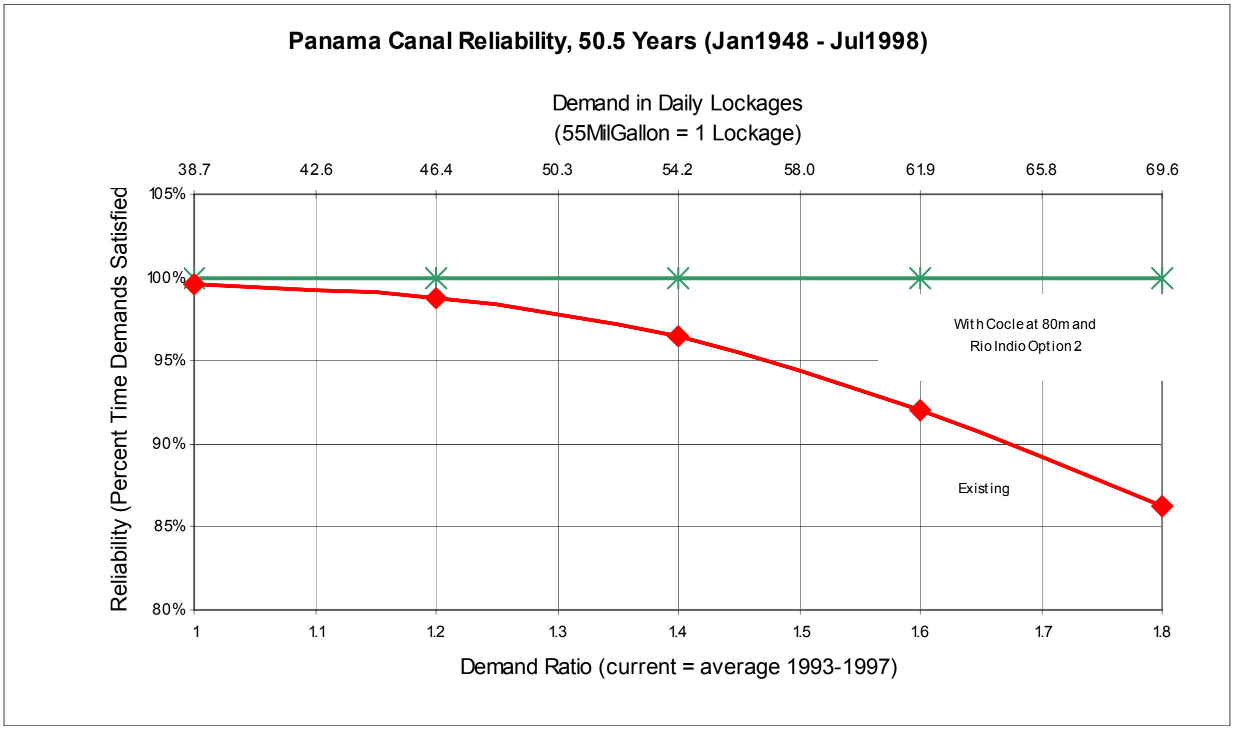


Figure 7 - 3 Panama Canal Hydrologic Reliability

Project Costs

GENERAL

The quantities estimated for the principal features required in the construction of this proposed project were derived from the layouts shown on Plate 7 - 2 and detailed in data provided separately. The unit prices applied to these quantities were 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, information gathered from Mobile District Construction Division personnel in the Republic of Panama, and the publication, <u>Feasibility Studies For Small Scale Hydropower Additions, A Guide Manual</u>, prepared by the Hydrologic Engineering Center, U.S. Army Corps of Engineers, 1979.

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

FIRST COSTS

The project first costs are estimated to be $834,484,000. Table 7 - 3 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 7 - 3 Summary of Project First Costs

Principal Feature	Costs ($)
Lands and Relocations	76,125,000
Access Roads	11,590,000
Clearing and / or Grubbing	6,966,250
Inter-basin Transfer Tunnel[1/]	251,323,010
Diversion Tunnel	34,204,575
Cofferdam	8,845,590
Dam	25,105,730
Spillway Gates and Operating Machinery	104,173,641
Intakes and Operating Machinery	19,211,553
Hydropower Plants	11,077,000
Transmission Lines	7,700,000
Subtotal	556,322,349
E&D ,S&A, Field Overhead	111,264,470
Contingencies	166,896,705
Project First Costs	834,483,524 approximately 834,484,000

[1/] The difference in costs to enlarge the inter-basin transfer tunnel connecting Indio Lake and the Panama Canal watershed from a 3 m finished diameter tunnel to a 6 m finished diameter tunnel are included.

OPERATION AND MAINTENANCE

Staff

A staff would operate and maintain the proposed Rio Cocle del Norte project during the day and then run the facility remotely. The full-time staff would ultimately consist of a total force of 11 who would include a station manager, a multi-skilled supervisor, 3 leaders (Electronics / Instrumentation, Electrical and Mechanical), 5 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 $500,000.

Ordinary Maintenance

Ordinary maintenance and care would be required and would include minor repair materials, lubricants and other supplies needed by the project staff. It is estimated that the costs of ordinary maintenance would be $20,000 per year for the access road and $300,000 per year for the main project facilities.

Major Replacements

The average service life of gates, electrical equipment, turbines, trash racks and other features would be less than the total useful life of the proposed project, which would be 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 would cost the same as at present. No allowance was made for salvageable fixed parts. Table 7 - 4 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 $269,000 and the average annual replacement costs would be $32,000.

Table 7 - 4 Major Replacement Costs

Component	Service Life (yrs)	Number of Times Replaced During Planning Period	Future Costs ($)	Present Worth of Replacement Costs ($)
Roads	50	1	16,170,000	56,000
Bridges	50	1	1,125,000	3,900
Intake / Outlet Gates and Machinery				
Head Gates	50	1	3,201,900	11,080
Stoplogs	50	1	477,750	1,650
Trashracks	50	1	155,250	540
Access Stairs	50	1	67,500	230
Minimum Flow Gates	50	1	90,000	310
Hydropower Plant				
Turbines and Generators	33	1	4,200,000	99,780
Slide Gates	50	1	60,000	210
Stoplogs	50	1	321,000	1,110
Station Electrical Equipment	33	1	1,170,000	27,800
Switchyard Equipment	33	1	810,000	19,240
Miscellaneous Plant Equipment	33	1	315,000	7,480
Transmission Lines	50	1	11,550,000	40,000
Total			39,713,400	269,000
Average Annual Replacement Costs				32,000

Annual Costs

The project first costs for the proposed Rio Cocle del Norte project are estimated to be $834,484,000, and includes $51,836,000 to enlarge the inter-basin transfer tunnel between Indio Lake and the Panama Canal watershed from a 3 m finished diameter tunnel to a 6 m finished diameter tunnel. The total project first costs also includes the $245,868,000 costs for the Rio Indio project (see Section 5) and are estimated to be $1,080,352,000. These total project first costs were distributed across the development period using generalized curves for contractor earnings for large, heavy construction jobs. It was assumed that the 6 m finished diameter inter-basin transfer tunnel from Indio Lake to the Panama Canal watershed would be constructed at the Rio Indio project instead of the 3 m finished diameter inter-basin transfer tunnel. Interest on the total project first costs of $782,648,000 ($834,484,000 - $51,836,000) was computed from mid-year throughout the 13.5-year development period from initiation of Planning and Design until the lake was filled. Interest during construction for the Rio Indio project including the enlarged inter-basin transfer tunnel at the Rio Indio project was computed from mid-year throughout its 19.5-year development period until lake filling was complete at the Rio Cocle del Norte project. The interest during construction at 12 percent would be

$801,887,000 for Rio Cocle del Norte, and $958,684,000 for Rio Indio for a total interest during construction of $1,760,571,000. These costs were added to the total project first costs for total project investment costs of $2,840,923,000. A capital recovery factor for the 50-year planning period was applied to get the annual average investment costs of $342,094,000. Annual operation and maintenance costs were added. Major replacement costs are estimated and were 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 7 - 5 contains a summary of the $344,093,000 total annual costs.

Table 7 - 5 Summary of Annual Costs

Item	Costs ($)
Total Project First Costs - Rio Cocle del Norte	782,648,000
Total Project First Costs – Rio Indio	245,868,000
Enlarged Tunnel at Rio Indio project	51,836,000
Interest During Construction – Rio Cocle del Norte	801,887,000
Interest During Construction – Rio Indio	958,684,000
Total Project Investment Costs	2,840,923,000
Annual Average Investment Costs	342,094,000
Operation and Maintenance Costs	
Staff Costs - Rio Cocle del Norte	500,000
Staff Costs - Rio Indio	500,000
Ordinary Maintenance Costs – Rio Cocle del Norte	320,000
Ordinary Maintenance Costs – Rio Indio	320,000
Major Replacement Costs – Rio Cocle del Norte	32,000
Major Replacement Costs – Rio Indio	326,000
Total Average Annual Costs	344,093,000

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 Rio Cocle del Norte project. The 50-year planning period for this proposal is 2020 to 2070.

The proposed Rio Cocle del Norte project would increase the reliability of providing water to accommodate the total daily number of lockages demanded. Table 7 - 6 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 were obtained from the data used to develop Figure 7 - 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 7 - 6 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 Rio Cocle del Norte [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	100.00
	2020	47.61	98.41	100.00
	2025	48.52	98.14	100.00
	2030	49.55	97.83	100.00
	2035	50.72	97.48	100.00
	2040	52.02	97.10	100.00
	2045	53.49	96.65	100.00
1.4		54.15	96.45	100.00
	2050	55.13	95.89	100.00
	2055	56.98	94.83	100.00
	2060	59.05	93.65	100.00
	2065	61.37	92.32	100.00
1.6		61.89	92.02	100.00
	2070	63.97	90.47	100.00
1.8		69.63	86.27	100.00

1/ Rio Cocle del Norte - the Lake fluctuates from the normal operating lake level at elevation 80 m MSL down to the minimum operating lake level at elevation 60 m MSL and Rio Indio Operating Option 2 the lake fluctuates from the normal operating lake level at elevation 80 m MSL down to the minimum operating lake level at elevation 50 m MSL.

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

With the proposed Rio Cocle del Norte project, there would be no water supply shortages for navigation. The demand for the M&I purposes will always be met first. As these demands grow, the amount of water available to meet the demands for navigation will decrease. Thus, the benefits for the additional water supply are estimated at the value for navigation. With the addition of the proposed Rio Cocle del Norte project, all demands for water supply for navigation would be met over the planning period. With a hydrologic reliability of 99.6 percent, the project would increase the amount of water supplied by more than 25.29 equivalent. The 99.6 percent hydrologic reliability would occur after the year 2070 with an equivalent daily average number of lockages of 63.76. 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 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 $220,219,000. Table 7 - 7 provides the estimate of daily shortages under the existing system, the remaining daily shortages with the proposed Rio Cocle del Norte project in operation, the annual benefits for meeting shortages and the average annual benefits.

Table 7 - 7 Benefits for Additional Water Supply for Navigation

Year	Daily Shortages In Lockages Under Existing System	Remaining Daily Shortages	Annual ($)
2020	8.93	0	184,110,000
2030	10.87	0	224,201,000
2040	13.34	0	275,147,000
2050	16.45	0	339,266,000
2060	20.37	0	419,966,000
2070	25.29	0	521,534,000
Average Annual Benefits			220,219,000
With the Rio Cocle del Norte @ 80 alternative, the system will provide 63.97+ lockages or will satisfy 100 percent of the forecast demands through 2070 or 30.95 more lockages than the existing system.			

With the proposed Rio Cocle del Norte project, the reliability of the system to provide all of the water demanded for 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 Rio Cocle del Norte project would be $17,690,000. Table 7 - 8 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 7 - 8 Average Annual Reliability Benefits For Navigation

Year	Daily Average Number of Lockages	Value Per Lockage ($)	Annual Benefits For Navigation ($)
2020	40.0	2,260,000	13,125,000
2030	40.0	2,260,000	17,913,000
2040	40.0	2,260,000	23,998,000
2050	40.0	2,260,000	33,878,000
2060	40.0	2,260,000	52,403,000
2070	40.0	2,260,000	78,610,000
Average Annual Benefits			17,690,000

M&I WATER SUPPLY

The future demand for water supply for M&I purposes was 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 was 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 Rio Cocle del Norte 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 would be $3,015,000. Table 7 - 9 displays the population forecast, the resulting number of equivalent lockages per day, the annual benefits for increased reliability, and the average annual benefits for M&I water supply.

Table 7 - 9 Average Annual Reliability Benefits For M&I Water Supply

Year	Population	Equivalent Lockages per Day	Annual M&I Water Supply Benefits ($)
2020	2,141,000	7.6	1,678,000
2030	2,688,000	9.6	2,877,000
2040	3,384,000	12.0	4,842,000
2050	4,259,000	15.1	8,605,000
2060	5,360,000	19.0	16,764,000
2070	6,746,000	24.0	31,653,000
Average Annual Benefits			3,015,000

HYDROPOWER

The amount of hydropower energy that could be produced by the system of Gatun Lake and Madden Lake would decline over time as the demands for navigation and M&I water supply increase. With the inclusion of the proposed Rio Cocle del Norte project, the system could produce net additional megawatt hours of hydropower. The value for hydropower energy used in this analysis was $0.070 / kWh. On an average annual basis, the project would have benefits of $20,750,000. Table 7 - 10 provides the net additional megawatt hours of hydropower generation and the resulting benefits.

Table 7 - 10 Average Annual Benefits For Hydropower Generation

Year	Net Generation [1/] (MWh)	Annual Benefits For Hydropower ($)
2020	295,198	20,664,000
2030	296,734	20,771,000
2040	298,668	20,907,000
2050	299,357	20,955,000
2060	299,134	20,939,000
2070	298,686	20,908,000
Average Annual Benefits		20,750,000
[1/] Net generation of Gatun, Madden, Indio, and Cocle hydropower plants above generation of Gatun and Madden hydropower plants.		

SUMMARY OF ANNUAL BENEFITS

As shown in Table 7 - 11, total average annual benefits for the proposed Rio Cocle del Norte project would be $261,674,000.

Table 7 - 11 Summary of Annual Benefits

Benefit Category	Average Annual Benefits ($)
Navigation – Water Supply	220,219,000
Navigation – Reliability	17,690,000
M&I - Reliability	3,015,000
Hydropower	20,750,000
Total	261,674,000

To perform an analysis of benefits versus costs, a common point in time was selected. This common point was at the completion of the filling of the proposed Rio Cocle del Norte project, the end of the year 2020. In these analyses, it was important to note that the average annual benefits or average annual costs were 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 Rio Cocle del Norte project would be to develop the Rio Indio project first (2001 – 2010) and then the Rio Cocle del Norte project second (2007 – 2020).

The benefits attributable to the proposed Rio Indio project would begin to accrue in 2010 when that reservoir is filled. Thus, the Rio Indio project benefits for the period 2010 to 2020 were escalated by the project discount rate, 12 percent, in order to estimate their total present worth of $3,181,236,000 in the year 2020. The average annual benefits for the proposed Rio Indio project that accrue during the construction of the proposed Rio Cocle del Norte project are estimated to be $383,074,000. The benefits for the proposed Rio Cocle del Norte project are estimated with the assumption that the Rio Indio project would use its Operating Option 2. Although the discharge tunnel would be larger, the proposed Rio Indio project would be operated for the period 2010 through 2020 just as if the proposed Rio Cocle del Norte project was not to be constructed.

To estimate the interest during construction, similar calculations were made for the costs of each proposed project. For the proposed Rio Indio project, interest during construction was taken from year 2001 to year 2020 and the interest during construction for the proposed Rio Cocle del Norte project was taken from the year 2007 to the year 2020. Additionally, there would be added costs for the larger inter-basin transfer tunnel between Indio Lake and the Panama Canal watershed that would only be required if the proposed Rio Cocle del Norte project were to be constructed. Those amounts were subtracted from the cost estimate for the proposed Rio Cocle del Norte project and added to the cost estimate for the proposed Rio Indio project. The revised estimated average annual costs for the Rio Indio portion of the overall project would be $152,436,000.

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) were computed. In the first instance, the analysis determines the feasibility of the proposal. The net benefits determines which proposal among several provides the greatest value for the investment dollars. Table 7 - 12 provides the benefit to cost ratios and the net benefits for this proposal.

Table 7 - 12 Economic Evaluation

Item	Value ($)
Average Annual Benefits	
Rio Indio	383,074,000
Rio Cocle del Norte	261,674,000
Sum	644,748,000
Average Annual Costs	
Rio Indio	152,436,000
Rio Cocle del Norte	191,656,000
Sum	344,093,000
Benefit to Cost Ratio	1.8
Net Benefits	282,299,000

For this proposed project, the operating scheme used in the simulation model does not draw the pool elevation down to the minimum elevation. Therefore, there is additional storage for which beneficial uses could be made. Since the proposed project meets all of the total demand for water over the planning period, there are no quantifiable remaining benefits to be estimated. The operating scheme could be revised to allow for additional hydropower production for which benefits could be estimated. The unused storage could also be used for increased forecast demands of navigation or M&I water uses. Should those forecast demands be increased, the net benefits for this proposed project would also be increased.

Internal Rate of Return

An internal rate of return analysis for the project was performed. To accomplish this analysis, the annual construction costs were used as the investment, and the undiscounted benefits were used as return cash flows. For The Rio Cocle del Norte project, the internal rate of return would be 19.7 percent.

Incremental Evaluation of Hydropower

Since the generation of hydropower would be provided through the conjunctive use of storage, an analysis of the incremental benefits and costs for this purpose was accomplished. The first costs of the Lands and Relocations and the Clearing and / or Grubbing, which were associated with hydropower, as well as the costs of the Hydropower Plants and the Transmission Lines were taken from Table 7 - 3. The portion of annual operation and maintenance costs associated with hydropower generation were derived from the data included in Table 7 - 5. The construction costs are estimated to be approximately $28,644,000. Interest during a two-year construction period is estimated to be $3,489,000 for a total hydropower investment cost of $32,123,000. The portion of annual operation and maintenance costs for hydropower were assumed to be $350,000 for staff, $250,000 for ordinary maintenance and $22,000 for major replacement. The total average annual costs for hydropower would be $4,491,000. The average annual benefits are estimated to be $20,750,000. The average annual benefits exceed the average annual costs for the proposed Rio Cocle del Norte project yielding a benefit to cost ratio of 4.6. It should be noted, however, that hydropower was valued at the current costs of production for the PCC. This value might underestimate the economic value of any additional hydropower generating capacity. Additional effort should be expended in any future planning studies to determine the economic value of added hydroelectric power generation.

Socio-Economic Impacts

The socio-economic impacts of the project could be substantial. The relocation of the towns of Coclesito, Cutevilla, Boca de La Encantada, El Calabazo, Platanal, Molejon, and La Boca del Guasimo and their approximately 5,600 residents would be an important issue. The average monthly income of families in the project area is $100 per month. No indigenous groups of peoples are known to reside in the impact area. Land use would be greatly impacted by the inundation of pastures and agricultural lands to create the Cocle del Norte Lake. The relocation of agricultural and ranching activities would be a substantial issue, because approximately 40 percent of the impoundment area is used for farming and ranching. The impoundment area would substantially impact the mineral and ore resources. The surface area of the proposed lake will encompass 28,830 ha with another 800 ha for the dam and construction areas including permanent disposal areas.

Post-construction revenues generated for the nation would be greater, because the project will create electric power generating potential. On a per hectare basis, revenues from the power generation would be greater than those produced by the current agricultural activity. It is estimated that after construction, 11 persons would be employed to operate and maintain the new facilities. During construction, the housing values in the areas adjacent to the dam site would increase, because there could be a higher demand by workers for livable homes. However, after project completion as the workers leave the area and housing demands decline, the housing values could drop 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 more public and community services may be offered to the local communities. After construction, these services should remain at the normal level.

To construct the dam, some existing roads would be improved and some new roads would be built. However, the dirt roads within the impoundment would be eliminated, which would change the 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 road systems would increase; however following cessation of construction, the traffic volumes could decline. Noise levels would increase during construction and could negatively impact noise-sensitive receptors, however, after construction, noise levels should return to pre-construction levels.

The communities that would receive the displaced people 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 through the division of communities, separation of families, and loss of livelihood. Following completion of the impoundment, tourism trade in the affected area, including fishing and ecotourism, could increase.

Environmental Setting

The Rio Cocle del Norte project would produce hydroelectric power and provide for 25.29 additional lockages per day on a continual basis. The structures for this proposed project would consist of a mass concrete gravity dam with a gated spillway, inter-basin transfer facilities, and a hydropower plant. The project encompasses the area to be flooded as well as the area downstream from the dam site. This area is sparsely populated. It is mountainous, has low coastal regions, and has primary forests. The Rio Cocle del Norte is located west of the Panama Canal, is used for navigation, and flows northward from the Continental Divide into the Atlantic Ocean. The Rio Cocle del Norte watershed above the dam is approximately 1,600 km^2. The impoundment area covers approximately 28,830 ha and consists of approximately 30 percent of forested land, 20 percent of pasture land (used by ranchers), 20 percent of cropland, 25 percent of newly slashed and burned land, and 5 percent of mining land. The lake water elevation will fluctuate from elevation 50 to 84 m MSL. The transmission lines, tunnel portals, and roads associated with the project could also have environmental impacts and should be sited to minimize those impacts.

LAND USE

The Rio Cocle del Norte project area encompasses the area to be flooded as well as the area downstream from the dam site. It is inhabited by about 5,600 people, dispersed throughout the area, with concentrations in the towns of Coclesito (population – 1,150), Cutevilla (population – 300), Boca de La Encantada (population – 250), El Calabazo (population – 250), Platanal (population – 230), Molejon (population –220) and La Boca del Guasimo (population – 220) and approximately 50 smaller settlements. Approximately 800 people live in eight communities downstream from the dam site at Cerro Pelado. The largest of these is Cocle del Norte with more than 300 people. San Lucas and Cocle del Norte are downstream towns, which should not be flooded.

Approximately 40 percent of the land in the project area is occupied by farms and ranches of various sizes. Farm crops include mandioc, maize, rice, beans, sugar, coffee, and tobacco. Ranchers raise cows, horses, chickens, and hogs. Most of the farmers and ranchers are small commercial enterprises, although there is also some cash crop and subsistence farming. There are also mineral and ore resources in the impoundment area.

INFRASTRUCTURE

Several towns have schools, 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 the Rio Cocle del Norte and its tributaries. Disposal of domestic waste is the responsibility of individual homeowners: each home has an outdoor latrine (a deep hole in the ground). There are some known health problems, such as hepatitis, dysentery, dermatitis, intestinal parasites, and respiratory illnesses associated with the present waste disposal methods. No major industries or poultry or beef processing plants are located in the project area. The roads in the project area are poorly maintained dirt roads that are usable only in the dry season (mid-December through March). The roads are rarely graded and receive little attention by either the

Ministry of Public Works or the local government. There are a limited number of paved roads around Coclesito. 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. People living in the Rio Cocle del Norte project area use the river as the primary means of transportation. The town of Cocle del Norte can only be reached by river from Coclesito or by sea from Colon.

The town of Coclesito supplies valuable services to many surrounding communities. Coclesito possesses schools, a hospital (with two resident doctors), a small diesel generating facility, and a museum honoring the late General Omar Torrijos, who is considered a national folk hero.

Coclesito has two elementary schools and one junior high school. The students of Coclesito and / or hospital patients come from Cocle del Norte, San Lucas, and other neighboring communities. The junior high school students stay in school dormitories during the week and return home for the weekend. The main road through Coclesito heads east to west and is gravel-packed. This road heads west to the Coclesito River Bridge that divides the town of Coclesito into northern and southern halves. Coclesito is connected by a gravel/dirt road to Llano Grande and from Llano Grande to La Pintada and Penonome by a paved road.

TERRESTRIAL HABITAT

Forests along the river that could support a diverse wildlife population cover about 90 percent of the area along the Rio Cocle del Norte and its tributaries. The forests extend to the upper mountainous areas above the Rio Cocle del Norte impoundment area. There are also some contiguous forests in the lowlands west of Coclesito within the Rio Cocle del Norte impoundment area.

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 it has not been determined, some of the listed species of the above list might be found in the project area.

AQUATIC HABITAT

The Rio Cocle del Norte in the project area displays traits characteristic of streams in mountainous regions. Its water is clear and cool, and the river bed ranges from sand to boulders, with numerous riffles, runs, and pools. The Rio Cocle del Norte has six major tributaries: Caño Rey, Rio San Lucas, Rio Toabre, Rio Cuatro Calles, Rio Don Juan, and Rio Cascajal; approximately 32 smaller creeks also flow into the Rio Cocle del Norte. The river is approximately 32 km long, its width ranges from 10 m (in the dry season) to 50 m at its mouth, and its depth ranges from less than 1 m to 25 m. The Rio Cocle del Norte and its tributaries appear to support some fish communities; however, information about fish communities that occur in the project area is limited.

WETLANDS

Areas that contain hydric soils and hydrophytic plant communities, and that are subject to hydrologic conditions are termed wetlands. The wetlands consist of forested riparian habitat along the immediate stream bank area. The width of the riparian habitat within the impoundment area varies from approximately 10 m to 75 m. In the west portion of the impoundment area, the wetlands become part of the dense forest. Approximately 90 percent of the streams above and below the dam site are bordered by forested riparian habitat along the Rio Cocle del Norte and its tributaries.

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 and early April, sizable areas of established forests and secondary growth are cleared and burned to prepare the land for agricultural use. Based on observations in the Rio Cocle del Norte project area, the amount of land burned varies annually.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

The El Cope National Park covers over 25,000 ha in the highlands of the Rio Cocle del Norte impoundment area and is important for its avifauna. The late General Omar Torrijos owned a home in Coclesito, which is now a museum. Also Pre-Columbian cultural resources have been identified by archaeological surveys located in the Rio Cocle del Norte impoundment area. 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 impoundment area would be substantial, since the forest covers approximately 8,650 ha, or 30 percent of the impoundment area. The forested area constitutes a relatively high quality terrestrial habitat. With the creation of the lake, migratory routes of some species could be adversely affected. The only forests that would remain near the Rio Cocle del Norte reservoir and its drainage basin would be confined to the higher elevations.

ANIMALS ON ENDANGERED LIST

Potential impacts on species on the endangered list could have a significant effect on the Rio Cocle del Norte project. The extent of potential effects cannot be determined at this time, because it is not known which of the listed species occur within the proposed project area. Furthermore, the significance of the forested riparian corridor along the area streams may increase if animals on the endangered list are found in the region. The Mesoamerican Biological Corridor is also promoting biodiversity conservation throughout the Atlantic basin, which could impose restrictions on the use of the project area.

WATER QUANTITY

The impacts of the project on water quantity should be positive, because construction of the dam should result in a significant increase in the volume of fresh water in surrounding areas during the dry season. The impacts downstream from the dam site could be important, because water rates would be reduced. Further, measures should be taken to release water at appropriate periods and amounts to avoid problems with water quality and temperature downstream. The cumulative impacts downstream of the dam site over time should also be minor.

WATER QUALITY

The impacts of the project on water quality are unknown. The impacts downstream from the dam site could be positive. The water should contain less silt due to minimum normal flow and should provide people downstream a higher quality water. It is unclear whether the proposed Cocle del Norte Lake will provide high quality water.

DOWNSTREAM AQUATIC FAUNAL HABITAT

The impacts on downstream aquatic fauna communities could be substantial, even though facilities would be included in the design of the dam to allow multi-level releases of water to avoid problems with water quality and temperature downstream. The Rio Cocle del Norte Dam should act as a large sediment trap, which should cause the released water to have low turbidity; therefore, siltation should not be a problem. The impacts of interference with migratory movements of natural stream fishes are unknown. Streambed degradation below the dam should be minimal.

FUTURE LAKE AQUATIC PLANT COMMUNITY

The impacts of the project on future aquatic plant communities in the proposed lake will depend on water level fluctuations, which are anticipated to range from 50 to 100 m over a 3-month period. Since the water levels would fluctuate widely, much of the shore would be covered with mud, where neither aquatic nor terrestrial plant communities could thrive. Rooted aquatic plants tend to grow as deep as light penetration allows.

AQUATIC FAUNA INHABITING AFFECTED AREAS

The impacts of the project on aquatic fauna inhabiting the Rio Cocle del Norte and its upstream tributaries could be important. If aquatic fauna is able to thrive in the new reservoir, they would be beneficially affected by having their habitat enlarged. Some unavoidable, adverse environmental impacts could occur and these impacts should be identified and appropriate mitigation measures addressed in feasibility level studies, should the alternative be recommended for further consideration. The new reservoir could provide excellent opportunities for recreational and subsistence fishing if it is responsibly managed and stocked with game fish by the Aquaculture Department. An increase in fish population could cause an increase in piscivorous predators, such as crocodiles, caimans, otters, and herons, etc. Other man-made lakes in the Republic of Panama have been stocked with peacock bass and tilapia, both of which have adapted well, but several riverine native species that formerly occupied the impoundments have disappeared. Loss of native species may affect their predator populations (otter, birds, and fish eating mammals).

WETLANDS

The impacts to upstream and downstream wetlands could be significant. Owing to the topography of the project area, a number of wetlands could be impacted by the project. It is possible that although the reservoir water levels will fluctuate, new wetlands could develop in the littoral zones. Due to minimum normal flow, the cumulative effects downstream of the dam site are expected to be minor.

AIR QUALITY

During construction of the dam, dust and emissions from equipment could impact the air quality in the project area. After construction, the air quality could improve because the Panamanian government currently discourages slash and burn activities.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

The impacts on cultural resources and historic properties could be substantial. The project area is large and is known to contain cultural resources and historic properties; therefore, the presence of cultural resources and historic properties is high. 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.

Additional Environmental Information Required

This section identifies the subject areas for which additional data are required to evaluate the scope and magnitude of the potential effects in further detail of the Rio Cocle del Norte alternative. The subject areas are discussed by impact category. This section identifies the subject areas for which insufficient data are available to fully evaluate the scope and magnitude of the potential effects of the Rio Cocle del Norte alternative. The data gaps are discussed by impact category.

SOCIO-ECONOMIC IMPACTS

- Conduct an 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).
  - Community and Regional Growth.
  - Transportation.
  - Housing.
  - Health (vector routes).
  - Population.
  - Community Cohesion.
  - Recreational Resources.
  - Mineral Resources.

TERRESTRIAL AND AQUATIC HABITAT

- Prepare site-specific habitat maps to ensure that all major terrestrial and aquatic habitat types are identified and quantified.
- Conduct field studies to locate special habitat features such as wetlands, roosting sites, reproductive sites, and the relative quality of forested areas.
- Determine the present quality and ecosystem value of existing habitats within the Rio Cocle del Norte project area.

ANIMALS ON THE ENDANGERED LIST

- Compile habitat maps to assess the availability and quality of suitable habitats for the animals on the endangered list.
- Conduct site surveys to determine the presence of selected species.
- Develop candidate mitigation measures for the appropriate project alternatives to be considered in the Conceptual Phase.
- Obtain other wildlife reports produced for the Rio Cocle del Norte project area.

WATER QUALITY

- As there are no water quality data available for the Rio Cocle del Norte 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 is incomplete. Additional evaluation studies need to be completed to identify cultural resources and historic 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 Section 35. Tables 7 - 13 through 7 - 15 present the evaluation of the proposed Rio Cocle del Norte project as related to developmental effects, environmental effects, and socio-economic effects.

Table 7 - 13 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	10	10	100
	Additional Hydropower Potential	7	5	35
Technical Viability	Design Constraints	3	6	18
	Feasibility of Concept	4	6	24
Operational Issues	Compatibility	8	6	48
	Maintenance Requirements	6	2	12
	Operational resources required	6	2	12
Economic feasibility	Net Benefits	10	9	90
	Total			539

[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 7 - 14 Environmental Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Terrestrial Habitat	1	8	8
Animals on Extinction List	1	10	10
Water Quantity Impacts – Lake	6	10	60
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			337

[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 7 - 15 Socio-Economic Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Land Use	1	7	7
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			302

[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

Pertinent data for the proposed Rio Cocle del Norte dam are presented in Table 7 - 16.

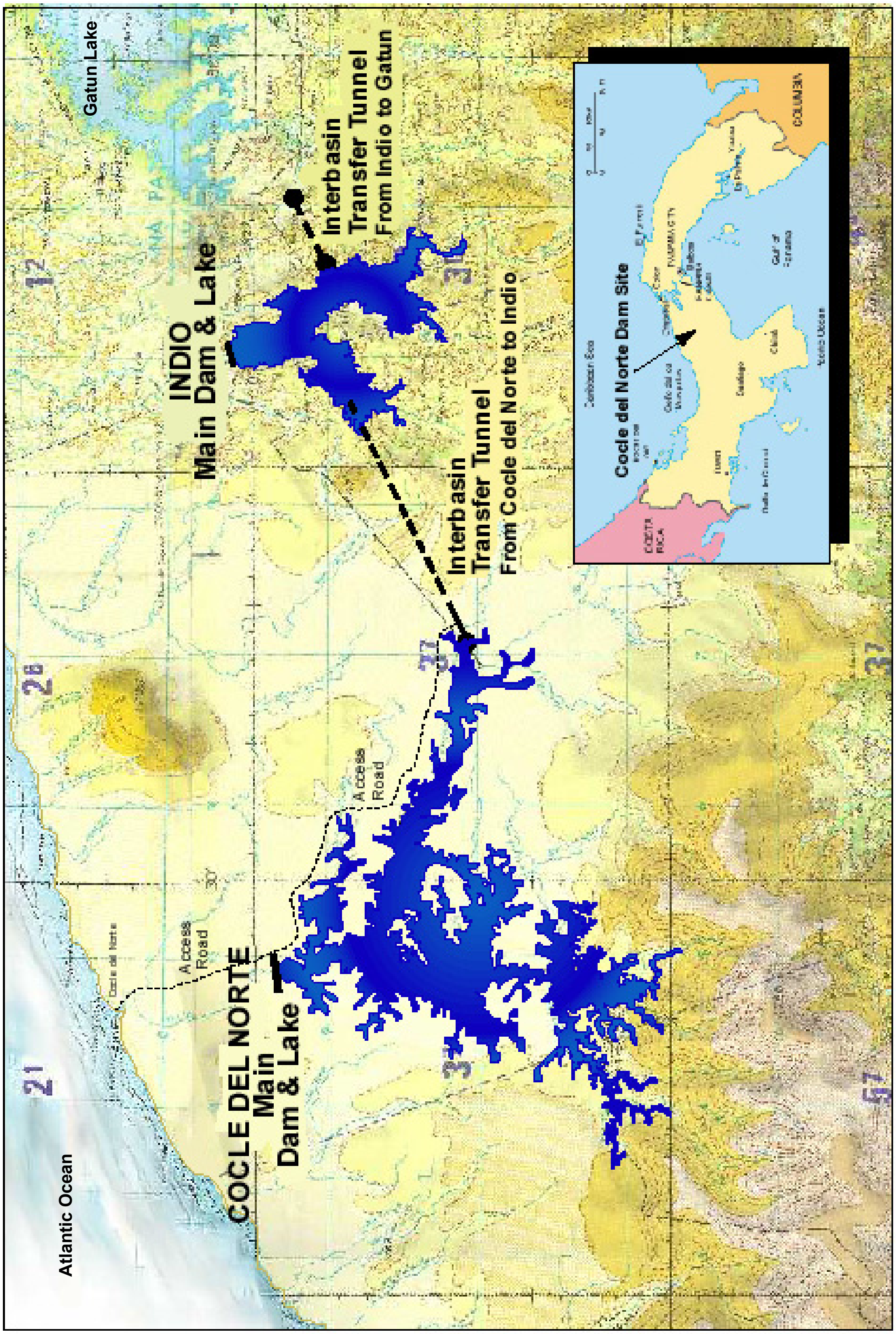
Table 7 - 16 Pertinent Data for The Rio Cocle del Norte Project

GENERAL	
Dam site, above mouth of Rio Cocle del Norte	15 km
Drainage area above dam site	1,600 km^2
Average annual flow at dam site	109 CMS
RESERVOIR	
Elevation, top of flood storage lake	84 m MSL
Area at top of flood storage lake	29,450 ha
Top clearing elevation	85 m MSL
Lower clearing elevation	60 m MSL
Elevation of normal operating lake	80 m MSL
Elevation of minimum operating lake	60 m MSL
Usable Storage between Max. and Min. Levels	4,155 MCM
Area at normal operating lake	26,580 ha
Area at minimum operating lake	15,520 ha
DAM AND APPURTENANT STRUCTURES	
Dam	
Type of dam	Rock Fill
Top elevation of dam (nominal)	85 m
Overall length of dam	848 m
Height above lowest foundation	85.0 m
Crest width (nominal)	13 m
Volume of rockfill dam	3,812,000 M^3
SPILLWAY	
Type of Spillway	Uncontrolled ogee
Total length at flow surface	346 m
Elevation of crest	80 m MSL
Maximum discharge	5,346 CMS

Table 7 - 16 Pertinent Data for The Rio Cocle del Norte Project (continued)

INTER-BASIN TRANSFER TUNNEL	
Rio Cocle del Norte to Rio Indio:	
Tunnel length	18.1 km
Tunnel diameter	7.6 m
Tunnel capacity at maximum head	188.4 CMS
Inlet invert	40 m MSL
Outlet invert	35 m MSL
Rio Indio to Gatun Lake:	
Tunnel length	5.5 km (+/-)
Tunnel diameter	6 m
Tunnel capacity at maximum head	216 CMS
Inlet invert	37 m MSL
Outlet invert	35 m MSL
HYDROPOWER PLANT	
Type of hydropower plant construction	Reinforced concrete, outdoor
Number of units	2
Capacity of each unit	9 MW
Type hydraulic turbine	Vertical Francis
CONSTRUCTION / POWERHOUSE DIVERSION	
Diversion length	400 m
Horseshoe tunnel dimensions	(2) 7.5 m x 7.5 m
Inlet invert	10 m MSL
Outlet invert	9 m MSL
Cofferdam Height above tunnel inlet invert	35 m
MINIMUM FLOW CONDUIT	
Conduit diameter	1.5 m
Conduit length	400 m
Inlet invert	8 m MSL
Outlet invert	6 m MSL
Conduit capacity	2.3 CMS

COCLE DEL NORTE (Lake - 80 m)



Project Location Map

Plate 7 - 1 Project Location Map

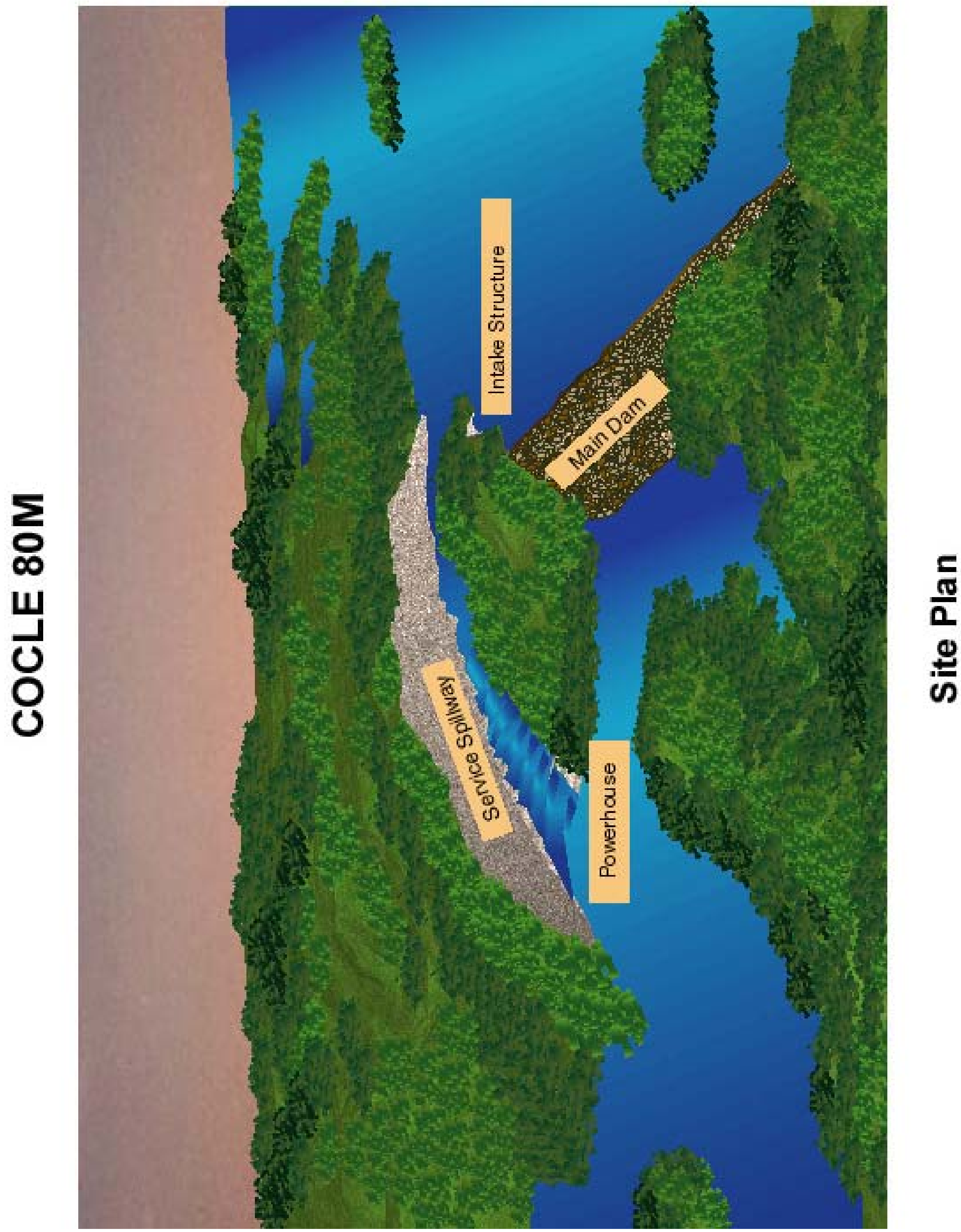


Plate 7 - 2   Site Plan

SECTION 8

LAKE AT ELEVATION 100
(Operated in conjunction with Caño Sucio and Indio Lakes)

Rio Cocle del Norte

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Synopsis

The development plan presented herein would include a dam and lake on the Rio Cocle del Norte with a normal lake level at 100 m MSL connected by a channel through the basin divide to the Caño Sucio Lake. The Caño Sucio Lake would be connected to the Indio Lake by tunnel. Indio Lake would be connected to the Panama Canal watershed at Gatun Lake via a second tunnel (see Section 5 of this report for details of the Rio Indio development). Water impounded in these lakes would be transferred to the Panama Canal watershed as needed to support navigation. Figure 8 – 1 below presents a profile of the proposed lake system.

The Rio Cocle del Norte watershed is located on to the western side of the Panama Canal watershed. The two watersheds are separated by the Rio Indio and Rio Caño Sucio watersheds. The proposed Rio Cocle del Norte dam site would be approximately 15 km inland from the Atlantic Ocean, and approximately 7 km downstream of the confluence of Rio Cocle del Norte and Rio Toabre. The structures for this proposed project would consist of a rock fill dam for both the Rio Cocle del Norte and Rio Caño Sucio Dams, a channel cut through the basin divide between the Rio Caño Sucio and Rio Cocle del Norte watersheds. Then a 2 km inter-basin transfer tunnel would connect the Caño Sucio Lake with Indio Lake, an enlarged inter-basin transfer tunnel connecting Indio Lake with the Panama Canal watershed, and a 20.5 MW hydropower plant. The total costs of the Rio Cocle del Norte project as described herein are estimated to be $665,805,000.

The Rio Cocle del Norte project would provide additional water, equivalent to approximately twenty five (25.29) lockages per day, for canal operations up to the year 2070. The Rio Cocle del Norte project would provide this amount of water at a 100 percent level of reliability. This would contribute measurably to the reliability of the Panama Canal to serve its customers as future demands increase and it would greatly reduce the need for imposing draft restrictions that results in light loading of vessels during periods of low water availability. Additional benefits would be realized in the form of increased hydropower. A 100 percent reliability implies that all demands were met and no shortages were realized. Furthermore, under the operating scheme, the lake elevation did not drop to the minimum operating lake elevation with demands at 180 percent of current levels, thus leaving storage in the Cocle del Norte Lake that was not required. This unused storage could be used to produce additional energy or to accommodate expansion of the Panama Canal that might take place in the future. The net increase in average annual energy produced by the hydropower plants, including a plant at the Rio Cocle del Norte Dam, the Rio Indio Dam and the existing plants, would be 227,200 MWh after sufficient water is used to meet current daily canal operations.

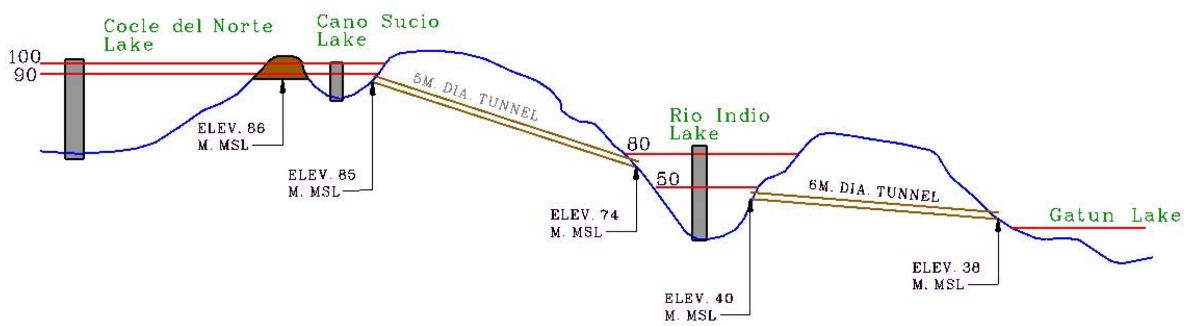


Figure 8 - 1   System Profile

Site Selection

The proposed Rio Cocle del Norte dam site was chosen 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. To maximize the water impounded, it was desirable to locate the dam as far downstream in the Rio Cocle del Norte watershed as possible. In choosing a site for the dam, a location was sought where the surrounding hillsides were relatively steep and high, and the valley was relatively narrow. The downstream portion of the Rio Cocle del Norte watershed contains several sites that meet these criteria.

The site chosen for the proposed Rio Cocle del Norte Dam would be approximately 15 km inland from the Atlantic Ocean and approximately 7 km downstream from the confluence of Rio Cocle del Norte and Rio Toabre. This site would accommodate construction of a dam with a normal operating lake level at elevation 100 m MSL and a maximum flood storage lake level at elevation 104 m MSL.

There are several watersheds between the Rio Cocle del Norte watershed and the Rio Indio watershed. Dam sites were considered in these watersheds in order to reduce the costs of the inter-basin transfer facilities connecting the Cocle del Norte Lake and Indio Lake. A location was identified for a proposed dam site on the Rio Caño Sucio. The proposed Rio Caño Sucio dam site would be approximately 25 km inland from the Atlantic Ocean. This site would also accommodate construction of a dam with a maximum operating lake level at elevation 100 m MSL and a maximum flood storage lake level at elevation 104 m MSL.

Plate 8 - 1 shows the location of the proposed Rio Cocle del Norte project and the Rio Caño Sucio project.

Hydrologic Considerations

The Rio Cocle del Norte flows northward from the Continental Divide to the Atlantic Ocean. The headwaters of the watershed begin at elevation 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 Cocle del Norte watershed varies from a high of 4,000 mm at the coast to a low of 2,500 mm in the middle watershed area and increases again to over 3,000 mm in the Continental Divide. The proposed Cocle del Norte Lake would receive runoff from approximately 1,600 km^2 of the upper portion of the watershed. Rainfall runoff produces an average annual flow of 109 CMS at the proposed dam site.

The discharge at the Rio Cocle del Norte dam site was obtained by extrapolating the recorded and correlated stream flow data of the Canoas hydrologic station, and adding the recorded and correlated flows of the Rio Toabre at Batatilla.

Two hydrologic stations have gauged the Rio Cocle del Norte. A staff gage read twice daily located at El Torno started operation in 1958 and was discontinued in 1986, and a continuous recorder located at Canoas that started operating in 1983. The recorder gage is located 6 km due south of where the staff gage was located. The recorded staff gage flows at El Torno, were extended by statistical correlation with the Rio Toabre at Batatilla. These flows at El Torno were then used as a transfer point to fill in missing data and extend the recorded flows at Canoas by further statistical correlation. The consistencies of the measured and correlated data were verified using the double mass curve method with satisfactory results.

Because of the proximity and in the absence of additional information, the monthly evaporation rates recorded at Gatun Lake were used to establish the evaporation of Cocle del Norte Lake.

The Rio Caño Sucio also flows from the north side of the Continental Divide to the Atlantic Ocean. The headwaters of the Rio Caño Sucio watershed begin at approximate elevation 240 m MSL approximately 30 km inland and fall to mean sea level at its mouth. Annual rainfall ranges from 3,000 mm along the coast to 2,000 mm in the higher ranges of the upper watershed. The proposed Rio Caño Sucio Lake would receive runoff from approximately 111 km^2 of the upper portion of the watershed. Rainfall runoff produces an average annual flow of 7.4 CMS at the proposed Rio Caño Sucio dam site.

The Rio Caño Sucio is a stream without hydrological historical records. In order to establish the discharge at the dam site, it was assumed that this watershed would have the same yield per unit area as the neighboring basin of the Rio Indio measured at Boca de Uracillo.

Because of the proximity and in the absence of additional information, the monthly evaporation rates recorded at Gatun Lake were used to establish the evaporation of Caño Sucio Lake.

It is recommended that a stream gage be installed in the vicinity of the dam site if this river is going to be subjected to additional studies.

Geologic Considerations

The proposed Rio Cocle del Norte project is located in an area of the Isthmus of Panama where volcanic or intrusive igneous rocks are encountered at the surface. The volcanic rocks consist of lava flows, breccias, tuffs and plugs of the Tucue Formation, which are andesitic or basaltic in nature. The intrusive igneous rocks consist of granodiorites, quartzmonzonites, gabrodiorites, diorites, or dacites. Little has been found concerning the engineering characteristics of the rocks of these formations. It is anticipated, however, that they may show a wide variation in quality, from high quality of the intrusive rocks and the extrusive lava flows, to possibly weathered and lesser quality volcanic tuffs.

Hard, high quality igneous rock (diabase or fine grained gabbro) outcrops occur along the river bank at the proposed dam site. This rock should be excellent for use as either rock fill or concrete aggregate. It is not known for certain what type of rock underlies the abutment slopes, since they are completely covered with vegetation, but there is no reason to believe that it differs from that exposed at the rivers edge.

In the absence of detailed geologic mapping for the proposed Rio Cocle del Norte dam site, a degree of extrapolation was necessary. It was predicted that rock, at the proposed Rio Cocle del Norte dam site, would be encountered at a shallow depth and would be of sufficient quality to serve as foundation for the dam and appurtenant structures. This prediction was based on available general geologic mapping and general data. Furthermore, it was assumed that sufficient rock for fill and concrete aggregate would be available from the required excavation and that impervious materials would be available within the immediate area for use in the construction of the project.

Lake Operation

Cocle del Norte Lake and Caño Sucio Lake would be connected by a channel and would be operated as one lake. An interbasin tunnel connecting the Caño Sucio Lake to Indio Lake would be provided to transfer waters to Indio Lake. Only one operating Option was considered in this alternative for periods when water would be transferred from Cocle del Norte / Caño Sucio Lake to the Panama Canal watershed for canal operations. The water surface of the Cocle del Norte / Caño Sucio Lake would fluctuate from the normal operating lake level at elevation 100 m MSL down to the minimum lake operating level at elevation 90 m MSL, providing a total of 3,688,000,000 M^3 of useable storage. Only one option was considered for this alternative because the topography in the Caño Sucio Lake limited the minimum lake level to 90 m MSL.

Maximum flood level of the Cocle del Norte / Caño Sucio Lake would be at elevation 104 m MSL. The volume between the maximum flood lake level and the normal operating lake level would be used to store flood waters and reduce peak flood flows. Some reduction in flooding would be realized in areas along the Rio Cocle del Norte downstream of the dam.

Water would be transferred from Cocle del Norte / Caño Sucio Lake to Indio Lake and then to the Panama Canal watershed for use in canal operations. The Indio Lake would operate between elevations 80 m and 50 m MSL. Thus, operation of the linked system of lakes, Cocle del Norte / Caño Sucio Lake, Indio Lake, and Panama Canal watershed, would allow some flexibility in approach. The water in storage at the Indio Lake could be transferred to the Panama Canal watershed initially with that in the Cocle del Norte Lake held at a higher level, or both lake levels could be allowed to fluctuate simultaneously. Once Cocle del Norte / Caño Sucio Lake levels reached elevation 90 m MSL the water surface in Indio Lake could be lowered further, down to elevation 50 m MSL, the lower limit of its operating range.

A description of the project features for the proposed Rio Indio project is included in Section 5.

Project Features

GENERAL

The structures for the proposed Rio Cocle del Norte / Rio Caño Sucio project would consist of rock fill dams on the Rio Cocle del Norte and the Rio Caño Sucio, uncontrolled ogee spillways on the Rio Cocle del Norte and Rio Caño Sucio, inter-basin transfer facilities, two hydropower plants, and other outlet works. The following paragraphs provide a description of the proposed structures and improvements. Plate 8 - 1 depicts the location of the two dams, the two spillways, the inter-basin transfer facilities, the hydropower plants, and the other 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 PCC that contained assumptions and design calculations for the reconnaissance level investigations of these structures. If this proposed project is carried into the planning studies, optimization of the project features and improvements must be accomplished.

EMBANKMENT

Dams

The proposed Rio Cocle del Norte Dam would be an embankment with the top at elevation 105 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 993666 north and 549697 east. The right abutment would be 993463 north and 550694 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 would be approximately 90 m high, and the overall length would be 1,017 m.

The proposed Rio Caño Sucio Dam would be an embankment with the top at elevation 105 m MSL and with a crest width of 13 m. 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 would be approximately 20 m high, and the overall length would be 185 m. Foundation grouting would be required across the entire base of all dams and up a portion of the valley walls. A blend of bentonite and native fill materials in a core trench could provide seepage cutoff in the embankment foundations. A concrete or bentonite cutoff wall could also provide seepage cutoff.

The actual side slopes and crest width 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. See Section 5 for typical embankment sections.

Saddle Dams

Three saddle dams would be required to complete the lake impoundment. For this study, all saddle dams were 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 elevation 105 m MSL, and they would have a crest width of 13 m. The length of the saddle dams would be 140 m, 340 m, and 120 m. 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**.** The embankment construction would be similar to that shown for the Rio Indio project, Section 5 of this report.

SPILLWAY

At the proposed Rio Cocle del Norte Dam an uncontrolled ogee spillway with a length of 346 m and a crest at elevation 100 m MSL would be required. The spillway crest would be 5 m below the elevation of the top of the dam. The maximum discharge from the spillway would be 5,346 CMS at a maximum flood storage lake level at elevation 104 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 right 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. A stilling basin would be excavated into the rock adjacent to the natural channel at the downstream end of the tailrace channel for energy dissipation. See Plate 8 - 2 for the location of the spillway and plates in Section 5 – Rio Indio for a typical section at the spillway.

At the proposed Caño Sucio Dam an uncontrolled ogee spillway with a length of 150 m and a crest at elevation 100 m MSL would be required. The spillway crest would be 5 m below the elevation of the top of the dam. The maximum discharge from the spillway would be 1,141 CMS at a maximum flood storage lake level at elevation 104 m MSL. The spillway design discharge was equivalent to a 1 in 1,000 frequency unregulated flow from the Rio Caño Sucio basin at the dam site. A spillway was included for the Rio Caño Sucio even though it would be more efficient to include the additional spillway capacity with the Rio Cocle del Norte Dam spillway. This was done to provide some higher flows to the Rio Caño Sucio with the intent of minimizing, as much as possible, the hydraulic, hydrologic, and environmental impacts to the Rio Caño Sucio downstream of the dam. 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. A stilling basin would be excavated into the rock adjacent to the natural channel at the downstream end of the tailrace channel for energy dissipation. See Plate 8 - 2 for the location of the spillway. The spillway profile would be similar to that shown in Section 5 – Rio Indio.

IMPOUNDMENT

The lake formed by the proposed Rio Cocle del Norte Dam would have a normal operating lake level at elevation 100 m MSL and would have a surface area of approximately 38,990 ha. At the minimum operating lake level, elevation 90 m MSL, the surface area would be approximately 32,580 ha. At maximum flood storage lake level, elevation 104 m MSL, the surface area would be approximately 41,690 ha. At the top of dam, elevation 105 m MSL, the surface area would be approximately 42,350 ha.

The lake formed by the proposed Caño Sucio Dam would have a normal operating lake level at elevation 100 m MSL and would have a surface area of approximately 1,360 ha. At the minimum operating lake level at elevation 90 m MSL, the surface area would be 244 ha. At maximum flood storage lake level, elevation 104 m MSL, the surface area would be approximately 2,040 ha. At the top of dam, elevation 105 m MSL, the surface area would be approximately 2,230 ha.

CLEARING AND / OR GRUBBING

Clearing and grubbing would be required for all areas required for construction of the dam (embankments and spillways), inter-basin transfer facilities, other outlet works, hydropower plants and switchyard sites, access roads, and disposal and staging areas. Clearing only would be required on the 10,900 ha in the cumulative lake area between the normal operating lake elevation at 104 m MSL and the minimum operating lake elevation at 90 m MSL.

INTER-BASIN TRANSFER FACILITIES

The natural connector between Cocle del Norte Lake and Caño Sucio Lake would be deepened to provide a bottom elevation of approximately 86 m MSL. Caño Sucio Lake, Indio Lake, and Gatun Lake would be connected by tunnels through the common basin divides.

The finished tunnel connecting the easternmost end of Caño Sucio Lake to the westernmost leg of Indio Lake would be 5 m in diameter and approximately 2 km in length. This tunnel would have an inlet invert elevation of 85 m MSL and an outfall invert elevation of 74 m MSL. The capacity of the tunnel would be approximately 155 CMS.

The 3 m finished diameter inter-basin transfer tunnel included in the proposed Rio Indio project between Indio Lake and the Panama Canal watershed would not be large enough to pass the additional flows from the Cocle del Norte Lake. This tunnel would need to be enlarged to a 6 m finished diameter to pass the combined flows from Indio Lake and Cocle del Norte Lake at elevation 100 m MSL. The maximum capacity of this tunnel would be 216 CMS, and it would have invert elevations at its inlet and outlet ends of 40 m and 38 m MSL respectively. This would result in a slight lengthening of the tunnel over that indicated in the Indio Lake alternative described in Section 5. The additional cost of this tunnel resulting from changes in diameter and length would be directly attributable to the Rio Cocle del Norte project.

The location and assumed alignment of these features are shown on Plate 8 - 1 and a profile of the entire transfer system is shown in Figure 8 - 1. The tunnels would be under pressure continually since flow through the tunnels would be controlled at the downstream end of each. This control would be in the form of a gate control structure and / or a hydropower plant. To allow for maintenance of the tunnel and to provide for rapid emergency closure of the tunnel, a gate / stoplog structure would be constructed at the upstream end of each. In the process of stopping flow through the tunnel, a water hammer effect could be generated. Therefore, sufficient surge protection shafts would be constructed. These shafts would require relatively minor surface structures to protect the openings and to provide for personnel safety.

It was assumed that the tunnels would be concrete lined and that rock bolting would be required over much of the length of the tunnel to stabilize the rock.

HYDROPOWER PLANTS

The flows, excess to the needs of the Panama Canal operation, at the proposed Rio Cocle del Norte Dam would support installation of a 21.3 MW hydropower plant. The flow and head available at the downstream end of the Sucio to Indio transfer tunnel would support a hydropower plant with a capacity of 6.2 MW. The plant discussed in Section 5 of this report for installation at the downstream end of the Indio to Gatun transfer tunnel could be increased in size from 5 MW to approximately 9.7 MW. These facilities would be designed and configured to function as part of the national power grid. Transmissions lines would be constructed to carry the energy from each of the plants to a connection with the grid near La Chorrera. Suggested design parameters are tabulated below in Table 8 - 1. Design head for the powerplants at the dams are based on the average lake elevation above the expected tailwater elevation. Design head for the Sucio to Indio Tunnel is based on the difference between the average lake elevations of Cocle del Norte and Indio Lakes. Design head for the plant at the Indio to Gatun Tunnel is based on the average Indio Lake elevation above the tunnel outlet.

Table 8 - 1 Powerplant Parameters

Project	Capacity (MW)	Design Head (m)	Design Flow (CMS)
Sucio to Indio Tunnel	6.2	15	49.0
Rio Cocle del Norte Dam	21.3	75	33.7
Indio to Gatun Tunnel	9.7	30	38.3
Rio Indio Dam	25.0	60	49.4

OUTLET WORKS

At the Rio Cocle del Norte Dam an outlet works system would be required. This system would provide for diversion of the Rio Cocle del Norte and the Rio Caño Sucio during construction, supply water for production of hydropower, allow for emergency drawdown of the lake after it is raised and placed in service, and allow minimum flow to pass by the dam.

These water handling facilities would consist of two 7.5 by 7.5 m horseshoe shaped tunnels passing through the dam abutment, an intake structure located in the lake, an outlet channel downstream, and various gate structures and water conduits. The diversion tunnel would be approximately 400 m in length; it would have an inlet invert elevation at 10 m MSL and an outlet invert elevation at 9 m MSL. The diversion tunnel would serve in combination with the cofferdam to protect the construction area from floods up to a 10 percent frequency. A 10 percent frequency flood would deliver a peak flow of approximately 2,820 CMS at the site without regulation from the dam. The cofferdam would measure 35 m above the upstream invert of the tunnel.

A separate 1.5 m diameter conduit, required for minimum flow, would be installed beneath the floor of this tunnel. The minimum flow conduit would be approximately 400 m in length and it would have an inlet end invert elevation of 8 m MSL and an outlet invert of 6 m MSL. Intake for minimum flow would be through individually gated water quality intake ports located at various levels in the intake structure. The elevations of these intakes would be established during environmental water quality investigations made during subsequent phases of study. The capacity of the minimum flow conduit would be 10.9 CMS.

At the downstream end of the tunnel, a bulkhead structure would be installed to close the construction diversion and to divert reservoir water into the hydropower penstock. The closure would be configured so that it could be removed in the event that the Cocle del Norte Lake had to be drawn down.

The channel connecting the Rio Caño Sucio basin to the Rio Toabre arm of the Rio Cocle del Norte basin would be constructed early in the construction sequence. This would allow normal stream flows and flood flows from the Rio Caño Sucio basin to pass into the Rio Cocle del Norte during construction. This would require only a small cofferdam at the Caño Sucio dam site.

ACCESS ROUTES

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

The access from Colon to the village of Cocle del Norte could be obtained by barging southwestward along the Atlantic Ocean. This route would require docking and offloading facilities at the village of Cocle del Norte. Approximately 100 m of dock facilities and minimal dredging for barge access would be required at the village of Cocle del Norte for offloading of construction materials and equipment.

Alternatively, access to Cocle del Norte Village could be gained via the north coast highway crossing the Panama Canal north of Gatun Locks. This would require extensive roadway improvement and new roadway construction and would require traversing the existing canal crossing at Gatun Locks which is mounted atop the lower lock gates. This would be very time consuming since the canal traffic is always given right-of-way at this crossing. Some difficulty might also be encountered in maneuvering construction and heavy transport equipment over this crossing.

From the Cocle del Norte Village, a new roadway would be required along the Rio Cocle del Norte to the dam site and the other construction sites with one exception. Access to the tunnel outlet at Indio Lake would be achieved by constructing a new road from the proposed roads constructed for the Rio Indio project. The proposed access road from the Cocle del Norte Village to the dam site would be approximately 13 km in length. An additional 30 km of roads would be required to provide access to the inlet and outlet of the inter-basin transfer tunnel.

The route from Panama City would be by roads previously constructed in conjunction with the Rio Indio project and then generally westward by new roads to the dam site and the other construction sites.

A route northward from the Inter-American Highway near the south coast was also considered but was abandoned because of the necessity of traversing the high mountains at the Continental Divide, because of the large number of stream crossings involved, and because of the excessive length of new roadway that this route would require.

The conclusion was that the land route from the Rio Indio project would be the best alternative because the new road construction would benefit the local population. Bridges and / or culverts would be required at five streams. Plate 8 - 1 shows the proposed route.

DISPOSAL AREA

Rock and earth and rock fill materials removed as a result of the required excavation for structures, tunnels or roadways that are unsatisfactory, in excess or are impractical for use in the finished work shall be stockpiled in designated areas and sloped in order to drain to provide a stable mass.

Sources of Construction Materials

Cement would be available within the Republic of Panama. Rock, obtained from the construction site or from the lake area, would be used for onsite manufacture of aggregates for the concrete. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) would be fabricated outside the Republic of Panama and imported for final assembly and installation at the proposed dam site.

Real Estate Requirements

The proposed Rio Cocle del Norte project would be located in the Cocle and Colon Provinces. Construction of this proposed project would require approximately 46,000 ha. Table 8 - 2 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 8 - 2 Real Estate Requirements

Project Feature	Land Required for Rio Cocle del Norte (ha)	Land Required for Rio Caño Sucio (ha)	Total Land Required (ha)
Lake	42,400	2,200	44,600
Dam Site	200	100	300
Staging Area	200	100	300
Housing and Facilities	200	0	200
Disposal Area	400	200	600
Total	43,400	2,600	46,000

Relocations

Much of the lake areas would be located in a moderately populated region with few roads and utilities. These areas are devoted primarily to subsistence farming, pineapple growing, and ranching. Some areas are densely forested. Structures and individuals located in the lake area below elevation 105 m MSL would require relocation because of the normal lake inundation and the need to secure the lake perimeter for flood considerations. The most significant village within the proposed lake area is Coclecito that is estimated to have a population of 1,150. It would require relocation of the entire village. Other relocations associated with the proposed project would be minimal.

Development Sequence

For the economical evaluation of this project, it was assumed that the planning for the Rio Cocle del Norte project would begin during the construction of the Rio Indio project and that construction would be started immediately following completion of the Rio Indio project.

Planning studies would be accomplished to evaluate the alternative features of each proposed project. Each potentially viable project would be evaluated to assure that the plan presented would provide all of the features required to make it functional. Each would also be assessed as to its effectiveness in meeting the project goal of providing M & I water supply in relief of current or future planned withdrawals from the Panama Canal, with due recognition of any secondary benefits. Environmental assessments of the proposed projects would begin during the planning studies phase and would continue during the final design, advertising and award phase, and on through construction of the project. The final design would be accomplished for the recommended project. After completion of the final design, plans and specifications would be prepared for the advertising and award phase.

Project implementation would begin 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 would then be acquired.

Access roads would be constructed to the dam site and the inter-basin transfer tunnel inlet and outlet sites. Once highway access to the sites has been established, a camp would be built to house workers during construction.

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

Construction of the dam would begin with the clearing and grubbing of the construction sites and the clearing of the lake area. Excavation for the inter-basin transfer tunnel and the intake structure and construction of the diversion tunnel(s) at the dam site and the spillway would follow with work being done simultaneously. Materials removed from the nearest of these sites would be stockpiled for future use in the earth and rock fill portions of the dam. Once the intake structure and diversion tunnel(s) were completed, the dam construction site would be isolated using upstream and downstream cofferdams, which would eventually become part of the main dam, and the stream would be diverted through the tunnel. The dam foundation would then be excavated and grouted, and the dam constructed. Concurrently with construction of the dam, the hydropower plant site downstream of the dam would be excavated, and the powerhouse construction would be started. Upon completion of the dam, the inter-basin transfer tunnel, and appurtenant structures, the diversion would be stopped and lake filling would begin. Simultaneously with this operation, the downstream gate and flow separation structure would be constructed to provide for closure of the diversion tunnel(s) and diversion of the tunnel flows to the hydropower penstock(s). The minimum flow conduit would also be installed through the diversion tunnel at this time. At the completion of the project, all facilities would undergo trial operations followed by commissioning for service.

Considering the climatic conditions and the obstacles posed by the remote location of the construction sites and the nature of the work, it is estimated that development of this project could be completed in approximately 14.5 years, from initial planning to lake filling. A development sequence of the various project features is presented in Figure 8 - 2.

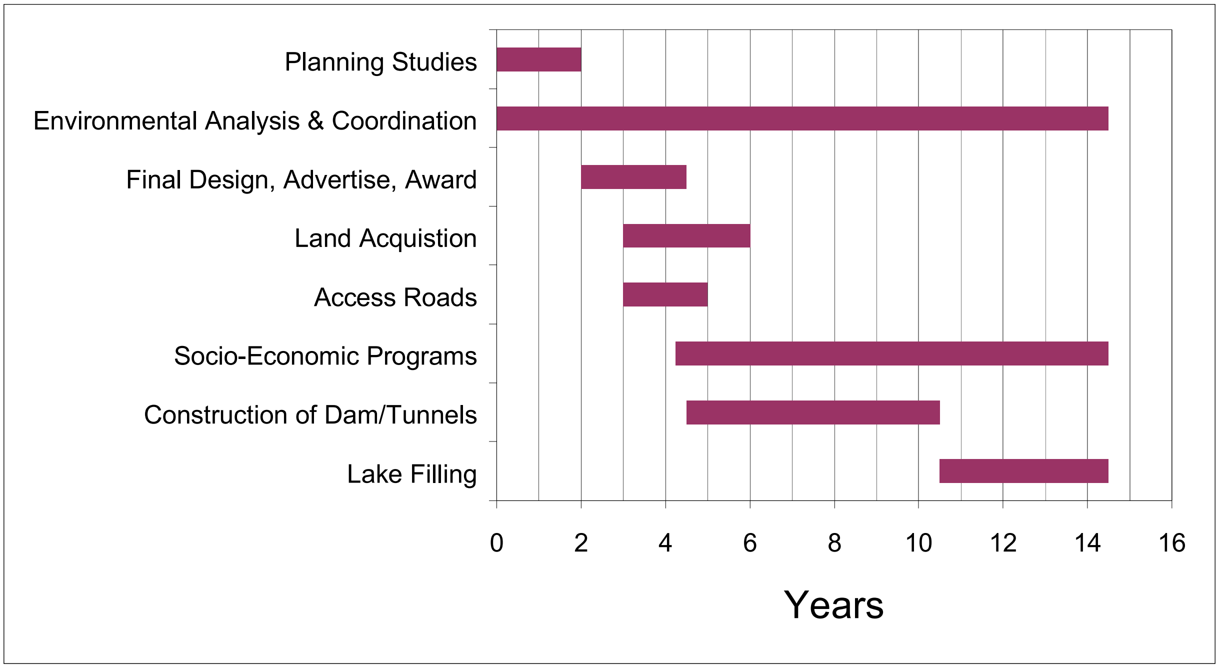


Figure 8 - 2 Development Sequence

Hydrologic Reliability

In order to determine the effect of the proposed Cocle del Norte Lake on the hydrologic reliability of the Panama Canal, the Cocle del Norte / Caño Sucio Lake was evaluated as linked with the Indio Lake and the Panama Canal watershed. A HEC-5 model was constructed with this linked configuration. Water stored in Cocle del Norte / Caño Sucio Lake was provided, as needed, to Gatun Lake when shortages were expected using the Indio Lake as a conduit. Excess flows in the Rio Cocle del Norte were still released down the Rio Cocle del Norte, taking advantage of the hydropower generation when possible. Minimum flow requirements were deducted from the waters made available to the Panama Canal watershed and released down the Rio Cocle del Norte and Rio Caño Sucio.

HEC-5 model simulations were conducted for both the current canal system and the system operating with Cocle del Norte Lake providing water through Caño Sucio and Indio Lakes to Gatun Lake. The simulations considered proportionally increasing demands beginning with current demand levels. The simulations considered proportionally increasing demands up to 180 percent of current demand levels. The period of simulation considered 50.5 years (Jan. 1948 through July 1998) of hydrologic records at Rio Cocle del Norte. Since the normal operating lake level for Cocle del Norte Lake is 100 m MSL and Indio Lake is 80 m MSL, water can be transferred from Cocle del Norte Lake to Indio Lake as needed. Lake operating scenarios are described above in the section titled Lake Operation. Separate documentation was provided to the PCC that contained the model code and simulation output for these investigations. Figure 8 - 1 is a schematic of the proposed linked lake system.

Figure 8 - 3 compares the resulting hydrologic reliability for the alternative to the reliability of the existing system. The horizontal axis along the bottom of Figure 8 - 3 reflects demands as a ratio of the last five year average and the axis along the top reflects demands in lockages (assuming 55 million gallons per lockage).

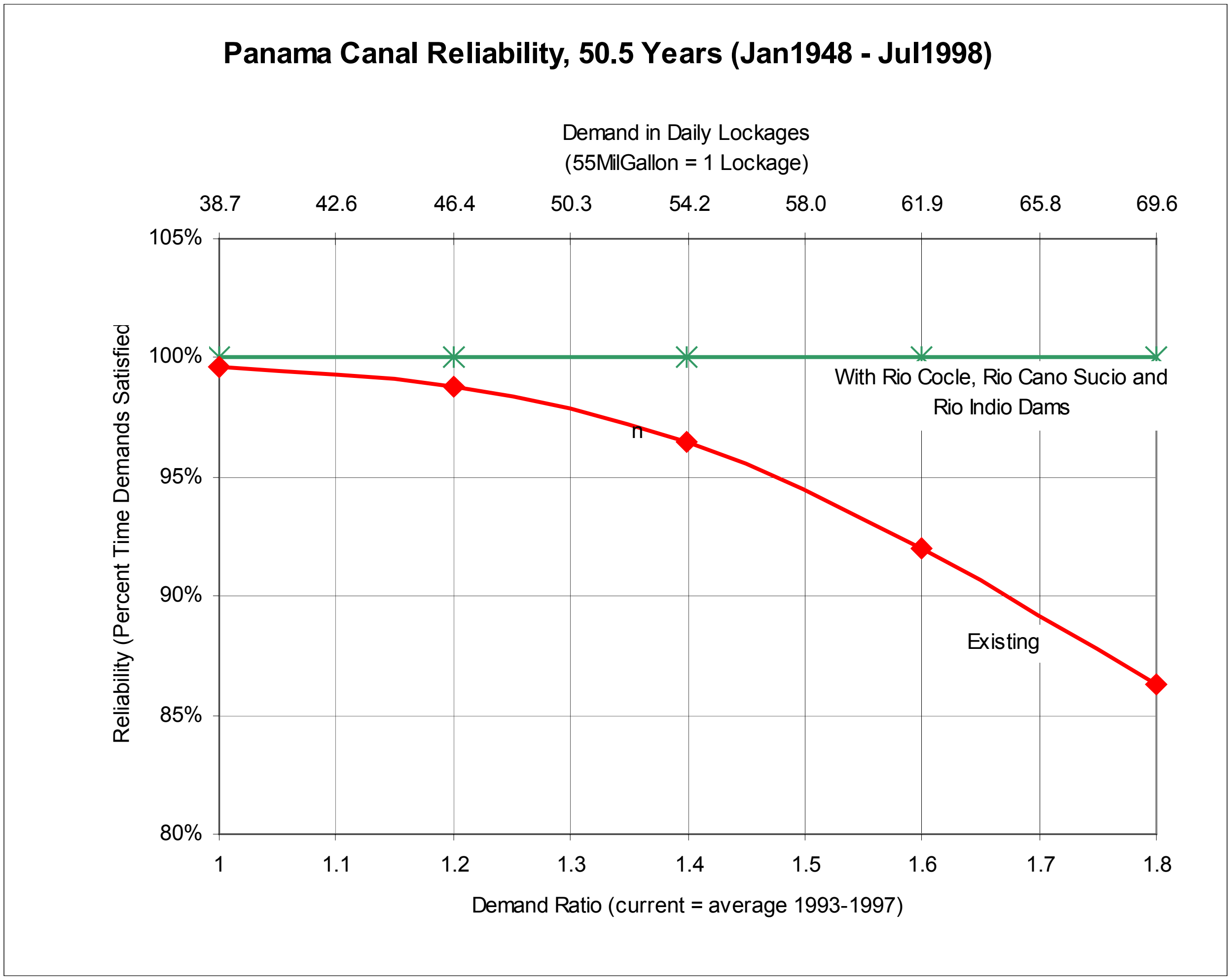


Figure 8 - 3 Panama Canal Hydrologic Reliability

The existing hydrologic reliability of the Panama Canal, based on the 50.5-year period of record, is 99.6 percent while the hydrologic reliability with a demand ratio of 1.8 would be 86.3 percent. With the Cocle del Norte / Caño Sucio Lake and Indio Lake transferring water to the Panama Canal watershed, the hydrologic reliability increased to 100 percent even up to a demand ratio of 1.8. A 100 percent reliability implies that all demands were met and no shortages were realized. Furthermore, under the operating scheme, the minimum pool elevation only drops to 96.29 meters with demands at 180 percent of current levels. This means that there is storage available for beneficial uses such as domestic water supply, water supply for canal operations or the production of hydroelectric power. Since all demands were met at the 100 percent level of reliability, the number of lockages represented by this storage was not estimated. Benefits for the storage between 96.29 and 90 meters were likewise not estimated.

Without additional water supplies the hydrologic reliability of the Panama Canal system would decrease. With the construction of the proposed Rio Cocle del Norte project and Rio Indio project, a hydrologic reliability near 100 percent could be realized as demand for lockages increases beyond 180 percent (30.95 additional lockages) of current demand levels. This study only addressed demand levels that would be required to meet the needs of the Panama Canal system through the year 2070, which approximated 25.29 additional lockages above the year 2000 demand levels. This project is capable of providing even more than required before the reliability drops below 99.6 percent. The unused storage could be used for increased forecast demands of navigation or M&I water uses.

Project Costs

GENERAL

The quantities estimated for the various items of work required in the construction of this proposed project have been derived from the layouts shown on Plates 8 - 3 through 8 - 4. The unit prices applied to these quantities were 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.

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

FIRST COSTS

The total project first costs are estimated to be $665,805,000. Table 8 - 3 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 8 - 3 Summary of First Costs

Item	Costs ($)
Lands and Relocations	115,000,000
Access Roads	11,590,000
Clearing and / or Grubbing	10,128,750
Diversion Tunnel	34,204,575
Inter-basin Transfer Tunnels[1/]	48,282,810
Cofferdam	8,982,735
Dam & Saddle Dams	52,055,872
Spillway	130,130,380
Intakes	15,585,272
Hydropower Plants	12,519,620
Transmission Lines	5,390,000
Subtotal	443,870,014
E&D, S&A, Field Overhead	88,774,003
Contingencies	133,161,004
Total Project First Cost	665,805,021 Approximately 665,805,000

[1/] The difference in costs to enlarge the inter-basin transfer tunnel connecting Indio Lake and the Panama Canal watershed from a 3 m finished diameter tunnel to a 6 m finished diameter tunnel are included.

OPERATION AND MAINTENANCE

Staff

A staff would operate and maintain the proposed Rio Cocle del Norte project during the day and then run the facility remotely. The full-time staff would ultimately consist of a total force of 11 who would include a station manager, a multi-skilled supervisor, 3 leaders (Electronics / Instrumentation, Electrical and Mechanical), 5 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 $500,000.

Ordinary Maintenance

Ordinary maintenance and care would be required and would include minor repair materials, lubricants and other supplies needed by project staff. It is estimated that the costs of ordinary maintenance would be $20,000 per year for the access road and $300,000 per year for the main project facilities.

Major Replacements

The average service life of gates, electrical equipment, turbines, trash racks and other features would be less than the total useful life of the proposed project, which would be 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 would cost the same as at present. No allowance was made for salvageable fixed parts. Table 8 - 4 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 $364,180 and the average annual replacement costs would be $44,000.

Table 8 - 4 Major Replacement Costs

Component	Service Life (years)	Number of Times Replaced During Planning Period	Future Costs ($)	Present Worth of Replacement Costs ($)
Roads	50	1	16,170,000	56,000
Bridges	50	1	1,125,000	3,900
Intake / Outlet Gates and Machinery				
Head Gates	50	1	1,594,650	5,520
Stoplogs	50	1	617,250	2,140
Trashracks	50	1	539,850	1,870
Access Stairs	50	1	82,500	290
Minimum Flow Gates	50	1	90,000	310
Hydropower Plant				
Turbines and Generators	33	1	7,650,000	181,750
Slide Gates	50	1	90,000	310
Stoplogs	50	1	642,000	2,220
Station Electrical Equipment	33	1	1,695,000	40,270
Switchyard Equipment	33	1	1,245,000	29,580
Miscellaneous Plant Equipment	33	1	510,000	12,120
Transmission Lines	50	1	8,085,000	27,980
Total			40,136,250	364,180
Average Annual Replacement Costs				44,000

Annual Costs

The project first costs for the proposed Rio Cocle del Norte project are estimated to be $665,805,000, and includes $61,507,000 to enlarge the inter-basin transfer tunnel between Indio Lake and the Panama Canal watershed from a 3 m finished diameter tunnel to a 6 m finished diameter tunnel. The total project first costs also includes the $245,868,000 costs for the Rio Indio project (see Section 5) and are estimated to be $911,673,000. These total project first costs were distributed across the development period using generalized curves for contractor earnings for large, heavy construction jobs. It was assumed that the 6 m finished diameter inter-basin transfer tunnel from Indio Lake to the Panama Canal watershed would be constructed at the Rio Indio project instead of the 3 m finished diameter inter-basin transfer tunnel. Interest on the total project first costs of $604,298,000 ($665,805,000 - $61,507,000) was computed from mid-year throughout the 14.5-year development period from initiation of Planning and Design until the lake was filled. Interest during construction for the Rio Indio project including the enlarged inter-basin transfer tunnel at the Rio Indio project was computed from mid-year throughout its 20.5-year development period until lake filling was complete at the Rio Cocle del Norte project. The interest during construction at 12 percent would be $1,016,500,000 for Rio Cocle del Norte, and $1,302,555,000 for Rio Indio for a total interest during construction of $2,319,055,000. These costs were added to the total project first costs for total project investment costs of $3,230,728,000. A capital recovery factor for the 50-year planning period was applied to get the annual average investment costs of $389,033,000. Annual operation and maintenance costs were added. Major replacement costs are estimated and were 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 8 - 5 contains a summary of the $391,025,000 total annual costs.

Table 8 - 5 Summary of Annual Costs

Item	Costs ($)
Total Project First Costs - Rio Cocle del Norte	604,298,000
Total Project First Costs – Rio Indio	245,868,000
Enlarged Tunnel at Rio Indio project	61,507,000
Interest During Construction – Rio Cocle del Norte	1,302,555,000
Interest During Construction – Rio Indio	1,016,500,000
Total Project Investment Costs	3,230,728,000
Annual Average Investment Costs	389,033,000
Operation and Maintenance Costs	
Staff Costs – Rio Cocle del Norte	500,000
Staff Costs – Rio Indio	500,000
Ordinary Maintenance Costs – Rio Cocle del Norte	320,000
Ordinary Maintenance Costs – Rio Indio	320,000
Major Replacement Costs – Rio Cocle del Norte	44,000
Major Replacement Costs – Rio Indio	307,000
Total Average Annual Costs	391,025,000

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 Rio Cocle del Norte project. The 50-year planning period for this proposal is 2022 to 2071

The proposed Rio Cocle del Norte project would increase the reliability of providing water to accommodate the total daily number of lockages demanded. Table 8 - 6 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 were obtained from the data used to develop Figure 8 - 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 8 - 6 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 (%)	Hydrologic Reliability: With Rio Cocle del Norte Operating Option 1 [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	100.00
	2020	47.61	98.41	100.00
	2025	48.52	98.14	100.00
	2030	49.55	97.83	100.00
	2035	50.72	97.48	100.00
	2040	52.02	97.10	100.00
	2045	53.49	96.65	100.00
1.4		54.15	96.45	100.00
	2050	55.13	95.89	100.00
	2055	56.98	94.83	100.00
	2060	59.05	93.65	100.00
	2065	61.37	92.32	100.00
1.6		61.89	92.02	100.00
	2070	63.97	90.47	100.00
1.8		69.63	86.27	100.00

[1/] Rio Cocle del Norte - the lake fluctuates from the normal operating lake level at elevation 100 m MSL down to the minimum operating lake level at elevation 90 m MSL and Rio Indio Operating Option 2 the lake fluctuates from the normal operating lake level at elevation 80 m MSL down to the minimum operating lake level at elevation 50 m MSL.

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

With the proposed Rio Cocle del Norte project, there would be no water supply shortages for navigation. The demand for the M&I purposes will always be met first. As these demands grow, the amount of water available to meet the demands for navigation will decrease. Thus, the benefits for the additional water supply are estimated at the value for navigation. With the addition of the proposed Rio Cocle del Norte project, all demands for water supply for navigation would be met over the planning. With a hydrologic reliability of 99.6 percent, the proposed project would increase the amount of water supplied by more than 25.29 equivalent lockages. The 99.6 percent hydrologic reliability would occur after the year 2070 with an equivalent daily average number of lockages of 63.76. 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 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 $229,253,000. Table 8 - 7 provides the estimate of daily shortages under the existing system, the remaining daily shortages with the proposed Rio Cocle del Norte project in operation, the annual benefits for meeting shortages and the average annual benefits.

Table 8 - 7 Benefits for Additional Water Supply for Navigation

Year	Daily Shortages In Lockages Under Existing System	Remaining Daily Shortages	Annual Benefits For Navigation ($)
2022	9.29	0	191,586,000
2032	11.34	0	233,805,000
2042	13.93	0	287,234,000
2052	17.19	0	354,479,000
2062	21.29	0	429,539,000
2070	25.29	0	521,534,000
Average Annual Benefits			229,253,000
With the Rio Cocle del Norte @ 100 alternative, the system will provide 63.97+ lockages, or will satisfy 100 percent of the forecast demands through 2070 or 30.95 more lockages than the existing system.			

With the proposed Rio Cocle del Norte 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 Rio Cocle del Norte project would be $18,856,000. Table 8 - 8 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 8 - 8 Average Annual Reliability Benefits For Navigation

Year	Daily Average Number of Lockages	Value Per Lockage ($)	Annual Benefits For Navigation ($)
2022	40.0	2,260,000	14,018,000
2032	40.0	2,260,000	19,060,200
2042	40.0	2,260,000	25,441,600
2052	40.0	2,260,000	37,370,400
2062	40.0	2,260,000	56,798,200
2070	40.0	2,260,000	78,610,000
Average Annual Benefits			18,856,000

M&I WATER SUPPLY

The future demand for water supply for M&I purposes was 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 was 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 Rio Cocle del Norte 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 would be $3,368,000. Table 8 - 9 displays the population forecast, the resulting number of equivalent lockages per day, and the benefits for M&I water supply.

Table 8 - 9 Average Annual Reliability Benefits For M&I Water Supply

Year	Population	Equivalent Lockages per Day	Annual M&I Water Supply Benefits ($)
2022	2,243,000	7.97	1,879,000
2032	2,819,200	10.02	3,223,000
2042	3,548,800	12.61	5,406,800
2052	4,466,600	15.87	10,019,800
2062	5,621,200	19.97	19,157,600
2070	6,746,000	24.0	31,653,000
Average Annual Benefits			3,368,000

HYDROPOWER

The amount of hydropower energy that could be produced by the system of Gatun Lake and Madden Lake would decline over time as the demands for navigation and M&I water supply increase. With the inclusion of the proposed Rio Cocle del Norte project, the system could produce net additional megawatt hours of hydropower. The value for hydropower energy used in this analysis was $0.070 / kWh. On an average annual basis, the proposed project would have benefits of $16,616,000. Table 8 - 10 provides the net additional megawatt hours of hydropower generation and the resulting benefits.

Table 8 - 10 Average Annual Benefits For Hydropower Generation

Year	Net Generation [1] (MWh)	Annual Benefits For Hydropower ($)
2022	235,971	16,518,000
2032	237,629	16,634,000
2042	239,729	16,781,000
2052	241,071	16,875,000
2062	243,286	17,030,000
2070	242,271	16,959,000
Average Annual Benefits		16,616,000
[1/] Net generation of Gatun, Madden, Indio, and Cocle hydropower plants above generation of Gatun and Madden hydropower plants.		

SUMMARY OF ANNUAL BENEFITS

As shown in Table 8 - 11, total average annual benefits for the proposed Rio Cocle del Norte project would be $268,093,000.

Table 8 - 11 Summary of Annual Benefits

Benefit Category	Average Annual Benefits ($)
Navigation – Water Supply	229,253,000
Navigation – Reliability	18,856,000
M&I - Reliability	3,368,000
Hydropower	16,616,000
Total	268,093,000

To perform an analysis of benefits versus costs, a common point in time was selected. This common point was at the completion of the filling of the proposed Rio Cocle del Norte project, the end of the year 2022. In these analyses, it was important to note that the average annual benefits or average annual costs were 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 Rio Cocle del Norte would be to develop the Rio Indio project first (2001 – 2010) and then the Rio Cocle del Norte project second (2007 – 2022).

The benefits attributable to the proposed Rio Indio project would begin to accrue in 2010 when that reservoir is filled. Thus, the Rio Indio project benefits for the period 2010 to 2022 were escalated by the project discount rate, 12 percent, in order to estimate their total present worth of $3,3,990,542,000 in the year 2022. The average annual benefits for the proposed Rio Indio project that accrue during the construction of the proposed Rio Cocle del Norte project are estimated to be $480,528,000. The benefits for the proposed Rio Cocle del Norte project are estimated with the assumption that the Rio Indio project would use its Operating Option 2. Although the discharge tunnel would be larger, the proposed Rio Indio project would be operated for the period 2010 through 2022 just as if the proposed Rio Cocle del Norte project was not to be constructed.

To estimate the interest during construction, similar calculations were made for the costs of each proposed project. For the proposed Rio Indio project, interest during construction was taken from year 2001 to year 2022 and the interest during construction for the proposed Rio Cocle del Norte project was taken from the year 2007 to the year 2022. Additionally, there would be added costs for the larger inter-basin transfer tunnel between Indio Lake and the Panama Canal watershed that would only be required if the proposed Rio Cocle del Norte project were to be constructed. Those amounts were subtracted from the cost estimate for the proposed Rio Cocle del Norte project and added to the cost estimate for the proposed Rio Indio project. The revised estimated average annual costs for the Rio Indio portion of the overall project would be $194,989,000.

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) were computed. In the first instance, the analysis determines the feasibility of the proposal. The net benefits determines which proposal among several provides the greatest value for the investment dollars. Table 8 - 12 provides the benefit to cost ratio and the net benefits.

Table 8 - 12 Economic Evaluation

Item	Value ($)
Average Annual Benefits	
Rio Indio	480,528,000
Rio Cocle del Norte	268,093,000
Total Average Annual Benefits	748,621,000
Average Annual Costs	
Rio Indio	194,989,000
Rio Cocle del Norte	196,035,000
Total Average Annual Costs	391,025,000
Benefit to Cost Ratio	1.9
Net Benefits	357,596 ,000

For this proposed project, the operating scheme used in the simulation model does not draw the pool elevation down to the minimum elevation. Therefore, additional storage for which beneficial uses could be made. Since the proposed project meets all of the total demand for water over the planning period, there are no quantifiable remaining benefits to be estimated. The operating scheme could be revised to allow for additional hydropower production for which benefits could be estimated. The unused storage could also be used for increased forecast demands of navigation or M&I water uses. Should those forecast demands be increased, the net benefits for this proposed project would also be increased.

Internal Rate of Return

An internal rate of return analysis for this proposed project was performed. To accomplish this analysis, the annual construction costs were used as the investment, and the undiscounted benefits were used as return cash flows. The internal rate of return would be 19.3 percent.

Incremental Evaluation of Hydropower

Since the generation of hydropower would be provided through the conjunctive use of storage, an analysis of the incremental benefits and costs for this purpose was accomplished. The first costs of the Lands and Relocations and the Clearing and / or Grubbing, which were associated with hydropower, as well as the costs of the Hydropower Plants and the Transmission Lines were taken from Table 8 - 3. The portion of annual operation and maintenance costs associated with hydropower generation were derived from the data included in Table 8 - 4. The construction costs are estimated to be approximately $27,343,000. Interest during a two-year construction period is estimated to be $3,330,000 for a total hydropower investment costs of $30,673,000. The portion of annual operation and maintenance costs for hydropower were assumed to be $350,000 for staff, $250,000 for ordinary maintenance and $35,000 for major replacement. The total average annual costs for hydropower would be $4,329,000. The average annual benefits are estimated to be $16,616,000. The average annual benefits exceed the average annual costs for the proposed Rio Cocle del Norte project yielding a benefit to cost ratio of 3.8. It should be noted, however, that hydropower was valued at the current costs of production for the PCC. This value might underestimate the economic value of any additional hydropower generating capacity. Additional effort should be expended in any future planning studies to determine the economic value of added hydroelectric power generation.

Socio-Economic Impacts

The socio-economic impacts of the project could be substantial. The relocation of the towns of Coclecito, Cutevilla, Boca de La Encantada, El Calabazo, Platanal, Molejon, and La Boca del Guasimo and their approximately 5,600 residents would be an important issue. The average monthly income of families in the project area is $100 per month. No indigenous groups of peoples are known to reside in the impact area. Land use would be greatly impacted by the inundation of pastures and agricultural lands to create the Cocle del Norte Lake. The relocation of agricultural and ranching activities would be a substantial issue, because approximately 40 percent of the impoundment area is used for farming and ranching. The impoundment area would substantially impact the mineral and ore resources. The surface area of the proposed lake will encompass 41,690 ha with another 800 ha for the dam and construction areas including permanent disposal areas.

Post-construction revenues generated for the nation would be greater, because the project will create electric power generating potential. On a per hectare basis, revenues from the power generation would be greater than those produced by the current agricultural activity. It is estimated that after construction, 11 persons would be employed to operate and maintain the new facilities. During construction, the housing values in the areas adjacent to the dam site would increase, because there could be a higher demand by workers for livable homes. However, after project completion as the workers leave the area and housing demands decline, the housing values would drop 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 more public and community services may be offered to the local communities. After construction these services should remain at the normal level.

To construct the dam, some existing roads would be improved and some new roads would be built. However, the dirt roads within the impoundment would be eliminated, which would change the 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 road systems would increase; however following cessation of construction, the traffic volumes would decline. Noise levels would increase during construction and could negatively impact noise-sensitive receptors, however, after construction, noise levels should return to pre-construction levels.

The communities that would receive the displaced people 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 through the division of communities, separation of families, and loss of livelihood. Following completion of the impoundment, tourism trade in the affected area, including fishing and ecotourism, could increase.

Environmental Setting

The Rio Cocle del Norte project will produce hydroelectric power and provide for 31 additional lockages per day on a continual basis. The structures for the proposed Rio Cocle del Norte / Rio Caño Sucio project would consist of rock fill dams on the Rio Cocle del Norte and the Rio Caño Sucio, uncontrolled ogee spillways, inter-basin transfer facilities, two hydropower plants, and other outlet works. The project encompasses the area to be flooded as well as the area downstream from the dam site. This area is moderately populated. It is mountainous, has low coastal regions, and has primary forests. The Rio Cocle del Norte is located west of the Panama Canal, is used for navigation, and flows northward from the Continental Divide into the Atlantic Ocean. The Rio Cocle del Norte watershed above the dam is approximately 1,600 km^2. The impoundment area covers approximately 41,690 ha and consists of approximately 30 percent of forested land, 20 percent of pasture land (used by ranchers), 20 percent of cropland, 25 percent of newly slashed and burned land, and 5 percent of mining land. The lake water elevation will fluctuate from elevation 50 to 84 m MSL. The transmission lines, tunnel portals, and roads associated with the project could also have environmental impacts and should be sited to minimize those impacts.

LAND USE

The Rio Cocle del Norte project area encompasses the area to be flooded as well as the area downstream from the dam site. It is inhabited by about 5,600 people, dispersed throughout the area, with concentrations in the towns of Coclecito (population – 1,150), Cutevilla (population – 300), Boca de La Encantada (population – 250), El Calabazo (population – 250), Platanal (population – 230), Molejon (population –220) and La Boca del Guasimo (population – 220) and approximately 50 smaller settlements. Approximately 800 people live in eight communities downstream from the dam site at Cerro Pelado. The largest of these is Cocle del Norte with more than 300 people. San Lucas and Cocle del Norte are downstream towns, which should not be flooded.

Approximately 40 percent of the land in the project area is occupied by farms and ranches of various sizes. Farm crops include mandioc, maize, rice, beans, sugar, coffee, and tobacco. Ranchers raise cows, horses, chickens, and hogs. Most of the farmers and ranchers are small commercial enterprises, although there is also some cash crop and subsistence farming. There are also mineral and ore resources in the impoundment area.

INFRASTRUCTURE

The towns of El Calabazo, Coclecito, and Platanal have schools. Several towns also 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 the Rio Cocle del Norte and its tributaries. Disposal of domestic waste is the responsibility of individual homeowners: each home has an outdoor latrine (a deep hole in the ground). There are some known health problems, such as hepatitis, dysentery, dermatitis, intestinal parasites, and respiratory illnesses associated with the present waste disposal methods. No major industries or poultry or beef processing plants are located in the project area. The roads in the project area are poorly maintained dirt roads that are usable only in the dry season (mid-December through March). The roads are rarely graded and receive little attention by either the Ministry of Public Works or the local government. There are a limited number of paved roads around Coclecito. 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. People living in the Rio Cocle del Norte project area use the river as their primary means of transportation. The town of Cocle del Norte can only be reached by river from Coclecito or by sea from Colon.

The town of Coclecito supplies valuable services to many surrounding communities. Coclecito possesses schools, a hospital (with two resident doctors), a small diesel generating facility, and a museum honoring the late General Omar Torrijos, who is considered a national folk hero.

Coclecito has two elementary schools and one junior high school. The students of Coclecito and / or hospital patients come from Cocle del Norte, San Lucas, and other neighboring communities. The junior high school students stay in school dormitories during the week and return home for the weekend. The main road through Coclecito heads east to west and is gravel-packed. This road heads west to the Coclecito River Bridge that divides the town of Coclecito into northern and southern halves. Coclecito is connected by a gravel/dirt road to Llano Grande and from Llano Grande to La Pintada and Penonome by a paved road.

TERRESTRIAL HABITAT

Forests along the river that could support a diverse wildlife population cover about 90 percent of the area along the Rio Cocle del Norte and its tributaries. The forests extend to the upper mountainous areas above the Rio Cocle del Norte project impoundment area. There are also some contiguous forests in the lowlands west of Coclecito within the Rio Cocle del Norte project impoundment area.

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 it has not been determined, some of the listed species of the above list might be found in the project area.

AQUATIC HABITAT

The Rio Cocle del Norte in the project area displays traits characteristic of streams in mountainous regions. Its water is clear and cool, and the river bed ranges from sand to boulders, with numerous riffles, runs, and pools. The Rio Cocle del Norte has six major tributaries: Caño Rey, Rio San Lucas, Rio Toabre, Rio Cuatro Calles, Rio Don Juan, and Rio Cascajal; approximately 32 smaller creeks also flow into the Rio Cocle del Norte. The river is approximately 32 km long; its width ranges from 10 m (in the dry season) to 50 m at its mouth, and its depth ranges from less than 1 to 25 m. The Rio Cocle del Norte and its tributaries appear to support some fish communities; however, information about fish communities that occur in the project area is limited.

WETLANDS

Areas that contain hydric soils and hydrophytic plant communities, and that are subject to hydrologic conditions are termed wetlands. The wetlands consist of forested riparian habitat along the immediate stream bank area. The width of the riparian habitat within the impoundment area varies from approximately 10 to 75 m. In the west portion of the impoundment area the wetlands become part of the dense forest. Approximately 90 percent of the streams above and below the dam site are bordered by forested riparian habitat along the Rio Cocle del Norte and its tributaries.

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 and early April, sizable areas of established forests and secondary growth are cleared and burned to prepare the land for agricultural use. Based on observations in the Rio Cocle del Norte project area, the amount of land burned varies annually.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

The El Cope National Park covers over 25,000 ha in the highlands of the Rio Cocle del Norte impoundment area and is important for its avifauna. The late General Omar Torrijos owned a home in Coclecito, which is now a museum. There are also Pre-Columbian cultural resources that have been identified by archaeological surveys located in the Rio Cocle del Norte impoundment area. 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 impoundment area would be substantial, since the forest covers approximately 12,500 ha, or 30 percent of the impoundment area. The forested area constitutes a relatively high quality terrestrial habitat. With the creation of the lake, migratory routes of some species could be adversely affected. The only forests that would remain in the vicinity of the Cocle del Norte Lake and its drainage basin would be confined to the higher elevations.

ANIMALS ON ENDANGERED LIST

Potential impacts on species on the endangered list could have a significant effect on the Rio Cocle del Norte project. The extent of potential effects cannot be determined at this time, because it is not known which of the listed species occur within the proposed project area. Furthermore, the significance of the forested riparian corridor along the area streams may increase if animals on the endangered list are found in the region. The Mesoamerican Biological Corridor is also promoting biodiversity conservation throughout the Atlantic basin, which could impose restrictions on the use of the project area.

WATER QUANTITY

The impacts of the project on water quantity should be positive, because construction of the dam should result in a significant increase in the volume of fresh water in surrounding areas during the dry season. The impacts downstream from the dam site could be important, because water rates would be reduced. Further, measures should be taken to release water at appropriate periods and amounts to avoid problems with water quality and temperature downstream. The cumulative impacts downstream of the dam site over time should also be minor.

WATER QUALITY

The impacts of the project on water quality are unknown. The impacts downstream from the dam site could be positive. The water should contain less silt due to minimum normal flow and should provide people downstream a higher quality water. It is unclear whether the proposed Cocle del Norte Lake will provide high quality water.

DOWNSTREAM AQUATIC FAUNAL HABITAT

The impacts on downstream aquatic fauna communities could be substantial, even though facilities would be included in the design of the dam to allow multi-level releases of water to avoid problems with water quality and temperature downstream. The Rio Cocle del Norte dam should act as a large sediment trap, which should cause the released water to have low turbidity; therefore, siltation should not be a problem. The impacts of interference with migratory movements of natural stream fishes are unknown. Streambed degradation below the dam should be minimal.

FUTURE LAKE AQUATIC PLANT COMMUNITY

The impacts of the project on future aquatic plant communities in the proposed lake will depend on water level fluctuations, which are anticipated to range from 50 m to 100 m over a 3-month period. Since the water levels would fluctuate widely, much of the shore would be covered with mud, where neither aquatic nor terrestrial plant communities could thrive. Rooted aquatic plants tend to grow as deep as light penetration allows.

AQUATIC FAUNA INHABITING AFFECTED AREAS

The impacts of the project on aquatic fauna inhabiting the Rio Cocle del Norte and its upstream tributaries could be important. If aquatic fauna are able to thrive in the new reservoir, they would be beneficially affected by having their habitat enlarged. Some unavoidable, adverse environmental impacts could occur and these impacts should be identified and appropriate mitigation measures addressed in feasibility level studies, should the alternative be recommended for further consideration. The new reservoir could provide excellent opportunities for recreational and subsistence fishing if it is responsibly managed and stocked with game fish by the Aquaculture Department. An increase in fish population could cause an increase in piscivorous predators, such as crocodiles, caimans, otters, and herons, etc. Other manmade lakes in the Republic of Panama have been stocked with peacock bass and tilapia, both of which have adapted well, but several riverine native species that formerly occupied the impoundments have disappeared. Loss of native species may affect their predator populations (otter, birds, and fish eating mammals).

WETLANDS

The impacts to upstream and downstream wetlands could be significant. Owing to the topography of the project area, a number of wetlands could be impacted by the project. It is possible that even though the reservoir water levels will fluctuate, new wetlands could develop in the littoral zones. Due to minimum normal flow, the cumulative effects downstream of the dam site are expected to be minor.

AIR QUALITY

During construction of the dam, dust and emissions from equipment could impact the air quality in the project area. After construction, the air quality could improve because the Panamanian government currently discourages slash and burn activities.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

The impacts on cultural resources and historic properties could be substantial. The project area is large and is known to contain cultural resources and historic properties; therefore, the presence of cultural resources and historic properties is high. 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.

Additional Environmental Information Required

This section identifies the subject areas for which additional data are required to evaluate the scope and magnitude of the potential effects in further detail of the Rio Cocle del Norte alternative. The subject areas are discussed by impact category. This section identifies the subject areas for which insufficient data are available to fully evaluate the scope and magnitude of the potential effects of the Rio Cocle del Norte alternative. The data gaps are discussed by impact category.

SOCIO-ECONOMIC IMPACTS

- Conduct an 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).
  - Community and Regional Growth.
  - Transportation.
  - Housing.
  - Health (vector routes).
  - Population.
  - Community Cohesion.

- Recreational Resources.
- Mineral Resources.

TERRESTRIAL AND AQUATIC HABITAT

- Prepare site-specific habitat maps to ensure that all major terrestrial and aquatic habitat types are identified and quantified.
- Conduct field studies to locate special habitat features such as wetlands, roosting sites, reproductive sites, and the relative quality of forested areas.
- Determine the present quality and ecosystem value of existing habitats within the Rio Cocle del Norte project area.

ANIMALS ON THE ENDANGERED LIST

- Compile habitat maps to assess the availability and quality of suitable habitats for the animals on the endangered list.
- Conduct site surveys to determine the presence of selected species.
- Develop candidate mitigation measures for the appropriate project alternatives to be considered in the Conceptual Phase.
- Obtain other wildlife reports produced for the Rio Cocle del Norte project area.

WATER QUALITY

- As there are no water quality data available for the Rio Cocle del Norte 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 is incomplete. Additional evaluation studies need to be completed to identify cultural resources and historic 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 Section 35. Tables 8 - 13 through 8 - 15 present the evaluation of the proposed Rio Cocle del Norte project as related to developmental effects, environmental effects, and socio-economic effects.

Table 8 - 13 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	10	10	100
	Additional Hydropower Potential	5	5	25
Technical Viability	Design Constraints	7	6	42
	Feasibility of Concept	6	6	36
Operational Issues	Compatibility	6	6	36
	Maintenance Requirements	8	2	16
	Operational resources required	6	2	12
Economic feasibility	Net Benefits	10	9	90
	Total			557

[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 8 - 14 Environmental Effects

Item	Measure 1/	Importance 2/	Composite3/
Terrestrial Habitat	1	8	8
Animals on Extinction List	1	10	10
Water Quantity Impacts – Lake	6	10	60
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			337

[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 8 - 15 Socio-Economic Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Land Use	1	7	7
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			302

[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

Pertinent data for the proposed Rio Cocle del Norte Dam are presented in Table 8 - 16.

Table 8 - 16 Pertinent Data for Option 1

GENERAL	
Rio Cocle del Norte	
Dam site, above mouth of Rio Cocle del Norte	15 km
Drainage area above dam site	1,600 km^2
Average annual flow at dam site	109 CMS
Rio Caño Sucio	
Dam site, above mouth of Caño Sucio	25 km
Drainage area above dam site	111 km^2
Average annual flow at dam site	7.4 CMS
LAKE	
Elevation of maximum operating lake level	100 m MSL
Elevation of maximum flood storage lake level	104 m MSL
Elevation of minimum operating lake level	90 m MSL
Useable Storage between Max and Min Lake	3,688 MCM
Area at maximum operating lake level	4,280 ha
Area at maximum flood storage lake level	4,440 ha
Area at minimum operating lake level	3,630 ha
Top clearing elevation	100 m MSL
Lower clearing elevation	90 m MSL
EMBANKMENTS	
Dam	
Type of dam	Rock fill embankment
Top elevation of dam	105 m MSL
Fixed crest width	13 m
Height above lowest foundation	90.0 m
Overall length of dam	891 m
Saddle dam (North)	
Type of saddle dam	Earth / Rock Fill Embankment
Top elevation of saddle dam	105 m MSL
Fixed crest width	13 m
Overall length of saddle dam	255 m
Saddle dam (Central)	
Type of saddle dam	Earth / Rock Fill Embankment
Top elevation of saddle dam	105 m MSL
Fixed crest width	13 m
Overall length of saddle dam	272 m
Saddle dam (South)	
Type of saddle dam	Earth / Rock Fill Embankment
Top elevation of saddle dam	105 m MSL
Fixed crest width	13 m
Overall length of saddle dam	272 m

Table 8 - 16 Pertinent Data for Option 1

SPILLWAY		
Type of Spillway		Uncontrolled ogee
Total length		346 m
Elevation of spillway		100 m MSL
Maximum discharge		5,346 CMS
INTER-BASIN TRANSFER TUNNEL		
Rio Caño Sucio to Rio Indio:		
Tunnel diameter		5 m
Tunnel length		2.0 km
Inlet invert		85 m MSL
Outlet invert		74 m MSL
Tunnel capacity		155 CMS
Rio Indio to Gatun Lake:		
Tunnel length		5.5 km (+/-)
Tunnel diameter		5 m
Tunnel capacity at maximum head		216 CMS
Inlet invert		40 m MSL
Outlet invert		38 m MSL
HYDROPOWER PLANTS		
Dam		
	Type of hydropower plant construction	Reinforced concrete
	Number of units	2
	Capacity of each unit	10 and 15 MW
Sucio-Indio Transfer Tunnel		
	Type of hydropower plant construction	Reinforced concrete
	Number of units	1
	Capacity of unit	6.2 MW
Indio-Gatun Transfer Tunnel		
	Type of hydropower plant construction	Reinforced concrete
	Number of units	1
	Capacity of unit	9.7 MW
CONSTRUCTION / POWERHOUSE DIVERSION		
Diversion length		400 m
Horseshoe tunnel dimensions		(2) 7.5 m X 7.5 m
Inlet invert		10 m MSL
Outlet invert		9 m MSL
Cofferdam Height above tunnel inlet invert		35 m
MINIMUM FLOW CONDUIT		
Conduit diameter		1.5 m
Conduit length		400 m
Inlet invert		8 m MSL
Outlet invert		6 m MSL
Conduit capacity		10.9 CMS

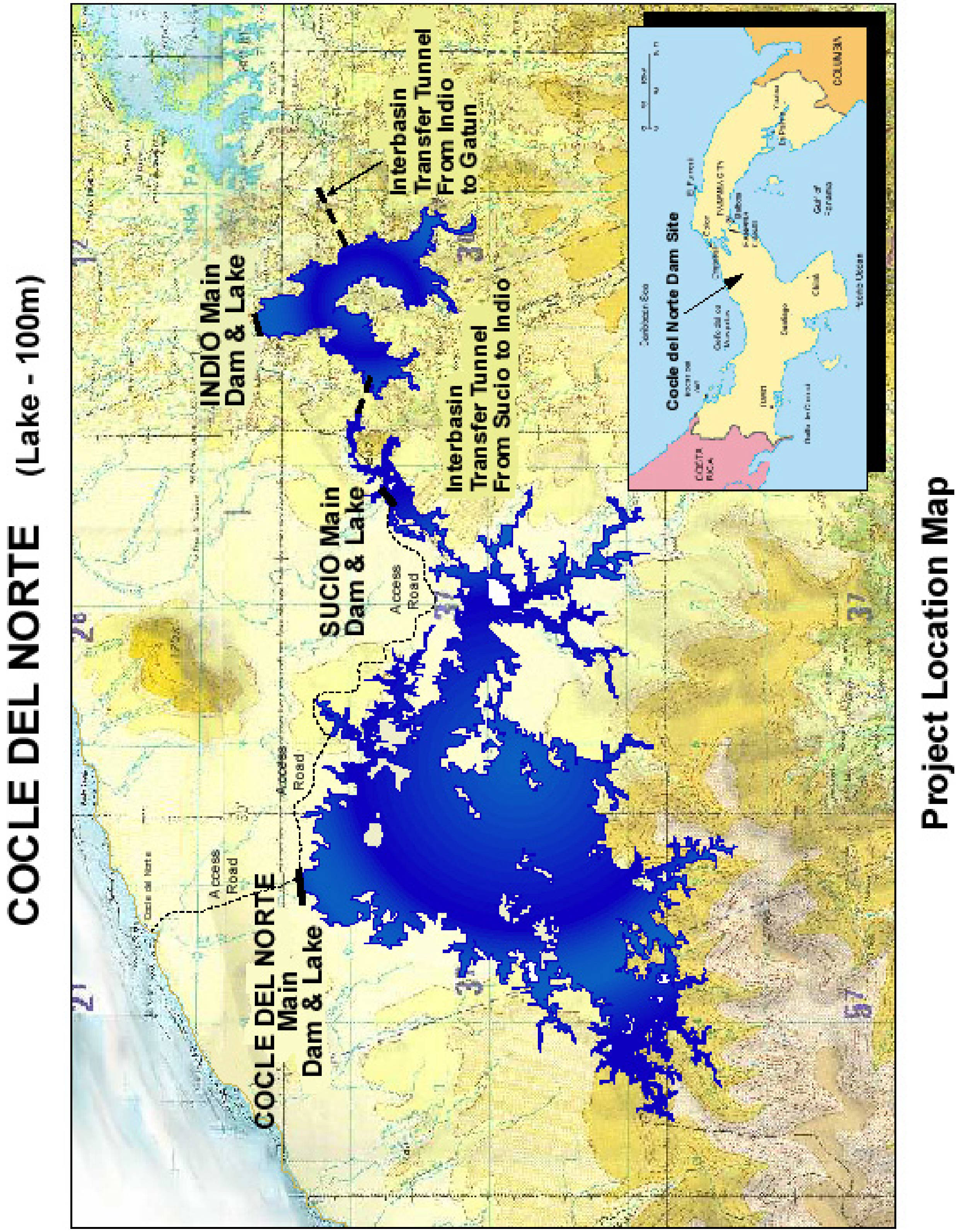
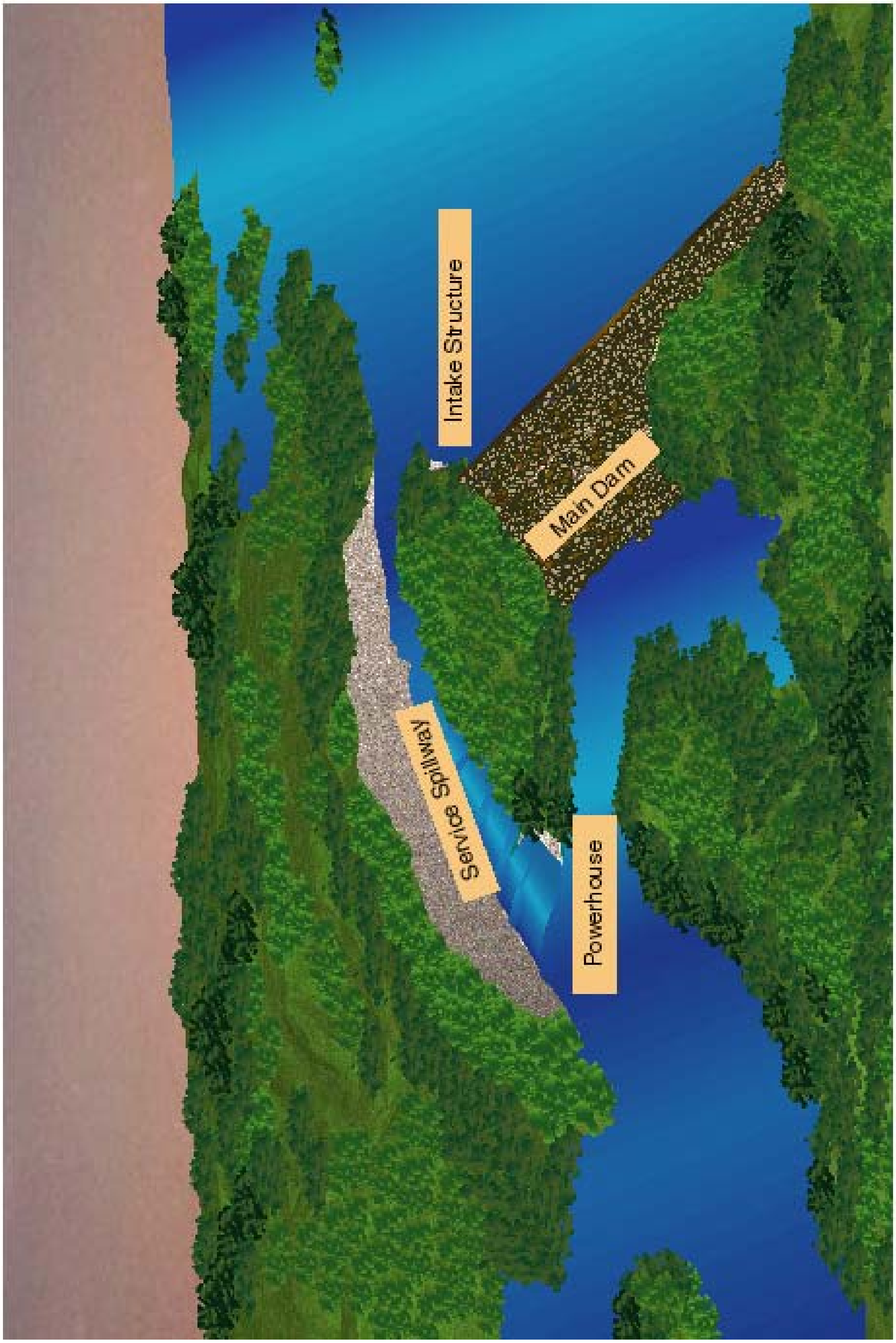


Plate 8 - 1 Project Location Map

COCLE 100M



Site Plan

Plate 8 - 2 Site Plan

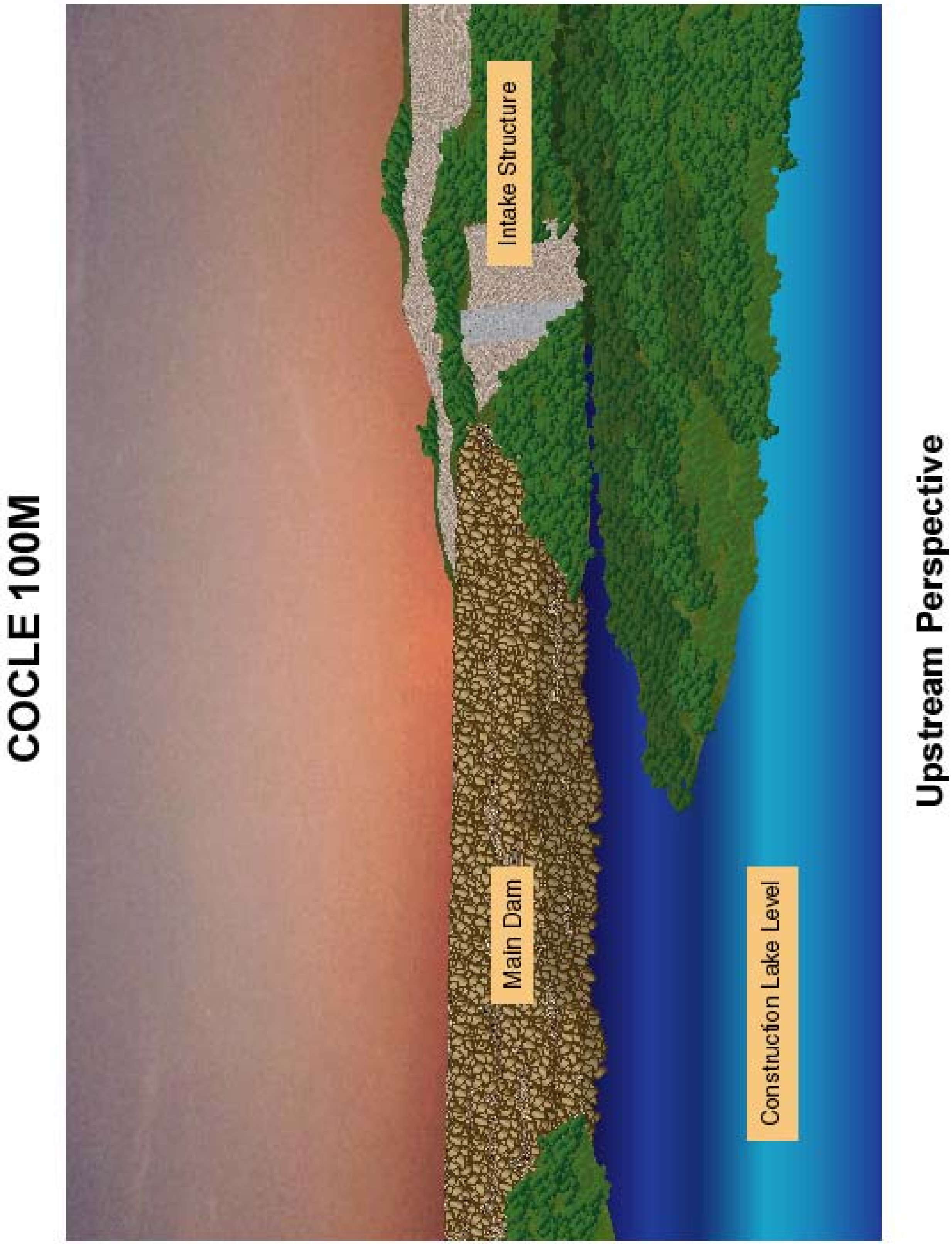


Plate 8 - 3   Upstream Perspective

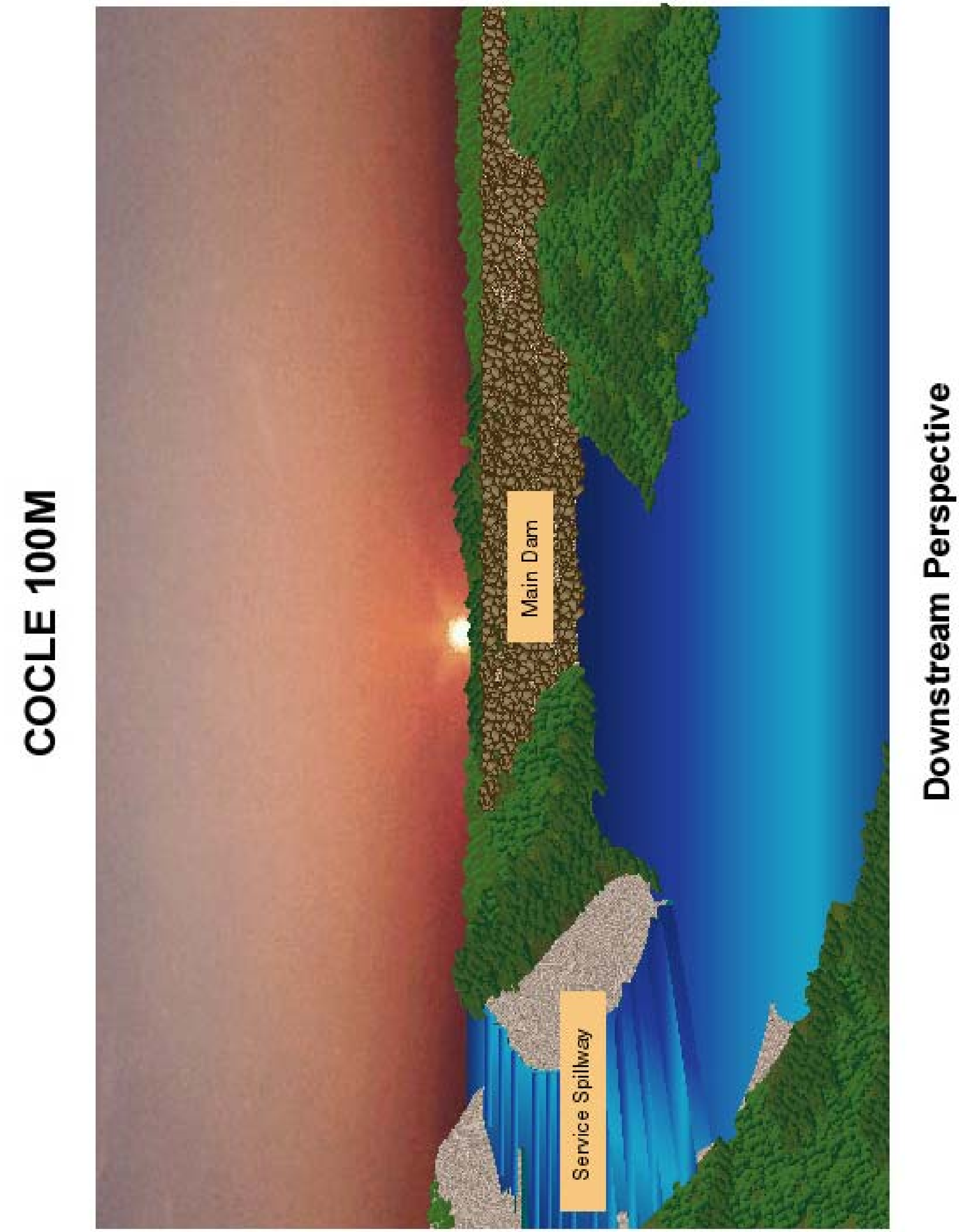
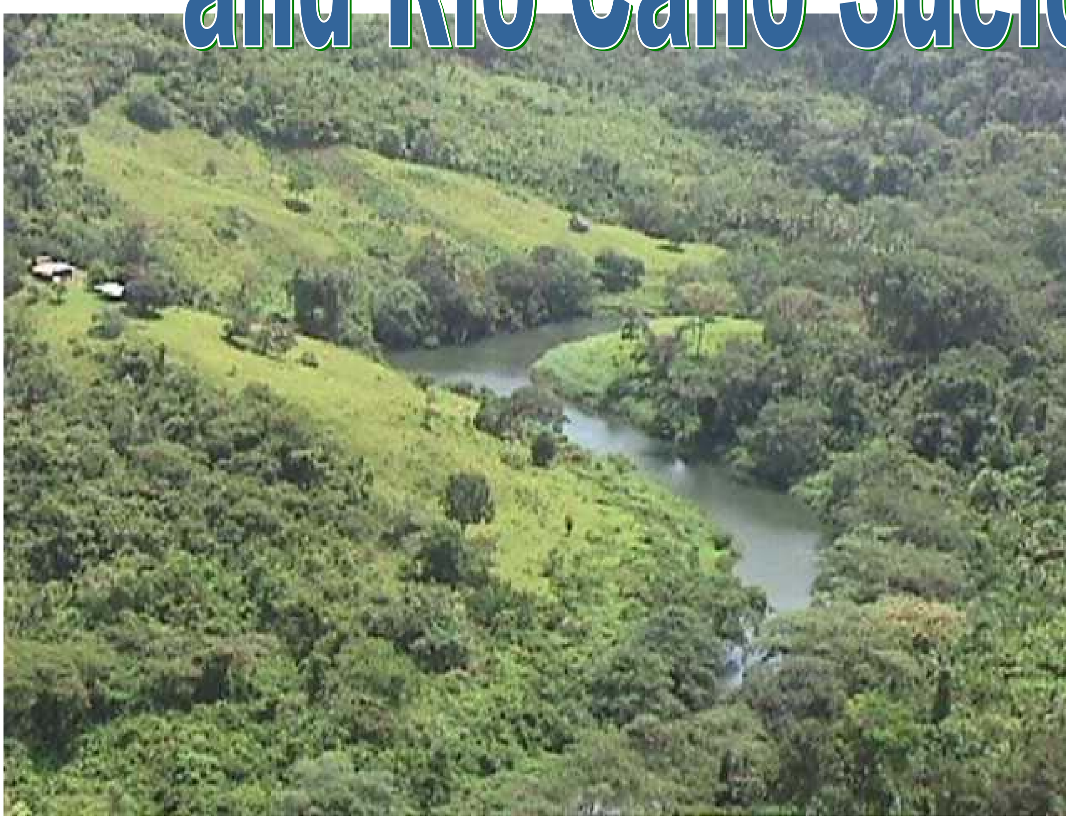


Plate 8 - 4   Downstream Perspective

SECTION 9

(Operated in conjunction with Indio Lake)

Rio Toabre and Rio Caño Sucio



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Synopsis

The development plan presented herein would include a dam and lake on the Rio Toabre and a dam and lake on the Rio Caño Sucio, connected by an open channel. Flow from these lakes would be passed via a tunnel to Rio Indio Lake. Rio Indio Lake would be connected to the Panama Canal watershed at Gatun Lake via a second tunnel (see Section 5 of this report for details of the Rio Indio development). Water impounded in these three lakes would be transferred to the Panama Canal watershed as needed to support navigation. Figure 9 – 1 presents a profile of the proposed system of lakes.

The Rio Toabre basin is an eastern tributary to the Rio Cocle del Norte that is located approximately 70 km west of the Panama Canal. The Rio Toabre flows into the Cocle del Norte approximately 17 km inland from the mouth of the Cocle del Norte. The development plan presented herein includes a normal operating pool at elevation 100 m MSL with operating withdrawal down to elevation 90 m MSL. The plan assumes that the Caño Sucio reservoir project will be incorporated into this development. The estimated total first cost of the proposed Toabre - Sucio project would be $398,016,000.

The current level of hydrologic reliability of the Panama Canal, based on the 50-year period of record from January 1949 through July 1998, is approximately 99.6 percent, while the hydrologic reliability with a demand ratio of 1.2 (46.42 lockages) would be 98.8 percent. With construction of the proposed Toabre Project, the current reliability could be continued as demand increases up to 60+ percent (23.37 lockages) above current levels. The proposed Toabre project would contribute measurably to the reliability of the Panama Canal to serve its customers and would greatly reduce the need for imposing draft restrictions and resulting light loading of vessels during traditional periods of low water availability. Additional benefits would be realized in the form of increased hydropower. The average annual energy production at the hydropower plant would be 72,000 MWh after sufficient water was transferred to the Panama Canal watershed for canal operations.

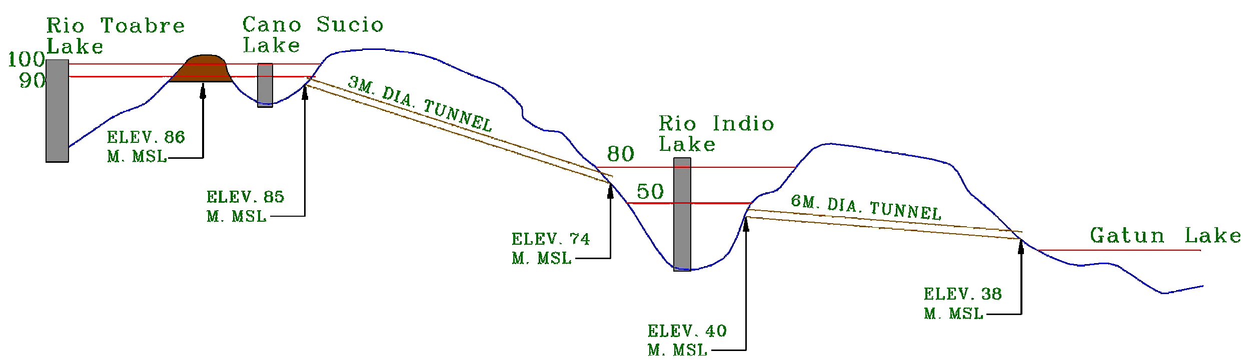


Figure 9 - 1 System Profile

Site Selection

The proposed Rio Toabre dam site was chosen 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. To maximize the water impounded, it was desirable to locate the dam as far downstream in the Rio Toabre watershed as possible. In choosing a site for the dam, a location was sought where the surrounding hillsides would be relatively steep and high, and the valley was relatively narrow.

The site chosen for the proposed Rio Toabre Dam would be approximately 30 km inland from the Atlantic Ocean and would be approximately 16 km upstream of the confluence of the Rio Cocle del Norte and Rio Toabre. This site would accommodate construction of a dam with a maximum operating lake level at elevation 100 m MSL and a maximum flood storage lake level at elevation 104 m MSL.

There are several watersheds between the Rio Toabre watershed and the Rio Indio watershed. dam sites were considered in these watersheds in order to reduce the costs of the inter-basin transfer facilities connecting the Toabre Lake and Indio Lake. A location was identified for a proposed dam site on the Rio Caño Sucio. The proposed Rio Caño Sucio dam site would be approximately 25 km inland from the Atlantic Ocean. This site would also accommodate construction of a dam with a maximum operating lake level at elevation 100 m MSL and a maximum flood storage lake level at elevation 104 m MSL.

Plate 9 - 1 shows the location of the proposed Rio Toabre and the Rio Caño Sucio projects.

Hydrologic Considerations

The Rio Toabre flows from the north side of the Continental Divide into the Rio Cocle del Norte and then to the Atlantic Ocean. The headwaters of the Rio Toabre watershed begin at approximate elevation 300 m MSL approximately 75 km inland and fall to approximately elevation 20 m MSL at its confluence with the Rio Cocle del Norte. Annual rainfall ranges from 3,000 mm along the coast to 2,000 mm in the higher ranges of the upper watershed. The proposed Toabre Lake would receive runoff from approximately 730 km^2 of the upper portion of the watershed. Rainfall runoff produces an average annual flow of 3.9 CMS at the proposed Rio Toabre dam site.

The discharge at the Rio Toabre dam site was obtained by extrapolating the recorded and correlated stream flow data of the Batatilla hydrologic station.

The Batatilla station, a continuous recorder, began operation in 1958 and is located on the Rio Toabre approximately 11 km downstream of the dam site. In order to complete missing data and to increase the period of record, a statistical correlation was established using standard hydrologic techniques with the discharge data of the Rio Indio at Boca de Uracillo. The consistencies of the measured and correlated data were verified using the double mass curve method.

The Rio Caño Sucio flows north northwestward from the north side of the Continental Divide into the Rio Miguel de la Borda, and then northeastward to the Atlantic Ocean. The headwaters of the Rio Caño Sucio watershed begin at approximate elevation 240 m MSL and fall to mean sea level at the mouth of the Rio Miguel de la Borda approximately 30 km downstream. Annual rainfall ranges from 3,000 mm along the coast to 2,000 mm in the higher ranges of the upper watershed. The proposed Caño Sucio Lake would receive runoff from approximately 111 km^2 of the upper portion of the watershed. Rainfall runoff produces an average annual flow of 7.4 CMS at the proposed Caño Sucio dam site.

The Rio Caño Sucio is a stream without any hydrological historical records. In order to establish the discharge at the dam site, it was assumed that this watershed would have the same yield per unit area as the neighboring basin of the Rio Indio measured at Boca de Uracillo.

Because of the relative proximity of the Toabre-Sucio project area to Gatun Lake, and in the absence of additional information, the monthly evaporation rates recorded at Gatun Lake were used to establish the evaporation of Indio Lake.

It is recommended that a stream gage be installed in the vicinity of the Caño Sucio dam site if this project is carried forward for additional study and development.

Geologic Considerations

The Toabre main dam portion of the proposed Rio Toabre / Rio Caño Sucio project is located in an area along the Atlantic coast of Panama 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, which are andesitic or basaltic in nature. These rocks probably show a wide variation in quality, from high quality of the extrusive lava flows, to possibly weathered and lesser quality volcanic tuffs.

It is anticipated that 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. Moderately weathered lithic tuff was observed along the riverbank of the Toabre River, though not at the exact site of the proposed dam. Volcanic rocks of the Tucue Formation may also contain constituents that are reactive with alkalies in cement. Neither weathered rock nor rock with reactive materials would be satisfactory for concrete aggregate. If this proposed project is carried forward, it is recommended that cores be drilled in the area of each abutment early during the planning studies to determine general depths of weathering and to determine the suitability of the rock for use as concrete aggregate.

The locations of the Caño Sucio saddle dam and transfer tunnel to the Indio Lake portions of the project are underlain by Oligocene aged sedimentary rocks of the Caimito Formation. Three recognized members of the Caimito Formation are the lower, middle and upper members. These rocks are mainly marine deposits 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 is made up of tuff, agglomeratic tuff, tuffaceous siltstone, and discontinuous sandy tuffaceous limestone. Moderately hard siltstone, fitting the description of strata of the principal member of the Caimito Formation, is well exposed in several waterfalls at the proposed Rio Caño Sucio saddle dam location. It is considered that this siltstone would make an acceptable foundation for an earth and rock fill dam, but would be unacceptable for use as concrete aggregate. The material is considered 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 Toabre dam site, a degree of extrapolation was necessary. It was predicted that rock at the proposed dam site would be encountered at a shallow depth and would be of sufficient quality to serve as foundation for the dam and appurtenant structures.

Lake Operation

Toabre Lake and Caño Sucio Lake would be connected by channel and would be operated as one lake. One operating option was considered in this study for periods when water would be transferred from Toabre / Caño Sucio Lake to the Panama Canal watershed for canal operations. The water surface of the Toabre / Caño Sucio Lake would fluctuate from the maximum operating lake level at elevation 100 m MSL down to the minimum lake operating level at elevation 90 m MSL, providing 468,000,000 M^3 of useable storage.

As described in Section 5, Rio Indio, two operating options were considered for periods when water would be transferred from Indio Lake to the Panama Canal watershed for canal operations. For combination with the Rio Toabre reservoir, Rio Indio Option 2 was selected. This would allow the water surface of Rio Indio Lake to fluctuate from elevation 80 m MSL down to elevation 50 m MSL.

Water would be transferred from Toabre / Caño Sucio Lake (minimum operating lake level at elevation 90 m MSL) to Indio Lake (maximum operating lake level at elevation 80 m MSL) and then to the Panama Canal watershed for use in canal operations. A description of the project features for the proposed Rio Indio project is included in Section 5.

Project Features

GENERAL

The structures for the proposed Rio Toabre / Caño Sucio project would consist of rock fill dams on the Rio Toabre and the Rio Caño Sucio, uncontrolled ogee spillways on the Rio Toabre and Rio Caño Sucio, inter-basin transfer facilities, two hydropower plants, and outlet works. The following paragraphs provide a description of the proposed structures and improvements. Plate 9 - 1 depicts the location of the two dams, the two spillways, the inter-basin transfer facilities, the hydropower plants, and the 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 PCC that contained assumptions and design calculations for the reconnaissance level investigations of these structures. If this proposed project is carried into the planning studies, optimization of the project features and improvements must be accomplished.

EMBANKMENT

The proposed Rio Toabre dam would be an embankment with the top at elevation 105 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 980907 north and 565169 east. The right abutment would be 981769 north and 565612 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 would be approximately 90 m high, and the overall length would be 1,130 m.

The proposed Rio Caño Sucio dam would be an embankment with the top at elevation 105 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 987292 north and 575960 east. The right abutment would be 987399 north and 576105 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 would be approximately 20 m high, and the overall length would be 185 m.

The actual side slopes and crest width 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. See Section 5 for typical embankment sections.

SPILLWAY

At the proposed Rio Toabre dam an uncontrolled ogee spillway with a length of 219 m and a crest at elevation 100 m MSL would be required. The spillway crest would be 5 m below the elevation of the top of the dam. The maximum discharge from the spillway would be 3,391 CMS at a maximum flood storage lake level at elevation 104 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 right 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. A stilling basin would be excavated into the rock adjacent to the natural channel at the downstream end of the tailrace channel for energy dissipation. See Plate 9 - 2 for the upstream perspective. A typical section at through spillway would be similar to that shown for the Rio Indio project, see Section 5.

At the proposed Rio Caño Sucio dam an uncontrolled ogee spillway with a length of 74 m and a crest at elevation 100 m MSL would be required. The spillway crest would be 5 m below the elevation of the top of the dam. The maximum discharge from the spillway would be 1,141 CMS at a maximum flood storage lake level at elevation 104 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. A stilling basin would be excavated into the rock adjacent to the natural channel at the downstream end of the tailrace channel for energy dissipation. See Plate 9 - 3 for the downstream perspective. The spillway profile would be similar to that shown for the Rio Indio project, see Section 5, though it would be much smaller at this location.

IMPOUNDMENT

The lake formed by the proposed Rio Toabre dam would have a maximum operating lake level at elevation 100 m MSL and would have a surface area of approximately 4,850 ha. At the minimum operating lake level elevation 90 m MSL, the surface area would be 3,220 ha. At maximum flood storage lake level elevation 104 m MSL, the surface area would be approximately 5,830 ha. At the top of dam, elevation 105 m MSL, the surface area would be approximately 6,115 ha.

The lake formed by the proposed Rio Caño Sucio dam would have a maximum operating lake level at elevation 100 m MSL and would have a surface area of approximately 1,355 ha. At the minimum operating lake level at elevation 90 m MSL, the surface area would be 245 ha. At maximum flood storage lake level, elevation 104 m MSL, the surface area would be approximately 2,040 ha. At the top of dam, elevation 105 m MSL, the surface area would be approximately 2,235 ha.

CLEARING, GRUBBING, AND RESERVOIR CLEARING

Clearing and grubbing would be required for all areas required for construction of the dam (embankments and spillways), inter-basin transfer facilities, other outlet works, hydropower plants and switchyard sites, transmission lines, access roads, and disposal and staging areas. Clearing only would be required on the 2,740 ha in the cumulative lake area between the maximum operating lake elevation at 100 m MSL and the minimum operating lake elevation at 90 m MSL.

INTER-BASIN TRANSFER FACILITIES

The natural connector between Toabre Lake and Caño Sucio Lake would be deepened to provide a bottom elevation of approximately 86 m MSL. Caño Sucio Lake, Rio Indio Lake, and Gatun Lake would be connected by tunnels through the common basin divides.

The finished tunnel connecting the easternmost end of Caño Sucio Lake to the westernmost leg of Rio Indio Lake would be 3 m in diameter and approximately 2 km in length. This tunnel would have an inlet invert elevation of 85 m MSL and an outfall invert elevation of 74 m MSL. The maximum flow through this tunnel would be approximately 27.8 CMS.

The 3 m finished diameter inter-basin transfer tunnel included in the proposed Rio Indio project between Indio Lake and the Panama Canal watershed would not be large enough to pass the additional flows from the Rio Toabre Lake. This tunnel would need to be enlarged to a 6 m finished diameter to pass the combined flows from Indio Lake and Rio Toabre Lake at elevation 80 m MSL. The maximum capacity of this tunnel would be 216 CMS, and it would have invert elevations at its inlet and outlet ends of 40 m and 38 m MSL respectively. This would result in a slight lengthening of the tunnel over that indicated in the Rio Indio Lake alternative described in Section 5. The additional cost of this tunnel resulting from changes in diameter and length would be directly attributable to the Rio Toabre project.

The location and assumed alignment of these features are shown on Plate 9 - 1 and a profile of the entire transfer system is shown in Figure 9 - 1. The tunnels would be under pressure continually since flow through the tunnels would be controlled at the downstream end of each.

This control would be in the form of a gate control structure and / or a hydropower plant. To allow for maintenance of the tunnel and to allow for rapid tunnel closure when required, a gate / stoplog structure would be constructed at the inlet. In the process of stopping flow through the tunnel, a water hammer effect could be generated. Therefore, sufficient surge protection shafts would be constructed. These shafts would require relatively minor surface structures to protect the openings and to provide for personnel safety.

It was assumed that the tunnels would be concrete lined and that rock bolting would be required over much of the length of the tunnel to stabilize the rock.

HYDROPOWER PLANTS

The flows, excess to the needs of the Panama Canal operation, at the proposed Toabre dam would support installation of a 22 MW hydropower plant. The flow and head available at the downstream end of the Sucio-Indio transfer tunnel would support a hydropower plant with a capacity in the range of 6 MW. The plant discussed in Section 5 of this report for installation at the downstream end of the Indio–Gatun transfer tunnel could be increased in size from 5 MW to approximately 10 MW. These facilities would be designed and configured to function as part of the national power grid. A 115 kV transmission line would be constructed to carry the energy to a connection with the grid near La Chorrera. The transmission line would start at Rio Toabre Dam and connect through each of the other noted hydropower facilities. Estimated electrical output and assumed plant configurations are included in the Pertinent Data listing at the end of this section.

OUTLET WORKS

An outlet works system at the Toabre Dam would provide for diversion of the Rio Toabre during construction. After completion of construction, it would be used to supply water for production of hydropower, allow for emergency drawdown of the lake after it is raised and placed in service, and allow minimum flow to pass by the dam.

These water handling facilities would consist of two 8 m by 8 m horseshoe shaped tunnels passing through the dam abutment, an intake structure located in the lake, an outlet channel downstream, and various gate structures. The diversion tunnel would be approximately 1,100 m in length. It would have an inlet invert elevation at 17 m MSL and an outlet invert elevation at 15 m MSL. The diversion tunnel would serve in combination with a cofferdam to protect the construction area from floods up to a 10 percent frequency. A 10 percent frequency flood would deliver a peak flow of approximately 1,789 CMS at the site without regulation from the dam. The cofferdam would measure 15.5 m above the upstream invert of the tunnel. A separate 0.9 m diameter conduit, required for minimum flow, would be installed beneath the floor of this tunnel. The minimum flow conduit would be approximately 1,100 m in length and it would have an invert elevation of 15 m MSL. Intake for minimum flow would be through individually gated water quality intake ports located at various levels in the intake structure. The elevations of these intakes would be established during environmental water quality investigations made during subsequent phases of study. The capacity of the minimum flow conduit would be 4.0 CMS. The hydropower intake would also be elevated to prevent silt from entering the power units. At the downstream end of the tunnel, a bulkhead structure would be installed to close the construction diversion and to divert reservoir water into the hydropower penstock. The closure would be configured so that it could be removed in the event that the RioToabre Lake had to be drawn down. The intake structure would be similar to that depicted for the Rio Indio site, Section 5.

At the Rio Caño Sucio Dam an outlet works system would be required only to provide minimum flows to the Rio Caño Sucio downstream of the dam. Diversion of the Rio Caño Sucio during construction could be provided by initially installing the Sucio-Indio tunnel and by providing for flood releases through the divide between the Rio Caño Sucio and the Rio Toabre basins to the west. The Sucio-Indio tunnel and the channel connecting Rio Caño Sucio to Rio Toabre would also allow for emergency drawdown of the lake after it is raised and placed in service.

These water handling facilities would consist of a 406 mm outlet pipe passing through the dam, an intake structure located in the lakeside face of the dam, and various gates and water conduits. Intake for minimum flow would be through individually gated water quality intake ports located at various levels in the intake structure. The elevations of these intakes would be established during environmental water quality investigations made during subsequent phases of study. The minimum flow outfall piping would be approximately 140 m in length. It would have an outlet invert elevation at 83 m MSL. The capacity of the minimum flow conduit would be 0.74 CMS.

ACCESS ROADS

Access to the lake site and the various construction sites must be provided from the main population centers on the Atlantic and Pacific coasts, Colon and Panama City respectively.

The route from Colon could be westward across the Panama Canal and then generally southwestward along existing roads to the village of Salud. From this point, new or vastly improved roadways would be constructed along the north coast to the village of Cocle del Norte and then along the Rio Cocle del Norte and the Toabre to the Toabre dam site, and thence to the Caño Sucio dam site and the other construction sites.

Alternately, this route could be by barge southwestward along the Atlantic Ocean to the village of Cocle del Norte and then by new roads as above. This route would also require docking facilities at the village of Cocle del Norte.

The above two scenarios could require a new road to be constructed extending from the existing roads at the Rio Indio project to access the tunnel inlet and outlet locations at Caño Sucio and Rio Indio.

The route from Panama City would be by existing roads to the Rio Indio project and then generally westward by newly constructed roads to the Inter-basin transfer tunnel entry and exit points and the Cocle del Norte dam site and the other construction areas. Note that this route, as well as the secondary access to the inter-basin tunnel outlet noted above, assumes that the Rio Indio project would be in place prior to construction of the Cocle del Norte project.

The route chosen for this study would originate at the Rio Indio dam site using the access routes constructed in conjunction with that project. It would cross the Rio Indio below the dam then proceed westward and southward to the outlet end of the Caño Sucio-Rio Indio inter-basin tunnel on the Rio Uricillo. From there it would extend westward to the inlet end of the tunnel, then westward to the Caño Sucio dam site, westward to the Toabre-Caño Sucio channel cut, then north and west to the Rio Toabre dam site. The entire route would cover approximately 32 km through mountainous terrain and would require 8 stream crossings. This route and the features it would connect are shown on Plate 9 - 1.

This new corridor into the interior of the country west of the Panama Canal would be of benefit to those living in that region by providing roadway access to the main centers of commerce. It would also provide continuous access for construction and maintenance of the power transmission lines connecting the new hydropower facilities with the transmission lines at the Rio Indio site.

DISPOSAL AREA

Rock and earth and rock fill materials removed as a result of the required excavation for structures, tunnels or roadways that are unsatisfactory, in excess or are impractical for use in the finished work shall be stockpiled in designated areas and sloped to drain in order to provide a stable mass.

Sources of Construction Materials

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

Cement would be available within the Republic of Panama. Rock, obtained from the construction site or from the lake area, would be used for onsite manufacture of aggregates for the concrete. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) would be fabricated outside the Republic of Panama and imported for final assembly and installation at the proposed dam site.

Real Estate Requirements

The proposed Rio Toabre and Rio Caño Sucio dam sites are located in the Cocle, Colon and Panama Provinces. Approximately 9,700 ha would be required for construction of this proposed project. The amount of land required for the various project features is shown in Table 9 - 1. Real estate for access roads is included in the estimated quantities for the other items listed in the table.

Table 9 - 1 Real Estate Requirements

Project Feature	Land Required for Rio Toabre (ha)	Land Required for Rio Caño Sucio (ha)	Total Land Required (ha)
Lake	6,100	2,200	8,300
Dam Site	200	100	300
Staging Area	200	100	300
Housing and Facilities	200	0	200
Disposal Area	400	200	600
Total	7,100	2,600	9,700

Relocations

This area is devoted primarily to subsistence farming, natural forest, and ranching. The lake area would inundate approximately six villages. Of these only two would be regarded as sizeable villages, El Guayabo o Toabre Abajo and El Valle de San Miguel. These villages would require major relocation efforts. The rest are small villages comprised of just a few houses. Structures and individuals located below elevation 105 m MSL within the lake would require relocation due to the normal lake inundation and the need to secure the lake perimeter for flood considerations.

Development Sequence

For the economic evaluation of this project, it was assumed that the planning for the Rio Toabre and Caño Sucio project would begin during the construction of the Rio Indio project. Construction would be started immediately following completion of the Rio Indio project.

Planning studies would be accomplished to evaluate the alternative features of each proposed project. Each potentially viable project would be evaluated to assure that the plan presented would provide all of the features required to make it functional. Each would also be assessed as to its effectiveness in meeting the project goal of providing M&I water supply in relief of current or future planned withdrawals from the Panama Canal, with due recognition of any secondary benefits. Environmental assessments of the proposed projects would begin during the planning studies phase and would continue during the final design, advertising and award phase, and on through construction of the project. The final design would be accomplished for the recommended project. After completion of the final design, plans and specifications would be prepared for the advertising and award phase.

Project implementation would begin 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 would then be acquired.

Access roads would be constructed to the dam sites and the inter-basin transfer tunnel inlet and outlet sites. Once highway access to the sites has been established, a camp would be built to house workers during construction.

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

Construction of the Rio Toabre and the Caño Sucio dams would begin with the clearing and grubbing of the construction sites and the clearing of the lake area. The channel connecting the Toabre and Sucio lake areas would be constructed first. The Sucio dam site would then be isolated using upstream and downstream cofferdams and the Sucio flows would be diverted to the Rio Toabre. The Sucio dam foundation would then be excavated and grouted, and the dam and minimum flow structure would be constructed. Excavation for the inter-basin transfer tunnel, the Toabre intake structure, the diversion tunnel at the Toabre dam site, and the spillways at both sites would proceed simultaneously. Where possible, materials removed from the excavations would be placed directly into the earth and rock fill portions of the dams. Once the intake structure and diversion tunnel at Rio Toabre were completed, the dam site would be isolated using upstream and downstream cofferdams, and would eventually become part of the main dam, and the stream would be diverted through the tunnel. The Toabre dam foundation would then be excavated and grouted, and the dam constructed. Concurrently with construction of the dam, the hydropower plant site downstream of the dam would be excavated, and the powerhouse construction would be started. The power transmission lines would be constructed during this time frame also. Upon completion of the Toabre dam and the inter-basin transfer tunnel and appurtenant structures, the diversion would be stopped using the head gates in the Toabre intake structure, and lake filling would begin. Simultaneously with this operation, the downstream gate and flow separation structure would be constructed to provide for closure of the diversion tunnel and diversion of the tunnel flows to the hydropower penstock(s). The Toabre minimum flow conduit would be installed through the diversion tunnel at this time. Upon completion of the project, all facilities would undergo trial operations followed by commissioning for service.

Considering the climatic conditions and the obstacles posed by the remote location of the construction sites and the nature of the work, it is estimated that development of this project could be completed in approximately 10 years, from initial planning to lake filling. Figure 9 - 2 depicts the development sequence of the various project features.

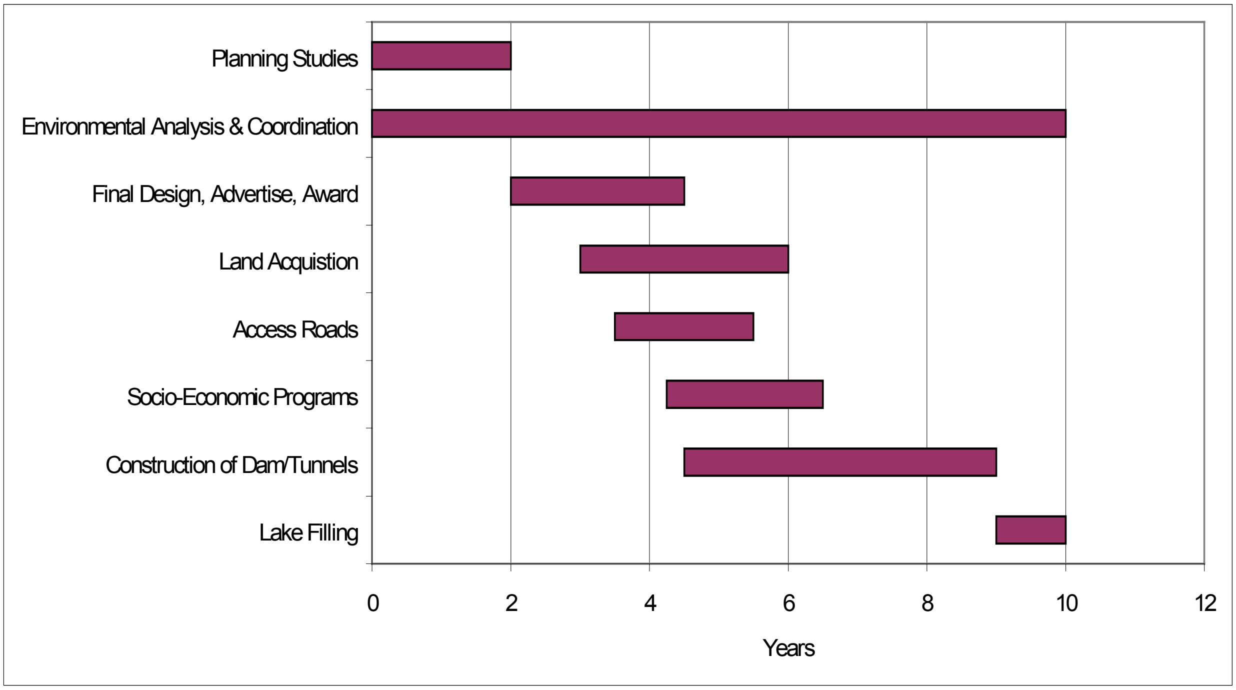


Figure 9 - 2 Development Sequence

Hydrologic Reliability

HEC-5 model simulations were conducted for both the current canal system and a system operating with Rio Toabre Lake providing water through Rio Caño Sucio and Rio Indio Lakes to Gatun Lake. The simulations considered proportionally increasing demands beginning with current demand levels. The designated period considered the existing 50.5-year hydrologic period of record at Rio Toabre. Figure 9 - 3 presents the resulting hydrologic reliability for the Toabre Lake alternative and the existing system, with demands increasing up to 180 percent of current demands.

The horizontal axis along the bottom of Figure 9 - 3 reflects demands as a ratio of the last five-year average and the axis along the top reflects demands in lockages (assuming 55 million gallons per lockage).

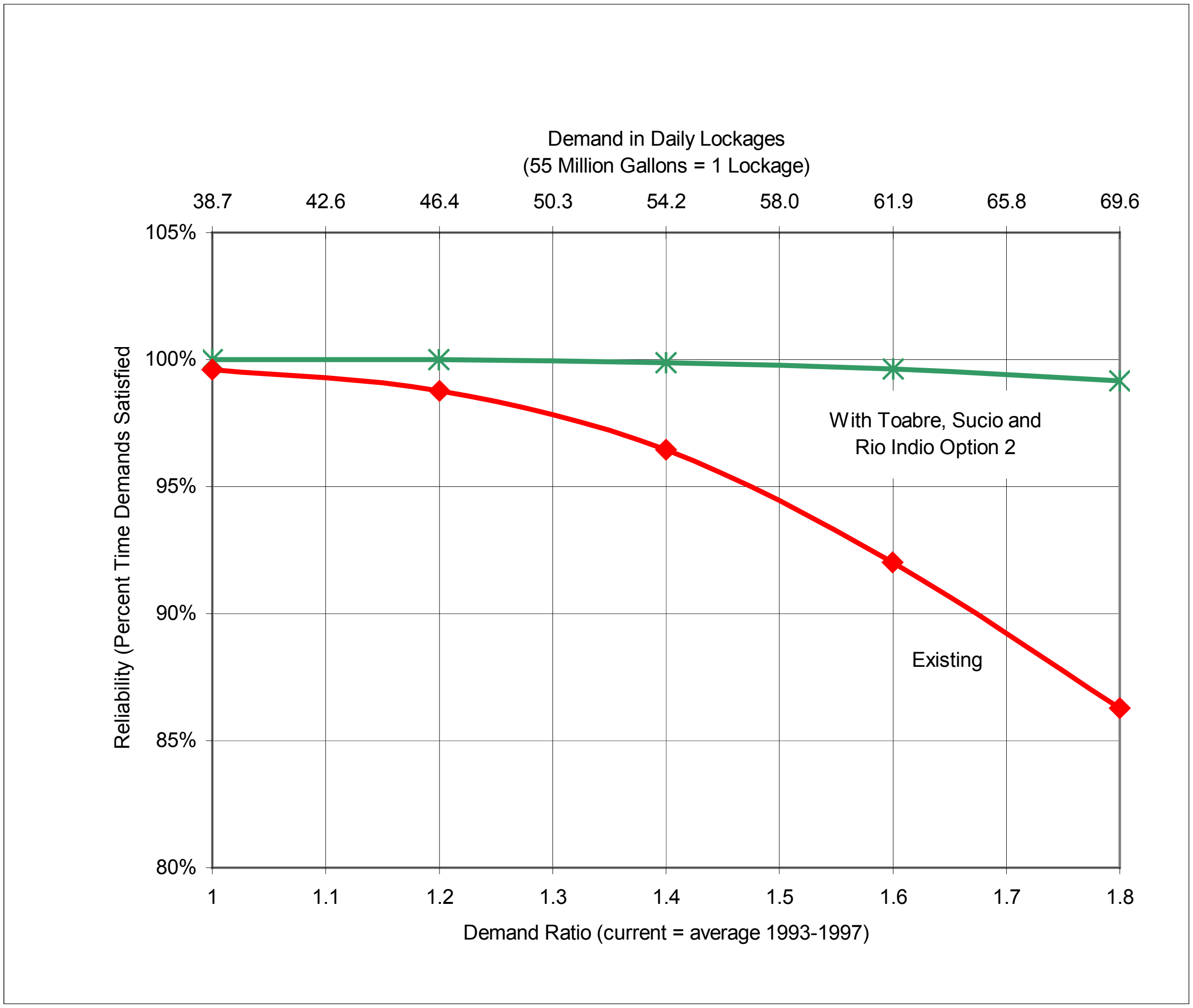


Figure 9 - 3   Panama Canal Hydrologic Reliability

As shown in Figure 9 - 3, the current level of hydrologic reliability of the Panama Canal based on the 50.5-year period of record is approximately 99.60 percent, while the hydrologic reliability with a demand ratio of 1.8 would be 86.27 percent. This includes the first six months of the 1998 drought year. The current level of hydrologic reliability would be 100 percent with Toabre Lake operating with a conservation lake between elevations 100 and 90 m MSL, and the hydrologic reliability with a demand ratio of 1.8 would be 99.15 percent.

Without additional water supplies, the reliability of the Panama Canal system would decrease. With the construction of the Toabre Lake, the current high level of reliability could be continued as demand increases up to 60+ percent (23.37 lockages) above current levels.

Project Costs

GENERAL

The quantities estimated for the various items of work required in the construction of this proposed project have been derived from the layouts shown on Plates 9 – 2 and 9 – 3, and detailed in material provided under separate cover. The unit prices applied to these quantities were 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.

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

FIRST COSTS

The project first costs are estimated to be $398,016,000. Table 9 - 2, 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 9 - 2 Summary of First Costs

Item	Costs ($)
Lands and Relocations	24,250,000
Access Roads	8,157,000
Clearing and / or Grubbing	3,123,750
Diversion Tunnel	38,111,483
Inter-basin Transfer Tunnels [1/]	41,421,960
Transfer Tunnel Intakes [1/]	3,621,523
Cofferdam	11,307,624
Dam	61,183,781
Spillway	52,931,320
Intakes	3,204,371
Hydropower Plants	16,051,134
Transmission Lines	1,980,000
Subtotal	265,343,946
E&D, S&A, Field Overhead	53,068,789
Contingencies	79,603,184
Total Project First Cost	398,016,000

[1/] The difference in costs to enlarge the inter-basin transfer tunnel connecting Indio Lake and the Panama Canal watershed from a 3 m finished diameter tunnel to a 6 m finished diameter tunnel are included.

OPERATION AND MAINTENANCE

Staff

A staff would operate and maintain the proposed Rio Toabre and Rio Caño Sucio project during the day and then run the facility remotely. The full-time staff would ultimately consist of a total force of 11 that would include a station manager, a multi-skilled supervisor, 3 leaders (Electronics / Instrumentation, Electrical and Mechanical), 5 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 $500,000.

Ordinary Maintenance

Ordinary maintenance and care would be required and would include minor repair materials, lubricants and other supplies needed by the project staff. It is estimated that the costs of ordinary maintenance would be $20,000 per year for the access road and $300,000 per year for the main project facilities.

Major Replacements

The average service life of gates, electrical equipment, turbines, trash racks and other features would be less than the total useful life of the proposed project, which would be 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 would cost the same as at present. No allowance was made for salvageable fixed parts. Table 9 - 3 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 $398,000 and the average annual replacement costs would be $48,000.

Table 9 - 3 Major Replacement Costs

Component	Service Life (years)	Number of Times Replaced During Planning Period	Future Costs ($)	Present Worth of Replacement Costs ($)
Roads	50	1	10,345,500	36,000
Bridges	50	1	1,800,000	6,000
Intakes				
Head Gates	50	1	285,600	1,000
Stoplogs	50	1	153,150	500
Trashracks	50	1	49,200	200
Access Stairs	50	1	81,750	300
Minimum Flow Gates	50	1	45,000	200
Hydropower Plant				
Turbines and Generators	33	1	9,945,000	236,300
Slide Gates	50	1	187,500	600
Stoplogs	50	1	1,260,000	4,400
Station Electrical Equipment	33	1	2,118,750	50,300
Switchyard Equipment	33	1	1,556,250	37,000
Miscellaneous Plant Equipment	33	1	622,500	14,800
Transmission Lines	50	1	2,970,000	10,300
Total			31,420,200	397,900
Average Annual Replacement Costs				48,000

Annual Costs

The project first costs for the proposed Rio Toabre and Rio Caño Sucio projects are estimated to be $398,016,000 and includes $61,507,000 to enlarge the inter-basin transfer tunnel between Indio Lake and the Panama Canal watershed from a 3 m finished diameter tunnel to a 6 m finished diameter tunnel. The total project first costs also include the $245,868,000 costs for the Rio Indio project (see Section 5) and are estimated to be $643,884,000. These total project first costs were distributed across the development period using generalized curves for contractor earnings for large, heavy construction jobs. It was assumed that the 6 m finished diameter inter-basin transfer tunnel from Indio Lake to the Panama Canal watershed would be constructed at the Rio Indio project instead of the 3 m finished diameter inter-basin transfer tunnel. Interest on the total project first costs of $336,509,000 ($398,016,000 - $61,507,000) was computed from mid-year throughout the 13.5-year development period from initiation of Planning and Design until the lake was filled. Interest during construction for the Rio Indio project including the enlarged inter-basin transfer tunnel at the Rio Indio project was computed from mid-year throughout its 17-year development period until lake filling was complete at the Rio Toabre and Rio Caño Sucio projects. The interest during construction at 12 percent would be $190,113,000 for Rio Toabre and Rio Caño Sucio, and $725,640,000 for Rio Indio for a total interest during construction of $915,753,000. These costs were added to the total project first costs for total project investment costs of $1,559,637,000. A capital recovery factor for the 50-year planning period was applied to get the annual average investment costs of $187,806,000.

Annual operation and maintenance costs were added. Major replacement costs are estimated and then 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 9 - 4 contains a summary of the $189,801,000 total annual costs.

Table 9 - 4 Summary of Annual Costs

Item	Costs ($)
Total Project First Costs – Rio Toabre y Sucio	336,509,000
Total Project First Costs – Rio Indio	245,868,000
Enlarged Tunnel at Rio Indio project	61,507,000
Interest During Construction – Rio Toabre y Sucio	190,113,000
Interest During Construction – Rio Indio	725,640,000
Total Project Investment Costs	1,559,637,000
Annual Average Investment Costs	187,806,000
Operation and Maintenance Costs	
Staff Costs – Toabre y Sucio	500,000
Staff Costs – Rio Indio	500,000
Ordinary Maintenance Costs – Toabre y Sucio	320,000
Ordinary Maintenance Costs – Rio Indio	320,000
Major Replacement Costs – Toabre y Sucio	48,000
Major Replacement Costs – Rio Indio	307,000
Total Average Annual Costs	189,801,000

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 Rio Toabre and Rio Caño Sucio project. The 50-year planning period for this proposal is 2018 to 2067.

The proposed Rio Toabre and Rio Caño Sucio project would increase the reliability of providing water to accommodate the total daily number of lockages demanded. Table 9 - 5 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 were obtained from the data used to develop Figure 9 - 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 9 - 5 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 Rio Toabre y Rio Caño Sucio [1/] (%)
1	2000	38.68 [2/]	99.60	100.00
	2010	45.11	98.91	99.99
1.2		46.42	98.76	99.99
	2015	46.82	98.64	99.99
	2020	47.61	98.41	99.97
	2025	48.52	98.14	99.96
	2030	49.55	97.83	99.95
	2035	50.72	97.48	99.93
	2040	52.02	97.10	99.91
	2045	53.49	96.65	99.89
1.4		54.15	96.45	99.88
	2050	55.13	95.89	99.85
	2055	56.98	94.83	99.78
	2060	59.05	93.65	99.72
	2065	61.37	92.32	99.64
1.6		61.89	92.02	99.62
	2070	63.97	90.47	99.49
1.8		69.63	86.27	99.15

[1/] Rio Toabre y Rio Caño Sucio – the Lake fluctuates from the normal operating lake level at elevation 100 m MSL down to the minimum operating lake level at elevation 90 m MSL and Rio Indio operating Option 2 the Lake fluctuates from the normal operating lake level at elevation 80 m MSL down to the minimum operating lake level at elevation 50 m MSL

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

With the proposed Rio Toabre and Rio Caño Sucio project, water supply shortages for navigation would continue. The demand for the M&I purposes will always be met first. As these demands grow, the amount of water available to meet the demands for navigation will decrease. Thus, the benefits for the additional water supply are estimated at the value for navigation. With the addition of the proposed Rio Toabre and Rio Caño project, these shortages would be less than they would be under the existing system. With a hydrologic reliability of 99.6 percent, the proposed project would increase the amount of water supplied by more than 23.37 equivalent lockages. The 99.6 percent hydrologic reliability would occur in the year 2066 with an equivalent daily average number of lockages of 62.05. 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 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 $200,541,000. Table 9 - 6 provides the estimate of shortages under the existing system, the remaining shortages with the proposed Rio Toabre and Rio Caño Sucio project in operation, the annual benefits for meeting shortages and the average annual benefits.

Table 9 - 6 Benefits for Additional Water Supply for Navigation

Year	Daily Shortages In Lockages Under Existing System	Remaining Daily Shortages	Annual Benefits for ($)
2018	8.61	0	168,221,000
2019	8.77	0	171,303,000
2020	8.93	0	174,385,000
2030	10.87	0	212,359,000
2040	13.34	0	260,613,000
2050	16.45	0	321,345,000
2060	20.37	0	397,782,000
2067	23.73	0.36	481,950,000
Average Annual Benefits			200,541,000
With the Rio Toabre and Rio Caño Sucio alternative, the system will provide a total of 62.05 equivalent lockages at the 99.6 percent level of reliability or 23.37 more lockages than the existing system.			

With The proposed Rio Toabre and Rio Caño Sucio 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 Rio Toabre and Rio Caño Sucio project would be $16,208,000. Table 9 - 7 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 9 - 7 Average Annual Reliability Benefits For Navigation

Year	Daily Average Number of Lockages	Value Per Lockage ($)	Annual Benefits For Navigation ($)
2018	40.0	2,260,000	12,045,000
2019	40.0	2,260,000	12,475,000
2020	40.0	2,260,000	12,908,000
2030	40.0	2,260,000	17,463,000
2040	40.0	2,260,000	23,251,000
2050	40.0	2,260,000	32,606,000
2060	40.0	2,260,000	50,052,000
2067	40.0	2,260,000	74,444,000
Average Annual Benefits			16,208,000

M&I WATER SUPPLY

The future demand for water supply for M&I purposes was 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 was 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 Rio Toabre and Rio Caño Sucio 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 would be $2,636,000. Table 9 - 8 displays the population forecast, the resulting number of equivalent lockages per day, and the benefits for M&I water supply.

Table 9 - 8 Average Annual Reliability Benefits For M&I Water Supply

Year	Population	Equivalent Lockages per Day	Annual M&I Water Supply Benefits ($)
2018	2,052,000	7.3	1,491,000
2019	2,097,000	7.5	1,570,000
2020	2,141,000	7.6	1,651,000
2030	2,688,000	9.6	2,805,000
2040	3,384,000	12.0	4,691,000
2050	4,259,000	15.1	8,281,000
2060	5,360,000	19.0	16,012,000
2067	6,746,000	24.0	27,999,000
Average Annual Benefits			2,636,000

HYDROPOWER

The amount of hydropower energy that could be produced by the system of Gatun Lake and Madden Lake would decline over time as the demands for navigation and M&I water supply increase. With the inclusion of the proposed Rio Toabre and Rio Caño Sucio project, the system could produce net additional megawatt hours of hydropower. The value for hydropower energy used in this analysis was $0.070 / kWh. On an average annual basis, the proposed project would have benefits of $12,637,000. Table 9 - 9 provides the net additional megawatt hours of hydropower generation and the resulting benefits.

Table 9 - 9 Average Annual Benefits For Hydropower Generation

Year	Net Generation Operating (MWh)	Annual Benefits For Hydropower ($)
2018	181,681	12,718,000
2019	181,476	12,703,000
2020	181,272	12,689,000
2030	180,168	12,612,000
2040	178,766	12,514,000
2050	176,873	12,381,000
2060	174,140	12,190,000
2067	171,663	12,016,000
Average Annual Benefits		12,637,000

SUMMARY OF ANNUAL BENEFITS

As shown in Table 9 - 10, total average annual benefits for operating Option 1 of the proposed Rio Toabre and Rio Caño Sucio project would be $232,022,000.

Table 9 - 10 Summary of Annual Benefits

Benefit Category	Average Annual Benefits ($)
Navigation – Water Supply	200,541,000
Navigation – Reliability	16,208,000
M&I - Reliability	2,636,000
Hydropower	12,637,000
Total	232,022,000

To perform an analysis of benefits versus costs, a common point in time was selected. This common point was at the completion of the filling of the proposed Rio Toabre and Rio Caño Sucio project, the end of the year 2018. In these analyses, it was important to note that the average annual benefits or average annual costs were 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 Rio Toabre and Rio Caño Sucio would be to develop the Rio Indio project first (2001 – 2010) and then the Rio Toabre and Rio Caño Sucio project second (2007 – 2018).

The benefits attributable to the proposed Rio Indio project would begin to accrue in 2010 when that reservoir is filled. Thus, the Rio Indio project benefits for the period 2010 to 2018 were escalated by the project discount rate, 12 percent, in order to estimate their total present worth of $2,076,755,000 in the year 2018. The average annual benefits for the proposed Rio Indio project that accrue during the construction of the proposed Rio Toabre and Rio Caño Sucio project are estimated to be $250,076,000. The benefits for the proposed Rio Toabre and Rio Caño Sucio project are estimated with the assumption that the Rio Indio project would use its operating Option 2. Although the discharge tunnel would be larger, the proposed Rio Indio project would be operated for the period 2010 through 2018 just as if the proposed Rio Toabre and Rio Caño Sucio project was not to be constructed.

To estimate the interest during construction, similar calculations were made for the costs of each proposed project. For the proposed Rio Indio project, interest during construction was taken from year 2001 to year 2018 and the interest during construction for the proposed Rio Toabre and Rio Caño Sucio project was taken from the year 2007 to the year 2018. Additionally, there would be added costs for the larger inter-basin transfer tunnel between Indio Lake and the Panama Canal watershed that would only be required if the proposed Rio Toabre and Rio Caño Sucio project were to be constructed. Those amounts were subtracted from the cost estimate for the proposed Rio Toabre and Rio Caño Sucio project and added to the cost estimate for the proposed Rio Indio project. The revised estimated average annual costs for the Rio Indio portion of the overall project would be $125,519,000.

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) were computed. In the first instance, the analysis determines the feasibility of the proposal. The net benefits determines which proposal among several provides the greatest value for the investment dollars. Table 9 - 11 provides the benefit to cost ratio and the net benefits.

Table 9 - 11 Economic Evaluation

Item	Value ($)
Average Annual Benefits	
Rio Indio	250,076,000
Rio Toabre and Rio Caño Sucio	232,022,000
Sum	482,098,000
Average Annual Costs	
Rio Indio	125,519,000
Rio Toabre and Rio Caño Sucio	64,282,000
Sum	189,801,000
Benefit to Cost Ratio	2.5
Net Benefits	292,296,000

Internal Rate of Return

An internal rate of return analysis for this proposed project was performed. To accomplish this analysis, the annual construction costs were used as the investment, and the undiscounted benefits were used as return cash flows. The internal rate of return would be 25.7 percent.

Incremental Evaluation of Hydropower

Since the generation of hydropower would be provided through the conjunctive use of storage, an analysis of the incremental benefits and costs for this purpose was accomplished. The first costs of the Lands and Relocations and the Clearing and / or Grubbing, which were associated with hydropower, as well as the costs of the Hydropower Plants and the Transmission Lines were taken from Table 9 - 2. The portion of annual operation and maintenance costs associated with hydropower generation were derived from the data included in Table 9 - 4. The construction costs are estimated to be approximately $27,075,000. Interest during a two-year construction period is estimated to be $3,298,000 for a total hydropower investment costs of $30,373,000. The portion of annual operation and maintenance costs for hydropower were assumed to be $350,000 for staff, $250,000 for ordinary maintenance and $50,000 for major replacement. The total average annual costs for hydropower would be $4,307,000. The average annual benefits are estimated to be $12,637,000. The average annual benefits exceed the average annual costs for the proposed Rio Toabre and Rio Caño Sucio project yielding a benefit to cost ratio of 2.9. It should be noted, however, that hydropower was valued at the current costs of production for the PCC. This value might underestimate the economic value of any additional hydropower generating capacity. Additional effort should be expended in any future planning studies to determine the economic value of added hydroelectric power generation.

Socio-Economic Impacts

The socio-economic impacts of the project could be substantial. The relocation of the towns of El Guayabo o Toabre Abajo, El Valle de San Miguel, El Caraño, Las Maravillas, Santa Maria or Caño Sucio, Riecito Abajo and their approximately 1,700 residents would be an important issue. The average monthly income of families in the project area is less than $100 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 create the Toabre Lake and the Caño Sucio Lake. The relocation of agricultural and ranching activities would be a substantial issue, because approximately 40 percent of the land in the impoundment area is used for farming and ranching. The impoundment would also substantially impact the potential to mine the mineral ore resources.

The Toabre project would not produce hydropower; however, the Toabre project would be built only in conjunction with Rio Indio, which would produce electricity. Therefore, post-construction revenues for the nation would be greater, because the project would create electric power generating potential. On a per hectare basis, the revenues from power generation would be greater than those produced by the current agricultural activity. During construction, the influx of workers could create a temporary demand for additional housing, which could result in an increase in housing values in the vicinity of the dam site. However, after completion of the project, the workers would leave, the housing demands would drop, and the housing values could drop to pre-construction levels. Currently, most 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 remain available at the normal level.

To construct the dams, some existing roads would be improved and some new roads would be built; however, the unpaved roads within the impoundment area would be significantly reduced, which would change the 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 would increase; however following completion of construction, the traffic volumes would decline. Noise levels would increase during construction and could negatively impact noise-sensitive receptors; however, after construction, noise levels should return to pre-construction levels.

The communities that could receive the 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 through the division of communities, separation of families, and loss of livelihood.

Environmental Setting

The structures for the proposed Rio Toabre / Caño Sucio project would consist of rock fill dams on the Rio Toabre and the Rio Caño Sucio, uncontrolled ogee spillways on the Rio Toabre and Rio Caño Sucio, inter-basin transfer facilities, two hydropower plants, and outlet works. Flow from these lakes would be passed via a tunnel to Rio Indio Lake. Rio Indio Lake will be connected to the Panama Canal watershed at Gatun Lake via a second tunnel. Water impounded in these three lakes will be transferred to the Panama Canal watershed as needed to support navigation. The project consists of rock fill dams on the Rio Toabre and the Rio Caño Sucio, uncontrolled ogee spillways on the Rio Toabre and the Rio Caño Sucio, inter-basin transfer facilities, two hydropower plants, and outlet works. The project area encompasses the area to be flooded as well as the area downstream from the dam site. This area is sparsely populated. It is characterized by rolling hills, low coastal regions, and scenic water falls. The Rio Toabre is located west of the Panama Canal and flows northward from the Continental Divide into the Cocle del Norte and then to the Atlantic Ocean. The Rio Caño Sucio is located west of the Panama Canal and flows northward from the Continental Divide into Rio Miguel de la Borda, and then northeastward into the Atlantic Ocean. The combined Rio Toabre and Rio Caño Sucio watershed above the dam is approximately 841 km^2. Both impoundment areas cover approximately 7,870 ha and consists of approximately 30 percent of forested land, 20 percent of pasture land (used by ranchers), 20 percent of cropland, 25 percent of newly slashed and burned land, and 5 percent of mining land. Both lake water elevations will fluctuate from elevation 90 to 104 m MSL. The transmission lines, tunnel portals, and roads associated with the project could also have environmental impacts and should be sited to minimize those impacts.

LAND USE

The project area encompasses the area to be flooded as well as the area downstream from the dam site. It is inhabited by about 700 people, dispersed throughout the area, with concentrations in the towns of El Guayabo o Toabre Abajo and (population – 150 El Valle de San Miguel (population – 250, El Caraño (population (population - 100), Las Maravillas (population - 70), Santa Maria or Caño Sucio (population - 60), Riecito Abajo (population - 50), and approximately 11 smaller settlements. Downstream from the dam site, are 11 communities with a combined population of approximately 300.

Approximately 8 percent of the land in the project area is occupied by farms and ranches of various sizes as well as some teak plantations. Major farm crops include maize, rice, beans, sugar, coffee, and tobacco. Ranchers raise cows, horses, chickens, and hogs. Some of the farmers and ranchers operate commercial enterprises, others rely on cash crops and subsistence farming. There are some mineral and ore deposits in the impoundment area.

INFRASTRUCTURE

The towns of El Guayabo o Toabre Abajo and El Valle de San Miguel have elementary schools. These towns have cemeteries and churches. All towns depend on both Rio Toabre and Rio Caño Sucio and their tributaries or groundwater wells for their 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 rivers. Disposal of domestic waste is the responsibility of individual homeowners: each home has an outdoor latrine (a hole in the ground). There are some health problems, such as hepatitis, dysentery, dermatitis, intestinal parasites, and respiratory illnesses attributable to the present waste disposal methods. The project area is traversed by unpaved horseback riding trails that link various communities. No major industries or poultry or beef processing plants are located in the project area. The dirt roads are extremely important to the residents for transportation, community cohesion, commerce, and communication with neighboring communities.

TERRESTRIAL HABITAT

About 80 percent of the land along the rivers are covered with forests that could support diverse wildlife populations. The forests extend to the upper mountainous areas above the impoundment areas; however, as a result of slash and burn activities, there are no large contiguous tracts of forests at lower elevations.

ANIMALS ON ENDANGERED LIST

La Autoridad Nacional del Ambiente (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 none have been identified to date, some animals and other species of concern on the threatened and / or endangered list may be found in the project area.

AQUATIC HABITAT

The rivers in the project area have characteristics typical of streams in mountainous regions. Its water is clear and cool, and its bed ranges from sand to boulders, with numerous riffles, runs, and pools and with accumulations of large boulders and rocks downstream from the dam site. Rio Toabre has three major tributaries: Rio de U, Rio Tulu, and Rio Qda La Sargenta; approximately 21 smaller creeks also flow into Rio Toabre. The river is approximately 37 km long; its width ranges from 5 m (in the dry season) to 20 m at the confluence of the Rio Cocle del Norte, and its depth ranges from less than 1 m to 10 m. The rivers appear to support some fish and other aquatic communities; however, information about these communities in the project area is limited.

WETLANDS

The wetlands consist of forested riparian habitat and are limited by the relatively steep topography of the project area to the immediate vicinity of the stream banks. The width of the riparian habitat within the impoundment area varies from approximately 10 m to 75 m. Approximately 80 percent of the streams above and below the dam site along the Rio Toabre and its tributaries are bordered by forested riparian habitat.

AIR QUALITY

Air quality in the project area is generally good, except during slash and burn activities. At the end of the dry season in March or early April, sizable areas of established forests and secondary growth are burned and cleared to prepare the land for agricultural use. Based on observations in the project area, the amount of forested land burned varies annually.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

No parks or other government-protected lands are known to be located in the impoundment area. Some Pre-Columbian cultural resources that have been identified by archaeological surveys are located in the impoundment area. It should 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 impoundment area would be scattered, since about 2,360 ha, or 30 percent of the impoundment area, is covered by patches of forest, which constitutes a relatively high quality terrestrial habitat. With the creation of the lake, migration routes of some species could be adversely affected. The only forests that would remain in the vicinity of the Rio Toabre and Rio Caño Sucio reservoirs and its drainage basin would be confined to the higher elevations.

ANIMALS ON ENDANGERED LIST

The extent of potential effects on endangered animals cannot be determined at this time, because it is not known which, if any, of the listed species occur within the proposed project area. The significance of the forested riparian corridor along area streams may increase if animals on the endangered list are found in the region. The Meso-American Biological Corridor is also promoting biodiversity conservation throughout the Atlantic basin, which could impose restrictions on the use of the project area.

WATER QUANTITY

The impacts of the project on water quantity should be positive, because construction of the dam should result in an increase in the volume of stored fresh water in surrounding areas during the dry season. The releases should be made at appropriate intervals and in amounts that should help significantly reduce problems with water quality and temperature downstream, and also minimize flooding.

WATER QUALITY

The impacts downstream from the dam sites could be positive. The water should contain less silt due to minimum normal flow and should provide people downstream higher quality water.

The proposed Toabre Lake and Caño Sucio Lake should also serve as a dependable high-quality water supply for the people living around the lake.

DOWNSTREAM AQUATIC FAUNAL HABITAT

The impacts of the project on downstream aquatic faunal communities should be minor, because the dam would be designed to allow releases of water from different reservoir levels, which could reduce problems with water quality and temperature downstream. The Rio Toabre and Rio Caño Sucio dams would act as a large sediment trap, which could cause the released water to have low turbidity; therefore, siltation is not expected to be a problem. The impacts of interference with the migratory movements of natural stream fishes are unknown. Streambed degradation below the dam should be minor due to minimum normal flow rate.

FUTURE LAKE AQUATIC PLANT COMMUNITY

The impacts of the project on future aquatic plant communities in the proposed lake would depend on water level fluctuations, which are anticipated to vary seasonally from 90 to more than 100 m MSL. Such fluctuations would cause much of the shore to be covered with mud, where neither aquatic nor terrestrial plant communities could thrive. Rooted aquatic plants tend to grow as deep as light penetration allows.

AQUATIC FAUNA INHABITING AFFECTED AREAS

The impacts of the project on aquatic fauna inhabiting the Rio Toabre, Rio Caño Sucio, and their upstream tributaries could be important. If aquatic fauna are able to thrive in the new reservoir they would be beneficially affected by having their habitat enlarged. Some unavoidable, adverse environmental impacts could occur and these impacts should be identified and appropriate mitigation measures addressed in feasibility level studies, should the alternative be recommended for further consideration. If the new reservoir is responsibly managed and stocked with game fish by the Aquaculture Department, it could provides good opportunities for recreational and subsistence fishing. Increase in fish populations could cause a corresponding increase in piscivorous predators, such as crocodiles, caimans, otters, and herons, among others. Some manmade lakes in the Republic of Panama have been stocked with peacock bass and tilapia, both of which have adapted well, but several riverine native species that formerly occupied the impoundments have disappeared.

WETLANDS

The impacts to wetlands could be significant, even though the wetlands are limited to forested riparian areas. However, owing to the topography of the project area, a number of wetlands could be impacted by the project. It is possible even though the reservoir water levels will fluctuate, new wetlands could develop in the littoral zones.

AIR QUALITY

During construction of the dams, dust and emissions from equipment could impact the air quality in the project area. Upon completion, the air quality could improve because the slash and burn activities are discouraged by the Panamanian government.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

The impacts of the project on cultural resources and historic properties could be moderate. The project area is relatively large and is known to contain Pre-Columbian sites; therefore, the presence of cultural resources is highly probable. Prior to construction, surveys would be conducted to locate cultural resources and historic properties, and the important sites would be preserved or salvaged as appropriate.

Additional Environmental Information Required

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

SOCIO-ECONOMIC IMPACTS

- Conduct an 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).
  - Community and Regional Growth.
  - Transportation.
  - Housing.
  - Health (vector routes).
  - Population.
  - Community Cohesion.
  - Recreational Resources.
  - Mineral Resources.

TERRESTRIAL AND AQUATIC HABITAT

- Prepare site-specific habitat maps to ensure that all major types of terrestrial and aquatic habitat are identified and quantified.
- Conduct field studies to locate special 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 Rio Toabre project area.
- Coordinate with local experts regarding terrestrial and aquatic habitats.
- Provide species inventory lists for each area, identifying their status as native or exotic and whether they are threatened and / or endangered species.
- Address cumulative effects downstream due to diversions.

ANIMALS ON THE ENDANGERED LIST

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

WATER QUALITY

- As only limited water quality data are available for the Rio Toabre area, additional information should be compiled on total suspended solids, conductivity, total dissolved solids, dissolved oxygen, nutrients, pH, and coliform bacteria content of the water.

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 Section 35. Tables 9 - 12 through 9 - 14 present the evaluation of the proposed Rio Toabre and Rio Caño Sucio project as related to developmental effects, environmental effects, and socio-economic effects.

Table 9 - 12 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	4	5	20
Technical Viability	Design Constraints	7	6	42
	Feasibility of Concept	6	6	36
Operational Issues	Compatibility	6	6	36
	Maintenance Requirements	8	2	16
	Operational Resources Required	6	2	12
Economic feasibility	Net Benefits	10	9	90
	Total			502

[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 9 - 13 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	7	10	70
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			369

[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 9 - 14 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	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			315

[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

Pertinent data for the proposed Toabre dam are presented in Table 9 - 15.

Table 9 - 15 Pertinent Data for Option 1

GENERAL	Toabre	Caño-Sucio
Dam Site, above Mouth of River	16 km	---
Drainage Area above Dam Site	730 km^2	111 km^2
Average Annual Flow at Dam Site	39 CMS	7.4 CMS
LAKE		
Elevation of Maximum Operating Lake Level	100 m MSL	100 m MSL
Elevation of Maximum Flood Storage Lake Level	104 m MSL	104 m MSL
Elevation of Minimum Operating Lake Level	90 m MSL	90 m MSL
Useable Storage between Max. and Min. levels	468 MCM	*(included in Toabre storage.)*
Area at Maximum Operating Lake Level	4,850 ha	1,355 ha
Area at Maximum Flood Storage Lake Level	5,830 ha	2,040 ha
Area at Minimum Operating Lake Level	3,220 ha	245 ha
Top Clearing Elevation	100 m MSL	100 m MSL
Lower Clearing Elevation	90 m MSL	90 m MSL
EMBANKMENTS		
Dam - Rock Fill Embankment		
Top Elevation of Dam	105 m MSL	105 m MSL
Fixed Crest Width	13 m	13 m
Height above Lowest Foundation	90 m	20 m
Overall Length of Dam	1,130 m	185 m
SPILLWAY		
Type of Spillway	Uncontrolled Ogee	Uncontrolled Ogee
Total Length	219 m	74 m
Elevation of Spillway	100 m MSL	100 m MSL
Maximum Discharge	3,391 CMS	1,141 CMS

Table 9 - 15   Pertinent Data for Option 1 (continued)

INTER-BASIN TRANSFER TUNNEL	**Sucio-Indio**	**Indio-Gatun**
Tunnel Diameter	3 m	6 m
Tunnel Length	2.0 km	5.2 km
Inlet Invert	85 m MSL	40 m MSL
Outlet Invert	74 m MSL	38 m MSL
Tunnel Capacity	27.8 CMS	216 CMS
HYDROPOWER PLANTS		
Toabre Dam		
Type of Hydropower Plant Construction	Reinforced Concrete	
Number of Units	2	
Capacity of Each Unit	11 MW	
Sucio-Indio Transfer Tunnel		
Type of Hydropower Plant Construction	Reinforced Concrete	
Number of Units	1	
Capacity of Unit	6 MW	
Indio-Gatun Transfer Tunnel		
Type of Hydropower Plant Construction	Reinforced Concrete	
Number of Units	1	
Capacity of Unit	10 MW	
CONSTRUCTION / POWERHOUSE DIVERSION	**(Toabre only)**	
Diversion Length	1,100 m	
Horseshoe Tunnel Dimensions	(2) 8 m x 8 m	
Inlet Invert	17 m MSL	
Outlet Invert	15 m MSL	
Cofferdam Height above Tunnel Inlet Invert	15.5 m	
MINIMUM FLOW CONDUIT	**Toabre**	**Caño-Sucio**
Conduit Diameter	0.9 m	406 mm
Conduit Length	1,100 m	140 m
Inlet Invert	15 m MSL	85 m MSL
Outlet Invert	15 m MSL	83 m MSL
Conduit Capacity	3.9 CMS	0.74 CMS

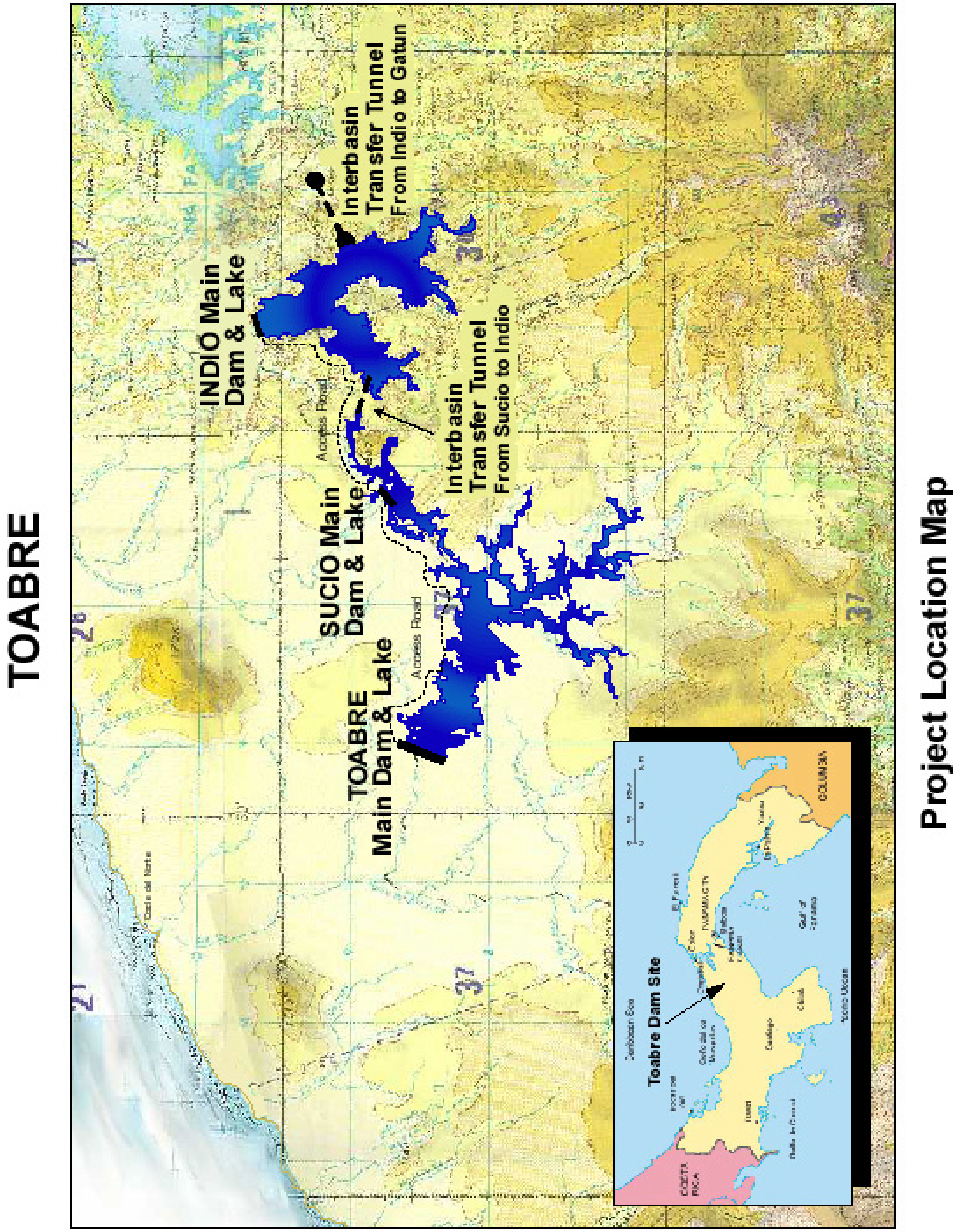


Plate 9 - 1   Project Location Map

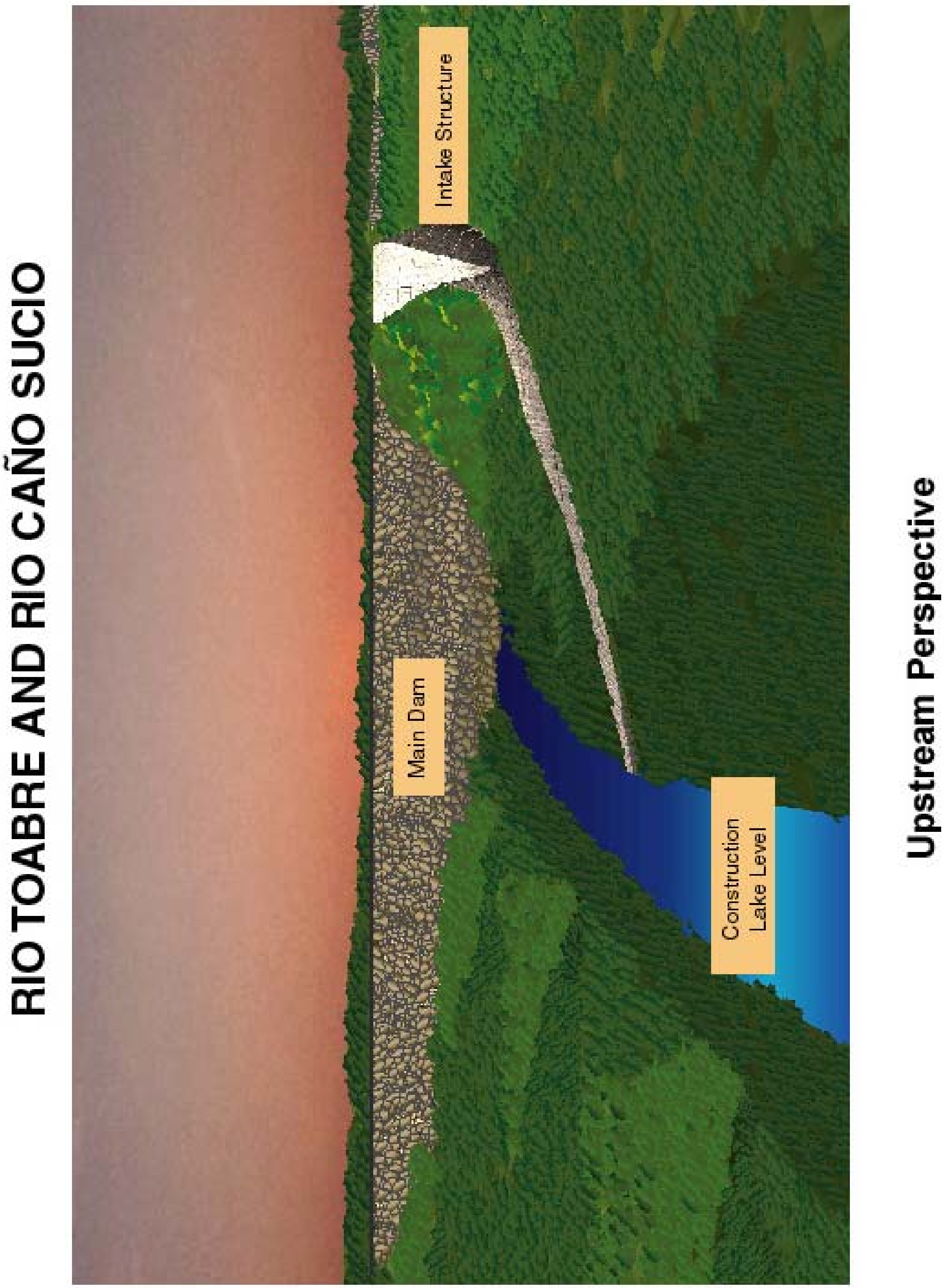


Plate 9 - 2   Upstream Perspective

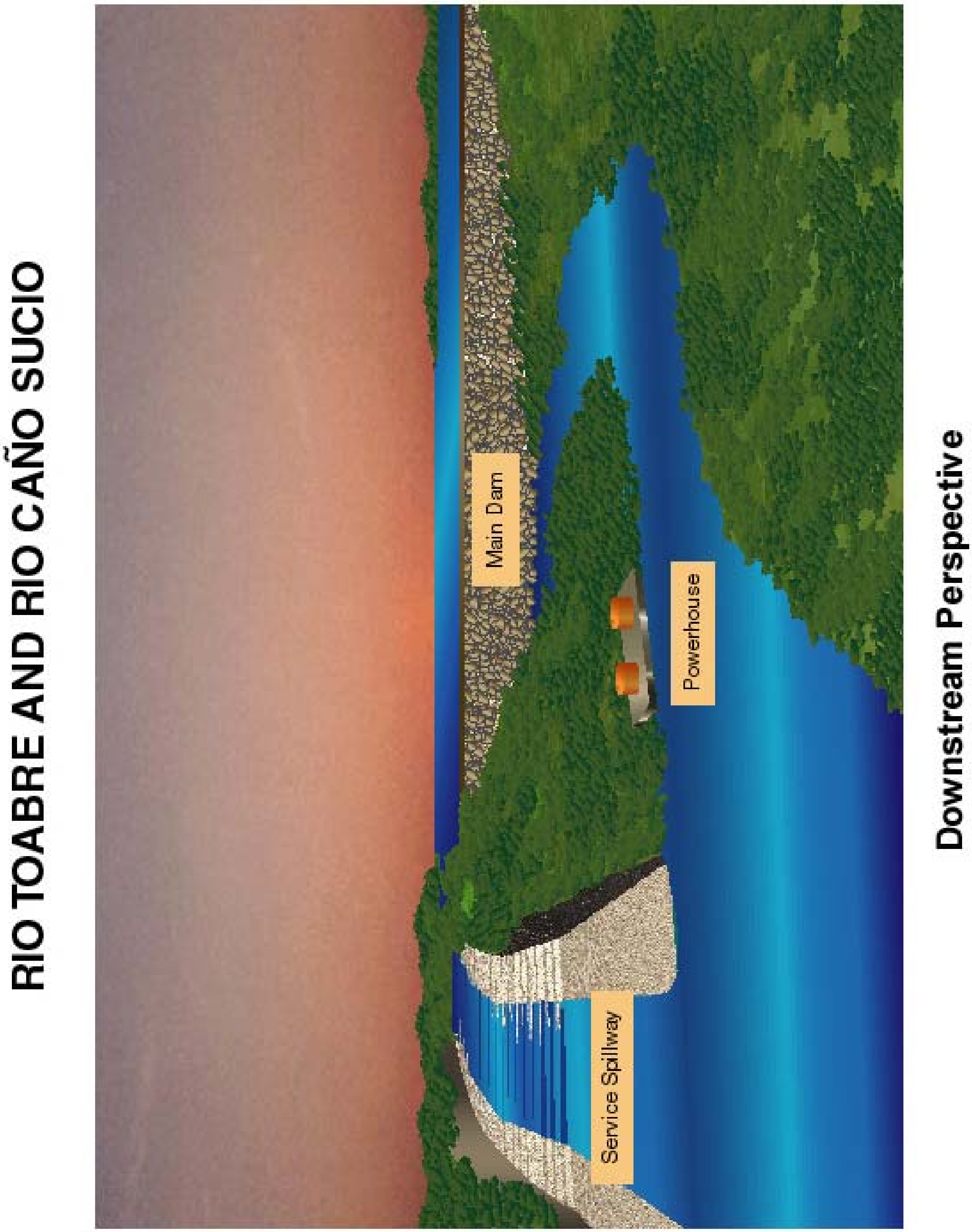
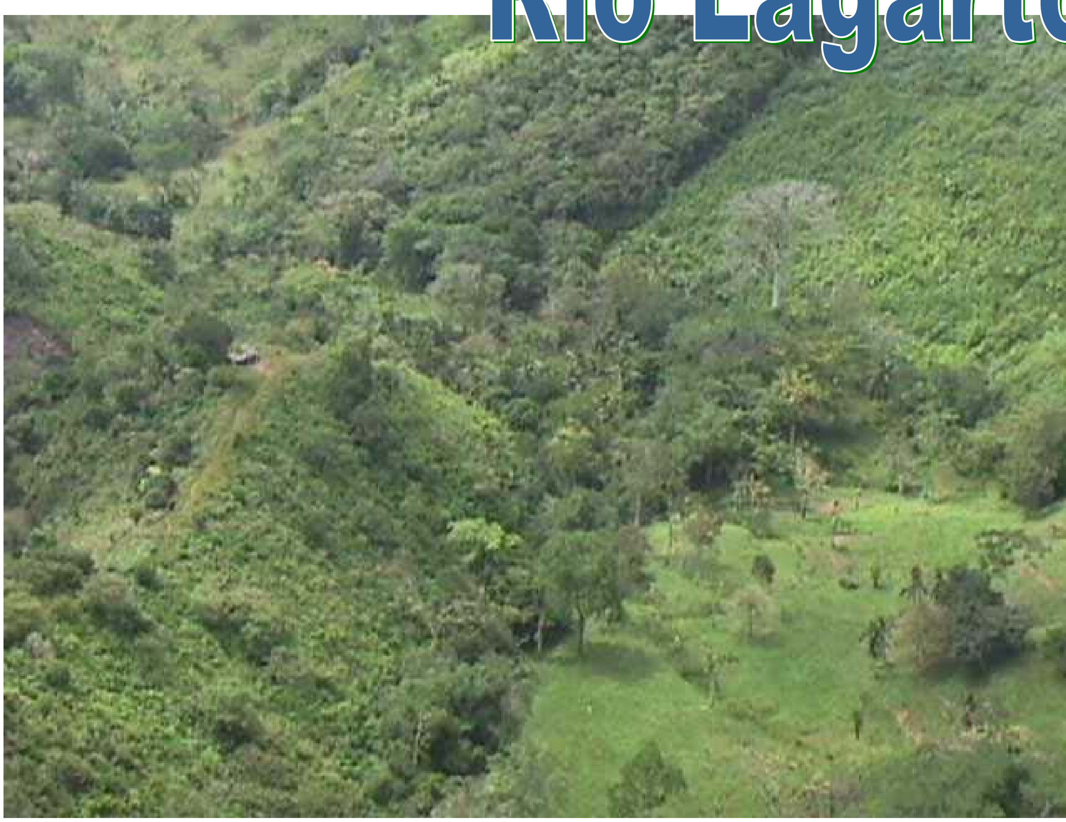


Plate 9 - 3   Downstream Perspective

SECTION 10

Rio Lagarto



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Synopsis

The development plan presented herein would include a dam creating a lake on the Rio Lagarto connected by tunnel to the western edge of Gatun Lake. Water impounded in Lagarto Lake would be transferred to the Panama Canal watershed on a continual basis to replace withdrawals made from the canal system for M&I water supply. See Figure 10 - 1.

The Rio Lagarto watershed is located adjacent to the western side of the Panama Canal watershed approximately 21 km west of Colon. The proposed Rio Lagarto dam site would be approximately 8 km inland from the Atlantic Ocean. The proposed project would include a 35 m high rock fill dam with a tunnel through the divide directly to the Panama Canal watershed. The tunnel would transfer water from Lagarto Lake to the Panama Canal watershed as required to replace water withdrawn for M&I water supply. The total project construction costs of the proposed Rio Lagarto project are estimated to be $32,038,000.

The proposed Rio Lagarto project would contribute to the hydrologic reliability of the Panama Canal to serve its customers, and would minimally reduce the need for imposing draft restrictions and resulting light loading of vessels during traditional periods of low water availability. Because of the limited storage capacity in Lagarto Lake, the project was designed to provide water on a steady flow basis to the Panama Canal watershed through a small tunnel through the basin divide. This differs slightly from other alternatives that were designed to provide water in larger volumes on demand. The existing hydrologic reliability of the Panama Canal, based on the 50.5-year period of record from January 1948 through July 1998, is approximately 99.60 percent, while the hydrologic reliability with a demand ratio of 1.2 (46.42 lockages) would be 99.0 percent. With construction of the proposed Lagarto Lake project, the existing high hydrologic reliability could be continued as withdrawals for potable water supply increase. Lagarto Lake would provide approximately 60 MGD (1.1 lockages) on a continual basis.

Hydropower potential at Rio Lagarto Dam was found to be very small and was not included in the project features. The amount of hydropower production expected from the facilities at Gatun Lake will decline over time as the demands for canal operation and M&I water increase. Water provided to Gatun Lake by the Lagarto Lake would help to offset the expected increasing demand for canal operation and M&I withdrawals and, thus, reduce the subsequent loss in hydropower production at the Gatun powerplant. However, the impact would be very small and was not considered as an economic benefit in this analysis.

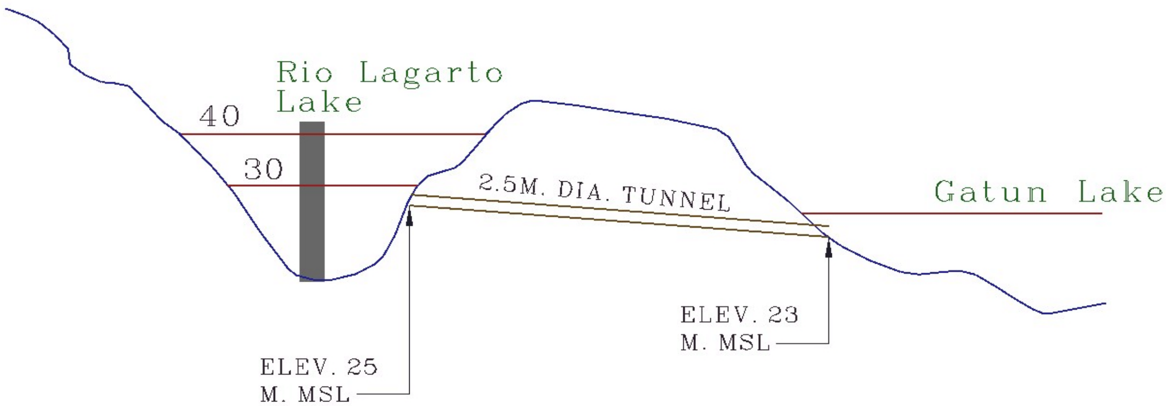


Figure 10 - 1 System Profile

Site Selection

The proposed Rio Lagarto dam site was chosen 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. To maximize the water impounded, it was desirable to locate the dam as far downstream in the Rio Lagarto watershed as possible. In choosing a site for the dam, a location was sought where the surrounding hillsides were relatively steep and high, and the valley was relatively narrow. The downstream portion of the Rio Lagarto watershed contains sites that adequately meet these criteria.

The site chosen for the proposed Rio Lagarto Dam would accommodate construction of a dam with a normal operating lake level at elevation 40 m MSL and a maximum flood storage lake level at elevation 44 m MSL. Plate 10 - 1 shows the location of the proposed Rio Lagarto project. The original idea for the Rio Lagarto alternative was to transfer water from the Rio Lagarto to the Panama Canal watershed over a low ridge via a small spillway. To accomplish this, a lake level of 60 m MSL or higher was required. Preliminary analysis for water yield from Rio Lagarto indicated that a lower operating option (40 to 30 m MSL) yielded essentially the same amount of water as the higher lake level. Evaporation losses combined with a small drainage basin above the lake inhibited timely recovery of the useable storage after significant drought periods. With the lower lake level, the construction of a cut or spillway to transfer flow to Gatun Lake was impractical and a tunnel was found to be more economical.

Hydrologic Considerations

The Rio Lagarto flows northward through the area immediately adjacent to the western edge of the Panama Canal watershed to the Atlantic Ocean.

The headwaters of the watershed begin at elevation 150 m MSL approximately 24 km inland and fall to mean sea level at its mouth. The distribution of the average annual rainfall over the Rio Lagarto watershed varies from a high of 4,000 mm at the coast to a low of 3,000 mm in the upper watershed area. The proposed Lagarto Lake would receive runoff from approximately 53 km^2 of the upper portion of the watershed. Rainfall runoff produces an average annual flow of 4.1 CMS at the proposed dam site.

The hydrologic record at the Rio Lagarto dam site was developed from gage data at Boca de Uracillo on the Rio Indio and the Trinidad River at El Chorro using standard hydrologic relationships. The gage at Boca de Uracillo is located approximately 2.5 km upstream of the Rio Indio dam site and has been in operation since 1979.

Because of the proximity and in the absence of additional information, the monthly evaporation rates recorded at Gatun Lake were used to establish the evaporation of Lagarto Lake.

Geologic Considerations

The proposed Lagarto dam site is located in an area of the Isthmus of Panama that is underlain by late Miocene to early Pliocene aged sedimentary rocks of the Chagres Formation. These rocks consist of sandstones and siltstones that are massively bedded, medium-soft, friable, and fine-grained. A few harder calcareous beds, usually less than 1 ft thick, are also present. In general, the dip of the beds is gently toward the Atlantic. The rocks of the Chagres Formation are soft enough that they can be excavated without blasting, though they are hard enough that blasting could probably be employed. Weathered rock is generally less than 10 ft deep in the strata of the Chagres Formation.

It is considered that the sandstones and siltstones of the Chagres Formation would make an acceptable foundation for an earth and rock fill dam. They would be unacceptable, however, for use as concrete aggregate and only marginally acceptable for use as fill in an earth and rock fill dam. If this proposed project is carried forward, it is recommended that cores be drilled in the abutments early during planning studies to identify the abutment materials and their general suitability for use as construction material. The cores should be drilled to sufficient depth to check for the occurrence of any soluble calcareous strata in the foundations.

In the absence of detailed geologic mapping for the proposed Rio Lagarto Dam, a degree of extrapolation was necessary. It was predicted that rock at the proposed site would be encountered at a shallow depth and would be of sufficient quality to serve as foundation for the dam. This prediction was based on available general geologic mapping and general data. Furthermore, it was assumed that impervious materials would be available within the immediate area for use in the construction of the dam. However, concrete aggregate and stone for erosion protection used in the dam construction will have to be obtained from commercial sources.

Lake Operation

Lagarto Lake would be operated to supplement water withdrawals from the Panama Canal watershed for M&I water supply. Initial analysis considered two operating lake levels, 40 to 30 m MSL and 60 to 40 m MSL. However, both options produced essentially the same water yield. Therefore, only the lower option was considered further since it would have the lower construction cost. The water surface of the lake would be allowed to fluctuate from the normal operating lake level at elevation 40 m MSL down to the minimum operating lake level at elevation 30 m MSL. This would provide approximately 131,340,000 M^3 of usable storage. The maximum flood lake level would be at elevation 44 m MSL. The volume between elevation 44 and 40 m MSL would be used to store flood waters and reduce peak flood flows. Some reduction in flooding would be realized in areas along the Rio Lagarto downstream of the dam.

Project Features

GENERAL

The structures for this proposed project would consist of a rock fill dam, an uncontrolled ogee spillway, inter-basin transfer facilities, and outlet works. The following paragraphs provide a description of the proposed structures and improvements. Plate 10 - 2 depicts the location of the dam. The spillway and the outlet works would be similar to those shown in Section 5 – Rio Indio.

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 containing assumptions and design calculations for the reconnaissance level investigations of these structures. If this proposed project is carried into planning studies, optimization of the project features and improvements must be accomplished.

EMBANKMENTS

The dam would be an embankment with the top at elevation 45 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 1012936 north and 598926 east. The right abutment would be 1013019 north and 599094 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 would be approximately 35 m high, and the overall length would be 192 m. The actual side slopes and crest width 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 section of the embankment at the dam can be seen in Section 5.

SPILLWAY

An uncontrolled ogee spillway with a length of 48 m and a crest at elevation 40 m MSL would be required. The spillway crest would be 5 m below the elevation of the top of the dam. The maximum discharge from the spillway would be 746 CMS at a maximum flood storage lake elevation of 44 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 include 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. A stilling basin would be excavated into the rock adjacent to the natural channel at the downstream end of the tailrace channel for energy dissipation. See Plate 10 - 2 for the location of the spillway.

IMPOUNDMENT

The lake formed by the proposed Rio Lagarto Dam would have a normal operating lake level at elevation 40 m MSL. The surface area at the normal operating lake level would be approximately 1,600 ha. With the minimum operating lake level at elevation 30 m MSL, the surface area would be approximately 1,140 ha. At the maximum flood storage lake level, elevation 44 m MSL, the surface area would be approximately 1,890 ha.

CLEARING AND / OR GRUBBING

Clearing and grubbing would be required for all areas necessary for construction of the dam (embankments and spillway), inter-basin transfer facilities, outlet works, access roads, and disposal and staging areas. Clearing only would be required for the 460 ha in the lake area between the normal operating lake level at elevation 40 m MSL and the minimum operating lake level at elevation 30 m MSL.

INTER-BASIN TRANSFER FACILITIES

A tunnel, approximately 2.5 m in diameter, would be excavated through the common watershed divide to connect the proposed Lagarto Lake to the Panama Canal watershed. The finished tunnel would be concrete lined, 2.0 m in diameter, and approximately 1.25 km in length. This tunnel would have an inlet invert at elevation 25 m MSL and an outlet invert at elevation 23 m MSL. The maximum capacity of the tunnel would be 14.4 CMS. It was assumed that rock bolting would be required over much of the tunnel length to stabilize the rock. The tunnel outlet would be on the southwest leg of Gatun Lake at the Caño Viviano inlet. A gate structure located at the tunnel outlet would control flow through the tunnel. The tunnel would be under pressure continually. To allow for maintenance of the tunnel and to allow for rapid tunnel closure when required, a gate / stoplog structure would be constructed at the inlet. In the process of stopping flow through the tunnel, a water hammer effect could be generated. Therefore, a series of surge protection shafts would be constructed. These shafts would require relatively minor surface structures for safety purposes. Plate 10 - 1 shows the location of the tunnel outlet.

HYDROPOWER PLANTS

Flow at the proposed Rio Lagarto Dam exceeding that needed for canal operation and M&I water supply was considered for hydropower production. These investigations indicated that the power production potential would be so small (approximately 80 kW for the plan presented herein) as to make such an installation infeasible.

OUTLET WORKS

An outlet works system would be required to provide for diversion of the Rio Lagarto flows during construction. This system would also provide for emergency drawdown of the lake, and minimum flow through the dam.

This outlet works system would 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 was no longer needed for construction, the structure would be used to control minimum flows and to provide for and emergency drawdown. It would 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 as minimum flow.

This system would consist of a 6 by 6 m horseshoe shaped tunnel passing through the dam abutment, an intake structure located in the lake, an outlet channel downstream, and various gate structures and water conduits. The diversion tunnel would be 65 m in length with a 43 m long intake structure at its upstream end. The intake structure would have an inlet invert at elevation 10 m MSL and the outlet invert elevation of the tunnel would be at 9 m MSL. The diversion tunnel would serve in combination with the cofferdam to protect the construction area from floods up to a 10 percent frequency. A 10 percent frequency flood would deliver a peak flow of 392 CMS at the site without regulation from the dam. The cofferdam would measure 7.3 m above the upstream invert of the tunnel. A separate 300 mm diameter conduit, required for minimum flow, would be installed beneath the floor of this tunnel. The minimum flow conduit would be approximately 100 m in length; it would have an upstream invert at elevation 9 m MSL and an outlet invert at elevation 8 m MSL. The capacity of the minimum flow conduit would be 0.4 CMS. A bulkhead structure would be required at the tunnel outlet to close the construction. The closure would be configured so that it could be removed in the event that the Lagarto Lake had to be drawn down. The details of the intake structure would be similar to those shown for the Rio Indio Intake Structure in Section 5.

ACCESS ROADS

Access to the lake site and the various construction sites was evaluated from Colon, the main population center on the Atlantic coast.

Construction access from Colon to the Rio Lagarto dam site and lake construction area could be gained by land, crossing the Panama Canal at Gatun Locks and traversing existing roads to the village of Palmas Bellas at the mouth of the Rio Lagarto. The route to the dam site from Palmas Bellas would be approximately 8 km over an existing trail, which would have to be improved. Access to the inlet and outlet ends of the inter-basin transfer tunnel would follow the existing roadway traversing the western edge of Gatun Lake to the area near Cuipo. From this point, new access roads would be required to the tunnel entrance and exit sites. Both of these routes would require that heavy materials and equipment cross the lock gate bridge at Gatun Locks introducing possible load and size restrictions. Also, there would be delays in transit along this route caused by closure of this roadway for operation of the Panama Canal, which always takes precedence.

Access from the Inter-America Highway northward to the construction area was considered. However, this alternative was discarded because of the distance involved and because of the extreme difficulty of roadway construction through the low lying and relatively undeveloped areas south and west of Gatun Lake.

Alternately, the access for heavy materials and equipment to the construction area could be by water to the western side of Gatun Lake near the Village of Escobal. A small amount of dredging might be required at Escobal to establish access for the size vessels required. Smaller items could be transported over the existing roadway crossing the lower gates at Gatun Lock. From Escobal, materials and equipment could be carried over existing roads to the immediate vicinity of the inter-basin transfer tunnel near Cuipo to the southwest, and to the village of Palmas Bellas at the mouth of the Rio Lagarto to the northwest. The route to the dam site from Palmas Bellas would be approximately 8 km over an existing trail, which would have to be improved. A small amount of access road work would be required near the inter-basin transfer tunnel inlet and exit sites.

The latter scenario described above was used in the development of this alternative for cost. Plate 10 - 1 shows the portion of the proposed access road from Escobal to the construction sites.

Sources of Construction Material

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

Cement would be available within the Republic of Panama. Rock, obtained from the construction site or from the lake area, would be used for onsite manufacture of aggregates for the concrete. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) would be fabricated outside the Republic of Panama and imported for final assembly and installation at the proposed dam site.

Real Estate Requirements

The proposed Rio Lagarto project would be located in the Cocle, Colon and Panama Provinces. Construction of this proposed project would require 2,740 ha. Table 10 - 1 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 10 - 1 Real Estate Requirements

Project Feature	Land Required (ha)
Lake	1,940
Dam Site	200
Staging Area	200
Disposal Area	400
Total	2,740

Relocations

The lake would be located in a sparsely populated 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 elevation 45 m MSL would require relocation because of the normal lake inundation and the need to secure the lake perimeter for flood considerations. The upper reaches of the lake would extend into an area identified on the mapping as the Goodyear Rubber Plantation. However, there are no settlements of any size within the lake impoundment area. Relocations required would include only isolated structures.

Development Sequence

Planning studies would be accomplished to evaluate the alternative features of each proposed project. Each potentially viable project would be evaluated to assure that the plan presented would provide all of the features required to make it functional. Each would also be assessed as to its effectiveness in meeting the project goal of providing supplemental water to the Panama Canal for the various uses, with due recognition of any secondary benefits. Environmental assessments of the proposed projects would also be made to assure environmental acceptability of the project features. Environmental assessments of the proposed projects would begin during the planning studies phase and would continue during the final design, advertising and award phase, and on through construction of the project. The final design would be accomplished for the recommended project. After completion of the final design, plans and specifications would be prepared for the advertising and award phase.

Project implementation would begin with land acquisition and construction of the access roads. Lands for the access roads would be acquired initially. Lands for the dam site, staging area, disposal area, and lake would then be acquired.

Access roads would be constructed to the dam site and the inter-basin transfer tunnel inlet and outlet sites. Because highway access to these construction sites would be good, and because of the relatively close proximity of the sites to populated areas on the western shore of Gatun Lake and the Caribbean coast, on-site construction camps would not be needed.

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

Construction of the dam would begin with the clearing and grubbing of the construction sites and the clearing of the lake area. Excavation for the inter-basin transfer tunnel and the intake structure and construction of the diversion tunnel at the dam site and the spillway would follow with work being done simultaneously. To the extent possible materials removed from these sites would be placed directly into the embankments. The excess would be stockpiled for future use in the finished earth and rock fill portions of the dam. Once the intake structure and diversion tunnel were completed, the dam construction site would be isolated using upstream and downstream cofferdams, which would eventually become part of the main dam, and the stream would be diverted through the tunnel. The dam foundation would then be excavated and grouted, and the dam constructed. Upon completion of the dam and the inter-basin transfer tunnel and appurtenant structures, the diversion would be stopped, and lake filling would begin. Simultaneously with this operation, the downstream bulkhead structure would be built to provide for closure of the diversion tunnel. The minimum flow conduit would also be installed through the diversion tunnel at this time. At the completion of the project, all facilities would undergo trial operations followed by commissioning for service.

The climatic conditions would have some impact on the progress of the work. However, it is estimated that development of this project could be completed in approximately nine and half years, from initial planning to lake filling. Figure 10 - 2 depicts the development sequence of the various project features.

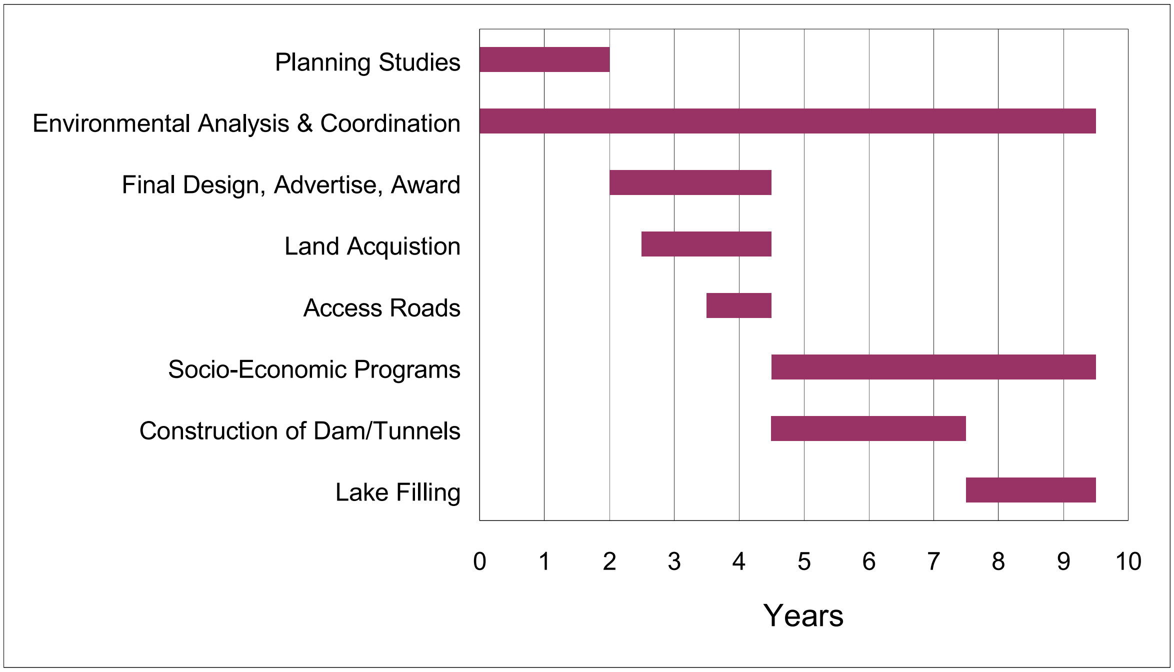


Figure 10 - 2   Development Sequence

Water Yield

The proposed Rio Lagarto project was modeled using the HEC-5 Analysis Package, Simulation of Flood Control and Water Conservation Systems. Because of the very small useable storage in Lagarto Lake, the project was only designed to provide a constant flow equivalent to the constant firm yield. The lake was not modeled to provide high flows in response to navigation water shortages in the Panama Canal operation or to include hydropower production. With the small constant flow applied to the canal a net yield would be realized but the change in reliability would be small and was thus considered insignificant.

Monthly discharge data for the proposed Rio Lagarto dam site, as described in the section titled Hydrologic Conditions were used as input to the simulation model. Elevation-volume values at the proposed Rio Lagarto dam site were developed from existing 1:50,000 scale topographic mapping. The operating parameters for the alternative are listed in Table 10 - 2.

Table 10 - 2   List of Operating Parameters

Pool Range (m)	Dam Height (m)	Spillway Length (m)	Minimum Flow (CMS)
40-30	45	48	0.4

The firm yield was determined by using a constant diversion from Lagarto Lake, while always maintaining the minimum downstream flow requirement and not allowing the lake to drop below the minimum lake operating level. Minimum flow requirements of 0.41 CMS were assumed to be 10 percent of the average annual flow. In addition, the lake was required to recover its full storage within 4 to 5 years, excluding the 1998 drought period. The 1998 period was excluded since it is considered to be a drought of much lower frequency than 100 year return. A 5-year recovery period was imposed to help select a practical low flow period to design the reservoir. The HEC-5 model was optimized to determine the greatest constant diversion based on the available hydrologic records (1958-1998). The results are shown in Table 10 - 3.

Table 10 - 3 Constant Firm Yield

Pool Range (m)	Minimum Flow (CMS)	Average Evaporation (CMS)	Firm Yield (CMS)	Lockages*
40-20	0.4	0.6	2.5	1.1
*Lockages are based on 55 million gallons for one ocean to ocean transit.				

Project Costs

GENERAL

The quantities estimated for the principal features required in the construction of this proposed project were derived from the layouts shown on Plates 10 - 2 through 10 - 4. The unit prices applied to these quantities were 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 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 and supervision and administration is estimated to be 6 percent of the construction costs features. An allowance of 2 percent of the construction costs was included for field overhead (construction camp, contractor facilities, etc.). An allowance of 25 percent was included for contingencies. The PCC provided the estimated costs of the land for the proposed project.

FIRST COSTS

The total project first costs are estimated to be $32,038,000. Table 10 - 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 10 - 4 Summary of Project First Costs

Principal Feature	Costs ($)
Lands and Relocations	6,850,000
Access Roads	2,420,000
Clearing and / or Grubbing	756,250
Diversion Tunnel	631,788
Inter-basin Transfer Tunnel	2,276,965
Cofferdam	440,350
Dam	2,443,475
Spillway	2,303,470
Intake	3,236,685
Subtotal	21,358,983
E&D, S&A, Field Overhead	4,271,797
Contingencies	6,407,695
Total Project First Costs	32,038,475 **approximately** 32,038,000

OPERATION AND MAINTENANCE

Staff
A staff would operate and maintain the proposed Rio Lagarto project during the day and then run the facility remotely. The full-time staff would ultimately consist of a total force of six that would include a station manager, a leader, three craftsmen and a laborer. The annual costs of the staff are estimated to be $235,000.

Ordinary Maintenance
Ordinary maintenance and care would be required and would include minor repair materials, lubricants and other supplies needed by the project staff. It is estimated that the costs of ordinary maintenance would be $20,000 per year for the access road and $100,000 per year for the main project facilities.

Major Replacements
The average service life of gates, electrical equipment, turbines, trash racks and other features would be less than the total useful life of the proposed project, which would be 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 would cost the same as at present. No allowance was made for salvageable fixed parts. Table 10 - 5 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 proposed replacements would be $15,590 and the average annual replacement costs would be $1,900.

Table 10 - 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	2,640,000	9,140
Bridges	50	1	900,000	3,110
Intake				
Head Gates	50	1	758,700	2,630
Stoplogs	50	1	103,050	360
Trashracks	50	1	33,150	120
Access Stairs	50	1	18,750	70
Minimum Flow Gates	50	1	45,000	160
Total			4,498,650	15,590
Average Annual Replacement Costs				1,900

Annual Costs

The total project first costs are estimated to be $32,038,000. These total project first costs were distributed across the construction period using generalized curves for contractor earnings for large, heavy construction jobs. Interest on the total project first costs was computed from mid-year throughout the 9.5-year period from initiation of the Planning Studies until the lake was filled. The interest during construction at 12 percent would be $24,018,000, and it was added to the total project first costs for total project investment costs of $56,057,000. A capital recovery factor for the 50-year planning period was applied to get the annual average investment costs of $6,750,000. Annual operation and maintenance costs were added. Major replacement costs are estimated and were converted to an annual cost by discounting the future replacement costs of major components of the project back to construction completion. Table 10 - 6 contains a summary of the $ 7,107,000 annual costs.

Table 10 - 6 Summary of Annual Costs

Item	Costs ($)
Total Project First Costs	32,038,000
Interest During Construction	24,018,000
Total Project Investment Costs	56,057,000
Annual Average Investment Costs	6,750,000
Operation and Maintenance Costs	
Staff Costs	235,000
Ordinary Maintenance Costs	120,000
Major Replacement Costs	2,000
Total Average Annual Costs	7,107,000

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 Rio Lagarto project. The 50-year planning period for this proposal is 2009 to 2058.

The proposed Rio Lagarto project would slightly increase the reliability of providing water to accommodate the daily number of lockages demanded. Since this increase is so small, benefits associated with an increase in reliability were not estimated. The 99.6 percent level of reliability for this proposal is used to estimate the water supply benefits for navigation.

With the addition of the proposed Rio Lagarto project, shortages in water supply would be less. At a reliability of 99.6 percent, the proposed project would increase the amount of water supplied for navigation by approximately 1.1 equivalent lockage. Benefits for this amount of additional water supply 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 number of daily lockages. The average annual benefits for water supply would be $22,349,000. Table 10 - 7 provides the estimate of daily shortages under existing conditions, the remaining daily shortages with the proposed Rio Lagarto project in operation, the annual benefits for meeting shortages, and the average annual benefits.

Table 10 - 7 Benefits for Additional Water Supply for Navigation

Year	Daily Shortages In Lockages Under Existing System	Remaining Daily Shortages	Annual Benefits ($)
2010	6.43	5.33	21,486,000
2020	8.93	7.83	22,685,000
2030	10.87	9.77	22,685,000
2040	13.34	12.24	22,685,000
2050	16.45	15.35	22,685,000
2060	20.37	19.27	22,685,000
Average Annual Benefits			22,349,000
With Rio Lagarto, the system will provide a total of 39.78 equivalent lockages at the 99.6 percent level of reliability or 1.1 more lockages than the existing system.			

SUMMARY OF ANNUAL BENEFITS

As shown in Table 10 - 8 total average annual benefits the proposed Rio Lagarto project would be $22,349,000.

Table 10 - 8 Summary of Annual Benefits

Benefit Category	Average Annual Benefits ($)
Navigation – Water Supply	22,349,000
Navigation - Reliability	Not Estimated
M&I - Reliability	Not Estimated
Hydropower	None
Total	22,349,000

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 determines which proposal among several provides the greatest value for the investment dollars. Table 10 - 9 provides the benefit to cost ratio and the net benefits.

Table 10 - 9 Economic Evaluation

Item	Value
Average Annual Benefits	$22,349,000
Average Annual Costs	$ 7,107,000
Benefit to Cost Ratio	3.1
Net Benefits	$15,242,000

Internal Rate of Return

An internal rate of return analysis for this proposed project was performed. To accomplish this analysis, the annual construction costs were used as the investment, and the undiscounted benefits were used as return cash flows. The internal rate of return would be 26.0 percent.

Socio-Economic Impacts

The socio-economic impacts of the project would be limited by the fact that the region is only sparsely populated, with few roads and utilities. The average monthly income of families in the project area is $100 per month. No indigenous groups or peoples are known to reside in the area. Land use would be impacted by the inundation of pastures and agricultural lands to create the Lagarto Lake; however, the relocation of agricultural and ranching activities would be minimal, because the area is so sparsely populated. The upper reaches of the lake would extend into an area identified on the map as Goodyear Rubber Plantation. The surface area of the proposed lake will encompass 1,890 ha with another 800 ha for the dam and construction areas including permanent disposal areas.

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.

To construct the dam, some existing roads would be improved and some new roads would be built. One unpaved trail within the impoundment area would be eliminated, which could cause some small settlements to lose overland transportation, communication, cohesion, and commerce with other settlements. During construction, the traffic volumes over both new and existing road systems would temporarily increase. Noise levels would increase during construction and could negatively impact noise-sensitive receptors, however, after construction, noise should return to pre-construction levels.

Although the number of people displaced as a result of the project is small, the communities that will receive the displaced people 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 through the division of communities, separation of families, and loss of livelihood. Following completion of the impoundment, tourism trade in the affected region, including fishing and ecotourism, could increase.

Environmental Setting

The Rio Lagarto project involves the construction of a dam on the Rio Lagarto and a connecting tunnel to Gatun Lake. Lagarto Lake will provide approximately 1.1 additional lockages per day on a continual basis. The structures for this proposed project would consist of a rock fill dam, an uncontrolled ogee spillway, inter-basin transfer facilities, and outlet works. The project area encompasses the area to be flooded as well as the area downstream from the dam site. This area is sparsely populated. It is characterized by rolling hills, low coastal regions, and cleared areas for livestock. Fragmented forests are all that remains of the terrestrial habitat within the project area. The Rio Lagarto is located west of the Panama Canal, is used for navigation and transportation of livestock, and flows northward from the Continental Divide into the Atlantic Ocean. The Rio Lagarto watershed above the dam is approximately 53 km^2. The impoundment area covers approximately 1,890 ha composed of approximately 25 percent of forested land, 40 percent of pastureland used by ranchers, 20 percent of cropland, and 15 percent of newly slashed and burned land. The lake water elevation will fluctuate from elevation 30 to 44 m MSL. The water pipelines, tunnel portals, and roads associated with the project could also have environmental impacts and should be sited to minimize those impacts.

LAND USE

The Rio Lagarto project area encompasses the area to be flooded as well as the area downstream from the dam site. The population of about 1,312 is dispersed throughout the area, with concentrations in the towns of Nuevo Chagres (population-272), Palmas Bellas (population-690), and Pueblo Nuevo (population-350), at the mouth of Rio Lagarto, and in half a dozen smaller settlements along Rio Lagarto, several kilometers upstream.

Farms and ranches of various sizes occupy approximately 60 percent of the land in the project area. Farm crops include maize, rice, beans, sugar, coffee, tobacco, and coconuts. There are also teak tree plantations in the area, including a large plantation approximately 1 km upstream from the mouth of Rio Lagarto. Ranchers raise cows, horses, chickens, and hogs. Some of the farmers and ranchers operate small commercial enterprises; others rely on cash crops and subsistence farming.

INFRASTRUCTURE

The towns of Nuevo Chagres, Palmas Bellas, and Pueblo Nuevo share an elementary school, a cemetery, and a medical center. All of the towns rely on Rio Lagarto or groundwater wells for their water supply. Some towns 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 Rio Lagarto and its tributaries. Disposal of domestic waste is the responsibility of individual homeowners: some homes have septic systems but most have an outdoor latrine (a deep hole in the ground). There are some health problems, such as hepatitis, dysentery, dermatitis, intestinal parasites, and respiratory illnesses associated with the present waste disposal methods. No major industries or poultry or beef processing plants are located in the project area. The only major road in the project area is the gravel surfaced Panama Route 82, which runs along the Atlantic coastline, and crosses Rio Lagarto approximately 100 m from its mouth. Other roads in the project area are poorly maintained dirt roads that are usable only in the dry season (mid-December through March). The roads are rarely graded and receive little attention by 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

Tropical forests consisting primarily of secondary growth, cover about 25 percent of the land along the Rio Lagarto and its tributaries, and extend to the upper mountainous areas above the Rio Lagarto impoundment area. These forests support diverse wildlife populations. As a result of slash and burn activities, there are no large contiguous tracts of primary forest at the lower elevations in the impoundment area.

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 none have been identified to date, some of the listed species may occur in the project area.

AQUATIC HABITAT

Rio Lagarto in the project area has characteristics typical of streams in mountainous regions. The substrate ranges from boulders to sand in the upper stretches and consists mostly of silt along the last few kilometers before it to reaches the sea. According to available topographic maps, Rio Lagarto has two major tributaries, Rio Caño Quebrada and Rio El Guabo, as well as more than 50 smaller tributaries. The river is approximately 32 km long; with a width ranging from less than 1 m at its headwaters (in the dry season) to 25 m at its mouth, and a depth ranging from less than 1 m to approximately 10 m. Rio Lagarto and its tributaries support fish and benthic communities; however, information about these species in the project area is limited.

WETLANDS

Areas that contain hydric soils and hydrophytic plant communities, and that are subject to hydrologic conditions are termed wetlands. The wetlands in the project area consist of forested riparian habitat, limited by the narrow river valley. Approximately 90 percent of the streams above and below the dam site along the Rio Lagarto and its tributaries are bordered by forested riparian habitat. In the impoundment area, the width of the riparian habitat varies from approximately 5 to 50 m.

AIR QUALITY

Although no applicable data are available, air quality in the project area appears to be generally good. At the end of the dry season, in March or early April, tracts along the Rio Lagarto with forests or secondary growth are usually burned and cleared to prepare the land for agricultural use. This slash and burn technique may still be practiced in the project area. Air quality monitoring has not yet been implemented. The natural environment may provide indicators that could be useful in evaluating air quality.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

No parks or other government-protected lands are known to be located in the Rio Lagarto impoundment area. Only limited surveys by independent investigators have been conducted in attempts to locate cultural resources in the project area; therefore, impacts of the project on cultural resources cannot be determined. It should 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 project area would be scattered, since the patches of forest cover approximately 473 ha, or 25 percent of the impoundment area, constituting a relatively high quality terrestrial habitat. With the creation of the lake, migratory routes of some species could be adversely affected. The only forests that would remain within the vicinity of the Rio Lagarto reservoir and its drainage basin would be confined to the higher elevations.

ANIMALS ON ENDANGERED LIST

The extent of potential effects on endangered animals cannot be determined at this time, because it is not known which of the listed species occur within the proposed project area. Some endangered and / or threatened species may use Rio Lagarto for portions or all of their life cycle. The significance of the forested riparian corridor along the streams may increase if animals on the endangered list are found to inhabit the region. The Mesoamerican Biological Corridor is also promoting biodiversity conservation throughout the Atlantic basin, which could impose restrictions on the use of the project area.

WATER QUANTITY

The impacts of the project on water quantity should be positive, because construction of the dam should result in an increase in the volume of stored fresh water during the dry season. The impacts downstream from the dam site should be minimal, although water should be released at lower rates, and seasonal flooding should be significantly reduced. The releases should be scheduled at appropriate intervals and in amounts to avoid problems with water quality and temperature downstream. The cumulative impacts downstream of the dam site over time should also be minor.

WATER QUALITY

The impacts of the project on the water quality downstream from the dam site cannot be determined at this time. The water should contain less silt due to minimum normal flow and should provide people downstream a higher quality supply. The proposed Lagarto Lake should also become a source of high-quality water for the people living around the lake.

DOWNSTREAM AQUATIC FAUNAL HABITAT

The impacts of the project on downstream aquatic fauna could be substantial, depending on the seasonal migration patterns of fishes and invertebrates and on the water release practices from the newly formed reservoir. Alteration of the normal flow patterns during the construction and the subsequent large fluctuations in temperature, flow rate, and turbidity caused by periodic releases of water, once the lake is complete, could have substantial impacts on the reproductive cycle of downstream fauna. The Rio Lagarto Dam should act as a large sediment trap, which should cause the released water to have low turbidity; therefore, siltation should not be a problem. Streambed degradation below the dam should be minimal, provided that release rates are low enough to avoid excessive erosion and scouring.

FUTURE LAKE AQUATIC PLANT COMMUNITY

The impacts of the project on future aquatic plant communities in the proposed lake could depend on water levels, which are anticipated to vary seasonably from 30 to 44 m MSL. Such wide fluctuations in water levels would cause much of the shoreline to turn into mud slopes where neither aquatic nor terrestrial plant communities could thrive. However, rooted aquatic plants, which may grow at considerable depths as long as light penetration allows photosynthesis to occur, may flourish.

AQUATIC FAUNA INHABITING AFFECTED AREAS

The impacts of the project on aquatic fauna inhabiting the Rio Lagarto and its upstream tributaries could be important. The reservoir could support species that thrive in lentic systems. Species that require highly oxygenated lotic systems could be extirpated from the stretch of Rio Lagarto covered by the reservoir. The dam could also create a barrier to seasonal migration that may be crucial in the reproductive cycle of some fishes and aquatic invertebrates. S ome unavoidable, adverse environmental impacts could occur and these impacts should be identified and appropriate mitigation measures addressed in feasibility level studies, should the alternative be recommended for further consideration. If the new reservoir is responsibly managed and stocked with game fish by the Aquaculture Department, it could provide opportunities for recreational and subsistence fishing. An increase in fish population could lead to an increase in piscivorous predators, such as crocodiles, caimans, otters, herons, and others. Other manmade lakes in the Republic of Panama have been stocked with exotic fish such as peacock bass and tilapia, both of which are efficient predators, which may have led to the extirpation of several native riverine fishes that formerly inhabited the impoundments.

WETLANDS

The impacts to upstream and downstream wetlands could be significant. Areas presently identified as wetlands could become aquatic habitat, permanently altering the established environment. Project activities may affect wetlands by increasing the water depth, sedimentation, and turbidity, which could cause changes in the biological processes of the wetlands and decrease productivity. These impacts are detrimental to the health and sustainability of Rio Lagarto. Fish and other aquatic species use shallow water areas as spawning areas as well as habitat for juvenile aquatic species. Juvenile aquatic species survive in shallow water wetland areas until they are large enough to venture out into deeper water. These areas are vital to the sustainability of Rio Lagarto. Due to minimum normal flow, the cumulative effects downstream of the dam site are expected to be minor.

AIR QUALITY

During construction of the dam, dust and emissions from equipment could impact the air quality in the project area. After construction, the air quality could improve because the Panamanian government currently discourages slash and burn activities.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

Information regarding cultural resources and historic properties is incomplete. Additional evaluation studies need to be completed to identify any such sites. Prior to construction, surveys would be conducted to locate cultural resources and historic properties, and any important sites would be preserved or salvaged as appropriate.

Additional Environmental Information Required

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

SOCIO-ECONOMIC IMPACTS

- Conduct an 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).
  - Community and Regional Growth.
  - 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 terrestrial and aquatic habitat are identified and quantified.
- Conduct field studies to locate special 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 project area.
- Coordinate with local experts regarding these habitats.
- Provide species inventory lists for each area, identifying their status as native or exotic and whether they are threatened or endangered.

ANIMALS ON THE ENDANGERED LIST

- Compile habitat maps to assess the availability and quality of suitable habitats for the animals on the endangered 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 the presence of these species.

WATER QUALITY

- Since no water quality data are available for Rio Lagarto, compile information on the total suspended solids, conductivity, total dissolved solids, dissolved oxygen, nutrients, pH, and coliform bacteria content of the water.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

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

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 Section 35. Tables 10 - 10 through 10 - 12 present the evaluation of the proposed Rio Lagarto project as related to developmental effects, environmental effects, and socio-economic effects.

Table 10 - 10 Developmental Effects

Evaluation Criteria	Function	Measure [1/]	Importance [2/]	Composite [3/]
Water Contribution (Water Yield)	Meets M&I demands	1	10	10
	Supplements Existing System	0	10	0
	Satisfies Future Canal needs/expansion	0	10	0
	Additional Hydropower Potential	0	5	0
Technical Viability	Design Constraints	9	6	54
	Feasibility of Concept	10	6	60
Operational Issues	Compatibility	10	6	60
	Maintenance Requirements	10	2	20
	Operational resources required	8	2	16
Economic feasibility	Net Benefits	1	9	9
	Total			229

[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 10 - 11 Environmental Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Terrestrial Habitat	4	8	32
Animals on Extinction List	4	10	40
Water Quantity Impacts – Lake	8	10	80
Water Quantity Impacts -- Downstream	4	7	28
Water Quality	5	10	50
Downstream Aquatic Fauna Habitat	4	8	32
Future Lake Aquatic Plant Community	6	8	48
Aquatic Faunal Inhabiting Affected Area and Upstream Tributaries	5	5	25
Potential for Fishing on Lake	6	6	36
Wetlands	4	4	16
Air Quality	5	3	15
Cultural Resources and Historic Properties	5	10	50
Total			452

[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 10 - 12 Socio-Economic Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Land Use	2	7	14
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	2	8	16
Community Cohesion	2	8	16
Tourism	6	5	30
Total			341

[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 10 - 13 presents pertinent data for a Maximum Operating Pool at Elevation 40 for the proposed Rio Lagarto project.

Table 10 - 13 Pertinent Data - Pool Elevation 40 m MSL

GENERAL	
Dam site, above mouth of Rio Lagarto	8 km
Drainage area above dam site	53 km^2
Average annual flow at dam site	4 CMS
LAKE	
Elevation of normal operating lake level	40 m MSL
Elevation of maximum flood storage lake level	44 m MSL
Elevation of minimum operating lake level	30 m MSL
Useable Storage between Max and Min levels	131.34 MCM
Area at normal operating lake level	1,600 ha
Area at maximum flood storage lake level	1,140 ha
Area at minimum operating lake level	1,890 ha
Top clearing elevation	40 m MSL
Lower clearing elevation	30 m MSL
EMBANKMENTS	
Dam	
Type of dam	Rock fill embankment
Top elevation of dam	45 m MSL
Fixed crest width	13 m
Height	35 m MSL
Overall length of dam	203 m
SPILLWAY	
Type of Spillway	Uncontrolled ogee
Total length	48 m
Elevation of spillway	40.0 m MSL
Maximum discharge	746 CMS
INTER-BASIN TRANSFER TUNNEL	
Tunnel diameter	2 m
Tunnel length	1.25 km
Inlet invert	35 m MSL
Outlet invert	25 m MSL
Tunnel capacity	14.4 CMS
CONSTRUCTION / POWERHOUSE DIVERSION	
Diversion length	108 m
Horseshoe tunnel dimensions	6 m x 6 m
Inlet invert	10 m MSL
Outlet invert	9 m MSL
Cofferdam Height above tunnel inlet invert	7.3 m

Table 10 - 13 Pertinent Data - Pool Elevation 40 m MSL (continued)

MINIMUM FLOW CONDUIT	
Conduit diameter	300 mm
Conduit length	100 m
Inlet invert	9 m MSL
Outlet invert	8 m MSL
Conduit capacity	0.4 CMS

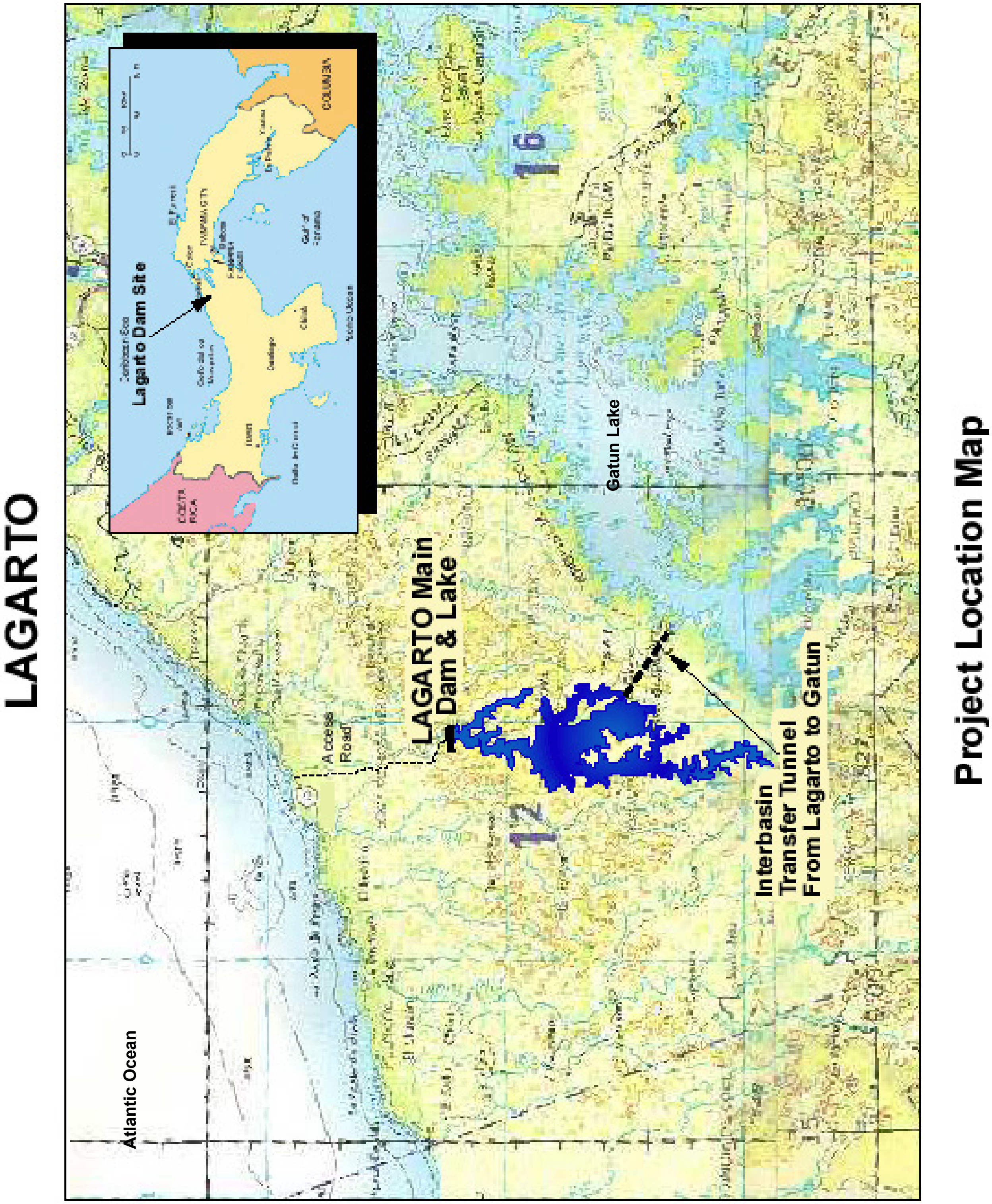
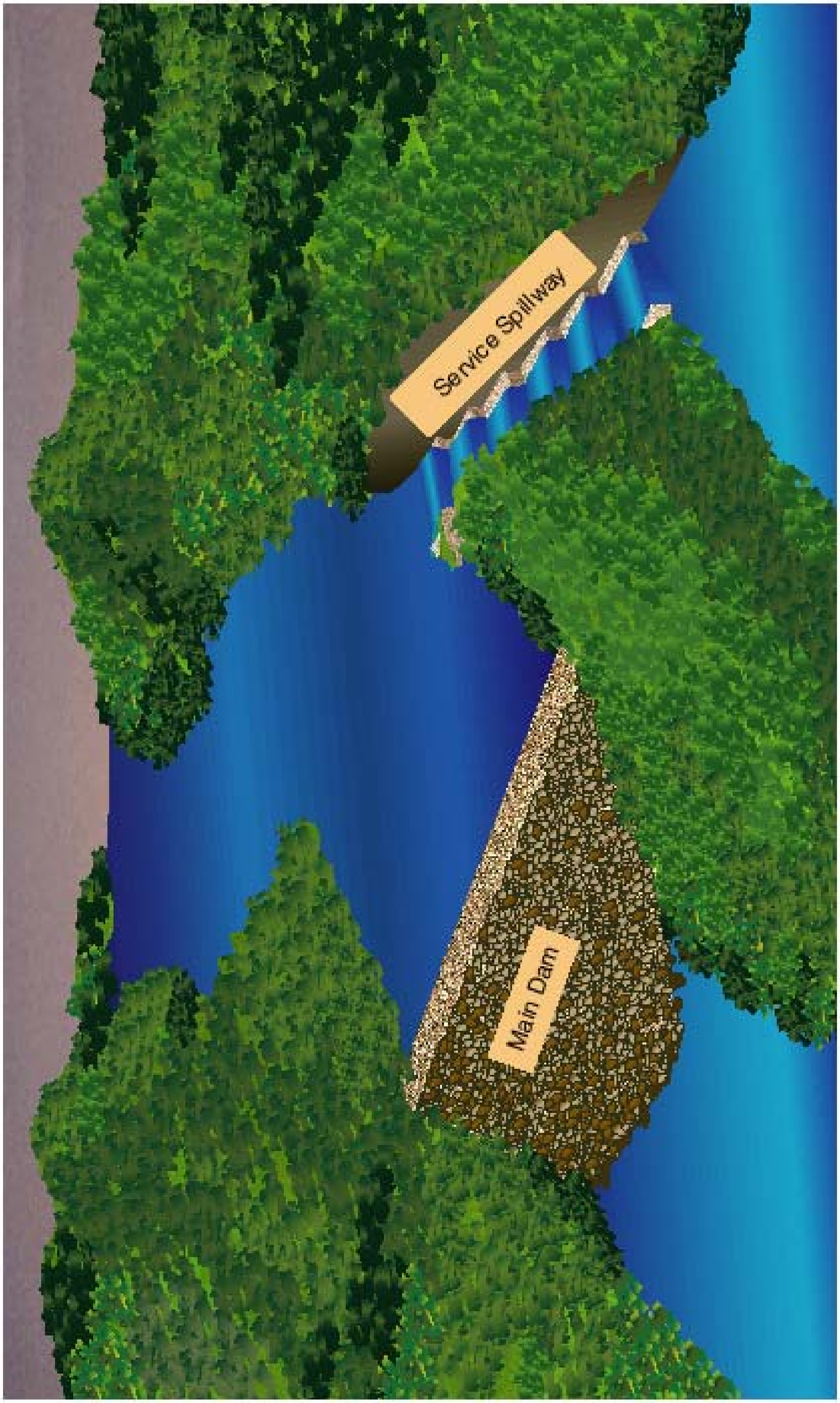


Plate 10 - 1   Project Location

LAGARTO



Site Plan

Plate 10 - 2 Site Plan

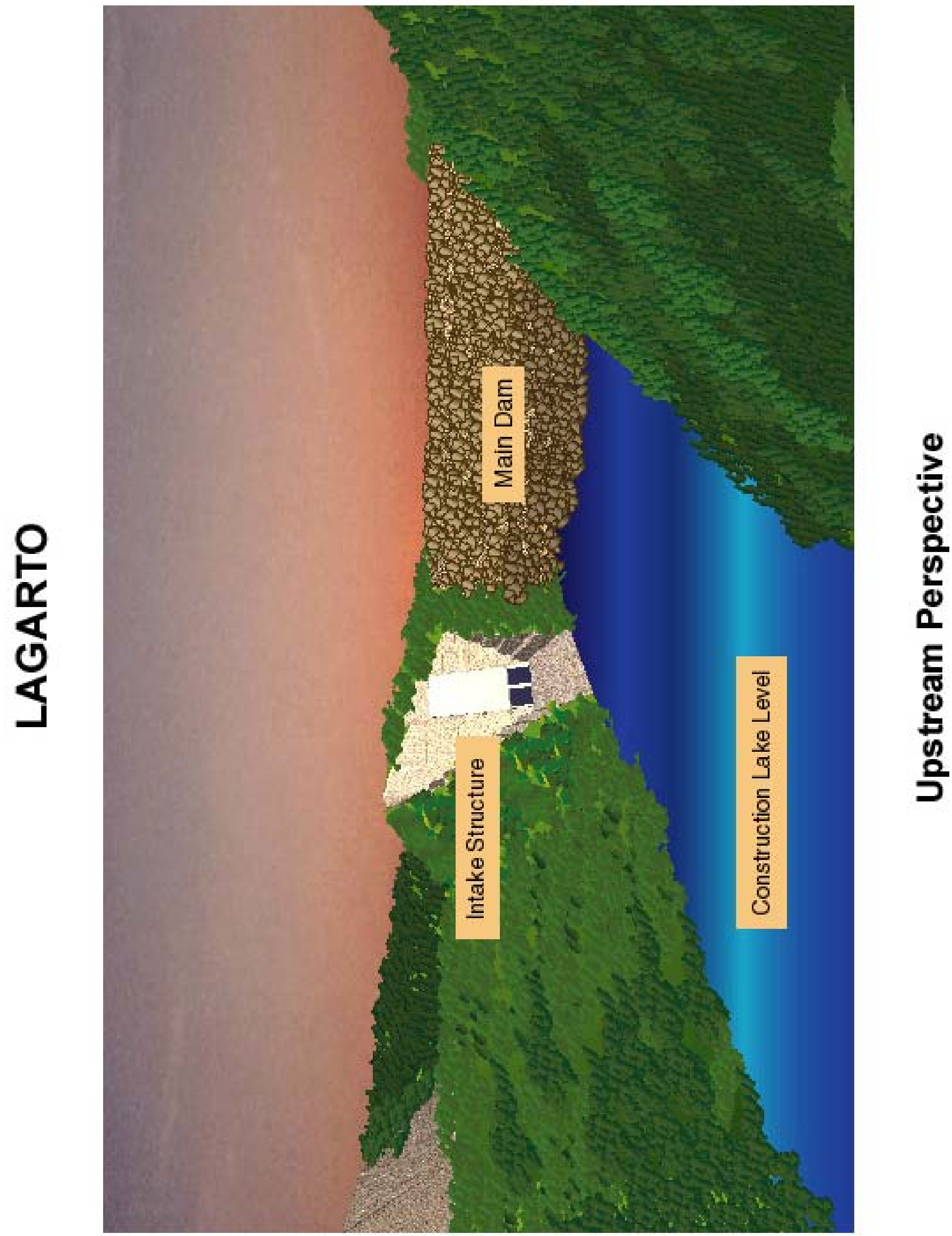
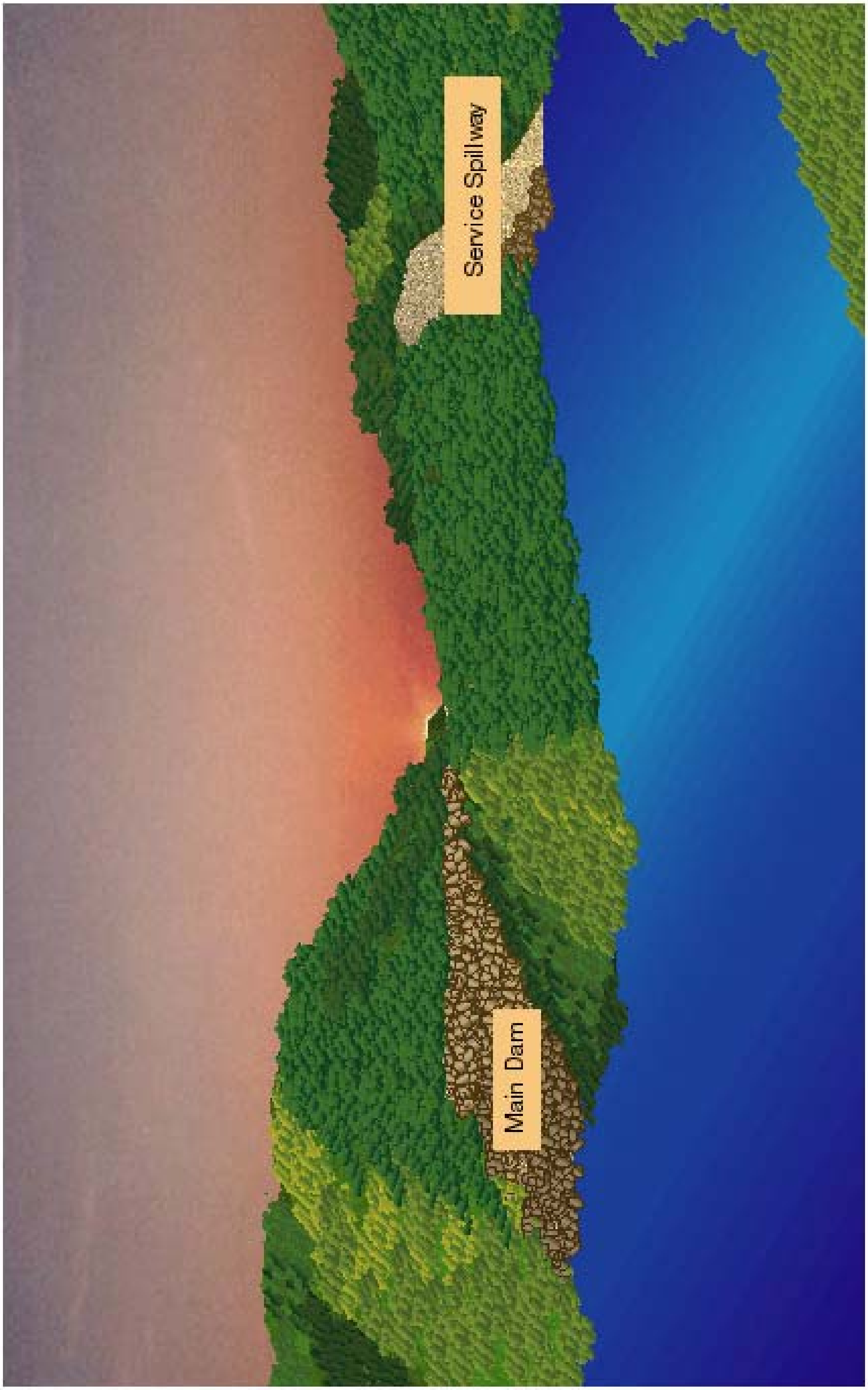


Plate 10 - 3 Upstream Perspective

LAGARTO



Downstream Perspective

Plate 10 - 4 Downstream Perspective

SECTION 11

(Working in conjunction with Lagarto Lake)

Rio Salud

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Synopsis

The development plan presented herein would include a dam and lake on the Rio Salud. Flow from this lake would be passed via a tunnel to Lagarto Lake. Lagarto Lake would be connected to the Panama Canal watershed at Gatun Lake via a second tunnel (see section 10 of this report for details of the Rio Lagarto project). Water impounded in these two lakes would be transferred to the Panama Canal watershed on a continual basis to supplement water withdrawn from the canal system for canal operation and M&I water supply. Because of the limited storage capacity in Salud Lake, the project was designed to provide water on a steady flow basis to the Panama Canal watershed. This differs slightly from other alternatives that were designed to provide water in larger volumes on demand. See Figure 11 - 1 for a profile of the system.

The Rio Salud drains a small watershed on the Atlantic coast of the Republic of Panama. The watershed is outside of the Panama Canal watershed at the northwest corner and is located approximately 25 km west of Colon. Rio Salud flows northward, from a point 28 km inland, to the Atlantic Ocean. The proposed Rio Salud dam site would be located approximately 10 km inland from the Atlantic Ocean.

The proposed Rio Salud project would provide a 46 m high rock fill dam with a tunnel through the watershed divide. The tunnel would transfer water from Salud Lake to Lagarto Lake and thence to Gatun Lake via the second tunnel to provide water for canal operations. The estimated total construction cost of the proposed Rio Salud project, including the change in tunnel and intake structure costs for the Lagarto to Gatun tunnel, is $68,464,000.

The proposed Rio Salud project would function in tandem with the Rio Lagarto project. Together these lakes would contribute to the hydrologic reliability of the Panama Canal to provide water for canal operations and M&I water supply, but would minimally 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 50-year period of record from January 1948 through July 1998, is approximately 99.6 percent, while the hydrologic reliability with a demand ratio of 1.2 (46.42 lockages) would be 99.0 percent. With construction of the proposed Rio Salud-Rio Lagarto Lake system, the existing high hydrologic reliability could be continued as withdrawals for potable water supply increase. Salud Lake alone would provide approximately 45.6 MGD (0.8 lockages) on a continual basis. When combined with the proposed Rio Lagarto project, the system will provide approximately 1.9 additional lockages per day.

The amount of hydropower production expected from the facilities at Gatun Lake and Madden Lake would decline over time as the demands for navigation and M&I water increase. With the inclusion of the proposed Rio Salud project, the system could produce net additional megawatt hours of hydropower because of the replacement of M&I water withdrawals from Gatun Lake.

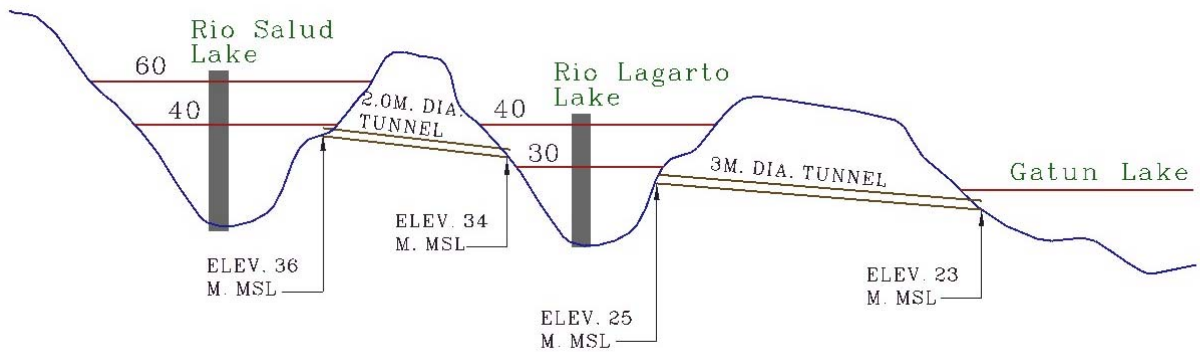


Figure 11 - 1   System Profile

Site Selection Considerations

The proposed Rio Salud dam site was chosen 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. To maximize the water impounded, it was desirable to locate the dam as far downstream in the Rio Salud watershed as possible. In choosing a site for the dam, a location was sought where the surrounding hillsides were relatively steep and high, and the valley was relatively narrow.

The site chosen for the proposed Rio Salud dam would be approximately 10 km inland from the Atlantic Ocean. This site would accommodate construction of a dam with a normal operating lake level at elevation 60 m MSL and a maximum flood storage lake level at elevation 62.5 m MSL. Plate 11 - 1 shows the location of the proposed Rio Salud project.

Hydrologic Considerations

The Rio Salud flows northward from the edge of the Panama Canal watershed to the Atlantic Ocean. The headwaters of the watershed begin at elevation 130 m MSL approximately 18 km inland and fall to mean sea level at its mouth. The distribution of the average annual rainfall over the Rio Salud watershed varies from a high of 3,000 mm at the coast to a low of 2,000 mm at the Continental Divide. The proposed Salud Lake would receive runoff from approximately 41 km^2 of the upper portion of the watershed. Rainfall runoff produces an average annual flow of 3.5 CMS at the proposed dam site.

Discharge data at the Rio Salud dam site were obtained by extrapolating the recorded and correlated stream flow data of the Rio Indio at Boca de Uracillo hydrologic station. Data at this station were obtained with a continuous recorder that began operation in 1979. The hydrological record was extended by means of statistical correlation using standard hydrologic techniques with the Trinidad River at El Chorro. It was assumed that the water yields per unit area at the dam site of the Rio Salud and the Rio Indio were of the same magnitude.

Because of the proximity and in the absence of additional information, the monthly evaporation rates recorded at Gatun Lake were used to establish the evaporation of Salud Lake.

Geologic Considerations

The proposed Salud Dam and inter-basin transfer tunnel sites are both located in an area of the Isthmus of Panama that is underlain by Miocene aged sedimentary rocks of the Gatun Formation. These rocks consist of siltstones, sandstones, conglomerates and tuffs that are moderately hard, massively jointed and thickly-to-massively bedded. The siltstones, sandstones, and conglomerates are variably marly and tuffaceous, highly fossiliferous, and massively jointed, with the joints in many places spaced at intervals greater than 6 m. The tuffs are uniformly fine-grained and are moderately jointed. Only light blasting is required for the excavation of Gatun Formation material. The depth of weathering in this formation averages 9 m.

With grouting of the joint system, the sandstones, siltstones, conglomerates and tuffs of the Gatun Formation would make an acceptable foundation for an earth and rock fill dam. These rocks would be unacceptable as a source for concrete aggregate and only marginally acceptable for use as fill in an earth and rock fill dam. If this proposed project is carried forward, it is recommended that cores be drilled in the abutments early during planning studies to check the general suitability of the rock for use as construction material, and to determine the depth of weathering. Angled cores should also be drilled to investigate jointing in the rock.

In the absence of detailed geologic mapping for the proposed Salud Dam, a degree of extrapolation was necessary. It was predicted that rock at the proposed site would be encountered at a relatively shallow depth and would be of sufficient quality to serve as the foundation for the dam. This prediction was based on available general geologic mapping and general data. It was assumed that impervious materials would be available within the immediate area for use in the construction of the dam. Concrete aggregate and stone for erosion protection used in the dam construction would have to be obtained from commercial sources.

Lake Operation

Two operating options were considered in this study for periods when water would be transferred from Salud Lake through Lagarto Lake to the Panama Canal watershed for canal operations. The water surface elevations associated with each Operating Option are listed in Table 11 - 1. Operating Option 1 would yield 252,000,000 M^3 of useable storage. Operating Option 2 would yield 69,000,000 M^3 of usable storage. The volume between the maximum flood storage lake level and the normal operating lake level would be used to store flood waters and reduce peak flood flows. Some reduction in flooding would be realized in areas along the Rio Salud downstream of the dam.

Table 11 - 1 Lake Operating Options

Lake Level (m MSL)	Operating Option 1	Operating Option 2
Normal Operating Lake Level	60	40
Minimum Operating Lake Level	40	30
Maximum Flood Storage Lake Level	64	44

Project Features

GENERAL

The structures for this proposed project would consist of a rock fill dam, two saddle dams, an uncontrolled ogee spillway, inter-basin transfer facilities, and other outlet works. The following paragraphs provide a description of the proposed structures and improvements for Operating Option 1. In some instances, the proposed structures and improvements for Operating Option 2 would be different; the differences are discussed where pertinent. The general project layout is shown on Plate 11 - 2. The configuration of the dam, spillway, and outlet works are similar to those shown on the plates accompanying the Rio Lagarto presentation, Section 10 of this report.

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 proposed project is carried into the planning studies, optimization of the project features and improvements must be accomplished.

EMBANKMENTS

Dam

The dam would be an embankment with the top at elevation 65 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 1011411 north and 595802 east. The right abutment would be 1011570 north and 596082 east coordinates. The embankment would be constructed with an impervious earthen core encased in rock fill, and the final side slopes would be 2 horizontal on 1 vertical. The dam, at its highest point, would be approximately 46 m high and the overall length would be 317 m. The actual side slopes and crest width 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. The typical section of the embankment shown in Section 5 represents the typical section for the main and saddle dams of this project.

Saddle Dams

Two saddle dams would be required to complete the lake impoundment. For this study, both saddle dams were configured with an impervious earth and rock fill, and the final side slopes would be 2 horizontal on 1 vertical. The top of the saddle dams would be set at elevation 65 m MSL, and they would have a crest width of 13 m. The length of the north saddle dam would be 170 m, while the length of the south saddle dam would be 138 m. 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.

SPILLWAY

An uncontrolled ogee spillway with a length of 84 m and a crest at elevation 60 m MSL would be required. The spillway crest would be 5 m below the elevation of the top of the dam. The maximum discharge from the spillway would be 644 CMS at a maximum flood storage lake level at elevation 64 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. A plunge pool would be excavated into the rock adjacent to the natural channel at the downstream end of the tailrace channel for energy dissipation.

IMPOUNDMENT

The lake formed by the proposed Salud Dam would have a normal operating lake level at elevation 60 m MSL. The surface area at the normal operating lake level would be approximately 1,690 ha. With the minimum operating lake level at elevation 40 m MSL, the surface area would be approximately 870 ha. At the maximum flood storage lake level, elevation 64 m MSL, the surface area would be approximately 1,877 ha.

CLEARING AND / OR GRUBBING

Clearing and grubbing would be required for all areas necessary for construction of the dam (embankments and spillway), inter-basin transfer facilities, other outlet works, access roads, and disposal and staging areas. Clearing only would be required for the 820 ha in the lake area between the normal operating lake level at elevation 60 m MSL and the minimum operating lake level at elevation 40 m MSL.

INTER-BASIN TRANSFER FACILITIES

A tunnel would be excavated through the common watershed divide to connect the proposed Salud Lake to the Lagarto Lake, which would pass the waters on to the Panama Canal watershed. The finished tunnel would be concrete lined, 2 m in diameter, and approximately 400 m in length under Operating Option 1. This tunnel would have an inlet invert at elevation 36 m MSL and an outlet invert at elevation 34 m MSL. The maximum capacity of the tunnel would be 27.7 CMS. (See Figure 11 - 1 for Operating Option 1 system profile).

The inter-basin transfer tunnel included in the proposed Rio Lagarto project between Lagarto Lake and the Panama Canal watershed would need to be enlarged to a 3 m finished diameter to pass the combined flows. The maximum capacity of this tunnel would be 41 CMS, and it would have invert elevations at its inlet and outlet ends of 25 m and 23 m MSL respectively. This would result in a slight lengthening of the tunnel over that indicated in the Lagarto Lake alternative described in Section 10.

It was assumed that rock bolting would be required over much of the tunnel length to stabilize the rock. A gate structure located at the tunnel outlet would control flow through the tunnel. The tunnel would be under pressure continually. To allow for maintenance of the tunnel and to provide for rapid closure of the tunnel in emergency situations, a gate / stoplog structure would be constructed at the inlet. Also, a somewhat larger gate / stoplog structure would be required at the entrance to the Lagarto to Gatun inter-basin transfer tunnel. The additional cost for the tunnel resulting from changes in diameter and length and the increase in the cost of the intake gate / stoplog structure would be directly attributable to the Rio Salud project. Plate 11 - 1 shows the location of the tunnel outlet.

HYDROPOWER PLANTS

Flow at the proposed Salud Dam exceeding that needed for canal operation was considered for hydropower production. These investigations indicated that the power production potential would be so small (approximately 34 kW for Operating Option 1) that hydropower plant installation would be infeasible. Therefore, no hydropower installation is included in the analyses presented herein.

OUTLET WORKS

An outlet works system would be required to provide water diversion of the Rio Salud during construction, to allow for emergency drawdown of the lake, and to allow minimum flow to pass the dam.

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 was no longer needed for construction, the structure would be used to control the flows for emergency drawdown. It would 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 as minimum flow.

This system would consist of two 3 m finished diameter tunnels passing through the dam abutment, an intake structure located in the lake, an outlet channel downstream, and various gate structures and water conduits. The diversion tunnels would be approximately 645 m in length and have an inlet invert at elevation 12 m MSL and an outlet invert at elevation 10 m MSL. The diversion tunnels would serve in combination with the cofferdam to protect the construction area from floods up to a 10 percent frequency. A 10 percent frequency flood would deliver a peak flow of 245 CMS at the site without regulation from the dam. The cofferdam would measure 20.5 m above the upstream invert of the tunnel. A separate 300 mm diameter conduit, required for minimum flow, would be installed beneath the floor of this tunnel. The minimum flow conduit would be approximately 650 m in length. It would have an inlet invert at elevation 10 m MSL and an outlet invert at elevation 8 m MSL. The capacity of the minimum flow conduit would be 0.3 CMS. A bulkhead closure would be required at the tunnel outlet to close the construction diversion. The closure would be configured so that it could be removed in the event that the Salud Lake had to be drawn down.

ACCESS ROUTE

Access to the lake site and the various construction sites was evaluated from Colon, the main population center on the Atlantic coast. Since this project assumes the existence of the Lagarto Lake project, the construction route established to the Lagarto dam site would be utilized for the Rio Salud project also. Lighter materials and equipment would be carried across the lock gates at Gatun Locks. The access for heavy materials and equipment to the construction area would be by water to the western side of Gatun Lake near the village of Escobal. From Escobal, materials and equipment could be carried over existing roads to the village of Palmas Bellas at the mouth of the Rio Lagarto, then up the Rio Lagarto to the Lagarto dam site. From the Rio Lagarto dam, a new access road approximately 4 km in length would be required to access the

Rio Salud dam site. Approximately 3.5 km of additional roadway would be required to reach the inter-basin transfer tunnel inlet on the eastern shore of Salud Lake. From this point approximately 0.25 km of additional road would be required to reach the tunnel outfall at the western edge of Rio Lagarto Lake.

Access from the Inter-American Highway northward across the isthmus to the construction area was considered. However, this route was discarded because of the length of roadway construction required through low-lying and relatively unsettled land.

Plate 11 - 1 shows the portion of the proposed access road connecting the Rio Lagarto dam with the Rio Salud construction sites.

Sources of Construction Material

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

Cement would be available within the Republic of Panama. Rock, obtained from the construction site or from the lake area, would be used for onsite manufacture of aggregates for the concrete. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) would be fabricated outside the Republic of Panama and imported for final assembly and installation at the proposed dam site.

Real Estate Requirements

The proposed Rio Salud project would be located in the Panama Province. Construction of this proposed project would require 2,925 ha. Table 11 - 2 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 11 - 2 Real Estate Requirements for Option 1

Project Feature	Land Required (ha)
Lake	1,925
Dam Site	200
Staging Area	200
Housing and Facilities	200
Disposal Area	400
Total	2,925

Relocations

The lake would be located in a moderately populated region with few roads and utilities. This area is devoted primarily to subsistence farming and ranching. Large forests are also located here. Structures and individuals located in the lake area below elevation 65 m MSL would require relocation because of the normal lake inundation and the need to secure the lake perimeter for flood considerations. Relocations required would include the three named villages in the lake area (Dos Hermanas, La Hicotea, and Espave) and numerous isolated structures.

Development Sequence

For the economic evaluation of this project, it was assumed that the planning for the Rio Salud project would begin during the construction of the Rio Lagarto project and that construction would be started immediately following completion of the Rio Lagarto project.

Planning studies would be accomplished to evaluate and optimize various features of the proposed project. Each potentially viable project would be evaluated to assure that the plan presented would provide all of the features required to make it functional. Each would also be assessed as to its effectiveness in meeting the project goal of providing M & I water supply in relief of current or future planned withdrawals from the Panama Canal, with due recognition of any secondary benefits. Environmental assessments of the proposed project would begin during the planning studies phase and would continue during the final design, advertising and award phase, and on through construction of the project. The final design would be accomplished for the recommended project. After completion of the final design, plans and specifications would be prepared for the advertising and award phase.

Project implementation would begin with land acquisition and construction of the access roads. Lands for the housing and facilities project feature, including the access roads, would be acquired initially. Lands for the dam site, staging area, disposal area, and lake would then be acquired.

Access roads would be constructed to the dam site and the inter-basin transfer tunnel inlet and outlet sites. Once road access to the sites is established, a camp would be built to house workers during construction.

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

Construction of the dam would begin with the clearing and grubbing of the construction sites and the clearing of the lake area. Excavation for the inter-basin transfer tunnel and the intake structure, construction of the diversion tunnel at the dam site, and the construction of the spillway would follow with work being done simultaneously. To the extent possible materials removed from these sites would be placed directly into the embankments. Excess materials would be stockpiled for future use in the finished earthen and rock fill portions of the dam. Once the intake structure and diversion tunnel were completed, the dam construction site would be isolated using upstream and downstream cofferdams and the stream would be diverted through the tunnel. These structures would become part of the main dam, as the construction is completed. The dam foundation would then be excavated and grouted, and the dam constructed. Upon completion of the dam and the inter-basin transfer tunnel and appurtenant structures, the diversion would be stopped, and lake filling would begin. Simultaneously with this operation, the downstream bulkhead structure would be constructed to provide for closure of the diversion tunnel. The minimum flow conduit would be installed through the diversion tunnel at this time. Upon completion of the project, all facilities would undergo trial operations followed by commissioning for service.

Considering the climatic conditions and the obstacles posed by the remote location of the construction sites and the nature of the work, it is estimated that development of this project could be completed in approximately 9 years, from initial planning to lake filling.
Figure 11 - 2 depicts the development sequence of the various project features.

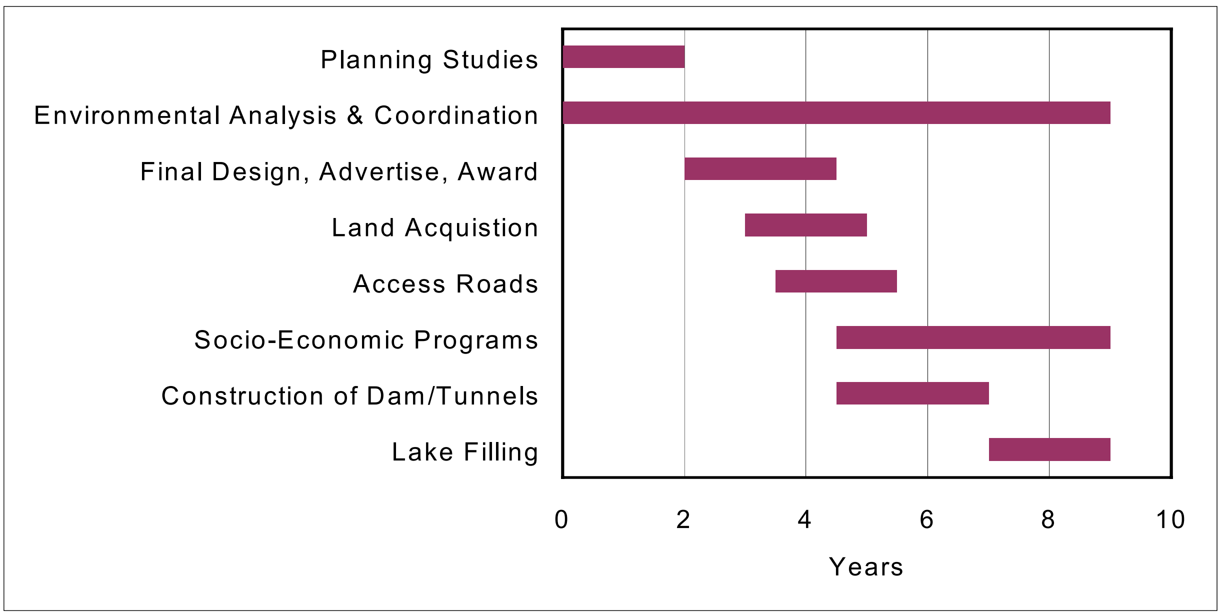


Figure 11 - 2 Development Sequence

Water Yield

The proposed Rio Salud project was modeled using the HEC-5 Analysis Package, Simulation of Flood Control and Water Conservation Systems. Because of the very small useable storage in Salud Lake, the project was only designed to provide a constant flow equivalent to the constant firm yield. The lake was not modeled to provide high flows in response to navigation water shortages in the Panama Canal operation or to include hydropower production. With the small constant flow applied to the canal, a net yield would be realized but the change in reliability would be small and was considered insignificant.

Monthly discharge data for the proposed Rio Salud dam site, as described in the section titled Hydrologic Conditions were used as input to the simulation model. Elevation-volume values at the proposed Rio Salud dam site were developed from existing 1:50,000 scale topographic mapping. The two operating options are listed in Table 11 - 3.

Table 11 - 3 List of Options

Option	Pool Range (m)	Dam Height (m)	Spillway Length (m)	Minimum Flow (CMS)
Salud1	60-40	65	84	0.3
Salud2	40-30	45	84	0.3

The firm yield was determined by using a constant diversion from Salud Lake, while always maintaining the minimum downstream flow requirement and not allowing the lake to drop below the minimum lake operating level. The lake was required to recover its full storage within 4 to 5 years, excluding the 1998 drought period. The 1998 period was excluded since it is considered to be a drought of much lower frequency than 100-year return. A 5-year recovery period was imposed to help select a practical low flow period to design the reservoir. The HEC-5 model was optimized to determine the greatest constant diversion based on the available hydrologic records (1958-1998). The results for each option are shown in Table 11 - 4.

Table 11 - 4 Constant Firm Yield

Option	Lake Range (m)	Minimum Flow (CMS)	Average Evaporation (CMS)	Firm Yield (CMS)	Additional Lockages Per Day*
Salud1	60-40	0.3	0.6	1.9	0.8
Salud2	40-30	0.3	0.3	2.0	0.8
*Lockages are based on 55 million gallons for one ocean to ocean transit.					

It should be noted that the higher lake elevation actually produces less constant firm yield. This can be attributed to the very small average inflow and higher evaporation losses because of greater lake surface area. All the storage in Option 1 between elevations 60 and 40 m MSL could not be completely used because the small drainage basin above the dam site did not provide enough runoff for the lake to recover in 4 to 5 years, the most significant drought period, and considered a reasonable recovery period. Therefore, the minimum lake elevation for Option 1 during the period of record was only 54.8 m MSL. However, the added hydraulic head obtained by setting the Salud Lake operating lake levels at the higher levels would be valuable in transferring water to Lagarto Lake and thence to the Panama Canal watershed.

Project Costs

GENERAL

The quantities estimated for the various items of work required in the construction of this prospective project have been derived from data generated for this project and from similar features developed for the Rio Indio project as indicated on the layouts shown in Section 5, Plates 5 - 3 through 5 - 9. The unit prices applied to these quantities were based on historical information from previous estimates prepared for similar construction by the PCC, estimates for similar construction in the U.S. Army Corps of Engineers, Mobile District, and information gathered from Mobile District Construction Division personnel in Panama.

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

FIRST COSTS

The total project first costs are estimated to be $66,509,000. Table 11 - 5 provides a summary of the first costs for the principal features, and separate documentation provided to the PCC includes a detailed cost estimate containing the sub-features of the work.

Table 11 - 5 Summary of First Costs for Option 1

Item	Costs ($)
Lands and Relocations	7,312,500
Access Roads	2,560,000
Clearing and / or Grubbing	715,625
Diversion Tunnel	4,883,000
Inter-basin Transfer Tunnel[1/]	564,000
Dam and Saddle Dams	11,736,873
Spillway	2,198,900
Intake	14,368,630
Subtotal	44,339,528
E&D, S&A, Field Overhead	8,867,906
Contingencies	13,301,858
Total Project First Cost	66,509,292 approximately 66,509,000

[1/] The difference in costs to enlarge the inter-basin transfer tunnel connecting Lagarto Lake and the Panama Canal watershed from a 2 m finished diameter tunnel to a 3 m finished diameter tunnel are included.

OPERATION AND MAINTENANCE

Staff

A staff would operate and maintain the proposed Rio Salud project during the day and then run the facility remotely. The full-time staff would ultimately consist of a total force of six that would include a station manager, a leader, three craftsmen and a laborer. The annual costs of the staff are estimated to be $235,000.

Ordinary Maintenance

Ordinary maintenance and care would be required and would include minor repair materials needed by project staff, lubricants and other supplies. It is estimated that the cost of ordinary maintenance would be $20,000 per year for the access road and $100,000 per year for the main project facilities.

Major Replacements
The average service life of gates, electrical equipment, turbines, trash racks and other features would be less than the over-all useful life of the proposed project, which is 100 years. In order to estimate the major replacements to be made during the life of this proposed project, it was assumed that specific items would cost the same as at present. No allowance was made for salvageable fixed parts. Table 11 - 6 presents the service life, number of times each component should be replaced, the future costs of each item, and the present worth of the replacement costs. On the basis of these values, the present worth of proposed replacements would be $19,300 and the average annual costs would be $2,300.

Table 11 - 6 Major Replacements

Item	Service Life (years)	Number of Times Replaced	Future Costs ($)	Present Worth of Replacement Costs ($)
Roads	50	1	3,300,000	11,419
Bridges	50	1	450,000	1,557
Intake				
Head gates	50	1	1,523,100	5,270
Stoplogs	50	1	22,800	79
Trashracks	50	1	7,350	25
Access Stairs	50	1	90,750	314
Minimum Flow Gates	50	1	180,000	623
Sums			4,698,000	19,300
Average Annual Replacement Costs				2,300

Annual Costs

The project first costs for the proposed Rio Salud project are estimated to be $68,463,740 and it includes $1,954,448 to enlarge the inter-basin transfer tunnel and modify the tunnel intake between Lagarto Lake and the Panama Canal watershed from a 2 m finished diameter tunnel to a 3 m finished diameter tunnel. The total project first costs should also include the $32,038,000 costs for the Rio Lagarto project (see Section 10) and are estimated to be $100,502,000. These total project first costs were distributed across the development period using generalized curves for contractor earnings for large, heavy construction jobs. It was assumed that the 3 m finished diameter inter-basin transfer tunnel from Lagarto Lake to the Panama Canal watershed would be constructed at the Rio Lagarto project instead of the 2 m finished diameter inter-basin transfer tunnel. Interest on the total project first costs of $66,509,000 ($68,463,740 - $1,954,448) was computed from mid-year throughout the 9-year development period from initiation of Planning and Design until the lake was filled. Interest during construction for the Rio Lagarto project including the enlarged inter-basin transfer tunnel at the Rio Lagarto project was computed from mid-year throughout its 16-year development period until lake filling was complete at the Rio Salud project. The interest during construction at 12 percent would be $36,122,000 for Rio Salud and $89,368,000 for Rio Lagarto for a total interest during construction of $125,490,000. These costs were added to the total project first costs for total project investment costs of $225,992,000. A capital recovery factor for the 50-year planning period was applied to get the annual average investment costs of $27,213,000. Annual operation and maintenance costs were added. Major replacement costs are estimated and were 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 11 - 7 contains a summary of the $27,929,000 total annual costs.

Table 11 - 7 Summary of Annual Costs for Option 1

Item	Costs ($)
Total Project First Costs - Rio Salud	66,509,000
Total Project First Costs – Rio Lagarto	32,038,000
Enlarged Tunnel and Modify the Tunnel Intake at Rio Lagarto project	1,954,000
Interest During Construction – Rio Salud	36,122,000
Interest During Construction – Rio Lagarto	89,368,000
Total Project Investment Costs	225,992,000
Annual Average Investment Costs	27,213,000
Operation and Maintenance Costs	
Staff Costs – Rio Salud	235,000
Staff Costs – Rio Lagarto	235,000
Ordinary Maintenance Costs – Rio Salud	120,000
Ordinary Maintenance Costs – Rio Lagarto	120,000
Major Replacement Costs – Rio Salud	2,300
Major Replacement Costs – Rio Lagarto	3,400
Total Average Annual Costs	27,929,000

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 Rio Salud project. The 50-year planning period for this proposal is 2013 to 2063.

The proposed Rio Salud project would slightly increase the reliability of providing water to accommodate the daily number of lockages demanded. Since this increase is so small, benefits associated with an increase in reliability were not estimated. The 99.6 percent level of reliability for this proposal is used to estimate the water supply benefits for navigation.

With the addition of the proposed Rio Salud project, shortages in water supply would be less. At a reliability of 99.6 percent, Operating Option 1 and Operating Option 2 would increase the amount of water supplied for canal operations by approximately 0.8 equivalent lockage. When combined with the yield from the proposed Rio Lagarto project, Operation Option 1 would supply approximately 1.7 equivalent lockages and Operation Option 2 would supply approximately 1.9 equivalent lockages. Benefits for these amounts of additional water supply 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 number of daily lockages. The average annual benefits for water supply would be $35,058,000 for Option 1 and $39,183,000 for Option 2. Table 11 - 8 provides the estimate of daily shortages under existing conditions, the remaining daily shortages with the proposed Rio Salud project in operation, the annual benefits for meeting shortages and the average annual benefits for both options.

Table 11 - 8 Benefits for Additional Water Supply for Navigation

Year	Daily Shortages In Lockages Under Existing System	Remaining Daily Shortages With Operating Option 1	Remaining Daily Shortages With Operating Option 2	Annual Benefits for Operating Option 1 ($)	Annual Benefits For Operating Option 2 ($)
2017	8.45	6.75	6.55	35,058,000	39,183,000
2020	8.93	7.23	7.03	35,058,000	39,183,000
2030	10.87	9.17	8.97	35,058,000	39,183,000
2040	13.34	11.64	11.44	35,058,000	39,183,000
2050	16.45	14.75	14.55	35,058,000	39,183,000
2060	20.36	18.66	18.46	35,058,000	39,183,000
2066	23.21	21.51	21.31	35,058,000	39,183,000
Average Annual				35,058,000	39,183,000

With Option 1, the system will provide a total of 40.38 equivalent lockages at the 99.6 percent level of reliability or 1.7 more lockages than the existing system.

With Option 2, the system will provide a total of 40.58 equivalent lockages at the 99.6 percent level of reliability or 1.9 more lockages than the existing system.

SUMMARY OF ANNUAL BENEFITS

As shown in Table 11 - 9, total average annual benefits for Operating Option 1 and Operating Option 2 of the proposed Rio Salud project would be $35,058,000 and $39,183,000, respectively.

Table 11 - 9 Summary of Annual Benefits

Benefit Category	Average Annual Benefits	
	Operating Option 1 ($)	Operating Option 2 ($)
Navigation – Water Supply	35,058,000	39,183,000
Navigation – Reliability	Not Estimated	Not Estimated
M&I - Reliability	Not Estimated	Not Estimated
Hydropower	None	None
Total	35,058,000	39,183,000

To perform an analysis of benefits versus costs, a common point in time was selected. This common point was at the completion of the filling of the proposed Rio Salud project, the end of the year 2013. In these analyses, it was important to note that the average annual benefits or average annual costs were 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 Rio Salud would be to develop the Rio Lagarto project first (2001 – 2008) and then the Rio Salud project second (2005 – 2013).

The benefits attributable to the proposed Rio Lagarto project would begin to accrue in 2008 when that reservoir is filled. Thus, the Rio Lagarto project benefits for the period 2008 to 2017 were escalated by the project discount rate, 12 percent, in order to estimate their total present worth of $261,475,000 in the year 2017. The average annual benefits for the proposed Rio Indio project that accrue during the construction of the proposed Rio Salud project are estimated to be $31,486,000. Although the discharge tunnel would be larger, the proposed Rio Lagarto project would be operated for the period 2008 through 2017 just as if the proposed Rio Salud project was not to be constructed.

To estimate the interest during construction, similar calculations were made for the costs of each proposed project. For the proposed Rio Lagarto project, interest during construction was taken from year 2001 to year 2017 and the interest during construction for the proposed Rio Salud project was taken from the year 2008 to the year 2017. Additionally, there would be added costs for the larger inter-basin transfer tunnel between Lagarto Lake and the Panama Canal watershed that would only be required if the proposed Rio Salud project were to be constructed. Those amounts were subtracted from the cost estimate for the proposed Rio Salud project and added to the cost estimate for the proposed Rio Lagarto project. The revised estimated average annual costs for the Rio Lagarto portion of the overall project would be $15,213,000.

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) were computed. In the first instance, the analysis determines the feasibility of the proposal. The net benefits determines which proposal among several provides the greatest value for the investment dollars. While there would be some differences in project features between Operating Option 1 and Operating Option 2, the differences would only have minimal impact on total project first costs at this level of investigation. Table 11 - 10 provides the benefit to cost ratios for Operating Option 1 and Operating Option 2 and the net benefits for both options.

Table 11 - 10 Economic Evaluation

Item	Operating Option 1	Operating Option 2
Average Annual Benefits		
Rio Lagarto	$ 31,486,000	$ 31,486,000
Rio Salud	35,058,000	39,183,000
Sum	$ 66,544,000	$ 70,669,000
Average Annual Costs		
Rio Lagarto	$ 15,213,000	$ 15,213,000
Rio Salud	12,715,000	12,715,000
Sum	$ 27,929,000	$ 27,929,000
Benefit to Cost Ratio	2.4	2.5
Net Benefits	$ 38,615,000	$ 42,740,000

Internal Rate of Return

An internal rate of return analysis for each operating option was performed. To accomplish this analysis, the annual construction costs were used as the investment, and the undiscounted benefits were used as return cash flows. For Operating Option 1, the internal rate of return would be 22.4 percent, and for Operating Option 2, the internal rate of return would be 22.9 percent.

Socio-Economic Impacts

The socio-economic impacts of the project could be significant, because the proposed dam, saddle dams, and lake on Rio Salud could require relocation of three towns: Dos Hermanas, La Hicotea, and Espave as well as numerous smaller establishments. No indigenous groups of people are known to reside in the impact region. The project is expected to cause major impacts on land use, as agricultural and grazing areas could no longer be usable. The surface area of the proposed lake will encompass 1,925 ha with another 800 ha for the dam site and staging area including permanent disposal areas.

Environmental Setting

The Rio Salud project involves the construction of a dam on the Rio Salud and would function in tandem with the Rio Lagarto project. Salud Lake would provide approximately 0.8 additional lockages per day on a continual basis. The structures for this proposed project would consist of a rock fill dam, two saddle dams, an uncontrolled ogee spillway, inter-basin transfer facilities, and other outlet works. The project encompasses the area to be flooded as well as the area downstream from the dam site. This area is moderately populated. It is characterized by rolling hills, low coastal regions, and cleared areas for livestock. Fragmented forests are all that remains of the terrestrial habitat within the project area. The Rio Salud is located west of the Panama Canal, is used for navigation and transportation of livestock, and flows northward from the Continental Divide into the Atlantic Ocean. The Rio Salud watershed above the dam is approximately 41 km^2. The impoundment area covers approximately 1,877 ha composed of approximately 50 percent of forested land, 20 percent of pastureland used by ranchers, 20 percent of cropland, and 10 percent of newly slashed and burned land. The lake water elevation will fluctuate from elevation 30 to 64 m MSL. The water pipelines, tunnel portals, and roads associated with the project could also have environmental impacts and should be sited to minimize those impacts.

LAND USE

Rio Salud drains a small watershed on the Atlantic coast of the Republic of Panama. It flows northward, from a point 28 km inland, to the Atlantic Ocean. The Rio Salud project would include a dam, two saddle dams and a lake on Rio Salud, located approximately 10 km inland from the Atlantic Ocean. Towns located in the project area include Dos Hermanas, (population-1), La Hicotea, (population-60), and Espave, (population-3), along with isolated settlements along Rio Salud. Some areas along Rio Salud have been cleared by slash and burn activities for farming and grazing. Farms of various sizes, ranging from commercial cash crop enterprises to subsistence farming, grow maize, rice, beans, sugar, coffee, tobacco, and teak trees. Ranchers raise cows, horses, chickens and hogs. There are no significant mineral resources or deposits known along Rio Salud. Fragmented forests remain between settled areas along Rio Salud.

INFRASTRUCTURE

Towns along Rio Salud have cemeteries, churches, and medical centers. Potable water is obtained from groundwater wells. Some 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 might reach Rio Salud. Disposal of domestic waste is the responsibility of individual homeowners: some homes have a septic system but most have an outdoor latrine (a hole in the ground). There are known health problems such as hepatitis, dysentery, dermatitis, intestinal parasites, and respiratory illness attributable to these waste disposal methods. No major poultry or beef processing plants are located in the project area. The only access to the project area other than Rio Salud is by dirt roads, which are rarely graded and receive little attention by either the Ministry of Public Works or the local government. These relatively isolated roads are valuable to the residents for transportation, community cohesion, commerce, and communication with neighboring communities.

TERRESTRIAL HABITAT

The terrestrial habitat along Rio Salud consists of sparse tropical ecosystems of secondary growth forests and patches of primary forest. Slash and burn activities have opened tracts of land between forested areas for farming and cattle grazing; however the majority of the river banks are forested. Terrestrial areas are used by migratory and native species as resting, breeding, and foraging habitat. The fragmented forest areas provide habitat for wildlife that have escaped from agricultural and grazing areas and house the remaining species that once existed throughout the project area. Competition for resources is high when habitat areas decrease. Many species cannot survive and sustain viable populations as their habitat shrinks. The complex and diverse tropical ecosystems offer habitat to connect a variety of wildlife communities. This area may provide critical wildlife habitat to many native species.

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 none have been identified to date, some of the listed species may occur in the project area.

AQUATIC HABITAT

The Rio Salud contains many different types of aquatic habitat at various water depths and a wide range of water quality. The river is used by a variety of wildlife species both resident and migratory, as well as by both native and introduced fish and other aquatic species. Trees growing along the banks of Rio Salud maintain the health of the river by providing shade and bank stabilization. Vegetation in the river provides habitat for aquatic life and contributes to water quality. Rio Salud also contains underwater habitat structures, such as fallen trees and debris.

WETLANDS

Areas that contain hydric soils and hydrophytic plant communities, and that are subject to hydrologic conditions, are termed wetlands. Wetlands in the Rio Salud project area consist of shallow water habitat and areas that experience frequent flooding. Wetlands occur along the banks of Rio Salud as shallow water areas with aquatic emergent vegetation. Shallow water areas along the banks of Rio Salud receive sunlight to approximately 1 m in depth, depending on water clarity. Sunlight stimulates plant growth in the forms of submergent, emergent, or floating mats of aquatic vegetation. The wetland areas contribute to water quality and aid in bank stabilization. They also provide aquatic organisms with refuge from the main currents and predatory species in the deeper aquatic habitats.

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 to prepare the land for agricultural use. During this period, the air is filled with smoke and ash. Air quality monitoring has not been implemented within the project area. The natural environment could provide indicators that could be useful in evaluating air quality.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

There are no known cultural resources or historic properties within the project area. 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 Rio Salud project area could be significant. The border between two types of habitats, in this case where a forest meets a river, is called an ecotone. Ecotones are composed of a mixture of species from neighboring habitats but are unique areas with high species diversity. The creation of the Salud Lake area could significantly reduce terrestrial wildlife habitat where areas become inundated areas. Local slash and burn practices continue to reduce the amount of forested land. Implementation of the project could significantly reduce forests along some reaches of Rio Salud.

ANIMALS ON ENDANGERED LIST

The severity of the impact of the project on endangered species cannot be determined at this time, because it is unknown which of the listed species occur within the proposed project area. The significance of the natural environmental features in this area may increase if species on the endangered list or their habitat are found in the region. Some endangered and / or threatened species may use Rio Salud for some or all parts of their life cycle. The Mesoamerican Biological Corridor is also promoting biodiversity conservation throughout the Atlantic basin, which could impose restrictions on the use of the project area.

WATER QUANTITY

The impacts of the project on water quantity should be beneficial, because the creation of Salud Lake and dam should increase the volume of stored freshwater, which should reduce the need for navigational restrictions in the Panama Canal during the dry season. The project should also reduce flooding downstream. The cumulative impacts downstream of the dam site over time should also be minor.

WATER QUALITY

Project impacts on water quality are unknown. Clearing and grubbing in the project area could increase the amount of nutrients and debris in the river. The rate at which nutrients and debris enter the river will determine the severity of their 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 organisms serve to help maintain water quality. Species that inhabit Rio Salud at specific depths could be impacted when the river becomes a lake. The velocity of water should decrease with dam construction, which should increase sedimentation. Downstream from the dam, erosion forces could increase and the ecology of the river could change as flow, sediment load, and species change.

DOWNSTREAM AQUATIC FAUNAL HABITAT

The impacts of the project on downstream aquatic faunal habitat could be significant. Project implementation may impact successful breeding and the nursery habitat of many juvenile aquatic species. Impacts to fish spawning areas may be detrimental when turbidity, nutrient content, and depth suddenly increase, which could alter the conditions needed for a successful hatching of fish. Plant populations may decrease as a result of an increase in depth and decrease of available sunlight; therefore, invertebrate populations may decline which could reduce the food supply for fish and other aquatic species. Plant communities and aquatic species could be displaced as water levels rise and currents change. The dam could prevent anadromous fish from traveling up Rio Salud. New aquatic habitats and species could become established as the lake is formed and the river system is permanently altered.

FUTURE LAKE AQUATIC PLANT COMMUNITY

The impacts of the project on future aquatic plant communities could depend on water quality and stability of water levels. The increase in depth and decrease in flow could impact plant species in Rio Salud. Aquatic plant communities could be permanently impacted during project implementation; however, after conditions stabilize, colonies could eventually re-establish themselves. Exotic plant species may colonize these areas before native species can re-colonize.

AQUATIC FAUNA INHABITING AFFECTED AREAS

The impacts of the project on aquatic fauna inhabiting the Rio Salud and its upstream tributaries could be important. The reservoir could support species that thrive in lentic systems. Species that require highly oxygenated lotic systems could be extirpated from the stretch of Rio Salud covered by the reservoir. The dam could also create a barrier to seasonal migration that may be crucial in the reproductive cycle of some fishes and aquatic invertebrates. Some unavoidable, adverse environmental impacts could occur and these impacts should be identified and appropriate mitigation measures addressed in feasibility level studies, should the alternative be recommended for further consideration. If the new reservoir is responsibly managed and stocked with game fish by the Aquaculture Department, it could provide opportunities for recreational and subsistence fishing. An increase in fish population could lead to an increase in piscivorous predators, such as crocodiles, caimans, otters, herons, and others. Other manmade lakes in the Republic of Panama have been stocked with exotic fish such as peacock bass and tilapia, both of which are efficient predators, which may have led to the extirpation of several native riverine fishes that formerly inhabited the impoundments.

WETLANDS

The impacts to upstream and downstream wetlands could be significant. Areas presently identified, as wetlands could become aquatic habitat, permanently altering the established environment. Project activities may affect wetlands by increasing the water depth, sedimentation, and turbidity, which could cause changes in the biological processes of the wetlands and decrease productivity. These impacts are detrimental to the health and sustainability of Rio Salud. Fish and other aquatic species use shallow water areas as spawning areas as well as habitat for juvenile aquatic species. Juvenile aquatic species survive in shallow water wetland areas until they are large enough to venture out into deeper water. These areas are vital to the sustainability of Rio Salud. Due to minimum normal flow, the cumulative effects downstream of the dam site are expected to be minor.

AIR QUALITY

During construction of the dam, dust and emissions from equipment could impact the air quality in the project area. After construction, the air quality could improve because the Panamanian government currently discourages slash and burn activities.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

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

Additional Environmental Information Required

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

SOCIO-ECONOMIC IMPACTS

- Conduct an 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 terrestrial and aquatic habitat types 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 migratory flyways.
- Determine the present quality and ecosystem value of existing habitats within the Rio Salud project area.
- Coordinate with local experts to identify and evaluate aquatic and terrestrial habitat areas.
- Provide species inventory lists for each site area identifying their status as native or exotic and whether they are threatened and or endangered species.

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 identify 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 the presence of these species.

WATER QUALITY

- Since no water quality data are available for the Rio Salud 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 is incomplete. Additional evaluation studies should be conducted to identify cultural resources and historic 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 Section 35. Table 11 - 11 through Table 11 - 13 present the evaluation of the proposed Rio Salud project as related to developmental effects, environmental effects, and socio-economic effects.

Table 11 - 11 Development Effects

Evaluation Criteria	Function	Measure [1/]	Importance [2/]	Composite [3/]
Water Contribution (Water Yield)	Meets M&I demands	2	10	20
	Supplements Existing System	0	10	0
	Satisfies Future Canal needs/expansion	0	10	0
	Additional Hydropower Potential	0	5	0
Technical Viability	Design Constraints	8	6	48
	Feasibility of Concept	9	6	54
Operational Issues	Compatibility	8	6	48
	Maintenance Requirements	8	2	16
	Operational resources required	8	2	16
Economic feasibility	Net Benefits	1	9	9
	Total			211

[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 11 - 12 Environmental Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Terrestrial Habitat	4	8	32
Animals on Extinction List	4	10	40
Water Quantity Impacts – Lake	8	10	80
Water Quantity Impacts – Downstream	4	7	28
Water Quality	5	10	50
Downstream Aquatic Fauna Habitat	4	8	32
Future Lake Aquatic Plant Community	6	8	48
Aquatic Faunal Inhabiting Affected Area and Upstream Tributaries	5	5	25
Potential for Fishing on Lake	6	6	36
Wetlands	4	4	16
Air Quality	5	3	15
Cultural Resources and Historic Properties	5	10	50
Total			452

[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 11 - 13 Socio-Economic Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Land Use	2	7	14
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	2	8	16
Community Cohesion	2	8	16
Tourism	6	5	30
Total			341

[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 11 - 14 presents data for the proposed Salud dam.

Table 11 - 14 Pertinent Data for Option 1

GENERAL	
Dam site, above mouth of SALUD	28 km
Drainage area above dam site	41 km^2
Average annual flow at dam site	3.5 CMS
LAKE	
Elevation of normal operating lake level	60 m MSL
Elevation of maximum flood storage lake level	64.0 m MSL
Elevation of minimum operating lake level	40 m MSL
Useable Storage between Max and Min Levels	252 MCM
Area at normal operating lake level	1,691 ha
Area at maximum flood storage lake level	1,877 ha
Area at minimum operating lake level	874 ha
Top clearing elevation	60 m MSL
Lower clearing elevation	40 m MSL
EMBANKMENTS	
Dam	
Type of dam	Rock fill embankment
Top elevation of dam	65.0 m
Fixed crest width	13 m
Height	46 m
Overall length of dam	317 m
Saddle dam (North)	
Type of saddle dam	Earth / Rock Fill Embankment
Top elevation of saddle dam	65.0 m MSL
Fixed crest width	13 m
Overall length of saddle dam	170 m
Saddle dam (South)	
Type of saddle dam	Earth / Rock Fill Embankment
Top elevation of saddle dam	65.0 m MSL
Fixed crest width	13 m
Overall length of saddle dam	138 m
SPILLWAY	
Type of Spillway	Uncontrolled ogee
Total length	84 m
Elevation of spillway	60.0 m MSL
Maximum discharge	644 CMS

Table 11 - 14 Pertinent Data for Option 1 (continued)

INTER-BASIN TRANSFER TUNNEL	
Salud to Lagarto	
Tunnel diameter	2 m
Tunnel length	400 m
Inlet invert	36 m MSL
Outlet invert	34 m MSL
Tunnel capacity	27.7 CMS
Lagarto to Gatun	
Tunnel diameter	3 m
Tunnel length	1.25 km
Inlet invert	25 m MSL
Outlet invert	23 m MSL
Tunnel capacity	41 CMS
CONSTRUCTION DIVERSION	
Diversion length	645 m
Tunnel diameter	two 3 m
Inlet invert	12 m MSL
Outlet invert	10 m MSL
Cofferdam Height above tunnel inlet invert	20.5 m
MINIMUM FLOW CONDUIT	
Conduit diameter	300 mm
Conduit length	650 m
Inlet invert	10 m MSL
Outlet invert	8 m MSL
Conduit capacity	0.3 CMS

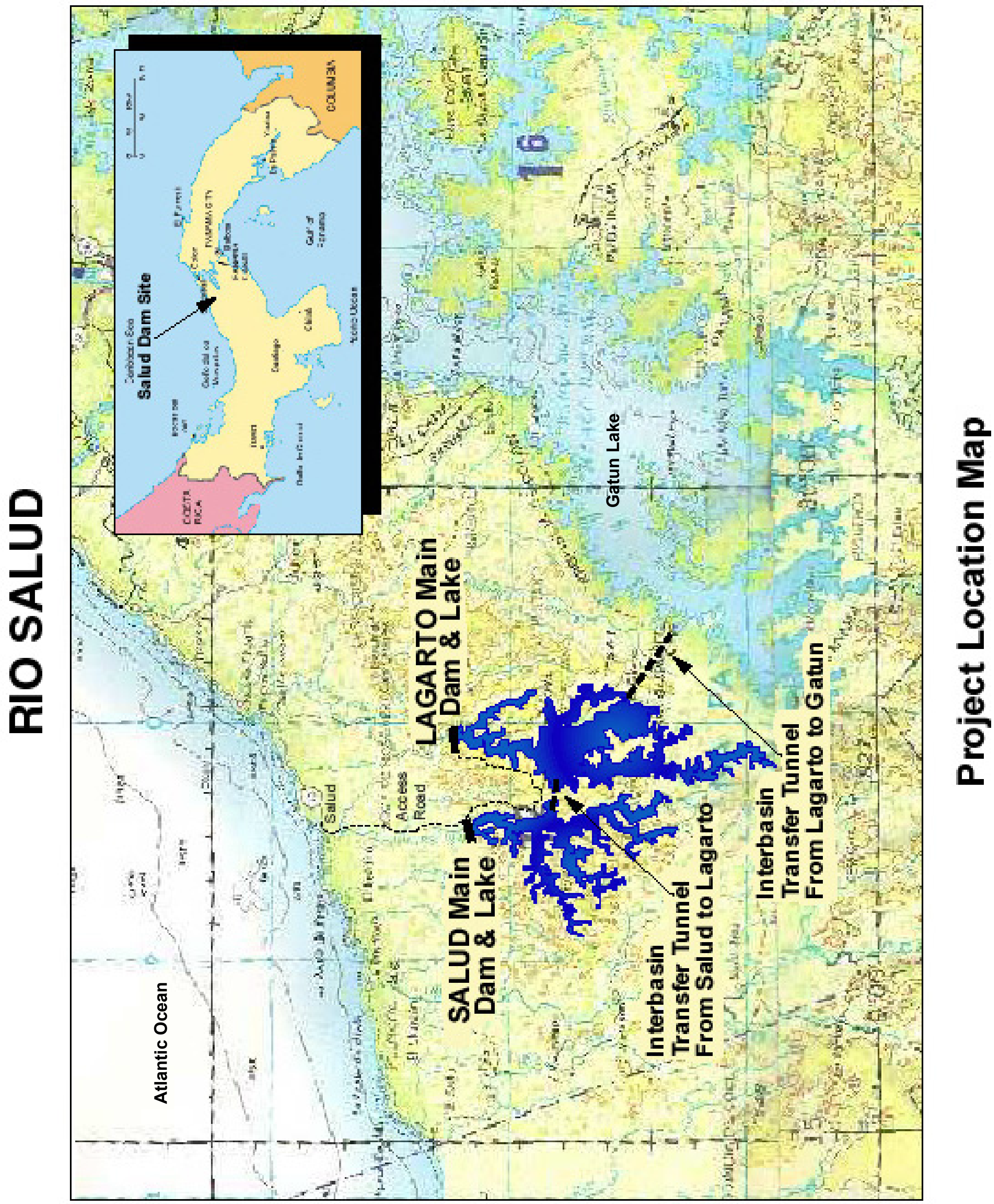
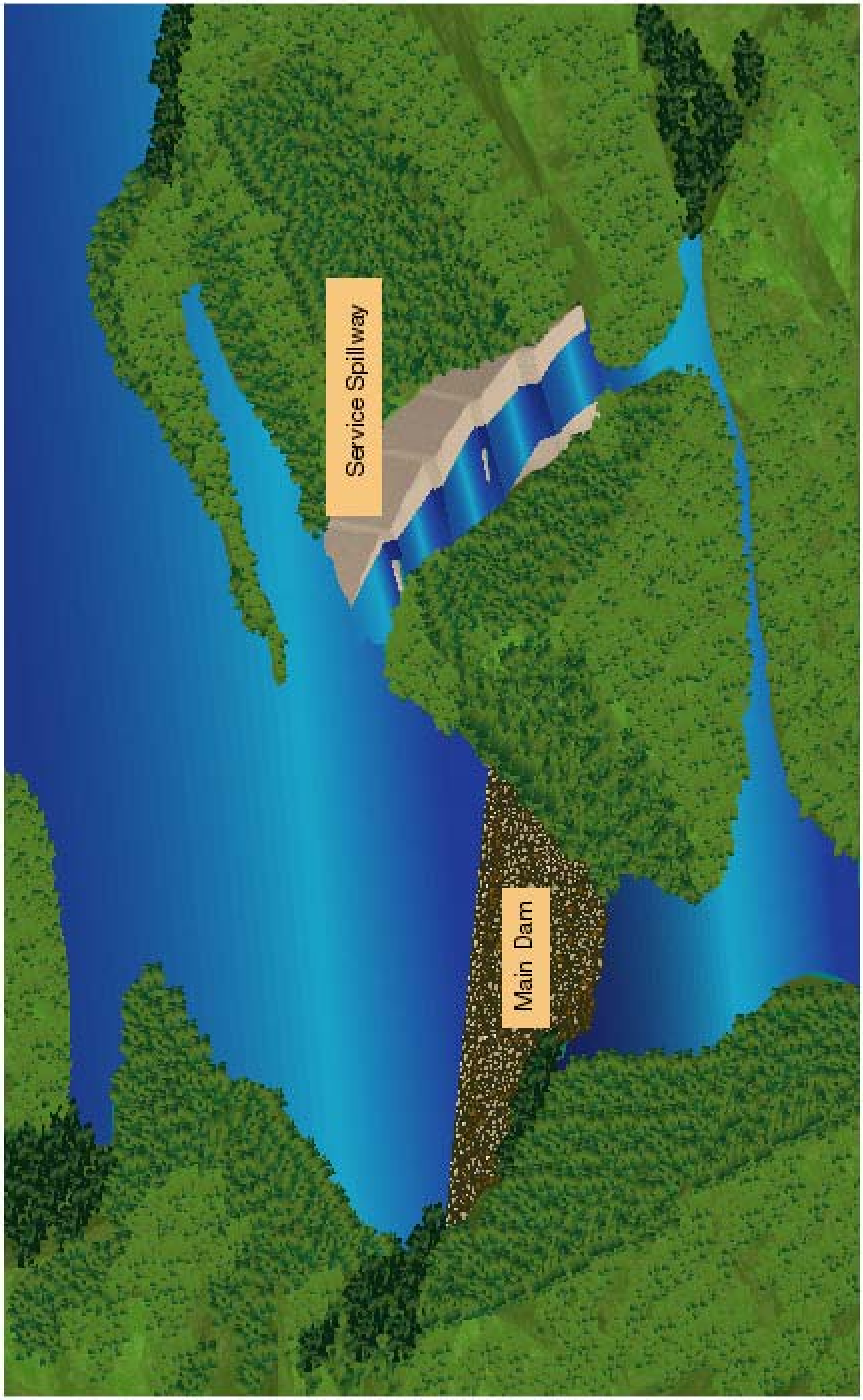


Plate 11 - 1 Project Location Map

RIO SALUD



Site Plan

Plate 11 - 2 Site Plan

SECTION 12

Rio Piedras

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Synopsis

The Rio Piedras drains a small watershed located on the Atlantic coast of the Republic of Panama and east of the Panama Canal watershed. The watershed is located approximately 25 km east northeast of the city of Colon. Colon is on the eastern side of the Panama Canal and is at the Atlantic entrance to the Panama Canal. The Rio Piedras flows westward out of the eastern mountains and then northward from the interior to the Atlantic Ocean. The proposed Rio Piedras dam site would be located approximately 7 km inland from the Atlantic Coast (approximately 12 km measured along the river channel). At the time of this study, the right to develop water use on the Piedras River was owned by the private company Ente Regulador de los Servicios Publicos. Therefore, these rights would need to be purchased from the owner before the project could be developed.

The structures for the proposed Rio Piedras project would consist of a rock fill dam, an uncontrolled ogee spillway, inter-basin transfer facilities, a hydropower plant at the dam, and outlet works. The tunnel would transfer water from Piedras Lake to the Panama Canal watershed as needed for canal operations.

The contribution of the proposed Rio Piedras project to the hydrologic reliability of the Panama Canal to serve its customers would be very small. Similarly, its contribution in reducing the need for draft restrictions and resulting light loading of vessels during traditional periods of low water availability would be imperceptible. The existing hydrologic reliability of the Panama Canal, based on the 50-year period of record from January 1949 through July 1998, is approximately 99.6 percent, while the hydrologic reliability with a demand ratio of 1.2 (46.42 lockages) would be 98.8 percent. These figures would be virtually unaffected by the installation of the Rio Piedras project.

The amount of hydropower that could be produced by the system of Gatun Lake and Madden Lake would decline over time as the demands for navigation and M&I water increase. Some net additional megawatt hours of hydropower could be realized in the system with the inclusion of the proposed Rio Piedras project and its added hydropower facilities.

The proposed Rio Piedras Project was weighed against the technical objectives stated in Section 4 of this report and found to be lacking in the following areas:

The volume of water produced by this project would not be enough to significantly impact the reliability of the Panama Canal water supply (approximately 0.53 lockages per day). The only apparent benefit to be derived by installation of this project would be the small amount of incidental hydropower that might be produced.

The technical viability of the development is questionable. The dam would be 145 m high; therefore, the structures required to allow access to the operating equipment would be either very high above the valley floor, or excavated deep into the abutment of the dam.

From an operational standpoint, the site is remote from Gatun Lake. The nearest point to the proposed Rio Piedras Lake from which water could be transferred to the Panama Canal watershed is approximately 30 km upstream of the mouth of the Rio Gatun on one of its high northern tributaries. From this point, the small amount of water derived from the project would travel through the natural stream over this very long distance before being introduced into the canal system. Natural losses would be significant. The alternative was considered operationally infeasible considering the small amount of water to be derived and the long distance that this water must be transported.

Therefore, the plan for development of the Rio Piedras was not pursued further and was eliminated from the list of technically viable projects to be subjected to further scrutiny in this report. No formal cost, economic or environmental analyses were made of this alternative.

Site Selection

The proposed Rio Piedras dam site was chosen 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. To maximize the water impounded, it was desirable to locate the dam as far downstream in the Rio Piedras watershed as possible. In choosing a site for the dam, a location was sought where the surrounding hillsides were relatively steep and high, and the valley was relatively narrow.

The site chosen for the proposed Rio Piedras Dam would accommodate construction of a dam with a normal operating lake level at elevation 500 m MSL and a maximum flood storage lake level at elevation 504 m MSL. Plate 12 - 1 shows the location of the proposed Rio Piedras project. At the time of this study, it was found that the water rights for generating electricity downstream were already awarded to the Ente Regulador de los Servicios Publicos, a private company. Therefore, the Piedras water rights would have to be purchased from the owner before the project could be developed.

Hydrologic Considerations

The Rio Piedras flows westward from the high mountains east of the Panama Canal watershed, then northward to the Atlantic Ocean. The headwaters of the watershed begin at elevation 980 m MSL approximately 16 km above the dam site and fall to mean sea level at its mouth. The Rio Piedras watershed is located high up in the northern slopes of the eastern coastal mountain ranges of Panama. This area receives average annual rainfall amounts ranging from 3,500 to 4,000 mm per year. The proposed Piedras Lake would receive runoff from approximately 39 km^2 of the upper portion of the watershed. Rainfall runoff produces an average annual flow of 4.15 CMS at the proposed dam site.

The discharge at the Rio Piedras dam site was obtained by extrapolating the recorded and correlated stream flow data of the Rio Gatun at Ciento. The recorded data at Ciento were extended and some missing monthly data obtained by means of a statistical correlation with the Rio Chagres at Chico using standard hydrologic techniques. Since the Rio Piedras dam site is located on a basin adjacent to the Gatun River, it was assumed for this level of study, that the yield of the Rio Piedras dam site was similar to the yield of the Gatun river basin at Ciento and the flows were derived accordingly.

Because of the proximity, and in the absence of additional information, the monthly evaporation rates recorded at Gatun Lake were used to establish the evaporation of the Rio Piedras Lake. Reservoir volume and elevation relationships were developed from 1:50,000 scale maps.

Geologic Considerations

The proposed Rio Piedras project is located east of the Panama Canal in an area covered by Cretaceous aged pillow basalt flows. Little geological information has been located concerning these rocks, and the site was not visited during this study. If this project is carried forward, the quality of the rock and depth of weathering should be investigated early in the process.

Lake Operation

Two operating options were considered in this analysis. Operating Option 1 included a water surface fluctuating from the normal operating lake level at elevation 500 m MSL down to the minimum operating lake level at elevation 480 m MSL. This would yield 52,670,000 M^3 of useable storage. The maximum flood lake level would be at elevation 504 m MSL. Operating Option 2 considered a lake elevation varying from 400 m MSL to elevation 380 m MSL. The maximum lake flood level for Option 2 would be elevation 404 m MSL and the lake would provide approximately 11,044,000 M^3 of useable storage. Option 2 site was located a few meters downstream of Option 1. The volume between the maximum flood lake level and the normal operating lake level would be used to store flood waters and reduce peak flood flows. Some reduction in flooding would be realized in areas along the Rio Piedras downstream of the dam. The following project features describe Option 1.

Project Features

GENERAL

The structures considered for this proposed project would consist of a rock fill dam, an uncontrolled ogee spillway, inter-basin transfer facilities, a hydropower plant, and outlet works. The following paragraphs provide a description of the proposed structures and improvements. Plate 12 - 2 depicts the location of the dam, the spillway, the hydropower plant, and the 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 PCC that contained assumptions and design calculations for the reconnaissance level investigations of these structures. If this proposed project is carried into the planning studies, optimization of the project features and improvements must be accomplished.

EMBANKMENTS

Dam

The dam would be a very large embankment with the top at elevation 505 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 1042629 north and 645160 east. The right abutment would be 1043717 north and 645185 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 would be approximately 145 m high, and the overall length would be 1,090 m. The actual side slopes and crest width 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. The total volume of this embankment would be approximately 15,694,500 M^3. Sections representing this project can be seen in the typical embankment section in Section 5.

Foundation grouting will 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 could provide seepage cutoff in the embankment foundations. A concrete or bentonite cutoff wall could also provide seepage cutoff.

SPILLWAY

An uncontrolled ogee spillway with a length of 40 m and a crest at elevation 500 m MSL would be required. The spillway crest would be 5 m below the elevation of the top of the dam. The maximum discharge from the spillway would be 624 CMS at a maximum flood lake level of elevation 504 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. A plunge pool would be excavated into the rock adjacent to the natural channel at the downstream end of the tailrace channel for energy dissipation. See Plate 12 - 2 for the location of the spillway.

IMPOUNDMENT

The lake formed by the proposed Rio Piedras Dam would have a normal operating lake level at elevation 500 m MSL. The surface area at the normal operating lake level would be approximately 299 ha. With the minimum operating lake level at elevation 480 m MSL, the surface area would be approximately 197 ha. At the maximum flood storage lake level at elevation 504 m MSL, the surface area would be approximately 318 ha. The area at elevation 505 m MSL, top of dam, will be approximately 324 ha.

CLEARING AND / OR GRUBBING

Clearing and grubbing would be necessary for construction of the dam (embankments and spillway), inter-basin transfer facilities, outlet works, hydropower plants, access roads, and disposal and staging areas. Clearing only would be required for the 109 ha in the lake area between the normal operating lake level at elevation 500 m MSL and the minimum operating lake level at elevation 480 m MSL and for the power transmission line.

INTER-BASIN TRANSFER FACILITIES

A 4 m diameter tunnel would be excavated beneath the common watershed divide to connect the proposed Piedras Lake to the Panama Canal watershed in the upper reaches of the Rio Chagres watershed approximately 30 km upstream from Gatun Lake. The finished tunnel would be concrete lined, 3 m in diameter, and approximately 2.1 km in length. This tunnel would have an inlet invert at elevation 475 m MSL, and an outlet invert at elevation 450 m MSL. The maximum flow through the tunnel would be 61.3 CMS. It was assumed that rock bolting would be required over much of the tunnel length to stabilize the rock. A gate structure located at the tunnel outlet would control flow through the tunnel. The tunnel would be under pressure continually. To allow for maintenance of the tunnel and to provide for rapid closure of the tunnel, a gate / stoplog structure would be constructed at the inlet. In the process of stopping flow through the tunnel, a water hammer effect could be generated. Therefore, a series of surge protection shafts would be constructed. These shafts would require relatively minor surface structures for safety purposes. Plate 12 - 1 shows the location of the tunnel outlet.

HYDROPOWER PLANTS

The flows, excess to the needs of the canal operation, at the proposed Rio Piedras Dam would support installation of a 2.8 MW hydropower plant at the dam for Option 1 and a 2.5 MW hydropower plant at the inter-basin transfer tunnel outlet. These facilities would be designed and configured to function as part of the national power grid. A transmission line would be required to carry the energy to a connection with the grid near Colon. Plate 12 - 2 shows the location of the hydropower plant at the dam.

OUTLET WORKS

An outlet works system would be required to provide for diversion of the Rio Piedras 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 system would include a 4.7 m by 4.7 m horseshoe shaped tunnel passing through the dam abutment, a control structure constructed in a vertical shaft within the left abutment, an outlet channel downstream, and various gate structures and water conduits.

This outlet works system would be included in a single control structure constructed in a vertical shaft in the right abutment. This structure would be configured to allow passage of channel flows up to the required level of protection during construction. Once diversion was no longer needed for construction, the structure would be used to control the flows for hydropower and emergency drawdown. It would also have separate controlled water intakes to allow flows to be withdrawn from the lake at various elevations to optimize the quality of the water passed as minimum flow. The hydropower intake would be elevated above the valley floor to protect the hydropower equipment from the adverse effects of silt.

The diversion tunnel would be 1,215 m in length; it would have an inlet invert at elevation 380 m MSL and an outlet invert at elevation 320 m MSL. The diversion tunnel would serve in combination with the cofferdam to protect the construction area from floods up to a 10 percent frequency. A 10 percent frequency flood would deliver a peak flow of 381 CMS at the site without regulation from the dam. The cofferdam would measure 10 m above the upstream invert of the tunnel. A separate 355 mm diameter conduit, required for minimum flow, would be installed beneath the floor of this tunnel. The minimum flow conduit would be 1,215 m in length; it would have an inlet invert at the control shaft at elevation 379 m MSL with intakes placed along the face of the abutment at various levels for water quality. The outlet invert would be at elevation 319 m MSL. The capacity of the minimum flow conduit would be 0.233 CMS. A bulkhead structure would be required at the tunnel outlet to close the construction diversion and to divert flows from the lake into the hydropower conduit. The closure would be configured so that it could be removed in the event that the Piedras Lake had to be drawn down.

ACCESS ROUTE

Access to the lake site and the various construction sites was evaluated from the nearest population center, Colon, on the Atlantic coast.

The route from Colon would be eastward along Panama Route 77 and then southward along the west bank of the Rio Piedras to a point approximately 1 km north of the confluence of the Rio Piedras and the Rio Mango Indio. From this point, the route would turn eastward, crossing the Rio Piedras and traversing the highlands to the dam site. The route eastward from Colon would require a new roadway from the mouth of the Rio Piedras to the dam site and from there to the tunnel entrance and exit sites. The access road to the dam site would be approximately 8 km in length and would have to be cut through heavy jungle for most of the way, except for the first 1.5 km where there is an existing trail. The only stream crossing required along this route would be the Rio Piedras crossing. Continuation of access within the construction area to the tunnel entrance would require approximately 5 km of additional access road through thick jungle and very rugged terrain and crossing some eight minor streams along the way. Further access to the tunnel outlet point would require approximately 5 km more of roadway.

In providing construction access, it is noted that this new corridor into the interior of the country east of the Panama Canal would open up an heretofore undisturbed area of primary forest and would be deleterious to the ecology of the area.

Sources of Construction Material

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

Cement would be available within the Republic of Panama. Rock obtained from the construction site or from the lake area would be used for onsite manufacture of concrete aggregates. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) would be fabricated outside the Republic of Panama and imported for final assembly and installation at the proposed dam site.

Real Estate Requirements

The proposed Rio Piedras project would be located in the Portobelo District of the Colon Province. Construction of this proposed project would require 1,124 ha. Table 12 - 1 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 12 - 1 Real Estate Requirements

Project Feature	Land Required (ha)
Lake	324
Dam Site & Staging Area	200
Housing and Facilities	200
Disposal Area	400
Total	1,124

Relocations

The lake would be located in a sparsely settled region with few roads and utilities. This area is primary forest having no local development and no apparent inhabitants. Thus, no significant relocations should be required in the project area.

Hydrologic Reliability

This alternative did not pass the first criterion in the initial assessment process described in Section 4. The first criterion requires that the project provide a constant firm yield equivalent to at least one lockage per day.

To determine the potential water yield for the Piedras Lake, single basin HEC-5 models were developed for the options defined below. Monthly discharge data for the proposed Rio Piedras dam site, as described in the section titled Hydrologic Conditions, were used as input to the simulation models. Elevation-volume values at the proposed Rio Piedras dam sites were developed from existing 1:50,000 scale topographic mapping.

- Operating Option 1 (Piedras Lake fluctuating between the normal operating lake level at elevation 500 m MSL and the minimum operating lake level at elevation 480 m MSL), and
- Operating Option 2 (Piedras Lake fluctuating between the normal operating lake level at elevation 400 m MSL and the minimum operating lake level at elevation 380 m MSL).

The firm yield was determined by using a constant diversion from Piedras Lake, while always maintaining the minimum downstream flow requirement and not allowing the lake to drop below the minimum lake operating level. In addition, the lake was allowed to recover its full storage within 4 to 5 years. The HEC-5 models were optimized to determine the greatest constant diversion based on the available hydrologic records (Jan. 1948-Jul. 1998). The results for each option are shown in Table 12 - 2.

Table 12 - 2 Constant Firm Yield

Option	Lake Range (m)	Minimum Flow (CMS)	Average Evaporation (CMS)	Firm Yield (CMS)	Additional Lockages Per Day*
Option 1	500-480	0.233	0.10	1.27	0.53
Option 2	400-380	0.233	0.02	0.42	0.18
*Lockages are based on 55 million gallons for one ocean to ocean transit.					

Summary

This alternative does not meet the first assessment criterion, which is to provide at least one lockage per day. Therefore, further consideration of this alternative is not recommended.

Pertinent Data

Table 12 - 3 presents pertinent data for the proposed Rio Piedras project with normal operating pool at elevation 500 m MSL.

Table 12 - 3 Pertinent Data for Operating Pool Elevation 500 m MSL

GENERAL	
Dam site, above mouth of Rio Piedras	12 km
Drainage area above dam site	39 km^2
Average annual flow at dam site	2.3 CMS
LAKE	
Elevation of normal operating lake level	500 m MSL
Elevation of maximum flood storage lake level	504 m MSL
Elevation of minimum operating lake level	480 m MSL
Useable Storage between Min and Max levels	52.67 MCM
Area at normal operating lake level	299 ha
Area at maximum flood storage lake level	318 ha
Area at minimum operating lake level	190 ha
Top clearing elevation	500 m MSL
Lower clearing elevation	480 m MSL
EMBANKMENTS	
Dam	
Type of dam	Rock fill embankment
Top elevation of dam	505 m
Fixed crest width	13 m
Height	145 m
Overall length of dam	1,090 m
SPILLWAY	
Type of Spillway	Uncontrolled ogee
Total length	40 m
Elevation of spillway	500 m MSL
Maximum discharge	624 CMS
INTER-BASIN TRANSFER TUNNEL	
Tunnel diameter	3 m
Tunnel length	2.1 km
Inlet invert	475 m MSL
Outlet invert	450 m MSL
Tunnel capacity	61.3 CMS

Table 12 - 3 Pertinent Data for Operating Pool Elevation 500 m MSL (continued)

HYDROPOWER PLANTS	
Dam	
Type of hydropower plant construction	Reinforced concrete
Number of units	1
Capacity of each unit	2.8 MW
Inter-basin Transfer Tunnel	
Type of hydropower plant construction	Reinforced concrete
Number of units	1
Capacity of unit	2.5 MW
CONSTRUCTION / POWERHOUSE DIVERSION	
Diversion length	1,215 m
Horseshoe tunnel dimensions	4.7 m x 4.7 m
Inlet invert	380 m MSL
Outlet invert	320 m MSL
Cofferdam Elevation	390 m MSL
MINIMUM FLOW CONDUIT	
Conduit diameter	356 mm
Conduit length	840 m
Inlet invert	360 m MSL
Outlet invert	319 m MSL
Conduit capacity	0.42 CMS

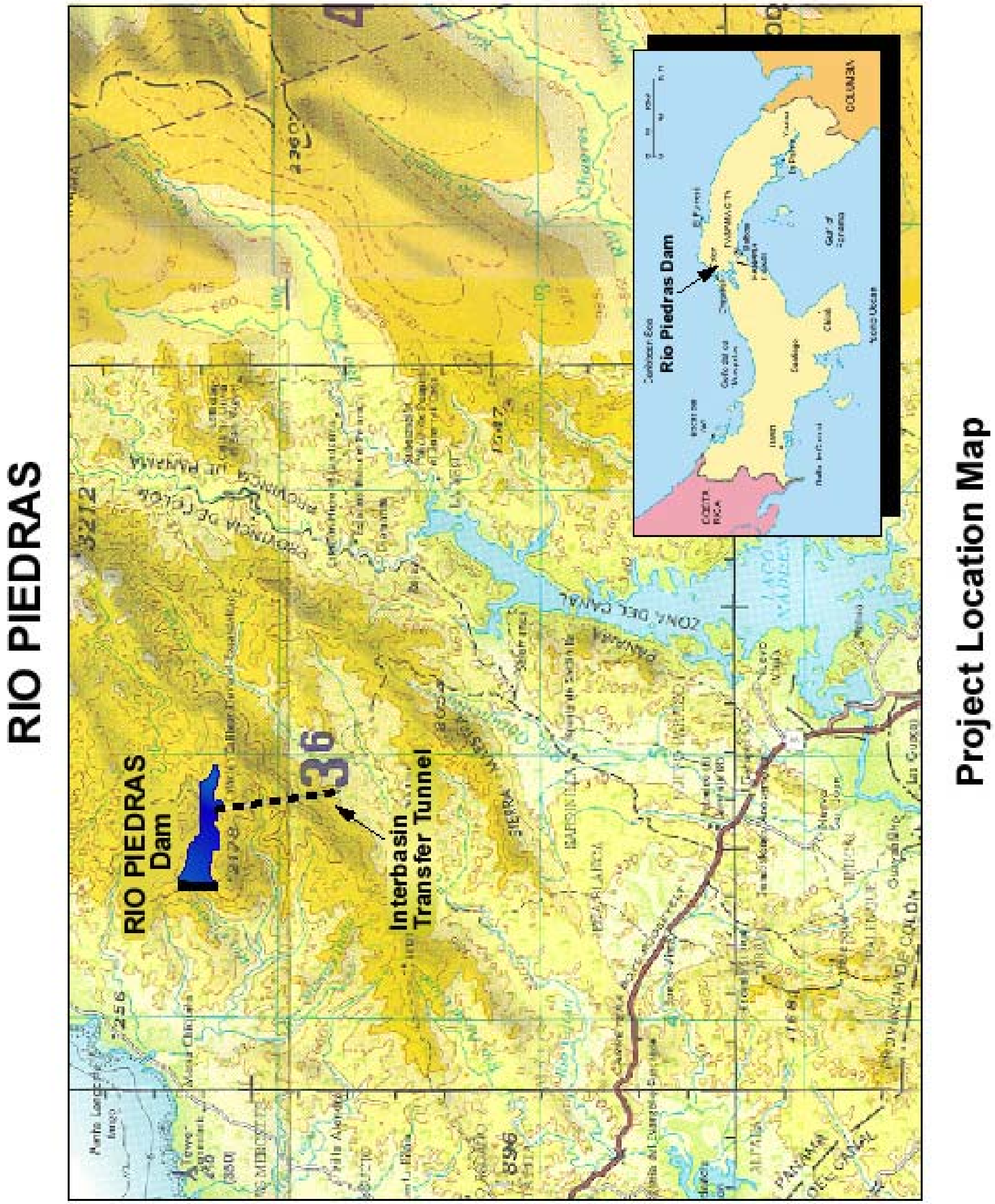


Plate 12 - 1   Project Location Map

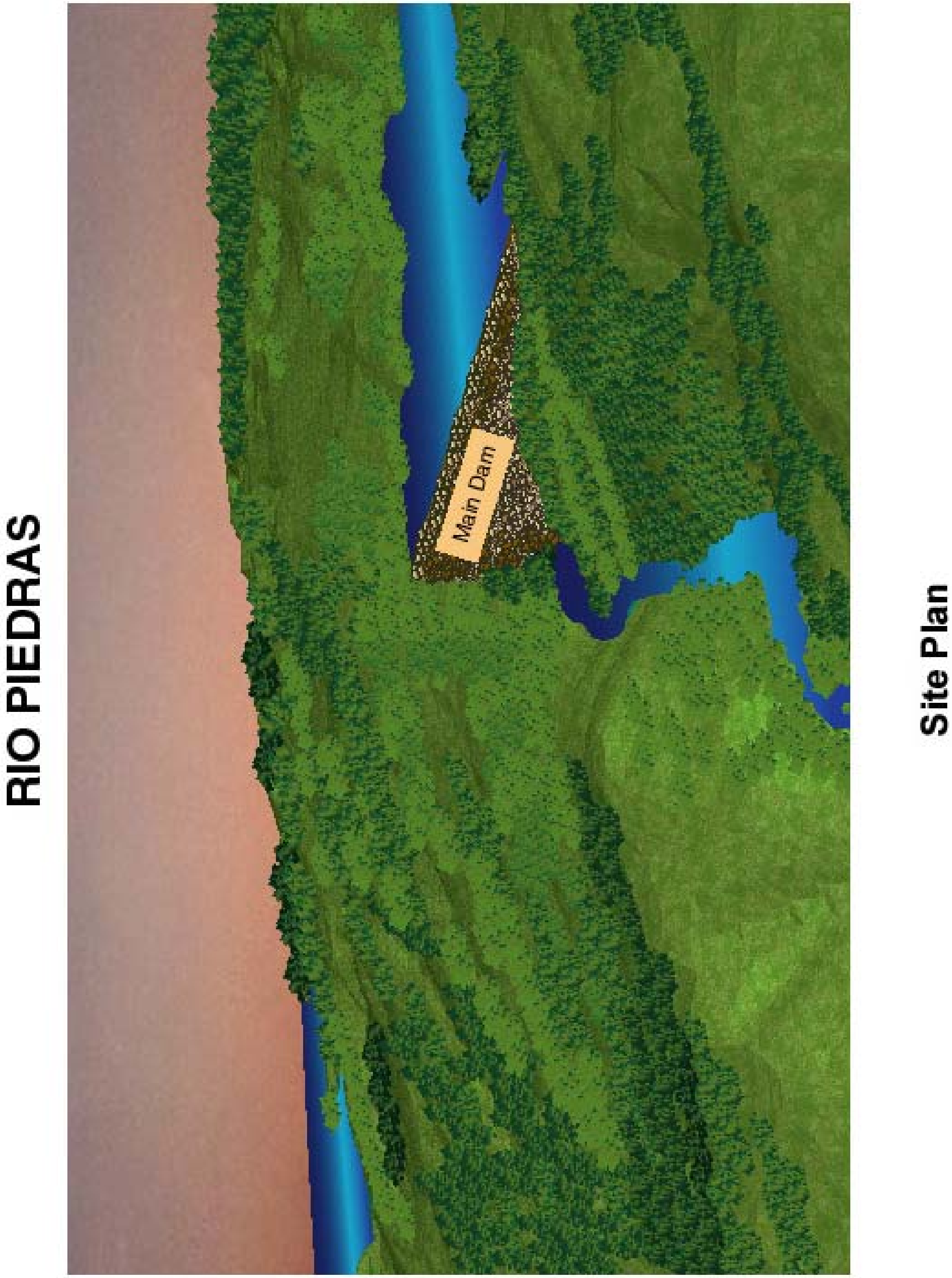
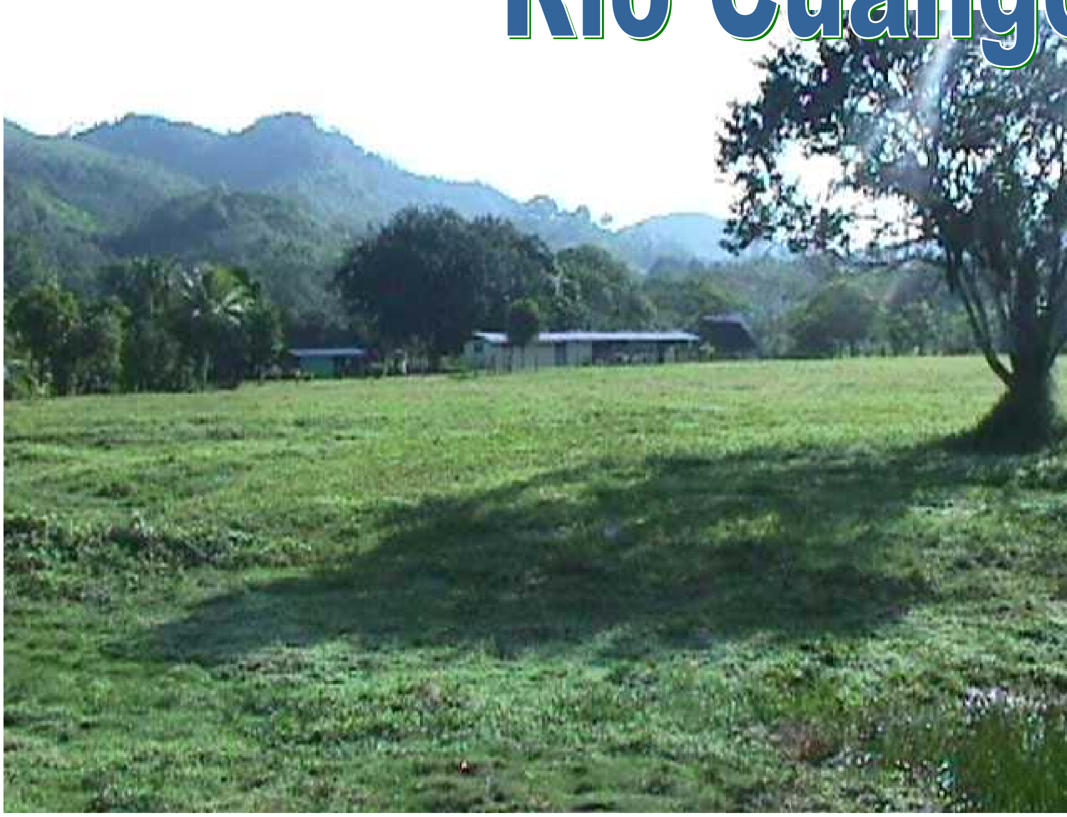


Plate 12 - 2 Site Plan

SECTION 13

Rio Cuango



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Synopsis

The Rio Cuango drains a small watershed located on the Atlantic coast of the Republic of Panama and east of the Panama Canal watershed. The watershed is located approximately 65 km east northeast of the city of Colon. Colon is on the eastern side of the Panama Canal and is at the Atlantic entrance to the Panama Canal. The Rio Cuango flows northeastward out of the eastern mountains and then northwestward to the Atlantic Ocean. The proposed Rio Cuango dam site would be located approximately 10 km inland from the Atlantic Coast (approximately 12 km measured along the river channel).

The structures for the proposed Rio Cuango project would consist of a rock fill dam, an uncontrolled ogee spillway, inter-basin transfer facilities, a hydropower plant at the dam, and outlet works. The tunnel would transfer water from Cuango Lake to the Panama Canal watershed as needed for canal operations.

The proposed Rio Cuango project appears to have the potential to contribute to the hydrologic reliability of the Panama Canal by reducing the need for draft restrictions and light loading of vessels during traditional periods of low water availability. The existing hydrologic reliability of the Panama Canal, based on the 50.5-year period of record from January 1948 through July 1998, is approximately 99.6 percent. The hydrologic reliability with a demand ratio of 1.2 (46.42 lockages) would be 98.8 percent. The analysis shows that, with Rio Cuango contributing to the operation of the Panama Canal, the reliability of 99.6 percent could be maintained up to an increase of 9.5 percent (3.67 lockages) of current demand levels on the system. Hydrologic data were very limited for this site and did not permit an appropriate level of analysis. Additional data are needed to verify this conclusion, and to bring this project into parity with others presented in this report.

The amount of hydropower that could be produced by the system of Gatun Lake and Madden Lake would decline over time as the demands for navigation and M&I water increase. Some net additional megawatt hours of hydropower could be realized in the system with the inclusion of the proposed Rio Cuango project.

Topographic and hydrologic data for this project were limited. If this project is considered for further development, additional topographic and hydrologic data should be acquired. This analysis should be verified and refined such that it can be equally compared to other alternatives presented in this report.

Because of the limited hydrologic and topographic data, the plan for development of the Rio Cuango was not pursued further, and was eliminated from the list of technically viable projects to be subjected to further scrutiny in this report. No formal cost or economic analyses were made of this alternative. If the apparent potential of this project is borne out by further data gathering, economic and environmental evaluation could prove it to be a valuable addition to the water supply resources of the Panama Canal.

Site Selection

The proposed Rio Cuango dam site was chosen 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. To maximize the water impounded, it was desirable to locate the dam as far downstream in the Rio Cuango watershed as possible. In choosing a site for the dam, a location was sought where the surrounding hillsides were relatively steep and high, and the valley was relatively narrow.

The site chosen for the proposed Rio Cuango project would accommodate construction of a dam with a normal operating lake level at elevation 100 m MSL and a maximum flood storage lake level at elevation 104 m MSL. Plate 13 - 1 shows the location of the proposed Rio Cuango project. Topographic data were very limited in this area and any quantity calculations are subject to contingencies.

Hydrologic Considerations

The Rio Cuango flows northeastward from the high mountains east of the Panama Canal watershed, then northwestward to the Atlantic Ocean. The headwaters of the watershed begin at elevation 600 m MSL approximately 15 km upstream of the dam site and fall to mean sea level at its mouth. The average annual rainfall over the Rio Cuango watershed is 4,000 mm. The proposed Cuango Lake would receive runoff from approximately 73.9 km^2 of the upper portion of the watershed.

Sixteen years (Jan. 1980 to Dec. 1996) of hydrologic data at the Cuango gage were extrapolated from four years of staff gage data on the Rio Cuango. The four years of record for this gage was not continuous and included many months with missing data. The gage is located downstream of the dam site and has a drainage area of 126 km^2. Data gaps in the period of record were filled by hydrologic correlation to the gage at Candelaria on the Rio Pequeni. Based on this extrapolated hydrologic data, it was predicted that rainfall runoff would produce an average annual flow of 9.2 CMS at the proposed dam site.

Because of the extremely short period of record available at Cuango and limited topographic data for the basin, the complete 50.5-year period of record used in the hydraulic reliability analysis could not be developed with any degree of certainty. Therefore, the following analysis is not considered comparable to other analyses in this report for which much longer periods of record were available. In order to bring this project into parity with others, additional data collection is needed.

Geologic Considerations

The proposed Rio Cuango project is located east of the Panama Canal in an area covered by Cretaceous aged intrusive igneous rocks, reportedly consisting of diorites, gabros, monzonites and ultrabasics. Little geological information has been located concerning these rocks, nor was the site visited during this study. If this project is carried forward, the quality of the rock and depth of weathering should be investigated early in the process.

Lake Operation

The operating condition presented includes a water surface fluctuating from the normal operating lake level at elevation 100 m MSL down to the minimum operating lake level at elevation 90 m MSL. This would yield 53,220,000 M^3 of useable storage. The maximum lake level, during flood conditions, would be at elevation 104 m MSL. The volume between the maximum lake level and the normal operating lake level would be used to store flood waters and reduce peak flood flows. Some reduction in flooding would be realized in areas along the Rio Cuango downstream of the dam. Because of the relatively small size of this lake, only one operating alternative was considered.

Project Features

GENERAL

The structures considered for this proposed project would consist of a rock fill dam, an uncontrolled ogee spillway, inter-basin transfer facilities, a hydropower plant, and outlet works. The following paragraphs provide a description of the proposed structures and improvements.

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 proposed project is carried into the planning studies, optimization of the project features and improvements must be accomplished.

EMBANKMENTS

Dam

The embankment will have a crest elevation of 105 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 1049184 north and 684446 east. The right abutment would be 1048455 north and 684829 east coordinates. The embankment would be constructed with an impervious earthen core encased in rock fill, and the final side slopes would be 2 horizontal on 1 vertical. The dam at its highest point would be approximately 50 m, and the overall length would be 823 m. The total fill required to complete the dam would be 3,094,500 M^3. The actual side slopes and crest width 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. Plate 13 - 2 shows the dam site in perspective view from the downstream left side.

Foundation grouting will 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 could provide seepage cutoff in the embankment foundations. A concrete or bentonite cutoff wall could also provide seepage cutoff.

Saddle Dams

No saddle dams would be required to complete the lake impoundment.

SPILLWAY

An uncontrolled ogee spillway with a length of 105 m and a crest at elevation 100 m MSL would be required. The spillway crest would be 5 m below the elevation of the top of the dam. The maximum discharge from the spillway would be 1,629 CMS at a maximum lake level at elevation 104 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 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. A stilling basin would be excavated into the rock adjacent to the natural channel at the downstream end of the tailrace channel for energy dissipation.

IMPOUNDMENT

The lake formed by the proposed Rio Cuango Dam would have a normal operating lake level at elevation 100 m MSL. The surface area at the normal operating lake level would be approximately 646 ha. With the minimum operating lake level at elevation 90 m MSL, the surface area would be approximately 418 ha. At the maximum lake level with flooding, elevation 104 m MSL, the surface area would be approximately 737 ha.

CLEARING AND / OR GRUBBING

Clearing and grubbing would be required for all areas required for construction of the dam (embankments and spillway), inter-basin transfer facilities, other outlet works, hydropower plants, access roads, and disposal and staging areas. Clearing would only be required for the 319 ha in the lake area between the maximum operating lake level at elevation 104 m MSL and the minimum operating lake level at elevation 90 m MSL and for the power transmission lines.

INTER-BASIN TRANSFER FACILITIES

Use of a gravity tunnel was considered for transport of water from Cuango Lake to the Panama Canal watershed upstream of Madden Lake. A 3.5 m diameter tunnel would be excavated beneath the common watershed divide to connect the proposed Cuango Lake to the Panama Canal watershed. The finished tunnel would be concrete lined, 3 m in diameter, and approximately 27 km in length. This tunnel would have an inlet invert at elevation 85 m MSL, and an outlet invert at elevation 80 m MSL. The maximum flow through the tunnel would be approximately 8.4 CMS. It was assumed that rock bolting would be required over much of the tunnel length to stabilize the rock. A gate structure located at the tunnel outlet would control flow through the tunnel. The tunnel would be under pressure continually. To allow for maintenance of the tunnel and to provide for rapid emergency closure of the tunnel, a gate structure would be constructed at the upstream end. In the process of stopping flow through the tunnel, a water hammer effect could be generated. Therefore, a series of surge protection shafts would be constructed. These shafts would require relatively minor surface structures for safety purposes. Plate 13 - 1 shows the location of the tunnel outlet.

Pumping water from the Cuango Lake over the divide into the uplands above Madden Lake was also considered. A quick overview of the area indicated that this would require the water to be raised approximately 600 m above the proposed level of Cuango Lake. In addition to the magnitude of this pumping operation, other factors considered included the initial expense of installing pumps and pipelines. Also of concern were, the remote location and the implications this would have on maintenance of the pumping equipment, the need to constantly supply power for pumping, and the need to properly care for a large volume of water as it is introduced into the uplands above Madden Lake.

Because of the complexity of the pumping alternative and the apparent expense involved, the gravity tunnel alternative was the only one considered in further detail.

HYDROPOWER PLANTS

The flows from the proposed Cuango Lake, excess to the needs of the canal operation, would support installation of a 0.4 MW hydropower plant at the dam. This facility would be designed and configured to function as part of the national power grid. Transmission lines would be required to carry the energy to a connection with the grid near Colon.

OUTLET WORKS

An outlet works system would be required to provide for diversion of the Rio Cuango flows during construction, to supply flows for production of hydropower, to allow for emergency drawdown of the lake, and to pass minimum flow to the river downstream of the dam.

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 would be used to control the flows for hydropower and emergency drawdown. It would also have separate controlled water intakes to allow flows to be withdrawn from the lake to optimize the quality of the water passed as minimum flow.

This system would include a horseshoe shaped tunnel passing through the dam abutment, an intake structure located in the lake, an outlet channel downstream, and various gate structures and water conduits. The diversion tunnel would serve in combination with the cofferdam to protect the construction area from floods up to a 10 percent frequency. A 10 percent frequency flood would deliver a peak flow of 693 CMS at the site without regulation from the dam. The pool provided by the cofferdam would provide some regulation. A separate 436 mm diameter conduit for minimum flow would be installed beneath the floor of this tunnel. The capacity of the minimum flow conduit would be 0.91 CMS at normal maximum lake level. A bulkhead structure would be required at the tunnel outlet to close the construction diversion tunnel to accommodate the minimum flow outlet and to divert flows from the lake into the hydropower conduit. The closure would be configured so that it could be removed in the event that the Cuango Lake had to be drawn down.

ACCESS ROUTE

Access to the lake site and the various construction sites was evaluated from the nearest population center, Colon, on the Atlantic coast.

Because of the high mountains surrounding the proposed reservoir area, it is apparent that the easiest land route from Colon would be eastward along the existing Panama Route 77 to the village of Portobelo. Available mapping indicates that land access from Portobelo eastward to the village of Cuango would require significant roadway improvement. A new access road would be required from Cuango Village approximately 12 km along the bank of the Rio Cuango to the proposed dam site. From the dam site, the route would continue along the south side of the proposed reservoir, approximately 3 km to the site of the inter-basin transfer tunnel inlet. The access road from Cuango Village would pass through heavy jungle.

A partial water route was considered as an alternate to the all land route. This would require that goods be transported by water through the Atlantic from the Colon area to Cuango Village and that adequate safe port facilities be constructed there. From this point, construction materials and equipment would be transported over a new access road as described above.

The all land route was selected for this study. This route would not require crossing the Panama Canal and would thus avoid delays in transport associated with this crossing. Also, the road construction along the coast could be more easily accomplished. Roadway construction from the coast to the construction area would be required in any case.

Sources of Construction Material

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

Cement would be available within the Republic of Panama. Rock, obtained from the construction site or from the lake area, would be used for onsite manufacture of aggregates for the concrete. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) would be fabricated outside the Republic of Panama and imported for final assembly and installation at the proposed dam site.

Real Estate Requirements

The proposed Rio Cuango project would be located in the eastern end of the Colon Province. Construction of this proposed project would require 1,760 ha. Table 13 - 1 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 13 - 1 Real Estate Requirements

Project Feature	**Land Required** (ha)
Lake	760
Dam Site	200
Staging Area	200
Housing and Facilities	200
Disposal Area	400
Total	1,760

Relocations

The lake would be located in a sparsely populated region with few roads and utilities. This area is primary forest having no local development and no apparent or very few inhabitants. Thus, no significant relocations should be required in the project area.

Development Sequence

No development sequence was developed for this project. This would be accomplished at a later time, should sufficient hydrologic data be gathered to support the basic plan presented herein as viable.

Hydrologic Reliability

In order to determine the effect of the proposed Cuango Lake on the hydrologic reliability of the Panama Canal, the existing HEC-5 model of the Panama Canal was used with water from the Cuango Lake provided to Madden Lake as a constant inflow.

A two step process was used to determine the additional water supply that the Cuango Lake would provide to the canal operation. Since only 16 years of hydrologic data were available for the Rio Cuango basin and its correlation with Candelaria was relatively weak (R2=0.8), the first step determined the constant firm yield for Cuango Lake by using an accumulative mass analysis. This approach considers a progressive sum of the flow at the site and a constant withdrawal over the existing period of record. These curves are balanced such that the maximum negative difference of summed flows less summed withdrawals reflects the total conservation storage in the reservoir. Figure 13 - 1 below illustrates this analysis. The critical period was from February 1985 through November 1986. This produced a firm yield of 7.96 CMS.

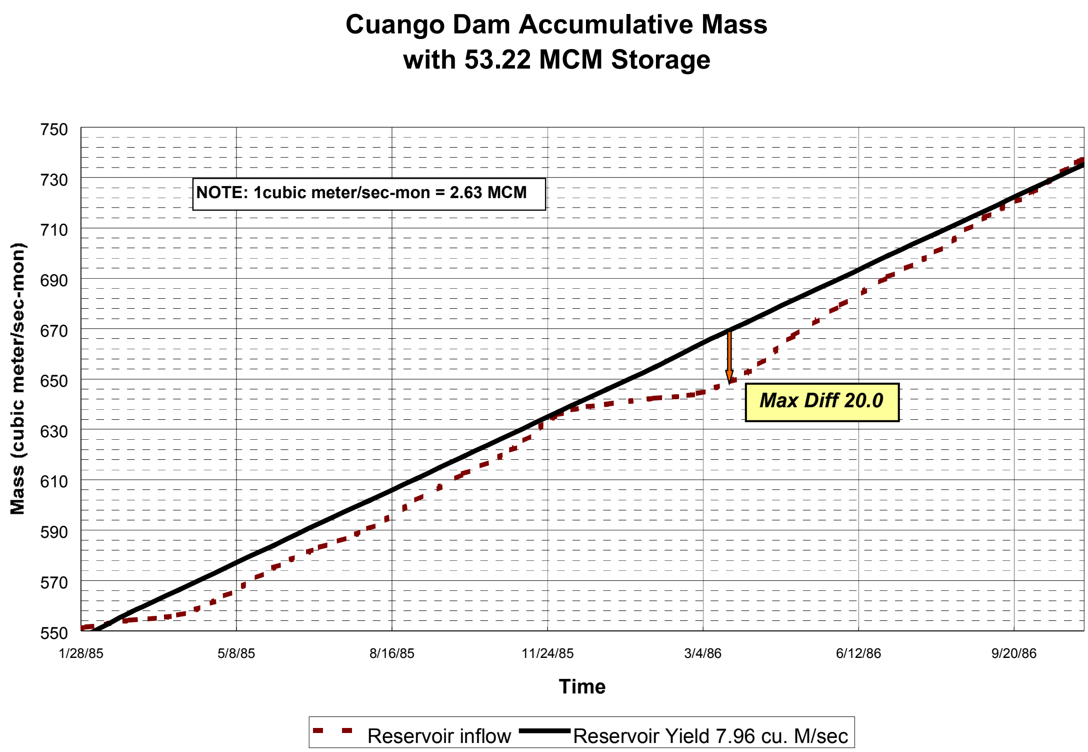


Figure 13 - 1 Accumulative Mass Analysis

In step two, HEC-5 model simulations were conducted for the existing canal system and the system operating with the proposed Cuango Lake providing water to the Panama Canal watershed. Water for the Cuango Lake was represented by reducing the withdrawals (diversions) from Madden Lake by the 7.97 CMS for each month. This resulted in negative diversions thus providing a net increase in flow to the basin. The simulations considered proportionally increasing demands up to 180 percent of current demand levels. The period of simulation considered 50.5 years (1948 through 1998) of hydrologic record.

The existing hydrologic reliability of the Panama Canal, based on the 50.5-year period of record, is approximately 99.6 percent, while the hydrologic reliability with a demand ratio of 1.8 would be 86.3 percent. This period of record includes the first six months of the 1998 drought year. The hydrologic reliability with a demand ratio of 1.0 would be 99.85 percent with Rio Cuango waters included, and the hydrologic reliability with a demand ratio of 1.2 would be 99.32 percent.

Without additional water supplies, the hydrologic reliability of the canal system would decrease. With the construction of the proposed Rio Cuango project, the existing high hydrologic reliability could be continued as demand for lockages increases up to 9.5 percent above current demand levels which represents an increase of 3.67 lockages per day.

Socio-Economic Impacts

Because of the nature of this project, its socio-economic impacts could be minor. Indigenous groups of people are known to reside in the impact region and would be impacted by this project. The surface area of the proposed lake will encompass 737 ha with another 800 ha for the dam and construction areas including permanent disposal areas.

Environmental Setting

The Rio Cuango project will produce hydroelectric power and provide for 3.67 additional lockages per day on a continual basis. The structures considered for this proposed project would consist of a rock fill dam, an uncontrolled ogee spillway, inter-basin transfer facilities, a hydropower plant, and outlet works. The project area encompasses the area to be flooded as well as the area downstream from the dam site. This area is very sparsely populated and is characterized by primary forests. The Rio Cuango is located east of the Panama Canal and flows northward from the Continental Divide into the Atlantic Ocean. The Rio Cuango watershed above the dam is approximately 126 km^2. The impoundment area covers approximately 737 ha composed of mostly forested land. The lake water elevation will fluctuate from elevation 90 to 104 m MSL. The transmission lines, tunnel portals, and roads associated with the project could also have environmental impacts and should be sited to minimize those impacts.

LAND USE

Rio Cuango drains a small watershed located on the Atlantic coast. The river originates in the eastern mountains and flows northeastward then northwestward to the Atlantic Ocean. The dam site would be located approximately 10 km inland from the Atlantic coast. The project would create a lake to supply water to the Panama Canal. Land-use in the area is limited. Populations in the area are sparse, with small concentrations populating the towns of Cuango (population - 119), Quebrada La Pita (population – 10) and San Juan Arriba (population - 30) below the dam site. Indigenous people could inhabit the project area. The project area contains vast expanses of primary tropical forests and rainforests.

INFRASTRUCTURE

The project area is sparsely populated, with few roads and utilities. There is no local development, and no treatment of community waste is provided. Wastewater is discharged into the environment. Disposal of domestic waste is the responsibility of individual residents. No data are available on health problems in this region, however, problems such as hepatitis, dysentery, dermatitis, intestinal parasites, and respiratory illness attributable to these waste disposal methods may occur. There are no industries, or poultry or beef processing plants in the project area. The only roads in the project area are dirt roads, which are rarely graded and receive little attention from either the Ministry of Public Works or the local government.

TERRESTRIAL HABITAT

The terrestrial habitat around Rio Cuango consists of vast expanses of primary tropical forests and rainforests. Terrestrial areas are used by migratory species as resting, breeding, and feeding habitat. The complex and diverse tropical ecosystems offer habitat to connect a variety of wildlife communities. This area is rich with species diversity and provides critical wildlife habitat to many native species of plants and animals.

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 none have been identified to date, some of the listed species might be found in the project area.

AQUATIC HABITAT

Rio Cuango contains many different types of aquatic habitat with various water depths and a wide range of water quality. It provides habitat for a variety of wildlife species both resident and migratory, as well as to native fish and other aquatic species. Forests along the banks of Rio Cuango maintain the health of the river by providing shade and bank stability. Vegetation in the river provides habitat for aquatic life and contributes to water quality. Rio Cuango contains underwater habitat in the form of fallen trees and debris.

WETLANDS

Areas that contain hydric soils and hydrophytic plant communities, and that are subject to hydrologic conditions are termed wetlands. Wetlands in the Rio Cuango project area are shallow water habitat and subject to frequent flooding. Shallow water areas along the banks of Rio Cuango receive sunlight to approximately 1 m in depth, depending on water clarity. Sunlight stimulates growth of submergent, emergent, or floating mats of aquatic vegetation. Wetlands occur in topographic areas where water remains pooled long enough to produce hydric soil conditions and wetland plant communities.

AIR QUALITY

Air quality in the project area is good, however no air quality monitoring has been implemented in the project area. The natural environment could provide indicators that could be useful in evaluating air quality.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

Indigenous people inhabit the project area; further research should be conducted and information should be gathered. 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 Rio Cuango project area would be significant. The destruction of primary tropical forests would be a significant loss to the natural resources of Panama and to the health and maintenance of the environment. Perhaps unique species of plants and animals exist within the project area and species diversity is high due to the age and complexities of the forest ecosystem. Terrestrial habitat in the project area may contain species that are currently unknown to science.

ANIMALS ON ENDANGERED LIST

The extent of potential effects on endangered species cannot be determined at this time, because it is not known how many of the listed species occur within the proposed project area. The terrestrial habitat itself, within the project area, is considered in danger of extinction. Some endangered and / or threatened species probably use the project area for some or all parts of their life cycle.

WATER QUANTITY

The impacts of the project on water quantity would be beneficial; as stored freshwater from the dam increases the volume of water available to the Panama Canal during the dry season, when navigational restrictions are imposed. The project should also reduce flooding downstream. The cumulative impacts downstream of the dam site over time should also be moderate.

WATER QUALITY

Project impacts on water quality have not been determined. Clearing and grubbing in the project area would increase the amounts of nutrients and debris in the river. The rate at which nutrients and debris enter the river would determine the severity of impact on water quality. Project implementation would increase turbidity and interfere with photosynthesis by depriving plants and other aquatic species from necessary sunlight. These conditions are expected to return to previous conditions after project completion. Aquatic plants and organisms help maintain water quality. Species inhabiting specific depths would be impacted when the river becomes a lake. The velocity of water would decrease with the dam construction, which would lead to increased sedimentation. Downstream from the dam, erosion would decrease due to a regulated minimum normal flow, and the ecology of the river would change as flow, sediment load, and species change.

DOWNSTREAM AQUATIC FAUNAL HABITAT

The impacts of the project on aquatic faunal habitat could be significant. Project implementation may impact 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. Plant populations may decrease as a result of an increase in water depth and lack of available sunlight; therefore invertebrate populations may decline, which would reduce the food supply for fish and other aquatic species. Plant communities and aquatic species would be displaced as water levels rise and currents change. New aquatic habitats and species would become established after the lake is formed and the river system is permanently altered.

FUTURE LAKE AQUATIC PLANT COMMUNITY

The impacts of the project on future aquatic plant communities would depend on water quality and water levels. Plant species existing in Rio Cuango would be impacted by the increase in depth and decrease in flow. Aquatic plant communities would be impacted during project implementation; however, colonies would re-establish themselves after construction. Exotic plant species may colonize these areas before native species can re-colonize.

AQUATIC FAUNA INHABITING AFFECTED AREAS

The impacts of the project on aquatic fauna inhabiting the Rio Cuango and its upstream tributaries could be important. If aquatic fauna are able to thrive in the new reservoir, they would be beneficially affected by having their habitat enlarged. Some unavoidable, adverse environmental impacts could occur and these impacts should be identified and appropriate mitigation measures addressed in feasibility level studies, should the alternative be recommended for further consideration. If the new reservoir is responsibly managed and stocked with game fish by the Aquaculture Department, it could provide good opportunities for recreational and subsistence fishing. An increase in fish population could cause a corresponding increase in piscivorous predators, such as crocodiles, caimans, otters, and herons, among others. Some manmade lakes in the Republic of Panama have been stocked with peacock bass and tilapia, both of which have adapted well, but several riverine native species that formerly occupied the impoundments have disappeared.

WETLANDS

The impacts to upstream and downstream wetlands could be significant. Present wetlands would become aquatic habitat; which would permanently alter the established environment. Project activities may affect wetlands by increasing depth, sedimentation, and turbidity and decreasing productivity. These impacts are detrimental to the health and sustainability of Rio Cuango. Fish and other aquatic species use shallow water areas as spawning areas as well as habitat for juvenile aquatic species. Juvenile aquatic species survive in shallow water wetland areas until they are large enough to venture out into deeper water. These areas are vital to the sustainability of Rio Cuango. Due to minimum normal flow requirements, the cumulative effects downstream of the dam site are expected to be minor.

AIR QUALITY

During construction of the dam, construction dust and emissions from equipment could impact the air quality in the project area. After construction, the air quality could improve because the Panamanian government currently discourages slash and burn activities.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

The potential impacts to cultural resources and historic properties cannot be defined at this stage of the study. Indigenous people could inhabit the project area and further research and investigations should be conducted. Prior to project implementation, surveys to locate cultural resources and historic properties should be conducted and sites should be preserved or salvaged as appropriate.

Additional Environmental Information Required

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

SOCIO-ECONOMIC IMPACTS

- Conduct an 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).
  - Indigenous people.
  - Population.
  - Community Cohesion.
  - Recreational Resources.
  - Mineral Resources.

TERRESTRIAL AND AQUATIC HABITAT

- Prepare site-specific habitat maps to ensure that all major terrestrial and aquatic habitat types are identified and quantified.
- Conduct field studies to locate rare and unique habitat features and the extent of wetlands, primary forests, rainforests, roosting sites, foraging areas, and migratory flyways.
- Determine the present quality and ecosystem value of existing habitats within the Rio Cuango project area.
- Coordinate with local experts to identify and evaluate aquatic and terrestrial habitat areas.
- Provide species inventory lists for each site area identifying their status as native or exotic and whether they are threatened and or endangered species.

ANIMALS ON THE ENDANGERED LIST

- Compile habitat maps to assess the availability and quality of suitable habitat 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 the presence of these species.

WATER QUALITY

- Since no water quality data are available for the Rio Cuango 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 is incomplete. Indigenous people inhabit the project area therefore; additional evaluation studies need to be completed to identify cultural resources and historic properties.

Pertinent Data

Table 13 - 2 presents pertinent data for the proposed Rio Cuango project with normal operating pool at elevation 100 m MSL.

Table 13 - 2 Pertinent Data for Operating Pool Elevation 100

GENERAL	
Dam site, above mouth of Rio Cuango	15 km
Drainage area above dam site	73.9 km^2
Average annual flow at dam site	9.2 CMS
LAKE	
Elevation of normal operating lake level	100 m MSL
Elevation of maximum flood storage lake level	104 m MSL
Elevation of minimum operating lake level	90 m MSL
Useable Storage between Max and Min levels	53.22 MCM
Area at normal operating lake level	646 ha
Area at maximum flood storage lake level	760 ha
Area at minimum operating lake level	418 ha
Top clearing elevation	104 m MSL
Lower clearing elevation	90 m MSL
EMBANKMENTS	
Dam	
Type of dam	Rock fill embankment
Top elevation of dam	105 m
Fixed crest width	13 m
Height	50 m
Overall length of dam	823 m
SPILLWAY	
Type of Spillway	Uncontrolled ogee
Total length	105 m
Elevation of spillway	100 m MSL
Maximum discharge	1,629 CMS
INTER-BASIN TRANSFER TUNNEL	
Tunnel diameter	3 m
Tunnel length	27 km
Inlet invert	85 m MSL
Outlet invert	80 m MSL
Tunnel capacity	8.4 CMS
HYDROPOWER PLANTS	
Dam	
Type of hydropower plant construction	Reinforced concrete
Number of units	1
Capacity of each unit	0.4 MW

Table 13 - 2 Pertinent Data for Operating Pool Elevation 100 (continued)

CONSTRUCTION / POWERHOUSE DIVERSION	
Diversion length	300 m
Horseshoe tunnel dimensions	8 by 8 m
Inlet invert	55 m
Outlet invert	54 m
MINIMUM FLOW CONDUIT	
Conduit diameter	436 mm
Conduit length	300 m
Inlet invert	54 m
Outlet invert	53 m
Conduit capacity	0.91 CMS

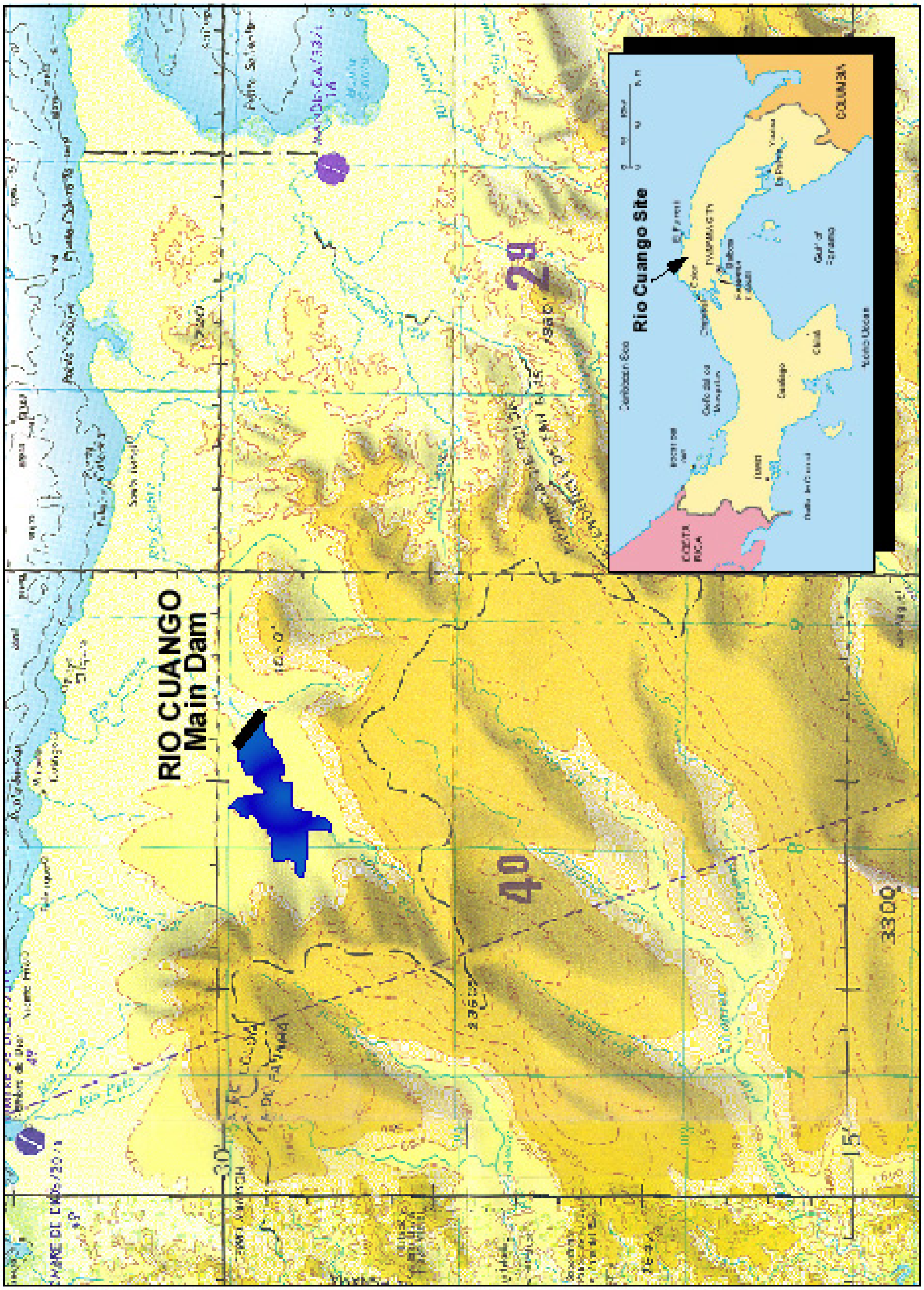
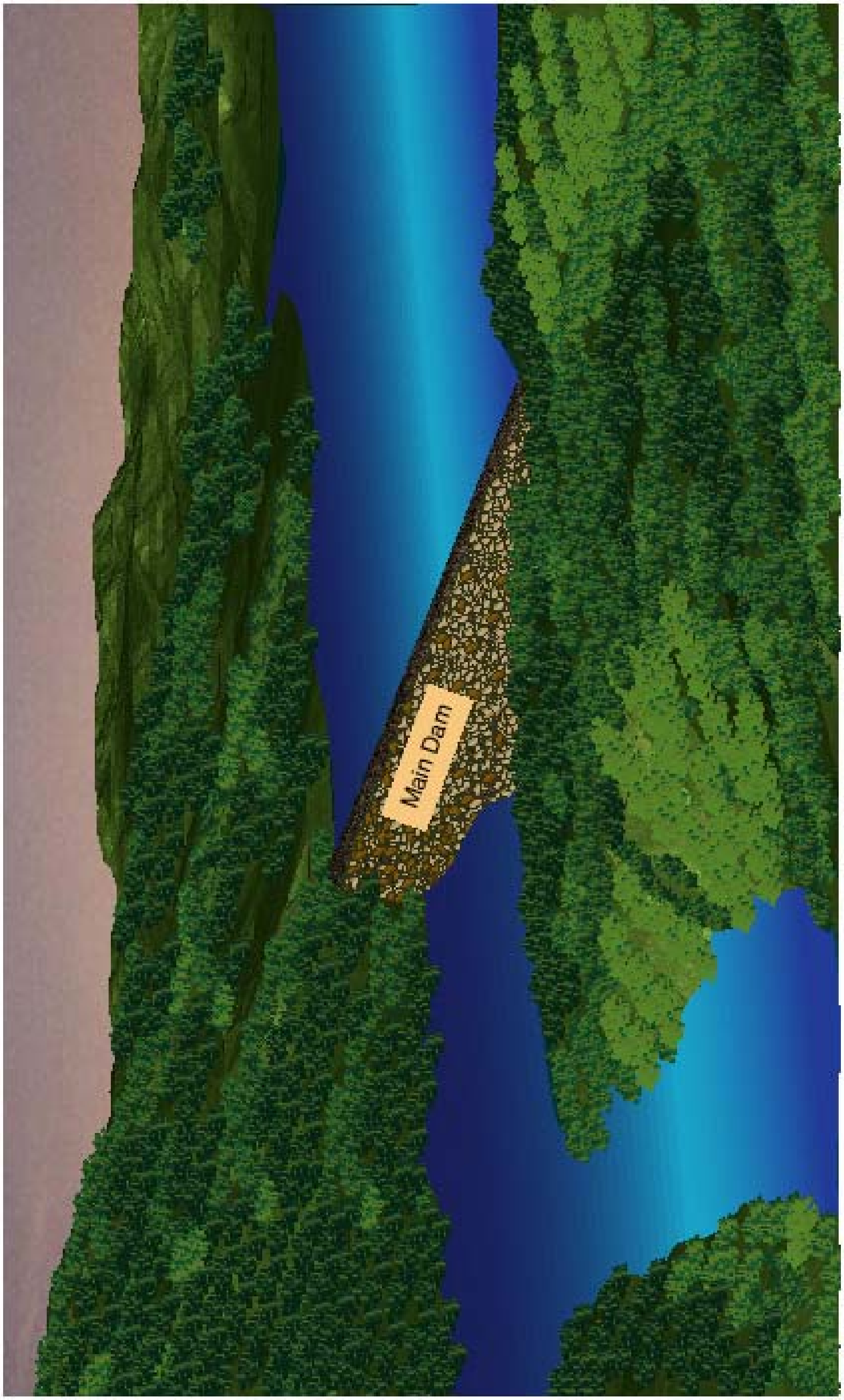


Plate 13 - 1   Project Location Map

RIO CUANGO DAM



Site Plan

Plate 13 - 2 Site Plan

SECTION 14

(M&I Water Supply Project)

Rio Caimito

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Synopsis

This alternative involves construction of a dam which creates a lake on the Rio Caimito for the purpose of supplying M&I water to areas adjacent to the Panama Canal that is, or would be withdrawing water from the canal system for M&I use. The communities Chorrera and Arraijan would be the primary recipients of water from the Rio Caimito project. Although the Caimito Lake would not be connected to the canal system, the water produced by the Rio Caimito project would offset waters that would be withdrawn from the canal system and, thus, leave more water for canal operation.

The Rio Caimito drains a small watershed located on the Pacific side of the Republic of Panama and outside the Panama Canal watershed. The proposed Rio Caimito Dam is located approximately 17 km west southwest of the city of Chorrera. The area of the watershed above Rio Caimito Dam would be approximately 136 km^2. The proposed Rio Caimito dam site would be located approximately 15 km inland from the Pacific Coast; however, the Rio Caimito turns slightly north northeast just below the damsite, flows north of Chorrera, then turns south and eventually reaches the Pacific Ocean after traveling a total of approximately 27 km.

The total project first costs of the proposed Rio Caimito project are estimated to be $277,954,000.

The traditional design approach for water supply was not used in this study. The lake was sized to provide the maximum water yield possible regardless of the local needs. It was assumed that these future increases in water supply demands would be taken from Gatun Lake if the project was not developed. Thus the proposed Rio Caimito project would, indirectly, contribute to the ability of the Panama Canal to provide water for canal operation and meet M&I demands, and would somewhat reduce the need for imposing draft restrictions and resulting light loading of vessels during traditional periods of low water availability. Because of the limited storage capacity in Caimito Lake, the project was analyzed strictly as a M&I water supply project. Water produced by the Rio Caimito project would help offset M&I water that would be withdrawn from the canal system and, thus, leave more water for canal operation. Caimito Lake would provide approximately 60 MGD (1.06 lockages) on a continual basis.

Hydropower was not considered for the Rio Caimito Dam since the lake will be used for M&I water supply. Some of the M&I water taken from Gatun Lake would be offset by the Rio Caimito project, which would help to lessen the decline in hydropower production at Gatun Lake, but the impact would be very small and was not considered as a benefit in this analysis.

Site Selection

The proposed Rio Caimito dam site was chosen 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. To maximize the water impounded, it was desirable to locate the dam as far downstream in the Rio Caimito watershed as possible. In choosing a site for the dam, a location was sought where the surrounding hillsides were relatively steep and high, and the valley was relatively narrow. Because the Rio Caimito dam site is located close to communities that need potable water and transferring of its water to the Panama Canal watershed would require a significantly long tunnel, it was determined that the project should be designed to provide M&I water to the local communities.

Some of these communities are currently using or plan to use water from Gatun Lake to meet their M&I water supply needs.

The site chosen for the proposed Rio Caimito Dam would be approximately 17 km west southwest of the city of Chorrera. This site would accommodate construction of a dam with a normal operating lake level at elevation 120 m MSL and a maximum flood storage lake level at elevation 124 m MSL. Plate 14 - 1 shows the location of the proposed Rio Caimito project.

Hydrologic Considerations

The Rio Caimito drains a small watershed located on the Pacific side of the Republic of Panama and west of the Panama Canal watershed. The Rio Caimito flows generally southeast at the dam site, turns slightly north northeast just below the dam site, flows north of La Chorrera, then turns south and eventually reaches the Pacific Ocean after traveling a total of approximately 27 km.

The headwaters of the watershed begin at elevations near 1,000 m MSL approximately 25 km inland adjacent to the Cerro Compana, travel northeast parallel to the coast and fall to mean sea level at its mouth. The distribution of the average annual rainfall over the Rio Caimito watershed varies from 1,800 to 1,900 mm across the watershed. The proposed Caimito Lake would receive runoff from approximately 132 km^2 of the upper portion of the watershed. Rainfall runoff produces an average annual flow of 4.2 CMS at the proposed dam site.

The discharge at the Rio Caimito dam site was obtained by extrapolating the recorded and correlated stream flow data of the El Trapichito hydrologic gaging station. In order to complete missing data and to increase the period of record, a statistical correlation was established with the discharge data of the Rio Trinidad at El Chorro using standard hydrologic techniques. The consistency of the data measured and correlated was satisfactorily verified using the double mass curve method.

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

Geologic Considerations

The proposed Rio Caimito project is located in an area of the Isthmus of Panama where Miocene aged volcanic rocks (andesites, basalts, breccias, and tuffs) of the Tucue Formation are encountered at the surface. A site visit made during the preparation of this report, however, found agglomerate (with basalt blocks measuring up to about 1/3 m in diameter) outcropping in the riverbed at the selected dam location and also at a small rapid located about 650 m downstream. The rock appeared to be hard and high quality. It is expected that this rock would be suitable for rock fill, and possibly for concrete aggregate. Additional commercial aggregate sources are located relatively near the dam site (within 25 km).

In the absence of detailed geologic information at the site, a degree of extrapolation was necessary. It was predicted that rock would be encountered at a shallow depth and would be of sufficient quality to serve as foundation material for the dam and appurtenant structures. It was assumed that sufficient rock for fill and concrete aggregate would be available from the required excavation and that impervious materials would be available within the immediate area for use in the construction of the project.

Lake Operation

Two operating options were considered in this study for periods when water would be transferred from Caimito Lake to the city of La Chorrera for M&I water supply. Operating Option 1 consists of the water surface of the lake fluctuating from the normal operating lake level at elevation 120 m MSL down to the minimum operating lake level at elevation 100 m MSL with 128,400,000 M^3 of useable storage. Operating Option 2 consists of the water surface of the lake fluctuating from the normal operating lake level at elevation 110 m MSL down to the minimum operating lake level at elevation 100 m MSL with 47,700,000 M^3 of usable storage. The maximum flood storage lake level would be at elevation 124 m MSL. The volume between the maximum flood storage lake level and the normal operating lake level would be used to store flood waters and reduce peak flood flows. Some reduction in flooding would be realized in areas along the Rio Caimito downstream of the dam. Table 14 - 1 shows the lake levels for the two operating options.

Table 14 - 1 Lake Operating Options

Lake Level (m MSL)	Operating Option 1	Operating Option 2
Normal Operating Lake Level	120	110
Minimum Operating Lake Level	100	100
Maximum Flood Storage Lake Level	124	114

Project Features

GENERAL

The structures for this proposed project would consist of a rock fill dam, one saddle dam, an uncontrolled ogee spillway, and outlet works, and M&I water withdrawal, transport, and treatment facilities. The following paragraphs provide a description of the proposed structures and improvements for the Rio Caimito Dam project. The major structural components indicated here are configured for operating Option 1. In some instances, the proposed structures and improvements for operating Option 1 and operating Option 2 would be slightly different. Plate 14 - 1 depicts the location of the dam, and the M&I water intake general routing of water supply piping and treatment facilities required.

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 proposed project is carried into the planning studies, optimization of the project features and improvements must be accomplished.

EMBANKMENTS

Dam

The dam would be an embankment with the top at elevation 125 m MSL for operating Option 1. The left abutment of the embankment would be located at Universal Transverse Mercator Grid, Zone 17, Clark 1866 Spheroid Coordinates 979158 north and 619763 east. The right abutment would be 979254 north and 620704 east coordinates. The embankment would be constructed with an impervious earth and rock fill core encased in a rock fill dam with final side slopes of 2 horizontal to 1 vertical and crest width of 13 m. The dam, at its highest point, would be approximately 35 m high, and the overall length would be approximately 946 m. Plate 14 - 2 shows the dam site in perspective view from the downstream left bank.

Saddle Dam

A small saddle dam would be required on the east side of the lake to complete the impoundment. The dam would have a crest width of 13 m and an elevation of 125 m MSL with 2 horizontal and 1 vertical side slopes, and an overall length of 153 m for operating Option 1. The dam construction would be similar to that of the main dam. Sections for the main and saddle dam of this project are similar to the typical section shown in Section 5.

SPILLWAY

An uncontrolled ogee spillway with a length of 83 m and a crest at elevation 120 m MSL would be required. The spillway crest would be 5 m below the elevation of the top of the dam. The maximum discharge from the spillway would be 755 CMS at a maximum flood storage lake level at elevation 124 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. A stilling basin would be excavated into the rock adjacent to the natural channel at the downstream end of the tailrace channel for energy dissipation. The typical section at the spillway would be similar to that shown for the Rio Indio Dam, Section 5.

IMPOUNDMENT

The lake formed by the proposed Rio Caimito Dam would have a normal operating lake level at elevation 120 m MSL. The surface area at the normal operating lake level would be approximately 990 ha. At the maximum flood storage lake level, elevation 124 m MSL, the surface area would be approximately 1,150 ha. With the minimum operating lake level at elevation 100 m MSL the surface area would be approximately 290 ha. The area at the elevation of the top of the dam, elevation 125 m MSL, would be approximately 1,190 ha.

CLEARING AND / OR GRUBBING

Clearing and grubbing would be required for all areas required for construction of the dam (embankments and spillway), inter-basin transfer facilities, outlet works, water treatment plants, access roads, and disposal and staging areas. Under operating Option 1, clearing only would be required for the 696 ha in the lake area between the normal operating lake level at elevation 120 m MSL and the minimum operating lake level at elevation 100 m MSL, and for the transmission lines.

M&I WATER SUPPLY FEATURES

In order to provide potable water to local water systems it would be necessary to construct a water treatment plant. Raw water would be pumped to the plant, then treated and re-pumped to La Chorrea. It is assumed that the treated water would be distributed either from the city or from the pipeline connecting the city and the treatment plant. Our objective was to deliver treated water to a point in an existing water distribution system. It was assumed that the existing water systems were adequate or that the end user would make the necessary adjustments to the system. Therefore, no water distribution system costs have been addressed in this report.

Caimito Lake would provide 60 MGD (221,000 CMD) of raw water to a potable water supply system. An intake structure and raw water pumping station would be constructed at the dam. Each of three raw water pumps would be 1,100 HP and would be capable of discharging 150,000 LPM. A 1.5 m diameter pipeline would convey raw water over a distance of 8 km to a water treatment plant. The water treatment plant would be located along Road 73 about 8 km east of the dam. Raw water and treated water pipelines would be sized for a maximum velocity of 1.5 MPS. A report entitled Optimizacion de los Sistemas de Agua Potable de Panama listed the following constituents on raw water of the Rio Camito:

pH	7.14
Turbidity (NTU)	45
Color	53
Alkalinity (mg/l)	40
Hardness (mg/l)	97
Calcium (mg/l)	38
Temperature (°C)	27

Although other processes should be considered (i.e. direct filtration) it is assumed that the treatment plant would be a conventional water treatment plant having a capacity of 60 MGD. The plant would include chemical feed and mixing, flocculation, sedimentation, filtration, disinfection, and sludge treatment. The plant would have a treated water storage capacity of 60 million gallons, or one-day storage. It is recommended that two or more tanks be used to allow maintenance to be performed without losing all the storage capacity. A treated water pumping station with three 230,000 LPM, 3,000 HP pumps would discharge into a treated water pipeline. The 2.1 m diameter treated water pipeline would extend 10 km from the plant to La Chorrera.

OUTLET WORKS

An outlet works system would be required to provide water diversion of the Rio Caimito flows during construction, to allow for emergency drawdown of the lake, and to allow minimum flow to pass through the dam.

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 was no longer needed for construction, the structure would be used to provide minimum flow and emergency drawdown of the lake. It would have separate water intake controls at various elevations to allow flows to be withdrawn from the lake to optimize the quality of the water passed as minimum flow.

This system would consists of a 5.5 m diameter tunnel passing through the right dam abutment, an intake structure located in the lake, an outlet channel downstream, and various gate structures and water conduits. The diversion tunnel would be 390 m in length; it would have an inlet invert at elevation 92 m MSL and an outlet invert at elevation 90 m MSL. The diversion tunnel would serve in combination with the cofferdam to protect the construction area from floods up to a 10 percent frequency. The cofferdam would measure 8 m above the upstream invert of the tunnel. A separate 300 mm diameter conduit, required for minimum flow, would be installed beneath the floor of this tunnel. The minimum flow conduit would be 390 m long, have an inlet invert at elevation 91 m MSL and an outlet invert at elevation 89 m MSL. The capacity of the minimum flow conduit would be 0.43 CMS. A bulkhead structure would be required at the tunnel outlet to close the construction diversion. The closure would be configured so that it could be removed in the event that the Caimito Lake had to be drawn down.

ACCESS ROUTE

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

The project location is within only a few kilometers of the Pacific coast. Therefore, access was developed from the Panama City area only.

The route from Panama City would follow the Panamerican Highway from Panama City westward to the city of El Espino. From this point, it would follow Panama Route 73 to a point immediately south of the proposed dam site where a new roadway would be constructed. The proposed access route would cover approximately 26 km from Panama City to El Espino, and 8 km from El Espino to the dam site. Approximately 5 km of new roadway would be required. Plate 14 - 1 shows the proposed access route.

In addition to providing construction access, this new corridor into the interior of the country west of the Panama Canal will be of benefit to those living in that region. It will provide ready access to main centers of commerce in the southern part of the country.

Sources of Construction Material

Rock removed from the spillway site would be used as fill in the embankment portion of the dam. Impervious materials for the core section could have to be obtained from outside the project area. For this study, it was assumed that these materials would be available locally in sufficient quantity to supply the project needs. If further study indicates that insufficient impervious materials are available, then other materials such as roller compacted concrete should be considered for construction of the dam.

Cement would be available within the Republic of Panama. Rock, obtained from the construction site or from the lake area, would be used for onsite manufacture of aggregates for the concrete. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) would be fabricated outside the Republic of Panama and imported for final assembly and installation at the proposed dam site.

Real Estate Requirements

The proposed Rio Caimito project would be located in the Cocle, Colon and Panama Provinces. Construction of this proposed project would require 1,690 ha. Table 14 - 2 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 14 - 2 Real Estate Requirements

Project Feature	**Land Required** (ha)
Lake	1,190
Dam Site & Staging area	200
Housing and Facilities	200
Disposal Area	100
Total	1,690

Relocations

The lake would be located in a rural region west of the City of Chorrera. This area is devoted primarily to farming and ranching. Structures and individuals located in the lake area below elevation 125 m MSL would require relocation because of the normal lake inundation and the need to secure the lake perimeter for flood considerations.

Development Sequence

Planning studies would be accomplished to evaluate the alternative features of each proposed project. Each potentially viable project would be evaluated to assure that the plan presented would provide all of the features required to make it functional. Each would also be assessed as to its effectiveness in meeting the project goal of providing M & I water supply withdrawals from the Panama Canal, with due recognition of any secondary benefits. Environmental assessments of the proposed projects would also be made to assure environmental acceptability of the project features. These environmental assessments would begin during the planning studies phase and would continue during the final design, advertising and award phase, and through construction of the project. The final design would be accomplished for the recommended project. After completion of the final design, plans and specifications would be prepared for the advertising and award phase.

Project implementation would begin with land acquisition and construction of the access facilities. Lands for the access roads would be acquired initially. Lands for the dam site, staging area, disposal area, pipeline right-of-way, and lake would then be acquired.

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

Construction of the dam would begin with the clearing and grubbing of the construction sites and the clearing of the lake area. Excavation for the intake structure and construction of the diversion tunnel at the dam site and the spillway would follow. Where possible, materials removed from these sites would be placed directly into the earth and rock fill portions of the dam. Once the intake structure and diversion tunnel was completed, the dam construction site would be isolated using upstream and downstream cofferdams. These would eventually become part of the main dam, and the stream would be diverted through the tunnel. The dam foundation would then be excavated and grouted, and the dam constructed. Concurrently with construction of the dam, the M & I water intake structure and appurtenances would be built / installed. Upon completion of the dam and appurtenant structures, the diversion would be stopped, and lake filling would begin. Simultaneously with this operation, the downstream gate and flow separation structure would be constructed to provide for closure of the diversion tunnel. The minimum flow conduit would also be installed through the diversion tunnel at this time. The water treatment facilities would be constructed concurrently with the dam and reservoir project and timed to begin operation immediately upon completion of the lake filling.

Upon completion of the project, all facilities would undergo trial operations followed by commissioning for service.

Considering the climatic conditions and the obstacles posed by the remote location of the construction sites and the nature of the work, it is estimated that development of this project could be completed in approximately 8 years, from initial planning to lake filling. Figure 14 - 1 depicts the development sequence of the various project features.

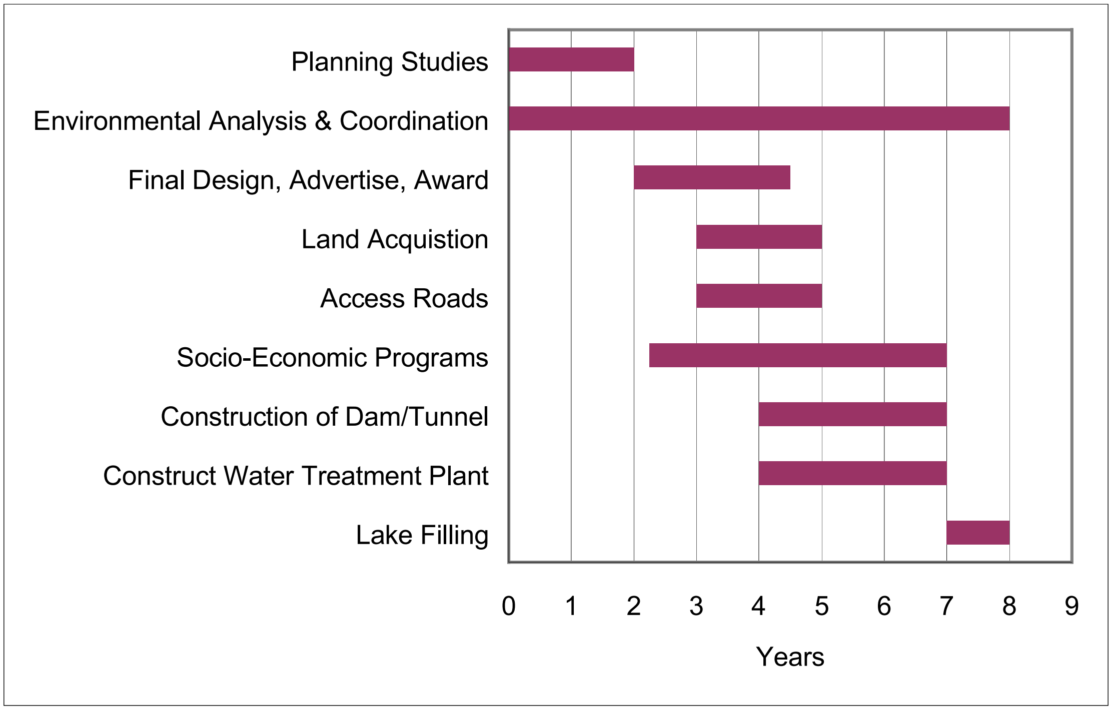

Figure 14 - 1 Development Sequence

Water Yield

The proposed Rio Caimito project was modeled using the HEC-5 Analysis Package, Simulation of Flood Control and Water Conservation Systems. The Rio Caimito Project was designed to supply M&I water to areas adjacent to the Panama Canal that is, or would be, withdrawing water from the canal system for M&I use. The communities Chorrera and Arraijan would be the primary recipients of water from the Rio Caimito project. Even though the Caimito Lake would not be connected to the canal system, the water produced by the Rio Caimito project would offset waters that would be withdrawn from the canal system and, thus, leave more water for canal operation. The Rio Caimito would not impact the reliability of the canal operation; therefore, only a constant firm yield was considered.

Monthly discharge data for the proposed Rio Caimito dam site, as described in the section titled Hydrologic Conditions were used as input to the simulation model. Elevation-volume values at the proposed Rio Caimito dam site were developed from existing 1:50,000 scale topographic mapping. The two operating options are listed in Table 14 - 3.

Table 14 - 3 Description of Operating Options

Operating Option	Lake Range (m MSL)	Dam Height (m MSL)	Spillway Length (m)
Caimito1	120-100	125	83
Caimito2	110-100	125	83

The firm yield was determined by using a constant diversion from Caimito Lake, while always maintaining the minimum downstream flow requirement and not allowing the lake to drop below the minimum lake operating level. The lake was required to recover its full storage within 4 to 5 years, excluding the 1998 drought period. The 1998 period was excluded since it is considered a drought of much lower frequency than 100-year return. A 5-year recovery period was imposed to help select a practical low flow period to design the reservoir. The HEC-5 model was optimized to determine the greatest constant diversion based on the available hydrologic records (1948 - 1998). The results for each option are shown in Table 14 - 4.

Table 14 - 4 Constant Firm Yield

Operating Option	Lake Range (m MSL)	Minimum Flow (CMS)	Average Evaporation (CMS)	Firm Yield (CMS)	Additional Lockages Per Day*
Caimito1	120-100	0.42	.32	2.55	1.06
Caimito2	110-100	0.42	.32	2.27	0.94
*Lockages are based on 55 million gallons for one ocean to ocean transit.					

Because of the 5-year recovery requirement, operating Option 1 did not utilize all of the available storage. The pool only dropped to elevation 110 m MSL; thus, only requiring 80.7 MCM of storage.

Project Costs

GENERAL

The quantities estimated for the principal features required in the construction of this proposed project were derived from similar layouts shown on the Rio Indio project Plates 5 - 3 through 5 - 9. The unit prices applied to these quantities were 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 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 and supervision and administration is estimated to be 6 percent of the construction cost features. An allowance of 2 percent of the construction costs was included for field overhead (construction camp, contractor facilities, etc.). An allowance of 25 percent was included for contingencies. The PCC provided the estimated costs of the land for the proposed project.

FIRST COSTS

The total project first costs are estimated to be $277,954,000. Table 14 - 5 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 14 - 5 Summary of Project First Costs

Principal Feature	Costs ($)
Lands and Relocations	4,225,000
Access Roads	1,760,000
Clearing and Grubbing	806,250
Interbasin Transfer Pipeline	17,033,200
Diversion Tunnel	3,131,079
Raw Water Pump/Pipe	25,210,000
Water Treatment Plant	60,000,000
Finished Water Pump/Pipe	29,200,000
Clearwater Storage Basin	10,500,000
Cofferdam	1,926,569
Dam	10,435,173
Spillway	17,764,532
Intake	1,791,900
Saddle Dam	1,519,163
Subtotal	185,302,866
E&D, S&A, Field Overhead	37,060,573
Contingencies	55,590,860
Total Project First Costs	277,954,299 **approximately** 277,954,000

OPERATION AND MAINTENANCE

Staff

A staff would operate and maintain the proposed Rio Camito project during the day and then run the facility remotely. The full-time staff would ultimately consist of a total force of 6 who would include a station manager, a leader, 3 craftsmen, and one laborer. The annual costs of the staff are estimated to be $235,000.

Ordinary Maintenance

Ordinary maintenance and care would be required and would include minor repair materials, lubricants and other supplies needed by the project staff. It is estimated that the costs of ordinary maintenance would be $20,000 per year for the access road and $100,000 per year for the main project facilities.

Major Replacements

The average service life of gates, trash racks and other features would be less than the total useful life of the proposed project, which would be 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 would cost the same as at present. No allowance was made for salvageable fixed parts. Table 14 - 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 would be $1,300,000 and the average annual replacement costs would be $157,000.

Table 14 - 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	1,650,000	5,700
Bridges	50	1	900,000	3,100
Water Supply System				
Pumps with Diesel Backup	25	2	34,230,000	1,066,000
Steel Water Lines	50	1	64,500,000	223,200
Intake				
Head Gates	50	1	375,000	1,300
Stoplogs	50	1	172,500	600
Trashracks	50	1	55,500	200
Access Stairs	50	1	42,750	100
Minimum Flow Piping	33	1	30,000	100
Total			101,955,750	1,300,000
Average Annual Replacement Costs				157,000

Annual Costs

The total project first costs are estimated to be $277,954,000. 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 total project first costs was computed from mid-year throughout the 7-year period from initiation of Planning and Design until the lake was filled. The interest during construction at 12 percent would be $89,355,000 and it was added to the total project first costs for total project investment costs of $367,309,000. A capital recovery factor for the 50-year planning period was applied to get the annual average investment costs of $44,230,000. Annual operation and maintenance costs were added. Major replacement costs are estimated and were 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 14 - 7 contains a summary of the annual costs.

Table 14 - 7 Summary of Annual Costs

Item	Costs ($)
Total Project First Costs	277,954,000
Interest During Construction	89,355,000
Total Project Investment Costs	367,309,000
Annual Average Investment Costs	44,230,000
Operation and Maintenance Costs	
Staff Costs	235,000
Ordinary Maintenance Costs	120,000
Major Replacement Costs	157,000
Total Average Annual Costs	44,742,000

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 Rio Camito project. The 50-year planning period for this proposal is 2008 to 2058.

The proposed Rio Camito project would slightly increase the reliability of providing water to accommodate the daily number of lockages demanded. Since this increase is so small, benefits associated with an increase in reliability were not estimated. The 99.6 percent level of reliability for this proposal is used to estimate the water supply benefits for navigation.

With the addition of the proposed Rio Camito project, shortages in water supply would be less. With a reliability of 99.6 percent, operating Option 1 would increase the amount of water supplied for navigation by approximately 1.06 equivalent lockages. For Operation Option 2, the amount of additional water for navigation would be 0.94 equivalent lockages. Benefits for these amounts of additional water supply 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 number of daily lockages. The average annual benefits for water supply would be $21,288,000 for Option 1 and $18,878,000 for Option 2. Table 14 - 8 provides the estimate of daily shortages under existing conditions, the remaining daily shortages with the proposed Rio Camito project in operation, the annual benefits for meeting shortages, and the average annual benefits.

Table 14 - 8 Benefits for Additional Water Supply for Navigation

Year	Daily Shortages In Lockages Under Existing System	Remaining Daily Shortages With Operating Option 1	Remaining Daily Shortages With Operating Option 2	Annual Benefits for Operating Option 1 ($)	Annual Benefits For Operating Option 2 ($)
2008	5.08	4.02	4.14	19,941,000	17,684,000
2010	6.43	5.37	5.49	20,705,000	18,361,000
2020	8.93	7.87	7.99	21,860,000	19,385,000
2030	10.87	9.81	9.93	21,860,000	19,385,000
2040	13.34	12.28	12.40	21,860,000	19,385,000
2050	16.45	15.69	15.51	21,860,000	19,385,000
2060	20.37	19.30	19.42	21,860,000	19,385,000
Average Annual Benefits				21,288,000	18,878,000
Wih Option 1, the system will provide a total of 39.74 equivalent lockages at the 99.6 percent level of reliability or 1.06 more lockages than the existing system. With Option 2, the system will provide a total of 39.62 equivalent lockages at the 99.6 percent level of reliability or 0.94 more lockages than the existing system.					

SUMMARY OF ANNUAL BENEFITS

As shown in Table 14 - 9, total average annual benefits for operating Option 1 and operating Option 2 of the proposed Rio Camito project would be $21,288,000 and $18,878,000, respectively.

Table 14 - 9 Summary of Annual Benefits

Benefit Category	Average Annual Benefits	
	Operating Option 1 ($)	Operating Option 2 ($)
Navigation – Water Supply	21,288,000	18,878,000
Navigation - Reliability	Not Estimated	Not Estimated
M&I - Reliability	Not Estimated	Not Estimated
Hydropower	None	None
Total	21,288,000	18,878,000

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 determines which proposal among several provides the greatest value for the investment dollars. While there would be small differences in some project features between operating Option 1 and operating Option 2, the differences would not have any impact on total project first costs at this level of investigation. The same facilities would be constructed for each operating option. Table 14 - 10 provides the benefit to cost ratios for operating Option 1 and operating Option 2 and the net benefits for both.

Table 14 - 10 Economic Evaluation

Item	Operating Option 1	Operating Option 2
Average Annual Benefits	$21,288,000	$18,878,000
Average Annual Costs	$44,742,000	$44,742,000
Benefit to Cost Ratio	0.5	0.4
Net Benefits	($23,454,000)	($25,864,000)

Internal Rate of Return

An internal rate of return analysis for each operating Option was performed. To accomplish this analysis, the annual construction costs were used as the investment, and the undiscounted benefits were used as return cash flows. For operating Option 1, the internal rate of return would be 6.2 percent, and for operating Option 2, the internal rate of return would be 5.4 percent.

Incremental Evaluation of Water Treatment

If only raw water is provided from this proposed project, the costs for the treatment and delivery of finished water can be subtracted from the costs of the proposal. The total first costs would then be $128,404,000. The inclusion of $42,548,000 for interest during construction yields a total investment cost of $170,952,000. A capital recovery factor for the 50-year planning period was applied to get the annual average investment costs of $20,585,000. Annual operation and maintenance costs were added. Major replacement costs are estimated and were converted to an annual cost by discounting the future replacement costs of major components of the project back to completion of the project construction. Total average annual costs would be $22,187,000.

The average annual benefits would remain the same. Once average annual 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 determines which proposal among several provides the greatest value for the investment dollars. The benefits to costs ratio for Option 1 would be 0.96 while this ratio for Option 2 would be 0.85. Neither operating scheme would provide a feasible project or positive net benefits.

Socio-Economic Impacts

The socio-economic impacts of the project could be substantial. The relocation of the towns of Santa Rita, Santa Cruz, Los Mortales, Caimito La Valdeza, and La Loma and their approximately 1,722 residents would be an important issue. The average monthly income of families in the project area is $100 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 create the Caimito Lake. The relocation of agricultural and ranching activities would be a substantial issue, because approximately 60 percent of the land in the impoundment area is used for farming and ranching. The impoundment would also substantially impact the mineral and ore resources. The surface area of the proposed lake will encompass 1,190 ha with another 500 ha for the dam site, housing for workers, and staging area 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 drop 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 should remain at the normal level.

To construct the dam, some existing roads would be improved and some new roads would be built; however, the number of unpaved roads within the impoundment area would be significantly reduced, which would change the 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 would decline. Noise levels would increase during construction and could negatively impact noise-sensitive receptors; however, after construction, noise levels should return to pre-construction levels.

The communities that would receive the 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 through the division of communities, separation of families, and loss of livelihood.

Environmental Setting

The Rio Caimito project involves the construction of a dam on the Rio Caimito for the purpose of supplying M&I water for the western section of the Panama Province. Rio Caimito Lake will provide the equivalent of approximately 1.1 additional lockages per day on a continual basis. The structures for this proposed project would consist of a rock fill dam, one saddle dam, an uncontrolled ogee spillway, and outlet works, and M&I water withdrawal, transport, and treatment facilities. The project area encompasses the area to be flooded as well as the area downstream from the dam site. This area is vastly populated. It is characterized by rolling hills, low coastal regions, and water falls that attract many visitors. The Rio Caimito is located west of the Panama Canal and flows southward from the Continental Divide into the Pacific Ocean. The Rio Caimito watershed above the dam is approximately 136 km^2. The impoundment area covers approximately 1,190 ha composed of approximately 30 percent of forested land, 20 percent of pasture land used by ranchers, 20 percent of cropland, 25 percent of newly slashed and burned land, and 5 percent of mining land. The lake water elevation will fluctuate from elevation 100 to 124 m MSL. The water pipelines and roads associated with the project could also have environmental impacts and should be sited to minimize those impacts.

LAND USE

The Rio Caimito project area encompasses the area to be flooded as well as the area downstream from the dam site. It is inhabited by about 47,760 people, dispersed throughout the area, with concentrations in the towns of Puerto Caimito (population – 1,449), La Chorrera (population – 44,444), Santa Rita (population. – 791), Santa Cruz (population – 199), Los Mortales (population – 251), Caimito La Valdeza (population – 464), La Loma (population – 17), and Caimitillo (population – 145), and approximately 10 smaller settlements. Downstream from the dam site, near Loma Las Tres Hermanas, are 10 communities with a combined population of approximately 50,000. The largest of these is La Chorrera with more than 45,000 residents.

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. Major farm crops include maize, rice, beans, sugar, coffee, and tobacco. Ranchers raise cows, horses, chickens, and hogs. Some of the farmers and ranchers operate commercial enterprises, others rely on cash crops and subsistence farming. There are also some mineral resources in the impoundment area. Existing industries use water downstream from the proposed impoundment and discharge into the Rio Caimito.

INFRASTRUCTURE

The towns of Puerto Caimito, La Chorrera, Santa Rita, Santa Cruz, Los Mortales, Caimito La Valdeza, and La Loma have elementary schools. The larger towns have cemeteries, churches, and medical centers. All towns depend on rivers or groundwater wells for their water supply. Most of the communities have electricity (from small generators) and limited telephone coverage. No treatment of community waste is provided. Wastewater from showers and washing is discharged into the environment; some of it may eventually reach the Rio Caimito and its tributaries. Disposal of domestic waste is the responsibility of individual homeowners: some homes have a septic system but most have an outdoor latrine (a hole in the ground). There are some health problems, such as hepatitis, dysentery, dermatitis, intestinal parasites, and respiratory illnesses attributable to the present waste disposal methods. Some poultry and beef processing plants are located in the project area. Some of the roads in the area are well-maintained gravel roads, others are poorly maintained dirt roads, usable only in the dry season (mid-December through March). The gravel roads are graded regularly; the dirt roads receive little attention by either the Ministry of Public Works or the local government. The dirt roads are extremely important to the residents for transportation, community cohesion, commerce, and communication with neighboring communities.

TERRESTRIAL HABITAT

About 70 percent of the land immediately adjacent to Rio Caimito and its tributaries is covered with forests along the river that could support diverse wildlife populations. The forests extend to the upper mountainous areas above the Rio Caimito impoundment area; however, as a result of slash and burn activities, there are no large contiguous tracts of forests at lower elevations.

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 it has not been determined, some of the listed species might be found in the project area.

AQUATIC HABITAT

Rio Caimito in the project area has characteristics typical of streams in mountainous regions. Its water is clear and cool, and its bed ranges from sand to boulders, with numerous riffles, runs, and pools, with accumulations of large boulders and rocks downstream from the dam site. Rio Caimito has four major tributaries: Rio Caimitillo, Rio Congo, Rio Martin Sanchez, and Rio Aquacate; approximately 22 smaller creeks also flow into Rio Caimito. The river is approximately 27 km long; its width ranges from 10 m (in the dry season) to 50 m at its mouth, and its depth ranges from less than 1 to 25 m. Rio Caimito and its tributaries support fish and benthic communities; however, information about these species in the project area is limited.

WETLANDS

Areas that contain hydric soils and hydrophytic plant communities, and that are subject to hydrologic conditions are termed wetlands. The wetlands consist of forested riparian habitat, and are limited by the relatively steep topography of the project area to the immediate vicinity of the stream banks. The width of the riparian habitat within the impoundment area varies from approximately 5 to 50 m. Approximately 70 percent of the streams above and below the dam site along the Rio Caimito and its tributaries are bordered by forested riparian habitat.

AIR QUALITY

Air quality in the project area is generally good, except during slash and burn activities. At the end of the dry season in March or early April, sizable areas of established forests and secondary growth are burned and cleared to prepare the land for agricultural use. Based on observations in the Rio Caimito project area, the amount of forested land burned varies annually.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

Some Pre-Columbian cultural resources that have been identified by archaeological surveys are located in the Caimito River impoundment area.

Environmental Impacts

TERRESTRIAL HABITAT

The impacts of the project on the terrestrial habitat in the impoundment area would be scattered, since approximately 357 ha, or 30 percent of the impoundment area is covered by patches of forest, constituting a relatively high quality terrestrial habitat. With the creation of the lake, migration routes of some species could be adversely affected. The only forests that would remain near the Caimito Lake and its drainage basin would be confined to the higher elevations.

ANIMALS ON ENDANGERED LIST

The extent of potential effects on endangered animals cannot be determined at this time because it is not known which of the listed species occur within the proposed project area. The significance of the forested riparian corridor along area streams may increase if animals on the endangered list are found in the region.

WATER QUANTITY

The impacts of the project on water quantity could be positive, because construction of the dam could result in an increase in the volume of stored fresh water in surrounding areas during the dry season. The main purpose of the dam is to provide M&I water. The impacts downstream from the dam site should be positive: water should still be released but at lower rates reducing flooding potential and significantly reducing seasonal flooding. The releases could be made at appropriate intervals and in amounts that could help reduce problems with water quality and temperature downstream. The cumulative impacts downstream of the dam site over time should also be minor.

WATER QUALITY

The impacts of the project on water quality downstream from the dam site could be positive. The water should contain less silt due to minimum normal flow and should provide people downstream with a higher-quality supply. The proposed Caimito Lake should also serve as a dependable high-quality water supply for the people living around the lake. Existing industries could cause increased degradation of downstream water quality.

DOWNSTREAM AQUATIC FAUNAL HABITAT

The impacts on the project on downstream aquatic faunal communities should be minimal, because the dam would be designed to allow releases of water from different reservoir levels which could help avoid problems with water quality and temperature downstream. The Rio Caimito dam should act as a large sediment trap, which should cause the released water to have low turbidity; therefore, siltation should not be a problem. The impacts of interference with the migratory movements of natural stream fishes are unknown. Streambed degradation below the dam should be minimal.

FUTURE LAKE AQUATIC PLANT COMMUNITY

The impacts on the project on downstream aquatic faunal communities should be minimal, because the dam would be designed to allow releases of water from different reservoir levels which could help avoid problems with water quality and temperature downstream. The Rio Caimito Dam should act as a large sediment trap, which should cause the released water to have low turbidity; therefore, siltation could not be a problem. The impacts of interference with the migratory movements of natural stream fishes are unknown.

AQUATIC FAUNA INHABITING AFFECTED AREAS

The impacts of the project on aquatic fauna inhabiting the Rio Caimito and its upstream tributaries could be important. If aquatic fauna are able to thrive in the new reservoir, they would be beneficially affected by having their habitat enlarged. Some unavoidable, adverse environmental impacts could occur and these impacts should be identified and appropriate mitigation measures addressed in feasibility level studies, should the alternative be recommended for further consideration. If the new reservoir is responsibly managed and stocked with game fish by the Aquaculture Department, it could provide good opportunities for recreational and subsistence fishing. An increase in fish population could cause a corresponding increase in piscivorous predators, such as crocodiles, caimans, otters, and herons, among others. Some manmade lakes in the Republic of Panama have been stocked with peacock bass and tilapia, both of which have adapted well, but several riverine native species that formerly occupied the impoundments have disappeared.

WETLANDS

The impacts to upstream and downstream wetlands could be significant. Owing to the topography of the project area, a number of wetlands could be impacted by the project. It is possible that even though the reservoir water levels will fluctuate, new wetlands could develop in the littoral zones. Due to minimum normal flow, the cumulative effects downstream of the dam site are expected to be minor.

AIR QUALITY

During construction of the dam, construction dust and emissions from equipment could impact the air quality in the project area. After construction, the air quality could improve because slash and burn activities are currently discouraged by the Panamanian government.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

The impacts of the project on cultural resources and historic properties could be moderate. 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 would be conducted to locate cultural resources and historic properties, and the important sites would be preserved or salvaged as appropriate.

Additional Environmental Information Required

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

SOCIO-ECONOMIC IMPACTS

- Conduct an 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).
  - Community and Regional Growth.
  - Transportation.
  - Housing.
  - Health (vector routes).
  - Population.
  - Community Cohesion.
  - Recreational Resources.
  - Mineral Resources.

TERRESTRIAL AND AQUATIC HABITAT

- Prepare site-specific habitat maps to ensure that all major types of terrestrial and aquatic habitat are identified and quantified.
- Conduct field studies to locate special 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 Rio Caimito project area.
- Coordinate with local experts regarding terrestrial and aquatic habitats.
- Provide species inventory lists for each area, identifying their status as native or exotic and whether they are threatened and / or endangered species.

ANIMALS ON THE ENDANGERED LIST

- Compile habitat maps to assess the availability and quality of suitable habitats for the animals on the endangered list.
- Establish field methodology to assess wildlife habitat values.
- Conduct site surveys to determine the presence of selected 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 Rio Caimito area, additional information should be compiled on total suspended solids, conductivity, total dissolved solids, dissolved oxygen, nutrients, pH, and coliform bacteria content of the water.

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 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 Section 35. Tables 14 - 11 through 14 - 13 present the evaluation of the proposed Rio Caimito project as related to developmental effects, environmental effects, and socio-economic effects.

Table 14 - 11 Developmental Effects

Evaluation Criteria	Function	Measure [1/]	Importance [2/]	Composite [3/]
Water Contribution (Water Yield)	Meets M&I Demands	1	10	10
	Supplements Existing System	0	10	0
	Satisfies Future Canal Needs/Expansion	0	10	0
	Additional Hydropower Potential	0	5	0
Technical Viability	Design Constraints	9	6	54
	Feasibility of Concept	10	6	60
Operational Issues	Compatibility	10	6	60
	Maintenance Requirements	10	2	20
	Operational Resources Required	8	2	16
Economic feasibility	Net Benefits	0	9	0
	Total			220

[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 14 - 12 Environmental Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Terrestrial Habitat	4	8	32
Animals on Extinction List	4	10	40
Water Quantity Impacts – Lake	9	10	90
Water Quantity Impacts - Downstream	4	7	28
Water Quality	5	10	50
Downstream Aquatic Fauna Habitat	4	8	32
Future Lake Aquatic Plant Community	7	8	56
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	5	10	50
Total			465

[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 14 - 13 Socio-Economic Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Land Use	2	7	14
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	2	8	16
Community Cohesion	1	8	8
Tourism	6	5	30
Total			333

[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 14 - 14 presents pertinent data for operating Option 1 of the proposed Rio Caimito project.

Table 14 - 14 Pertinent Data for Operating Option 1

GENERAL	
Dam Site, above Mouth of Rio Caimito	27 km
Drainage Area above Dam Site	136 km^2
Average Annual Flow at Dam Site	4.2 CMS
LAKE	
Elevation of Normal Operating Lake Level	120 m MSL
Elevation of Maximum Flood Storage Lake Level	124 m MSL
Elevation of Minimum Operating Lake Level	100 m MSL
Useable Storage between Max and Min levels	128.4 MCM
Area at Normal Operating Lake Level	990 ha
Area at Maximum Flood Storage Lake Level	1,147 ha
Area at Minimum Operating Lake Level	294 ha
Top Clearing Elevation	120 m MSL
Lower Clearing Elevation	100 m MSL
EMBANKMENTS	
Dam	
Type of Dam	Rock Fill Embankment
Top Elevation of Dam	125 m MSL
Fixed Crest Width	13 m
Height	35 m
Overall Length of Dam	946 m
Saddle Dam (North)	
Type of Saddle Dam	Earth / Rock Fill Embankment
Top Elevation of Saddle Dam	125 m MSL
Fixed Crest Width	13 m
Overall Length of Saddle Dam	153 m
SPILLWAY	
Type of Spillway	Uncontrolled Ogee
Total Length	83 m
Elevation of Spillway	120 m MSL
Maximum Discharge	4,200 CMS

Table 14 - 14 Pertinent Data for Operating Option 1 (continued)

M & I WATER TREATMENT FACILITIES	
Caimito Lake Raw Water Capacity	221,000 CMD
Raw Water Pump Capacity	150,000 LPM
Raw Water Pipeline Diameter	1.5 m
Raw Water Pipeline Length	8 km
Water Treatment Plant Type	Conventional
Water Treatment Plant Capacity	221,000 CMD
Treated Water Storage Capacity	221,000 M^3
Treated Water Pump Capacity	230,000 LPM
Treated Water Pipeline Diameter	2.1 m
Treated Water Pipeline Length	10 km
CONSTRUCTION DIVERSION	
Diversion Length	390 m
Tunnel Diameter	5.5 m
Inlet Invert	92 m MSL
Outlet Invert	90 m MSL
Cofferdam Height above Tunnel Inlet Invert	8 m
MINIMUM FLOW CONDUIT	
Conduit Diameter	300 mm
Conduit Length	390 m
Inlet Invert	91 m MSL
Outlet Invert	89 m MSL
Conduit Capacity	0.43 CMS

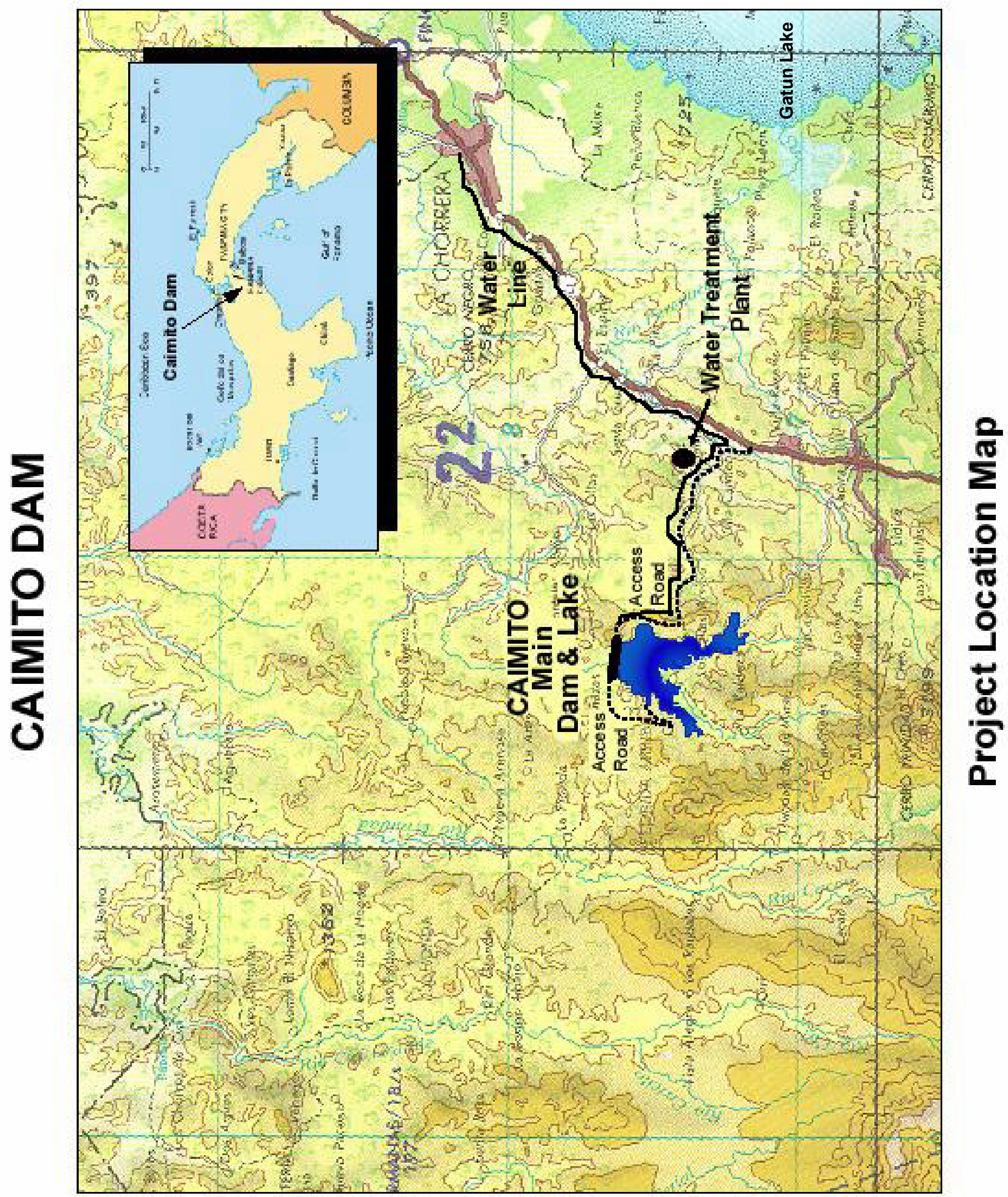

Plate 14 - 1   Project Location Map

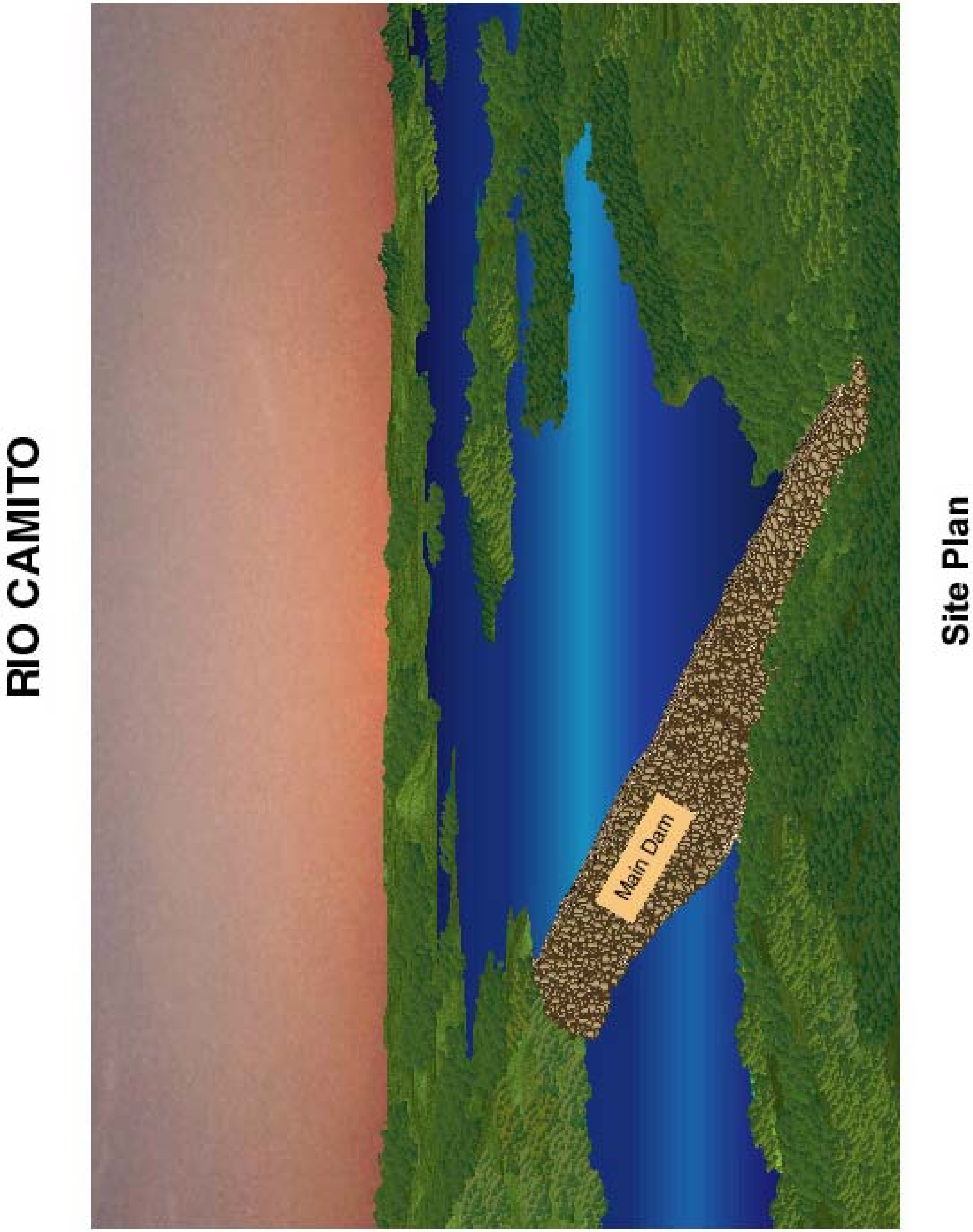

Plate 14 - 2 Site Plan

SECTION 15

(M&I Water Supply Project)

Rio Pacora

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Synopsis

The basic concept of the Pacora Dam alternative is that the lake will provide M&I water to local potable water supply systems, including those which currently withdraw, or plan to withdraw, raw water from the canal system. This water from Pacora Lake would replace waters that would be withdrawn from the Panama Canal for M&I water demand allowing it to be used for canal operation.

The Rio Pacora watershed is located outside of, and adjacent to, the eastern side of the Panama Canal watershed and drains to the Pacific Ocean. The proposed Rio Pacora dam site would be approximately 20 km inland from the Pacific Ocean and would be near the community of Caña Blanca. The structures for this proposed project would consist of a rock fill dam, an uncontrolled ogee spillway, minimum flow structure and appropriate outlet works to transfer raw water to a treatment plant. The total project first costs of the proposed Rio Pacora project are estimated to be $291,721,000.

The traditional design approach for water supply was not used in this study. The lake was sized to provide the maximum water yield possible regardless of the local needs. It was assumed that these future increases in water supply demands would be taken from Gatun Lake if the project was not developed. The proposed Rio Pacora project would, indirectly, contribute to the ability of the Panama Canal to serve its customers, and would minimally reduce the need for imposing draft restrictions and resulting light loading of vessels during traditional periods of low water availability. Because of the limited storage capacity in Rio Pacora Lake, the project was analyzed strictly as a M&I water supply project. Water produced by the Rio Pacora project would help offset M&I waters that would be withdrawn from the canal system and, thus, leave more water for canal operation. Pacora lake would provide approximately 55 million gallons (1 lockage) on a continual basis.

Hydropower was not considered for the Pacora Dam since the lake will be used for M&I water supply. Some of the M&I waters taken from Gatun Lake would be offset by the Rio Pacora project and would help to lessen the decline in hydropower production at Gatun Lake but the impact would be very small and was not considered as a benefit in this analysis.

Topographic and hydrologic data for this project were limited. If this project is considered for further development, acquistion of additional topographic and hydrologic data would be required. This analysis would be verified and refined such that it can be equally compared to other alternatives presented in this report.

Site Selection

The proposed Rio Pacora dam site was chosen 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. To maximize the water impounded, it was desirable to locate the dam as far downstream in the Rio Pacora watershed as possible. In choosing a site for the dam, a location was sought where the surrounding hillsides were relatively steep and high, and the valley was relatively narrow. The location of the Rio Pacora dam site does not easily accommodate a means to transfer water to the Panama Panama Canal watershed but rather affords an opportunity to provide water for local M&I use.

This would help to offset waters that would be withdrawn from the canal system for potable water.

The site chosen for the proposed Rio Pacora Dam would be approximately 20 km east northeast of the Tocumen Airport and 5 km north of Highway 1. This site would accommodate construction of a dam with a normal operating lake level at elevation 100 m MSL and a maximum flood storage lake level at elevation 104 m MSL. Plate 15 - 1 shows the location of the proposed Rio Pacora project.

Hydrologic Considerations

The Rio Pacora drains a small watershed located on the Pacific side of the Republic of Panama outside and to the west of the Panama Canal watershed. The Rio Pacora flows approximately southwest below the dam site, then turns south and eventually reaches the Pacific Ocean after traveling a total of approximately 25 km.

The headwaters of the watershed begin at elevation 800 m MSL approximately 32 km inland and fall to mean sea level at its mouth. The distribution of the average annual rainfall over the Rio Pacora watershed varies from a low of 1,600 mm at the coast to a high of 3,000 mm in the upper watershed. The proposed Pacora Lake would receive runoff from approximately 126 km^2 of the upper portion of the watershed. Rainfall runoff produces an average annual flow of 5.38 CMS at the proposed dam site.

Discharge data for the proposed dam site were obtained by correlation with the Rio Pacora hydrologic gage station. The Rio Pacora gage is located downstream of the proposed dam site on the Inter-American Highway and has a drainage area of approximately 277 km^2. The Rioi Pacora gage station only operated from April 1974 until January 1978. Therefore, the data for this station were extended using a correlation equation with the Mamoni River Station data. Then a drainage area ratio was used to develop the hydrologic data for the dam site. This process permitted development of 41 years of hydrologic data (1958 – 1998), falling short of the 50.5 years available for other alternatives. It should also be noted that only 4 years of common data were available to establish the correlation between the two data stations. Additional hydrologic data are needed at the Rio Pacora gage to establish a full period of record.

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

Geologic Considerations

The proposed Rio Pacora project is located in an area of the Isthmus of Panama where Miocene aged volcanic rocks (andesites, basalts, breccias, and tuffs) of the Tucue Formation are encountered at the surface. A site visit made during the preparation of this report found agglomerate (with basalt blocks measuring up to about 1/3 m in diameter) outcropping in the riverbed at the selected dam location and also at a small rapid located about 650 m downstream. The rock appeared to be hard and high quality. It is expected that this rock would be suitable for rock fill, and for concrete aggregate. Commercial aggregate sources are located relatively near the dam site (within 25 km).

In the absence of detailed geologic information at the site, a degree of extrapolation was necessary. It was predicted that rock would be encountered at a shallow depth and would be of sufficient quality to serve as foundation material for the dam and appurtenant structures. Furthermore, it was assumed that sufficient rock for fill and concrete aggregate would be available from the required excavation and that impervious materials would be available within the immediate area for use in the construction of the project.

Lake Operation

Two operating options were considered in this study for periods when water would be transferred from Pacora Lake to the city of Panama for M&I water supply. Operating Option 1 consists of the water surface of the lake fluctuating from the normal operating lake level at elevation 100 m MSL down to the minimum operating lake level at elevation 85 m MSL with 31,065,000 M^3 of useable storage. Operating Option 2 consists of the water surface of the lake fluctuating from the normal operating lake level at elevation 100 m MSL down to the minimum operating lake level at elevation 80 m MSL with 36,530,000 M^3 of usable storage. The maximum flood lake level would be at elevation 104 m MSL. The volume between the maximum flood lake level and the normal operating lake level would be used to store flood waters and reduce peak flood flows. Some reduction in flooding would be realized in areas along the Rio Pacora downstream of the dam. Table 15 - 1 shows the lake levels for the two operating options.

Table 15 - 1 Lake Operating Options

Lake Level (m MSL)	Operating Option 1	Operating Option 2
Normal Operating Lake Level	100	100
Minimum Operating Lake Level	85	80
Maximum Flood Storage Lake Level	104	104

Project Features

GENERAL

The structures for this proposed project would consist of a rock fill dam, an uncontrolled ogee spillway, M&I water withdrawal, transport, water treatment facilities, and outlet works. The following paragraphs provide a description of the proposed structures and improvements for the Rio Pacora lake project. The major structural components indicated here are configured for operating Option 2. In some instances, the proposed structures and improvements for operating Option 1 and operating Option 2 would be slightly different. Plate 15 - 2 depicts the location of the dam. Plate 15 – 1 depicts a general routing of water supply piping and treatment 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 proposed project is carried into the planning studies, optimization of the project features and improvements must be accomplished.

EMBANKMENTS

Dam

The dam would be an embankment with the top at elevation 105 m MSL for operating Option 2. The left abutment of the embankment would be located at Universal Transverse Mercator Grid, Zone 17, Clark 1866 Spheroid Coordinates 1019178 north and 692903 east. The right abutment would be 1017268 north and 693794 east coordinates. The embankment would be constructed with an impervious earth and rock fill core encased in a rock fill dam with final side slopes of 2 horizontal on 1 vertical and crest width of 13 m. The dam, at its highest point, would be approximately 35 m high, and the overall length would be approximately 2,135 m. A total volume of approximately 1,372,350 M^3 would be required to construct the embankment. Plate 15 - 2 shows the dam site in downstream perspective view.

SPILLWAY

An uncontrolled ogee spillway with a length of 79.3 m and a crest at elevation 100 m MSL would be required. The spillway crest would be 5 m below the elevation of the top of the dam. The maximum discharge from the spillway would be 1,225 CMS at a maximum flood storage lake level at elevation 104 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. A stilling basin would be excavated into the rock adjacent to the natural channel at the downstream end of the tailrace channel for energy dissipation. The typical section of the spillway would be similar to that shown for the Rio Indio Dam, Section 5.

IMPOUNDMENT

The lake formed by the proposed Rio Pacora Dam would have a normal operating lake level at elevation 100 m MSL. The surface area at the normal operating lake level would be approximately 295 ha. At the maximum flood lake level, elevation 104 m MSL, the surface area would be approximately 352 ha. With the minimum operating lake level at elevation 85 m MSL the surface area would be approximately 116 ha. The area at the elevation of the top of the dam, elevation 105 m MSL, would be approximately 367 ha.

CLEARING AND / OR GRUBBING

Clearing and grubbing would be required for all areas required for construction of the dam (embankments and spillway), inter-basin transfer facilities, outlet works, hydropower plants, access roads, and disposal and staging areas. Under operating Option 2, clearing only would be required for the 251 ha in the lake area between the top of dam level at elevation 105 m MSL and the minimum operating lake level at elevation 85 m MSL, and for the transmission lines.

M&I WATER SUPPLY FEATURES

In order to provide potable water to local water systems it would be necessary to construct a water treatment plant. Raw water would be pumped to the plant, then treated and re-pumped to the Tocumen International Airport in Panama City. It is assumed that the treated water would be distributed either from the airport or from the pipeline, lying along Highway 1, connecting the airport and the treatment plant. Our objective was to deliver treated water to a point in an existing water distribution system. It was assumed that the existing water systems were adequate or that the end user would make the necessary adjustments to the system. Therefore, no water distribution system costs have been addressed in this report.

Pacora Lake would provide 55 million gallons (208,180 M^3) of raw water to a potable water supply system. An intake structure and raw water pumping station would be constructed at the dam. Three pumped intakes would be required to supply water to the water treatment plant. Each of three raw water pumps would be 1,500 HP and would be capable of discharging 145,000 LPM. A 1.5 m diameter pipeline would convey raw water over a distance of 11 km to a water treatment plant. The water treatment plant would be located along the road that leads to the dam, at the intersection of Highway #1, about 11 km south of the dam. Raw water and treated water pipelines would be sized for a maximum velocity of 1.5 MPS. No raw water quality data are available for the Rio Pacora. Although other processes should be considered when water quality data are available, it is assumed that the treatment plant would be a conventional water treatment plant having a capacity of 55 million gallons. Conventional treatment is the process of choice for most surface waters. The plant would include chemical feed and mixing, flocculation, sedimentation, filtration, disinfection, and sludge treatment. The plant would have a treated water storage capacity of 55 million gallons, or one day storage. It is recommended that two or more storage tanks be used to allow maintenance to be performed without losing all the storage capacity. A treated water pumping station with three 217,000 LPM, 4,700 HP pumps would discharge into a treated water pipeline. The treated water pipeline would extend 17 km from the plant to the Tocumen International Airport and would be 2.1 m in diameter.

OUTLET WORKS

An outlet works system would be required to provide water diversion of the Rio Pacora flows during construction, to allow for emergency drawdown of the lake, and to allow minimum flow to pass through the dam.

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 was no longer needed for construction, the structure would be used to provide minimum flow and emergency drawdown of the lake. It would 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 as minimum flow.

This system would consists of an 7.7 m by 7.7 m horseshoe shaped tunnel passing through the right dam abutment, an intake structure located in the lake, an outlet channel downstream, and various gate structures and water conduits. The diversion tunnel would be 100 m in length; it would have an inlet invert at elevation 75 m MSL and an outlet invert at elevation 74 m MSL. The diversion tunnel would serve in combination with the cofferdam to protect the construction area from floods up to a 10 percent frequency. The cofferdam would measure 9.2 m above the upstream invert of the tunnel. A separate 300 mm diameter conduit, required for minimum flow, would be installed beneath the floor of this tunnel. The minimum flow conduit would be 100 m in length. It would have an inlet invert at elevation 74.5 m MSL and an outlet invert at elevation 73.5 m MSL. The capacity of the minimum flow conduit would be 0.53 CMS. A bulkhead structure would be required at the tunnel outlet to close the construction diversion. The closure would be configured so that it could be removed in the event that the Pacora Lake had to be drawn down.

ACCESS ROUTE

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

The project location is within only a few kilometers of the Pacific coast. Therefore, access was developed from the Panama City area only.

The route from Panama City would follow the Inter-American Highway from Panama City eastward to the cities of Paso Blanco on the east side and San Diego on the west. From this point it would follow existing Route 73 to a point immediately west of the proposed dam site. From here a new roadway would be constructed. The proposed access route would cover approximately 17 km from the Tocumen International Airport to Paso Blanco and San Diego, and 5 km from Paso Blanco and San Diego to the dam site. Approximately 3 km of new roadway would be required. Plate 15 - 1 shows the proposed access route.

In addition to providing construction access this new corridor into the interior of the country east of the Panama Canal will be of benefit to those living in that region. It would provide additional access to main centers of commerce in the southern part of the country.

Sources of Construction Material

Rock removed from the spillway site would be used as fill in the embankment portion of the dam. Impervious materials for the core section could have to be obtained from outside the project area. For this study, it was assumed that these materials would be available locally and in sufficient quantity to supply the project needs. If further study indicates that insufficient impervious materials are available, then other materials such as roller compacted concrete should be considered for construction of the dam.

Cement would be available within the Republic of Panama. Rock, obtained from the construction site or from the lake area, would be used for onsite manufacture of aggregates for the concrete. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) would be fabricated outside the Republic of Panama and imported for final assembly and installation at the proposed dam site.

Real Estate Requirements

The proposed Rio Pacora project would be located in the Province of Panama. Construction of this proposed project would require 667 ha. Table 15 - 2 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 15 - 2 Real Estate Requirements

Project Feature	Land Required (ha)
Lake	367
Pipeline Right of Way	100
Dam Site & Staging Area	200
Total	667

Relocations

Structures and individuals located in the lake area below elevation 104 m MSL would require relocation because of the normal lake inundation and the need to secure the lake perimeter for flood considerations. The lake would inundate the small communities of San Miguel, Rio Indio, Carriazo and part of Caña Blanca and roads leading to these communities follow the valley and would need to be relocated. This area is devoted primarily to subsistence farming and ranching; therefore, inundated areas may disrupt or impact some farms or ranches.

Development Sequence

Planning studies would be accomplished to evaluate the alternative features of this proposed project. Each of the potentially viable features would be evaluated to assure that the plan presented would provide all of the features required to make it functional. Each would also be assessed as to its effectiveness in meeting the project goal of providing M&I water supply in relief of current or future planned withdrawals from the Panama Canal, with due recognition of any secondary benefits. Environmental assessments of the proposed projects would also be made to assure environmental acceptability of the project features. These environmental assessments would begin during the planning studies phase and would continue during the final design, advertising and award phase, and on through construction of the project. The final design would be accomplished for the recommended project. After completion of the final design, plans and specifications would be prepared for the advertising and award phase.

Project implementation would begin with land acquisition and construction of the access facilities. Lands for the access roads would be acquired initially. Lands for the dam site, staging area, disposal area, pipeline right-of-way, and lake would then be acquired.

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

Construction of the dam would begin with the clearing and grubbing of the construction sites and the clearing of the lake area. Excavation for the intake structure and construction of the diversion tunnel at the dam site and the spillway would follow. Where possible, materials removed from the nearest of these sites would be placed directly into the earth and rock fill portions of the dam. Once the intake structure and diversion tunnel was completed, the dam construction site would be isolated using upstream and downstream cofferdams. These would eventually become part of the main dam, and the stream would be diverted through the tunnel. The dam foundation would be excavated and grouted, and the dam constructed. Concurrently with construction of the dam, the M&I water intake structure and appurtenances would be built / installed. Upon completion of the dam and appurtenant structures, the diversion would be stopped, and lake filling would begin. Simultaneously with this operation, the downstream gate and flow separation structure would be constructed to provide for closure of the diversion tunnel. The minimum flow conduit would also be installed through the diversion tunnel at this time.

The water treatment facilities would be constructed concurrently with the dam and reservoir project and timed to begin operation immediately upon completion of the lake filling.

Upon completion of the project, all facilities would undergo trial operations followed by commissioning for service.

Considering the climatic conditions and the obstacles posed by the remote location of the construction sites and the nature of the work, it is estimated that development of this project could be completed in approximately 7.5 years, from initial planning to lake filling. Figure 15 - 1 depicts the development sequence of the various project features.

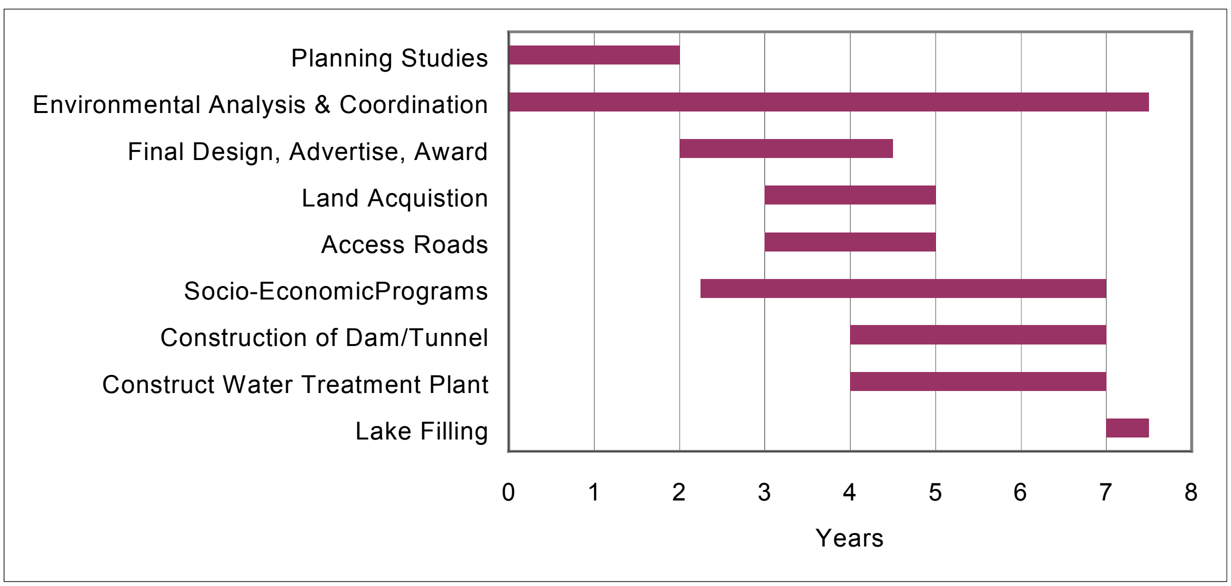

Figure 15 - 1 Development Sequence

Water Yield

The proposed Rio Pacora project was modeled using the HEC-5 Analysis Package, Simulation of Flood Control and Water Conservation Systems. Since the Pacora Lake would only be used for M&I water supply, only a constant firm yield was considered. The lake was not modeled to provide high flows in response to navigation water shortages in the Panama Canal operation or to include hydropower production. With the small constant flow applied to the Panama Canal a net yield would be realized but the change in reliability would be small and was thus considered insignificant.

Monthly discharge data for the proposed Rio Pacora dam site, as described in the section titled Hydrologic Conditions were used as input to the simulation model. Elevation-volume values at the proposed Rio Pacora dam site were developed from existing 1:50,000 scale topographic mapping. The two operating options are listed in Table 15 - 3.

Table 15 - 3 Description of Operating Options

Operating Option	Lake Range (m MSL)	Dam Height (m MSL)	Spillway Length (m)	Minimum Flow (CMS)
Pacora1	100-85	105	79.3	0.53
Pacora2	100-80	105	79.3	0.53

The firm yield was determined by using a constant diversion from Pacora Lake, while always maintaining the minimum downstream flow requirement and not allowing the lake to drop below the minimum lake operating level. In addition, the lake was required to recover its full storage within 4 to 5 years, excluding the 1998 drought period. The 1998 period was excluded since it is considered a drought of much lower frequency than 100-year return. A 5-year recovery period was imposed to help select a practical low flow period to design the reservoir. The HEC-5 model was optimized to determine the greatest constant diversion based on the available hydrologic records (1958-1998). The results for each option are shown in Table 15 - 4.

Table 15 - 4 Constant Firm Yield

Operating Option	Lake Range (m MSL)	Minimum Flow (CMS)	Average Evaporation (CMS)	Firm Yield (CMS)	Additional Lockages Per Day*
Option1	100-85	0.53	.10	2.27	0.94
Option2	100-80	0.53	.09	2.41	1.00
*Lockages are based on 55 million gallons for one ocean to ocean transit.					

Project Costs

GENERAL

The quantities estimated for the principal features required in the construction of this proposed project were derived from the layout of the main dam shown on Plate 15 - 2 and detailed in materials provided separately. The unit prices applied to these quantities were 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 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 and supervision and administration is estimated to be 6 percent of the construction cost features. An allowance of 2 percent of the construction costs was included for field overhead (construction camp, contractor facilities, etc.). An allowance of 25 percent was included for contingencies. The PCC provided the estimated costs of the land for the proposed project.

FIRST COSTS

The total project first costs are estimated to be $291,721,000. Table 15 - 5 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 15 - 5 Summary of Project First Costs

Principal Feature	Costs ($)
Lands and Relocations	1,667,500
Access Roads	1,580,000
Clearing and / or Grubbing	712,500
Diversion Tunnel	5,249,910
Raw Water Pump/Pipe	31,780,000
Water Treatment Plant	55,500,000
Finished Water Pump/Pipe	46,220,000
Clearwater Storage Basin	10,500,000
Cofferdam	1,502,453
Dam	8,962,721
Spillway	25,713,491
Intake	5,091,890
Subtotal	194,480,465
E&D, S&A, Field Overhead	38,896,093
Contingencies	58,344,140
Total Project First Costs	291,720,698 **approximately** 291,721,000

OPERATION AND MAINTENANCE

Staff

A staff would operate and maintain the proposed Rio Pacora project during the day and then run the facility remotely. The full-time staff would ultimately consist of a total force of 6 who would include a station manager, a leader, 3 craftsmen, and one laborer. The annual costs of the staff are estimated to be $235,000.

Ordinary Maintenance

Ordinary maintenance and care would be required and would include minor repair materials, lubricants and other supplies needed by the project staff. It is estimated that the costs of ordinary maintenance would be $20,000 per year for the access road and $100,000 per year for the main project facilities.

Major Replacements

The average service life of gates, trash racks and other features would be less than the total useful life of the proposed project, which would be 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 would cost the same as at present. No allowance was made for salvageable fixed parts. Table 15 - 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 would be $1,375,300 and the average annual replacement costs would be $166,000.

Table 15 - 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	1,650,000	5,700
Bridges	50	1	675,000	2,300
Water Supply System				
Pumps with Diesel Backup	25	2	32,640,000	1,016,500
Steel Water Lines	50	1	100,680,000	348,400
Intake				
Head Gates	50	1	375,000	1,300
Stoplogs	50	1	172,500	600
Trashracks	50	1	55,500	200
Access Stairs	50	1	42,750	100
Minimum Flow Gates	50	1	45,000	200
Total			136,335,750	1,375,300
Average Annual Replacement Costs				166,000

Annual Costs

The total project first costs are estimated to be $291,721,000. 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 total project first costs was computed from mid-year throughout the 10-year period from initiation of Planning and Design until the lake was filled. The interest during construction at 12 percent would be $92,584,000 and it was added to the total project first costs for total project investment costs of $384,305,000. A capital recovery factor for the 50-year planning period was applied to get the annual average investment costs of $46,277,000. Annual operation and maintenance costs were added. Major replacement costs are estimated and were 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 15 - 7 contains a summary of the annual costs.

Table 15 - 7 Summary of Annual Costs

Item	Costs ($)
Total Project First Costs	291,721,000
Interest During Construction	92,584,000
Total Project Investment Costs	384,305,000
Annual Average Investment Costs	46,277,000
Operation and Maintenance Costs	
Staff Costs	235,000
Ordinary Maintenance Costs	120,000
Major Replacement Costs	166,000
Total Average Annual Costs	46,798,000

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 Rio Pacora project.

The proposed Rio Pacora project would slightly increase the reliability of providing water to accommodate the daily number of lockages demanded. Since this increase is so small, benefits associated with an increase in reliability were not estimated. The 99.6 percent level of reliability for this proposal is used to estimate the water supply benefits for navigation.

With the addition of the proposed Rio Pacora project, there would be fewer shortages in water supply. With a reliability of 99.6 percent, operating Option 1 would increase the amount of water supplied for navigation by approximately 0.94 equivalent lockage. For operating Option 2, the amount of additional water for navigation would be 1.00 equivalent lockage. Benefits for this amount of additional water supply 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 number of daily lockages. The average annual benefits for water supply would be $18,878,000 for Option 1 and $20,083,000 for Option 2. Table 15 - 8 provides the estimate of daily shortages under existing conditions, the remaining daily shortages with the proposed Rio Pacora project in operation, the annual benefits for meeting shortages and the average annual benefits.

Table 15 - 8 Benefits for Additional Water Supply for Navigation

Year	Daily Shortages In Lockages Under Existing System	Remaining Daily Shortages With Operating Option 1	Remaining Daily Shortages With Operating Option 2	Annual Benefits for Operating Option 1 ($)	Annual Benefits For Operating Option 2 ($)
2008	5.08	4.14	4.08	17,910,000	19,053,000
2010	6.43	5.49	5.43	18,361,000	19,533,000
2020	8.93	7.99	7.93	19,385,000	20,622,000
2030	10.87	9.93	9.87	19,385,000	20,622,000
2040	13.34	12.40	12.34	19,385,000	20,622,000
2050	16.45	15.51	15.45	19,385,000	20,622,000
2060	20.37	19.42	19.36	19,385,000	20,622,000
Average Annual Benefits				18,878,000	20,083,000
With Option 1, the system will provide a total of 39.62 equivalent lockages at the 99.6 percent level of reliability or 0.94 more lockages than the existing system. With Option 2, the system will provide a total of 39.68 equivalent lockages at the 99.6 percent level of reliability or 1.00 more lockages than the existing system.					

SUMMARY OF ANNUAL BENEFITS

As shown in Table 15 - 9, total average annual benefits for operating Option 1 and operating Option 2 of the proposed Rio Pacora project would be $18,878,000 and $20,083,000, respectively.

Table 15 - 9 Summary of Annual Benefits

Benefit Category	Average Annual Benefits	
	Operating Option 1 ($)	Operating Option 2 ($)
Navigation - Water Supply	18,878,000	20,083,000
Navigation – Reliability	Not Estimated	Not Estimated
M&I – Reliability	Not Estimated	Not Estimated
Hydropower	None	None
Total	18,878,000	20,083,000

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 determines which proposal among several provides the greatest value for the investment dollars. While there would be small differences in some project features between operating Option 1 and operating Option 2, the differences would not have any impact on total project first costs at this level of investigation. The same facilities would be constructed for each operating option. Table 15 - 10 provides the benefit to cost ratios for operating Option 1 and operating Option 2 and the net benefits for both.

Table 15 - 10 Economic Evaluation

Item	Operating Option 1	Operating Option 2
Average Annual Benefits	$18,878,000	$20,083,000
Average Annual Costs	$46,798,000	$46,798,000
Benefit to Cost Ratio	0.4	0.4
Net Benefits	($27,920,000)	($26,715,000)

Internal Rate of Return

An internal rate of return analysis for each operating option was performed. To accomplish this analysis, the annual construction costs were used as the investment, and the undiscounted benefits were used as return cash flows. For operating Option 1, the internal rate of return would be less than 5.1 percent, and for operating Option 2, the internal rate of return would be less than 5.5 percent.

Incremental Evaluation of Water Treatment

If only raw water is provided from this proposed project, the costs for the treatment and delivery of finished water can be subtracted from the costs of the proposal. The total first costs would then be $123,391,000. The inclusion of $39,900,000 for interest during construction yields a total investment cost of $163,290,000. A capital recovery factor for the 50-year planning period was applied to get the annual average investment costs of $19,663,000. Annual operation and maintenance costs were added. Major replacement costs are estimated and were converted to an annual cost by discounting the future replacement costs of major components of the project back to completion of the project construction. Total average annual costs would be $21,210,000.

The average annual benefits would remain the same. Once average annual 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 determines which proposal among several provides the greatest value for the investment dollars. The benefits to costs ratio for Option 1 would be 0.89 while this ratio for Option 2 would be 0.95. Neither operating scheme would provide a feasible project or positive net benefits.

Socio-Economic Impacts

The socio-economic impacts of the project would be limited by the fact that the towns in the impoundment area (San Miguel, Rio Indio, Carriazo, and Cana Blanca) are only sparsely populated with few roads and utilities. The average monthly income of families in the project area is $200-454 per month. There may be indigenous groups or peoples residing in the impact area. Land use would be impacted by the inundation of pastures and agricultural lands to create the Pacora Lake. The proposed project might require the relocation of the existing penitentiary. The surface area of the proposed lake will encompass 352 ha with another 300 ha for the dam site, pipeline right-of-way, and staging area.

Currently, all residents have access to public schools and health centers. During construction, these services should continue to be available and more public and community services may be offered to the local residents. After construction, these services could continue to be available.

To construct the dam, some existing roads would be improved and a new road, 3 km in length, would be built. Only a dirt trail within the impoundment area would be eliminated, which could cause some small settlements to lose overland transportation, communication, cohesion, and commerce with other settlements. New roads constructed during the implementation of the project could increase development and would allow for easier access to the major centers of commerce in Panama. During construction, the traffic volumes over both new and existing road systems would increase; however, following completion of construction, the traffic volumes would decline. Noise levels would increase during construction and could negatively impact noise-sensitive receptors; however, after construction, noise should return to pre-construction levels.

Although the number of displaced people resulting from the project is small, the communities that would receive displaced people 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 through the division of communities, separation of families, and loss of livelihood. Following completion of the impoundment, tourism trade in the affected region, including fishing and ecotourism, could increase.

Environmental Setting

The Rio Pacora project involves the construction of a dam on the Rio Pacora for the purpose of supplying M&I water for the eastern section of the Panama Province. Rio Pacora Lake will provide the equivalent of approximately 1 additional lockages per day on a continual basis. The structures for this proposed project would consist of a rock fill dam, an uncontrolled ogee spillway, M&I water withdrawal, transport, water treatment facilities, and outlet works. The project area encompasses the area to be flooded as well as the area downstream from the dam site. This area is sparsely populated. It is characterized by rolling hills as well as low coastal regions. There is a large national penitentiary near Rio Pacora. The Rio Pacora is located east of the Panama Canal and flows southward from the Continental Divide into the Pacific Ocean. The Rio Pacora watershed above the dam is approximately 126 km^2. The impoundment area covers approximately 352 ha composed of approximately 25 percent of forested land, 60 percent of pastureland used by ranchers, 10 percent of cropland, and 5 percent of newly slashed and burned land. The lake water elevation should fluctuate from elevation 80 to 104 m MSL. The water pipelines and roads associated with the project could also have environmental impacts and should be sited to minimize those impacts.

LAND USE

The Rio Pacora project area encompasses the area to be flooded as well as the area downstream from the dam site. It is inhabited by about 4,250 people dispersed through the area. The towns of San Miguel (population - 320), Rio Indio (population - 160), Carriazo (population - 240) and Cana Blanca (population - 60) would be inundated. The towns of Pacora (population - 3,700), La Vega (population - 15), Sacramento (population - 30), La Cabanga (population - 75), and Boca de Pacora (population - 10) are downstream of the dam site.

Farms and ranches of various sizes occupy approximately 75 percent of the land in the project area. Major farm crops include rice, maize, beans, papayas and teak trees. Ranchers raise cows, horses, chickens, and hogs. Some of the farmers and ranchers operate small commercial enterprises while others utilize cash crop and subsistence farming. A gravel supply company is operated where the Inter-American Highway (Panama Highway 1) crosses the Rio Pacora.

INFRASTRUCTURE

The town of Pacora has an elementary school, cemetery, and medical center. Other towns have these facilities nearby. The towns obtain drinking water from the Rio Pacora or groundwater wells. Some towns 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 Rio Pacora and its tributaries. Disposal of domestic waste is the responsibility of individual homeowners: some have septic systems but most have an outdoor latrine (a hole in the ground). There are some health problems, such as hepatitis, dissentary, dermatitis, intestinal parasites, and respiratory illnesses attributed to the present waste disposal methods. No known major industries or poultry or beef processing plants are located in the project area. The Inter-American Highway (Panama Highway 1) crosses the Rio Pacora about 2 km north of the town of Pacora. The towns of Sacramento, La Cabanga, Boca de Pacora and La Vega are accessible by poorly maintained dirt roads that are usable only in the dry season. The roads are rarely graded and receive little attention by either the Ministry of Public Works or the local government. The towns of Cana Blanco, Carriazo and San Miguel are only accessible by trails. Because of 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.

TERRESTRIAL HABITAT

Forests consisting primarily of secondary growth are found along the river and could support diverse wildlife populations. These forests cover about 25 percent of the areas along the upper stretches of the Rio Pacora and its tributaries. As a result of slash and burn activities, there are no large contiguous tracts of primary forest in the Rio Pacora watershed.

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 none have been identified to date, some animals and other species of concern may be found in the project area.

AQUATIC HABITAT

In the impoundment area, Rio Pacora displays characteristics of streams in mountainous regions. The current is usually swift and is punctuated by riffles, runs, and pools. The river substrate ranges from bedrock to sand in the upper stretches and is dominated by silt along its last 10 km prior to reaching the Pacific Ocean. The Rio Pacora, according to available topographic maps, has major tributaries that include the Rio Tatare, Rio Agua Congo, and Rio Indio. Numerous smaller streams also flow into the Rio Pacora. The river is approximately 40 km long; its width ranges from less than one meter at the headwaters in the dry season to

50 m at its mouth with a depth ranging from less than 1 to approximately 10 m. The Rio Pacora and its tributaries do support fish and other aquatic communities; however, information about fish and benthic organisms occurring within the project area is limited.

WETLANDS

Areas that contain hydric soils and hydrophytic plant communities, and that are subject to hydrologic conditions are termed wetlands. The wetlands in the project area consist of forested riparian habitat, and are limited in some areas by the narrow river valley. The width of the riparian habitat within the impoundment area varies from approximately 5 to 50 m. Approximately 25 percent of the Rio Pacora above the dam site and 20 percent below the dam site is bordered by forested riparian habitat.

AIR QUALITY

Although no applicable data are available, air quality in the project area appears to be generally good. At the end of the dry season, in March or early April, tracts along the Rio Pacora with forests or secondary growth have been burned and cleared to prepare the land for agricultural use. This slash and burn technique may still be practiced in the project area. Air quality monitoring has not yet been implemented in the project area. The natural environment may provide indicators that could be useful in evaluating air quality.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

No parks or other government-protected lands are known to be located in the Rio Pacora impoundment area. There have been limited cultural resource investigations completed in the project area; therefore, impacts to cultural resources are unknown.

Environmental Impacts

TERRESTRIAL HABITAT

The impacts of the project on the terrestrial habitat in the project area would be scattered, since patches of forest cover approximately 167 ha, or 25 percent of the impoundment area. Although primarily comprised of secondary growth, the forested area constitutes a relatively high quality terrestrial habitat. With the creation of the lake, some migration routes of species could be adversely affected. The only forests that would remain within the vicinity of the Rio Pacora reservoir and its drainage basin would be confined to the higher elevations above the maximum proposed lake level of 104 m MSL.

ANIMALS ON ENDANGERED LIST

The extent of potential effects on endangered animals cannot be determined at this time, because it is not known which of the listed species occur within the proposed project area. Some endangered and / or threatened species may use Rio Pacora for some or all parts of their life cycle. Furthermore, the significance of the forested riparian corridor along area streams may increase if animals on the endangered list are found in the region.

WATER QUANTITY

The impacts of the project on water quantity should be positive, because construction of the dam should result in an increase in the volume of stored fresh water during the dry season and, along with the construction of a water treatment plant, would provide a potable water supply for the region in the future. The impacts downstream from the dam site could be substantial if future potable water demands from the water treatment plant significantly decrease the amount of water allowed to flow through the spillway downstream. Downstream seasonal extremes should be eliminated.

WATER QUALITY

The impacts downstream from the dam site could be positive. The water should contain less silt and should provide residents downstream higher quality. The water taken directly from Pacora Lake or from the new water treatment plant should also provide higher quality water.

DOWNSTREAM AQUATIC FAUNAL HABITAT

The impacts on downstream aquatic faunal communities could be substantial depending on the seasonal migration patterns of fishes and invertebrates and water demands of the new water treatment plant. Large fluctuations in temperature flow rate, and turbidity resulting from periodic releases of water could substantially impact the reproductive cycle of downstream fauna. Alteration of the normal flow patterns during the construction phase could also substantially impact downstream fauna. A decrease from the normal flow rate downstream of the dam site may eliminate downstream aquatic habitat in the shallower sections of the Rio Pacora. The Rio Pacora Dam should act as a large sediment trap, which should cause the released water to have low turbidity; therefore, siltation should not be a problem. Streambed degradation should be minimal below the dam provided that water release rates are low enough so as not to cause excessive erosion and scouring.

FUTURE LAKE AQUATIC PLANT COMMUNITY

The impacts of the project on future aquatic plant communities in the proposed lake will depend on water levels, which are anticipated to range from 80 to 104 m MSL. Since the water levels would fluctuate widely, much of the shore of the lake would have mud slopes where neither aquatic nor terrestrial plant communities could thrive. However, rooted aquatic plants, which tend to grow to depths where light penetration allows photosynthesis to occur, may flourish depending on turbidity.

AQUATIC FAUNA INHABITING AFFECTED AREAS

The impacts of the project on aquatic fauna inhabiting the Rio Pacora and its upstream tributaries could be important. The reservoir will support species that thrive in lentic systems. Species that require highly oxygenated lotic systems could be extirpated from the stretch of Rio Pacora covered by the reservoir. The dam could also create a barrier to any seasonal migration patterns that may be crucial in the reproductive cycle of some fishes and aquatic invertebrates. Some unavoidable, adverse environmental impacts could occur and these impacts should be identified and appropriate mitigation measures addressed in feasibility level studies, should the alternative be recommended for further consideration. The new reservoir could provide opportunities for recreational and subsistence fishing if it is responsibly managed and stocked with game fish by the Aquaculture Department. An increase in fish population could cause an increase in piscivorous predators, such as crocodiles, caimans, otters, herons, etc. Other manmade lakes in the Republic of Panama have been stocked with exotic fish such as peacock bass and tilapia, both of which are efficient predators, which may have led to the extirpation of several native riverine fishes that formerly occupied the impoundments.

WETLANDS

The impacts to wetlands could be significant even though wetlands in the impoundment area are limited to the riparian corridor. The riparian wetlands inundated by the new impoundment would be destroyed; however, new wetlands could form in shallow water areas along the shoreline of the newly created reservoir depending on water level fluctuation. Wetlands downstream of the dam site could also be impacted. A decrease in the total amount of water flowing through the downstream floodplain and a decrease in seasonal flooding could result in a narrowing of the current floodplain, resulting in a loss of wetlands.

AIR QUALITY

During construction of the dam and new access road, dust and emissions from equipment could impact the air quality in the project area. Upon project completion, air quality could improve due to a decrease in slash and burn activities currently discouraged by the Panamanian government.

CULTURAL RESOURCES AND HISTORIC PROPERTIES

Information regarding cultural resources and historic properties is incomplete. Additional evaluation studies need to be completed to identify cultural resources and historic properties. Prior to construction, surveys would be conducted to locate cultural resources and historic properties, and the important sites would be preserved or salvaged as appropriate.

Additional Environmental Information Required

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

SOCIO-ECONOMIC IMPACTS

- Conduct an 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).
  - Community and Regional Growth.
  - Transportation.
  - Housing.

- Health (vector routes).
- Population.
- Community Cohesion.
- Recreational Resources.
- Mineral Resources

TERRESTRIAL AND AQUATIC HABITAT

- Prepare site-specific habitat maps to ensure that all major types of terrestrial and aquatic habitat are identified and quantified.
- Conduct field studies to locate special 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 project area.
- Coordinate with local experts regarding these habitats.
- Provide species inventory lists for each area, identifying their status as native or exotic and whether they are threatened or endangered.
- 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 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 the presence of these species.

WATER QUALITY

- As there are limited water quality data available for the Rio Pacora 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 is incomplete. Additional evaluation studies need to be completed to identify cultural resources and historic 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 Section 35. Tables 15 - 11 through 15 - 13 present the evaluation of the proposed Rio Pacora project as related to developmental effects, environmental effects, and socio-economic effects.

Table 15 - 11 Developmental Effects

Evaluation Criteria	Function	Measure 1/	Importance 2/	Composite 3/
Water Contribution (Water Yield)	Meets M&I demands	1	10	10
	Supplements Existing System	0	10	0
	Satisfies Future Canal needs/expansion	0	10	0
	Additional Hydropower Potential	0	5	0
Technical Viability	Design Constraints	9	6	54
	Feasibility of Concept	10	6	60
Operational Issues	Compatibility	10	6	60
	Maintenance Requirements	10	2	20
	Operational resources required	8	2	16
Economic feasibility	Net Benefits	0	9	0
	Total			220

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 15 - 12 Environmental Effects

Item	Measure 1/	Importance 2/	Composite 3/
Terrestrial Habitat	4	8	32
Animals on Extinction List	4	10	40
Water Quantity Impacts – Lake	9	10	90
Water Quantity Impacts - Downstream	4	7	28
Water Quality	5	10	50
Downstream Aquatic Fauna Habitat	4	8	32
Future Lake Aquatic Plant Community	7	8	56
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	5	10	50
Total			465

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 15 - 13 Socio-Economic Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Land Use	2	7	14
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	2	8	16
Community Cohesion	1	8	8
Tourism	6	5	30
Total			333

[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 15 - 14 presents pertinent data for operating Option 2 of the proposed Rio Pacora project.

Table 15 - 14 Pertinent Data for Operating Option 2

GENERAL	
Dam site, above mouth of Rio Pacora	20 km
Drainage area above dam site	126 km^2
Average annual flow at dam site	5.38 CMS
LAKE	
Elevation of normal operating lake level	100 m MSL
Elevation of maximum flood storage lake level	104 m MSL
Elevation of minimum operating lake level	80 m MSL
Useable Storage between Max and Min levels	36.53 MCM
Area at normal operating lake level	295 ha
Area at maximum flood storage lake level	352 ha
Area at minimum operating lake level	116 ha
Top clearing elevation	105 m MSL
Lower clearing elevation	80 m MSL
EMBANKMENTS	
Dam	
Type of dam	Rock fill embankment
Top elevation of dam	105 m MSL
Fixed crest width	13 m
Height	35 m
Overall length of dam	2,135 m
SPILLWAY	
Type of Spillway	Uncontrolled ogee
Total length	79.3 m
Elevation of spillway	100 m MSL
Maximum discharge	1,225 CMS
M & I WATER TREATMENT FACILITIES	
Pacora lake raw water capacity	208,180 M^3 per day
Raw water pump capacity	145,000 LPM
Raw water pipeline diameter	1.5 m
Raw water pipeline length	11 km
Water treatment plant type	Conventional
Water treatment plant capacity	208,180 M^3 per day
Treated water storage capacity	55 million gallons
Treated water pump capacity	217,000 LPM
Treated water pipeline diameter	2.1 m
Treated water pipeline length	17 km

Table 15 - 14 Pertinent Data for Operating Option 2 (continued)

CONSTRUCTION DIVERSION	
Diversion length	100 m
Horseshoe tunnel dimensions	7.7 m by 7.7 m
Inlet invert	75 m MSL
Outlet invert	74 m MSL
Cofferdam Height above tunnel inlet invert	9.2 m
MINIMUM FLOW CONDUIT	
Conduit diameter	300 mm
Conduit length	100 m
Inlet invert	74.5 m MSL
Outlet invert	73.5 m MSL
Conduit capacity	0.53 CMS

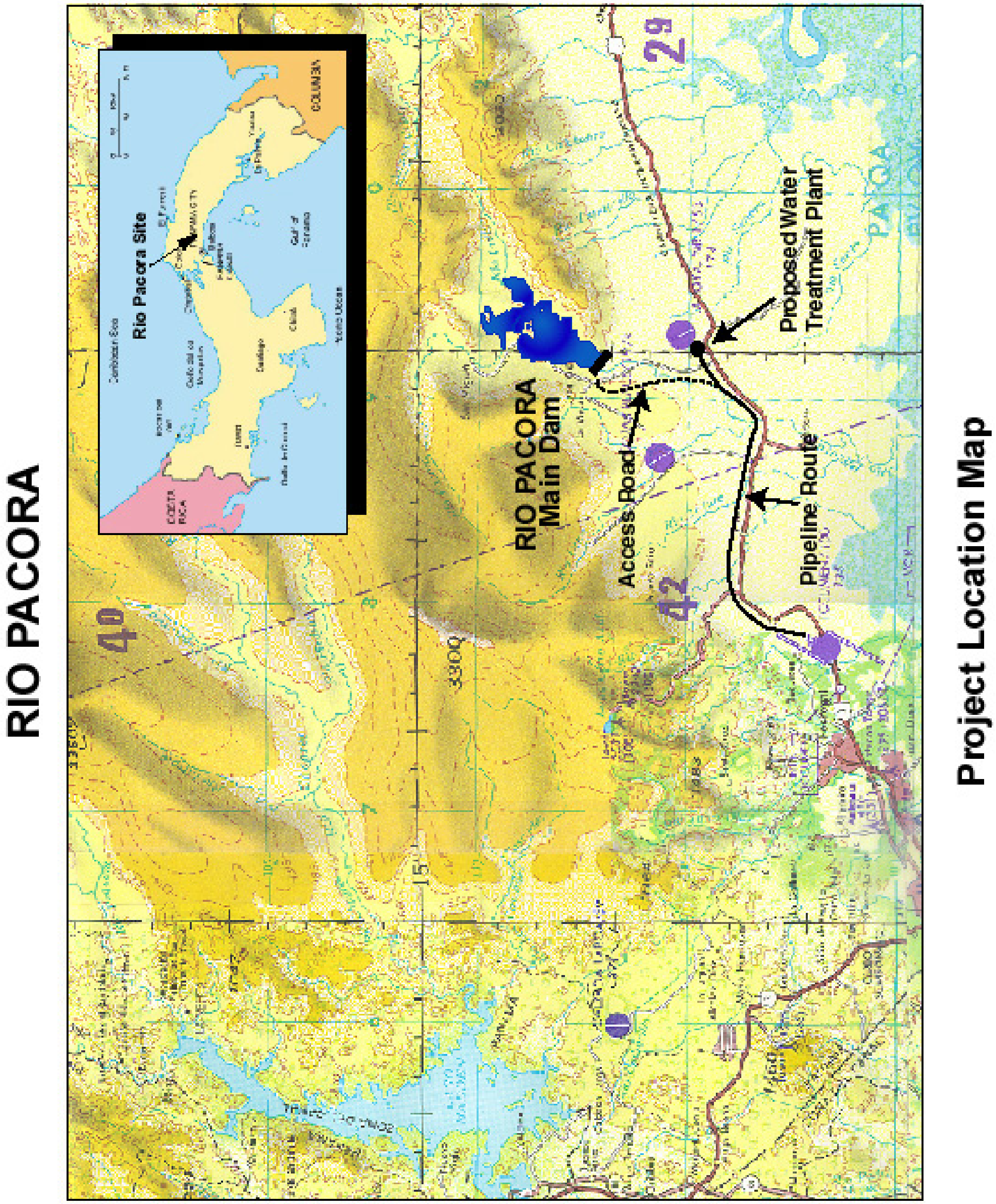

Plate 15 - 1   Project Location Map

RIO PACORA DAM

Site Plan

Plate 15 - 2 Site Plan

SECTION 16

Lower Rio Trinidad

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Synopsis

The development plan presented herein considers a dam creating a lake on the Trinidad basin within the Panama Canal watershed at Gatun Lake southwest of Gatun Locks. Water impounded in Lower Trinidad Lake would only add storage to the Panama Canal system of lakes. The water would 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 would be located within Gatun Lake across the Trinidad arm near the city of Escobal. The dam would 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 16 - 1 shows the location of the proposed Lower Rio Trinidad Dam project. The structures for the proposed Lower Rio Trinidad project would consist of a rock fill dam constructed by underwater deposition of fill materials, and a small navigation lock and a gated spillway, both constructed in the dry on Guacha Island. This spillway would have 15 gate bays, each measuring 18.3 m wide. The lock would be 7.6 m wide and 23 m long. It would allow movement of local small navigation vessels between Lower Trinidad Lake and Gatun Lake. The total project first costs of the proposed Lower Rio Trinidad project are estimated to be $351,692,000.

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

The proposed Lower Rio Trinidad Dam project would contribute to the hydrologic reliability of the Panama Canal to serve its customers and would 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 project, 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 proposed Lower Rio Trinidad dam site was recommended in previous reports and was also chosen as a potential alternative for this study. 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. Project area was also reviewed for other possible dam sites that might be more feasible.

The site chosen for the proposed Lower Rio Trinidad Dam would be 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 would accommodate construction of a dam with a maximum operating lake level at elevation 30.5 m MSL. Flood storage would be accommodated between elevations 30.5 and 28.7 m MSL.

Hydrologic Considerations

The Rio Trinidad flows northward from the Continental Divide to the Gatun Lake. The headwater of the watershed begins at elevation 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 would receive runoff from approximately 750 km^2 of the upper portion of the watershed. Rainfall runoff would produce 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 was 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 Trinidad Lake is located within Gatun Lake the monthly evaporation rates established for Gatun Lake were 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 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 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 peaty phase 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 Booby Island, the Atlantic Muck Formation was not found. In this area, recent aged soft silt and clay with thin zones of organic material were found to overlay weathered rock. Virtually all the overburden was characterized by high water content and low plasticity and moderate to high compressibility.

Guacha, Tern and Booby Islands 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 elevation 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 siltstone (tentatively classified by Robert H. Stewart, geologist for the Panama Canal Company, as belonging to the Gatun 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.

It is judged that satisfactory foundation for construction of a lock and dam and spillway exist at the Lower Rio Trinidad site. Serious consideration, however, must be given to problems that will be caused by the anticipated settlement of the embankment materials. Additionally, it is assumed that all concrete aggregates must be obtained from commercial sources.

Lake Operation

Two operating options were considered in this study for periods when water would be transferred from Lower Trinidad Lake to Gatun Lake for canal operations. Operating Option 1 consists of the water surface of the lake fluctuating from the normal operating lake level at elevation 30 m MSL down to the minimum operating lake level at elevation 24.8 m MSL with 798 MCM of useable storage. Operating Option 2 consists of the water surface of the lake fluctuating from the normal operating lake level at elevation 30 m MSL down to the minimum operating lake level at elevation 25.9 m MSL with 655 MCM of usable storage. The maximum flood lake level would be at elevation 30.5 m MSL. Flood storage would be accommodated between elevations 30.5 and 28.7 m MSL by seasonally varying lake elevation of the Lower Trinidad Lake. Trinidad Lake rule curve was designed to function similar to the rule curve for Madden Lake. Table 16 - 1 shows the lake levels for the two operating options.

Table 16 - 1 Lake Operating Options

Lake Level (m MSL)	Operating Option 1	Operating Option 2
Normal Operating Lake Level	30	30
Minimum Operating Lake Level	24.8	25.9
Maximum Flood Lake Level	30.5	30.5

Project Features

GENERAL

The structures for the proposed Lower Rio Trinidad project would consist of a rock fill dam, a small navigation lock, and a gated spillway. Modification of one existing saddle dam and construction of two additional saddle dams would also be required. The following paragraphs provide a description of the proposed structures and improvements for the Lower Trinidad Lake project. The major structural components indicated here are configured for operating Option 1. In some instances, the proposed structures and improvements for operating Option 1 and operating Option 2 would be slightly different. Plate 16 - 2 shows the dam site in downstream left bank perspective and indicates the location of the lock.

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 proposed project is carried into the planning studies, optimization of the project features and improvements must be accomplished.

EMBANKMENTS

Dam

The dam would be an embankment with the top at elevation 31 m MSL and with a crest width of 7 m. The left abutment of the embankment would be located at Universal Transverse Mercator Grid, Zone 17, Clark 1866 Spheroid Coordinates 1015858 north and 614864 east. The right abutment would be 1013937 north and 618229 east coordinates. The embankment 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 consolidation within the subgrade had stabilized. The assumed side slopes would be 15 horizontal on 1 vertical within the submerged sections and transitioning to 2 horizontal on 1 vertical in the portions traversing the existing islands. The subgrade would be extremely soft and considerable displacement could be anticipated as evidenced by the original construction experience at Gatun Dam. The dam would be approximately 30 m high, and the overall length would be 4,473 m. The top of the dam would be 5 m above the normal Gatun Lake level. The total volume of fill material required to construct the main dam would be approximately 29,550,850 M^3. Water access must be used from the main channel to Guacha Island.

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 would be 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 would 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 elevation of 31 m MSL. The total volume of fill material required for these three dams would 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 Rio Indio project, Section 5 of this report.

SPILLWAY

Water would be passed from Lower Trinidad Lake to Gatun Lake through a gated spillway. This spillway would have 15 gate bays, each 18.33 m wide. The gate bays would be separated / flanked by 3 m wide reinforced concrete piers (16 piers in all) which would provide support for the gates and access to the gate operating machinery. Each of the 15 spillway gates would have a nominal width of 18.33 m and a height of 5.4 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 323 m. The spillway sills would be placed at the minimum lake operating level, elevation 24.8 m MSL for Option 1.

A bridge would be provided across the tops of the spillway piers. This bridge should be at least substantial enough to allow small-motorized golf cart type service carts to traverse the spillway to service the gate operating machinery.

For the study, it was assumed that stop logs for servicing the gates, guides, etc. would be placed from barges using floating cranes. It should be noted that, with the spillway sills at the prescribed levels, stoplogs would be required both upstream and downstream to allow work on the gate sills in the dry.

The spillway would be situated along the axis of the dam approximately centered in the western leg of Guacha Island. This should allow 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 could be opened.

NAVIGATION LOCK

A small navigation lock measuring approximately 23 m from upper to lower pintle and 7.6 m in width would be constructed adjacent to the western end of the spillway. It would serve local fishing and other commercial interests. The maximum lock lift would be approximately 5.2 m, and the lock would be configured to provide a minimum draft of 3 m over the gate sills with the common lake levels at 25 m MSL. The top of the lock walls would be set approximately at elevation 32 m MSL, 2 m above the maximum lake operation level.

The filling and emptying of the lock would be handled using reinforced concrete tunnels on either side of the lock chamber with intakes and exit ports located in the vertical wingwall faces at either end of the lock, and filling and emptying manifolds made of large diameter steel pipe recessed into the lock floor. Filling and emptying would be controlled by manually operated slide gates recessed into the faces of the lock walls. Concept drawings of this facility were provided separately.

A horizontally sliding bridge would be provided across the lock to provide for vehicle access to the gated spillway.

As noted above for the spillway, the lock should be situated to allow the construction to be done completely in the dry with only a minimum of dewatering.

IMPOUNDMENT

The lake formed by the proposed Lower Rio Trinidad Dam would have a normal operating lake level at elevation 30 m MSL. The surface area at the normal operating lake level would be approximately 17,650 ha. At the maximum flood lake level, elevation 30.5 m MSL, the surface area would be approximately 17,850 ha. With the minimum operating lake level at elevation 24.8 m MSL (operating Option 1), the surface area would be approximately 12,000 ha. With the minimum operating lake level at elevation 25.9 m MSL (operating Option 2), the surface area would be approximately 13,330 ha. It should be noted that the current operating levels of Gatun Lake vary up to elevation 26.67 m MSL; therefore areas below the maximum Gatun Lake level are already subject to inundation.

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 elevation 30.5 m MSL.

ACCESS ROUTE

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

The route from Colon would be 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 would be 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 to the spillway and lock construction sites would be by water since these structures would be placed on Guacha Island. This being true, 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 would 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 16 - 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 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 land contact. 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 was assumed that rock fill required for armoring the slopes would be available within the immediate lake area.

Cement would be available within the Republic of Panama. Rock, obtained from the construction site or from the lake area, would be used for onsite manufacture of aggregates for the concrete. Concrete additives and cement replacement materials (fly ash, etc.) would be imported. All metal items and fabrications (hydraulic gates, trashracks, embedded metal, etc.) would 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 Trinidad Lake would be located within the former Panama Canal Zone and is presently managed and controlled by the PCC. It is assumed that the Panama Canal Authority will retain the same authority; therefore, acquisition of lands for the lake area would not be required. Construction of this proposed project would require acquisition of approximately 800 ha. Table 16 - 2 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 16 - 2 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 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 elevation 30 m MSL would need to be relocated or modified. This would include a major portion of the Village of Escobal. Additionally, there are only a few small communities and isolated individual structures along the lake shore with very limited access by land.

Development Sequence

Planning studies would be accomplished to evaluate the alternative features of each proposed project. Each potentially viable project would be evaluated to assure that the plan presented would provide all of the features required to make it functional. Each would also be assessed as to its effectiveness in meeting the project goal of providing navigation water to the Panama Canal, with due recognition of any secondary benefits. Environmental assessments of the proposed projects would also be made to assure environmental acceptability of the project features. These environmental assessments would begin during the planning studies phase and would continue during the final design, advertising and award phase. Environmental coordination would begin with planning studies and would continue through completion of construction. The final design would be accomplished for the recommended project. After completion of the final design, plans and specifications would be prepared for the advertising and award phase and through construction.

Project implementation would begin 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 would 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 navigation lock. The lock would then be opened for through traffic as a boat passage until the eastern leg of the dam is completed at which time the pool would be raised and actual lock operations would begin.

Socio-economic programs would begin 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 would continue throughout the construction phase.

Construction of the dam would begin with the clearing and grubbing of the construction sites at Guacha Island and the clearing of the perimeter of the Lower Trinidad Lake area. Some construction would 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 was assumed that rock fill required for armoring the slopes would be available within the immediate lake area.

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

Once the western leg of the dam and the lock and spillway were completed, the eastern leg would be constructed, completing the dam. The pool would then be raised. Upon completion of this phase of construction, all facilities would undergo trial operations followed by commissioning for service.

Considering the construction methods required by this project and the nature of the work, it is estimated that development of this project could be completed in approximately 10 years, from initial planning to lake filling. Figure 16 - 1 depicts the development sequence of the various project features.

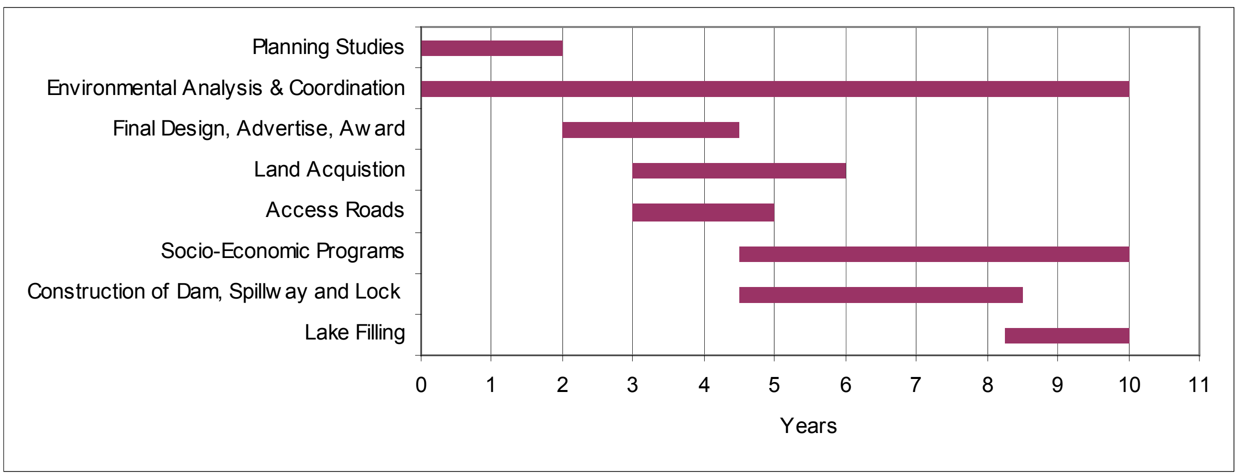


Figure 16 - 1 Development Sequence

Hydrologic Reliability

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

HEC-5 model simulations were conducted for both the existing canal system and the system operating with the proposed Lower Trinidad Lake providing water to the Panama Canal watershed. The simulations considered proportionally increasing demands up to 180 percent of current demand levels. The period of simulation considered 50.5 years (January 1948 through July 1998) of hydrologic record.

Figure 16 - 2 presents the resulting hydrologic reliability for three configurations with demands increasing up to 180 percent of current demands. These configurations were:

- Existing system,
- Operating Option 1 (Lower Trinidad Lake fluctuating between the normal operating lake level at elevation 30 m MSL and the minimum operating lake level at elevation 24.5 m MSL), and
- Operating Option 2 (Lower Trinidad Lake fluctuating between the normal operating lake level at elevation 30 m MSL and the minimum operating lake level at elevation 25.9 m MSL).

The horizontal axis along the bottom of
Figure 16 - 2 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 16 - 2, the existing hydrologic reliability of the Panama Canal, based on the period of record of 50.5 years, is approximately 99.6 percent, while the hydrologic reliability with a demand ratio of 1.8 would be 86.3 percent. This period of record includes the first six months of the 1998 drought year. The hydrologic reliability with a demand ratio of 1.0 would be 99.89 percent for operating Option 1, and the hydrologic reliability with a demand ratio of 1.8 would be 88.67 percent. With operating Option 2, the hydrologic reliability with a demand ratio of 1.0 would be 99.79 percent, and the hydrologic reliability with a demand ratio of 1.8 would be 88.14 percent. Table 16 - 6 displays the number of lockages associated with various levels of reliability.

Without additional water supplies, the hydrologic reliability of the canal system would decrease. With the construction of the proposed Lower Rio Trinidad project using operating Option 1, the existing high hydrologic reliability could be continued as demand for water increases up to 10 percent (4.06 lockages) above current demand levels. Option 2 would support an increase up to 7 percent (2.68 lockages).

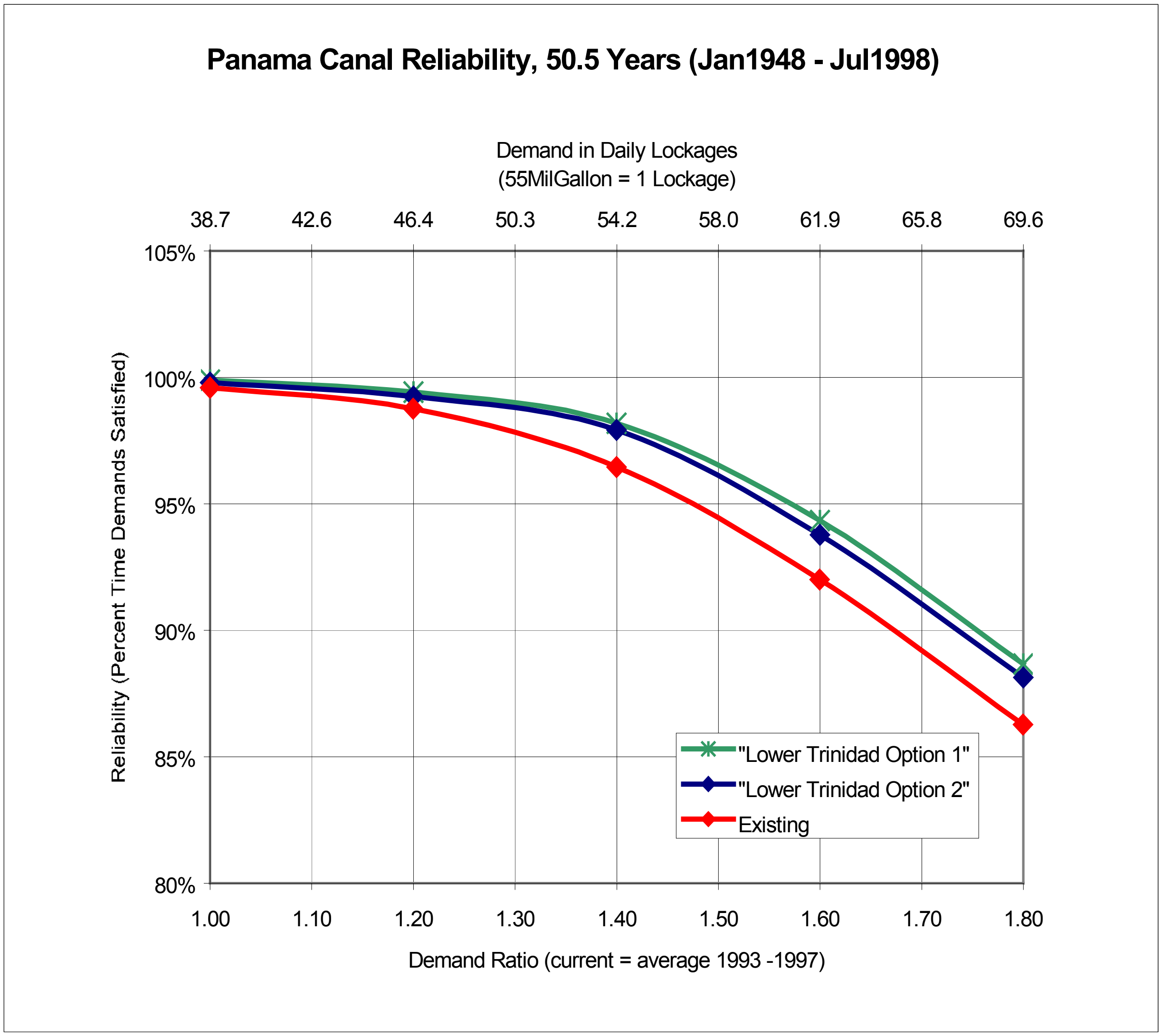


Figure 16 - 2   Panama Canal Hydrologic Reliability

Project Costs

GENERAL

The quantities estimated for the principal features required in the construction of this proposed project were derived from the layouts shown on Plates 16 - 1 and 16 - 2 and on data derived from the Tudor report. The unit prices applied to these quantities were 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 and supervision and administration is estimated to be 6 percent of the construction cost features. An allowance of 2 percent of the construction costs was included for field overhead (construction camp, contractor facilities, etc.). An allowance of 25 percent was included for contingencies. The PCC provided the estimated costs of the land for the proposed project.

FIRST COSTS

The total project first costs are estimated to be $351,692,000. Table 16 - 3 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 16 - 3 Summary of Project First Costs

Principal Feature	Costs ($)
Lands and Relocations	2,000,000
Access Roads	2,680,000
Clearing and / or Grubbing	556,250
Cofferdam	425,000
Dam	214,906,792
Spillway	11,439,785
Lock	2,453,176
Subtotal	234,461,003
E&D, S&A, Field Overhead	46,892,201
Contingencies	70,338,301
Total Project First Costs	351,691,505 Approximately 351,692,000

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 12 who would include a station manager, leaders (Electronics / Instrumentation, Electrical and Mechanical), 4 craftsmen, a laborer, and a lock operator. The annual costs of the staff are estimated to be $300,000.

Ordinary Maintenance

Ordinary maintenance and care would be required and would include minor repair materials, lubricants and other supplies needed by the project staff. It is estimated that the costs of ordinary maintenance would be $10,000 per year for the access road and $100,000 per year for the main project facilities.

Major Replacements

The average service life of gates, electrical equipment, trash racks and other features would be less than the total useful life of the proposed project, which would be 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 would cost the same as at present. No allowance was made for salvageable fixed parts. Table 16 - 4 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 $146,600 and the average annual replacement costs would be $18,000.

Table 16 - 4 Major Replacement Costs

Component	Service Life (years)	Number of Times Replaced During Planning Period	Future Costs ($)	Present Worth of Replacement Costs ($)
Roads	50	1	3,300,000	11,400
Bridges	50	1	675,000	2,300
Lock				
Lock Gates	50	1	334,800	1,200
Electrical Motors	25	2	334,800	10,400
Lock Control Gates	50	1	36,600	100
Service Bridge	50	1	99,300	300
Diesel Generator	25	2	42,000	1,300
Stoplogs	50	1	193,300	700
Misc, Equipment & Communications	25	2	62,700	2,000
Spillway				
Bridge Girders	50	1	119,000	400
Tainter Gates	50	1	2,550,000	8,800
Tainter Gate Hoists	50	1	1,800,000	6,200
Tainter Gate Operating Systems	50	1	360,000	1,200
Stoplogs	50	1	476,000	1,600
Trashracks	50	1	176,800	600
Miscellaneous Mechanical Items	25	2	1,500,000	46,700
Electrical Controls	25	2	1,650,000	51,400
Total			13,710,225	146,600
Average Annual Replacement Costs				18,000

Annual Costs

The total project first costs are estimated to be $62,101,000. 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 total project first costs was computed from mid-year throughout the 10-year period from initiation of Planning and Design until the lake was filled. The interest during construction at 12 percent would be $32,635,000 and it was added to the total project first costs for total project investment costs of $94,736,000. A capital recovery factor for the 50-year planning period was applied to get the annual average investment costs of $11,408,000. Annual operation and maintenance costs were added. Major replacement costs are estimated and were 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 16 - 5 contains a summary of the annual costs.

Table 16 - 5 Summary of Annual Costs

Item	Costs ($)
Total Project First Costs	62,101,000
Interest During Construction	32,635,000
Total Project Investment Costs	94,736,000
Annual Average Investment Costs	11,408,000
Operation and Maintenance Costs	
Staff Costs	350,000
Ordinary Maintenance Costs	110,000
Major Replacement Costs	18,000
Total Average Annual Costs	11,886,000

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 project. The 50-year planning period for this proposal is 2010 to 2060.

The proposed Lower Rio Trinidad project would increase the reliability of providing water to accommodate the total daily number of lockages demanded. Table 16 - 6 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 were obtained from the data used to develop Figure 16 - 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 16 - 6 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 Operating Option 1 [1/] (%)	With Operating Option 2 [2/] (%)
1	2000	38.68 [3/]	99.60	99.89	99.79
	2010	45.11	98.91	99.43	99.34
1.2		46.42	98.76	99.42	99.24
	2015	46.82	98.64	99.35	99.17
	2020	47.61	98.41	99.23	99.04
	2025	48.52	98.14	99.08	98.88
	2030	49.55	97.83	98.92	98.71
	2035	50.72	97.48	98.73	98.51
	2040	52.02	97.09	98.53	98.29
	2045	53.49	96.65	98.29	98.04
1.4		54.15	96.45	98.19	97.92
	2050	55.13	95.89	97.70	97.40
	2055	56.98	94.83	96.78	96.41
	2060	59.05	93.65	95.75	95.30
	2065	61.37	92.32	94.60	94.06
1.6		61.89	92.02	94.34	93.78
	2070	63.97	90.47	92.81	92.26
1.8		69.63	86.27	88.67	88.14

[1/] Includes Lower Trinidad Lake Operating Option 1 - the lake fluctuates from the normal operating lake level at elevation 30 m MSL down to the minimum operating lake level at elevation 24.5 m MSL.

[2/] Includes Lower Trinidad Lake Operating Option 2 - the lake fluctuates from the normal operating lake level at elevation 30 m MSL down to the minimum operating lake level at elevation 25.9 m MSL.

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

Regardless of the operating option, water supply shortages for navigation would continue. The demand for the M&I purposes will always be met first. As these demands grow, the amount of water available to meet the demands for navigation will 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 project, these shortages would be less than they would be under the existing system. With a hydrologic reliability of 99.6 percent, operating Option 1 would increase the amount of water supplied for navigation by approximately 4.74 equivalent lockages, and operating Option 2 would increase that amount by 2.68 equivalent lockages. For operating Option 1, the 99.6 percent hydrologic reliability would occur in the year 2007 with an equivalent daily average number of lockages set to 43.42. For operating Option 2, the 99.6 percent hydrologic reliability level would occur in the year 2004 with an equivalent daily average number of lockages of 41.36. 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 would be attributable to navigation. The benefits are estimated using the toll revenue per lockage and the increased daily average number of lockages provided by each option. The average annual benefits for water supply would be $82,513,000 for operating Option 1 and $54,395,000 for operating Option 2. Table 16 - 7 provides the estimate of daily shortages under the existing system, the remaining daily shortages with the proposed Lower Rio Trinidad project in operation, the annual benefits for meeting shortages, and the average annual benefits for both options.

Table 16 - 7 Benefits for Additional Water Supply for Navigation

Year	Daily Shortages In Lockages Under Existing System	Remaining Daily Shortages With Operating Option 1	Remaining Daily Shortages With Operating Option 2	Annual Benefits for Operating Option 1 ($)	Annual Benefits For Operating Option 2 ($)
2010	6.43	2.37	3.75	79,327,800	52,295,000
2020	8.93	4.87	6.25	83,751,751	55,212,000
2030	10.87	6.81	8.19	83,751,751	55,212,000
2040	13.34	9.28	10.66	83,751,751	55,212,000
2050	16.45	12.39	13.77	83,751,751	55,212,000
2060	20.37	16.30	17.69	83,751,751	55,212,000
Average Annual Benefits				82,513,000	54,395,000

With Option 1, the system will provide a total of 42.74 equivalent lockages at the 99.6 percent level of reliability or 4.06 more lockages than the existing system.

With Option 2, the system will provide a total of 41.36 equivalent lockages at the 99.6 percent level of reliability or 2.68 more lockages than the existing system.

With either operating option, 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 project would be $6,220,000 for operating Option 1 and $4,965,000 for operating Option 2. Table 16 - 8 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 for each operating option.

Table 16 - 8 Average Annual Reliability Benefits For Navigation

Year	Daily Average Number of Lockages	Value Per Daily Lockage ($)	Annual Navigation Benefits For Operating Option 1 ($)	Annual Navigation Benefits For Operating Option 2 ($)
2010	39.0	2,086,000	3,987,000	3,266,000
2020	40.0	2,260,000	6,748,000	5,202,000
2030	40.0	2,260,000	8,992,000	7,258,000
2040	40.0	2,260,000	11,876,000	9,905,000
2050	40.0	2,260,000	14,908,000	12,415,000
2060	40.0	2,260,000	17,376,000	13,637,000
Average Annual Benefits			6,220,000	4,965,000

M&I WATER SUPPLY

The future demand for water supply for M&I purposes was 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 was 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 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 would be $856,000 for operating Option 1 and $685,000 for operating Option 2. Table 16 - 9 displays the population forecast, the resulting number of equivalent lockages demanded per day, the annual benefits for increased reliability, and the average annual benefits for M&I water supply.

Table 16 - 9 Average Annual Reliability Benefits For M&I Water Supply

Year	Population	Equivalent Lockages per Day	Annual M&I Water Supply Benefits for Operating Option 1 ($)	Annual M&I Water Supply Benefits for Operating Option 2 ($)
2010	1,724,000	6.1	445,000	365,000
2020	2,141,000	7.6	863,000	665,000
2030	2,688,000	9.6	1,444,000	1,166,000
2040	3,384,000	12.0	2,396,000	1,999,000
2050	4,259,000	15.1	3,786,000	3,153,000
2060	5,360,000	19.0	5,559,000	4,363,000
Average Annual Benefits			856,000	685,000
The value of a daily lockage for M&I is $0.69 x 55,000 = $37,950				

SUMMARY OF ANNUAL BENEFITS

As shown in Table 16 - 10, total average annual benefits for operating Option 1 and operating Option 2 of the proposed Lower Rio Trinidad project would be $89,589,000 and $60,045,000, respectively.

Table 16 - 10 Summary of Annual Benefits

Benefit Category	Average Annual Benefits	
	Operating Option 1 ($)	Operating Option 2 ($)
Navigation – Water Supply	82,513,000	54,395,000
Navigation - Reliability	6,220,000	4,965,000
M&I - Reliability	856,000	685,000
Hydropower	None	None
Total	89,589,000	60,045,000

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 determines which proposal among several provides the greatest value for the investment dollars. While there would be small differences in some project features between operating Option 1 and operating Option 2, the differences would not have any impact on total project first costs at this level of investigation. The same facilities would be constructed for each operating option. Table 16 - 11 provides the benefit to cost ratios for operating Option 1 and operating Option 2 and the net benefits for both.

Table 16 - 11 Economic Evaluation

Item	Operating Option 1	Operating Option 2
Average Annual Benefits	$ 89,589,000	$ 60,045,000
Average Annual Costs	$ 63,151,000	$ 63,151,000
Benefit to Cost Ratio	1.4	0.95
Net Benefits	$ 26,438,000	- $ 3,106,000

Internal Rate of Return

An internal rate of return analysis for each operating option was performed. To accomplish this analysis, the annual construction costs were used as the investment, and the undiscounted benefits were used as return cash flows. For operating Option 1, the internal rate of return would be 16.0 percent, and for operating Option 2, the internal rate of return would be 11.7 percent.

Socio-Economic Impacts

The socio-economic impacts of the project could be substantial. The relocation of the village 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 should be greatly impacted by the inundation of pastures and agricultural lands to create the lake. 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 is raised, additional agricultural land could be lost due to creation of islands that were once isthmuses. The incremental surface area of the proposed lake is 4,125 ha with another 600 ha for 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 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 should return to pre-construction levels.

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 through the division of communities, separation of families, and loss of livelihood. Following completion of the impoundment, tourism trade in the affected region, including fishing and ecotourism, could increase.

Environmental Setting

The Lower Rio Trinidad project will provide water to Gatun Lake and 4.1 additional lockages per day on a continual basis. The structures for the proposed Lower Rio Trinidad project would consist of a rock fill dam, a small navigation lock, and a gated spillway. The project encompasses the additional area to be flooded and surrounding areas in Gatun Lake. This area is sparsely populated and has 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 watershed above the dam is approximately 750 km^2. The incremental impoundment area covers approximately 4,125 ha and consists of approximately 60 percent of forested land, 20 percent of pasture land (used by ranchers), 10 percent of cropland, and 10 percent of newly slashed and burned land. The lake water elevation will fluctuate from elevation 24.8 to 30.5 m MSL. The roads associated with the project could also have environmental impacts and should be sited to minimize those impacts.

LAND USE

The Lower Rio Trinidad project area encompasses the southwestern portion of Gatun Lake and areas along the shores. The village of Escobal (population – 75) and a few small communities are in the area to be flooded or partially flooded.

Some areas along the shores of the Lower Rio Trinidad portion 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 some teak plantations occupy the remaining land. Farm crops include maize, rice, beans, sugar, coffee, and tobacco. Ranchers raise cows, horses, chickens, and hogs. Some of the farmers and ranchers operate commercial enterprises, others rely on cash crops and subsistence farming.

INFRASTRUCTURE

The village of Escobal has an elementary school, a cemetery, a church, and a medical center. The village 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 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 transversed by unpaved horseback riding trails that link various communities and by dirt roads used by the PCC 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 60 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 communities. 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.

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 none have been identified to date, some of the listed species of interest on the threatened might be found in the project area.

AQUATIC HABITAT

Gatun Lake is one of the largest manmade lakes in the world created by the Panama Canal construction. It contains many different types of aquatic habitat and has various water depths with a wide range of water quality. There are various submerged topographical features including inundated forests and the water is clear in areas distant from the shipping lanes. 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 areas and are subject to frequent flooding. Shallow water areas along the banks of the Lower Rio Trinidad portion of Gatun Lake receive sunlight to approximately 1 m in depth. Sunlight stimulates growth of submergent, emergent, or floating mats of aquatic vegetation. Wetlands occur in topographic areas where water remains pooled long enough to produce hydric soil conditions and wetland plant communities. Wetlands in the project area are currently stressed by wave action from passing ships and sediment-laden runoff from the slash and burn sites.

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 to prepare land 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 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. 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 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. Permanently raising of the Lower Rio Trinidad could impact the wildlife habitat of the project area.

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. It is expected that 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 existing ecosystems.

WATER QUALITY

Project impacts on water quality are unknown. Damming the Lower Rio Trinidad could increase the amounts of nutrients and debris in this portion of Gatun Lake. The rate at which nutrients and debris enter the lake will determine the severity of impact on water quality. Project implementation could cause an increase in turbidity and interfere with photosynthesis in the impacted areas. The increase in turbidity could deprive plants and other aquatic species from necessary sunlight. Aquatic plants and organisms serve to maintain water quality. Species inhabiting specific depths could be impacted when lake depth increases.

DOWNSTREAM AQUATIC FAUNAL HABITAT

The impacts of the project on aquatic faunal habitat could be substantial. Project implementation may impact the breeding and the nursery habitat of many juvenile aquatic species. Impacts to fish spawning areas may be detrimental when turbidity, nutrient content, and depth of the water suddenly increase, by altering the conditions needed for successful hatching of the fish. Plant populations may decrease as a result of the increase in water depth and decrease in sunlight; therefore, 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 stable water levels. Plant species in the Lower Rio Trinidad portion of Gatun Lake could be impacted by the increase in water depth. Aquatic plant communities could be impacted during project implementation; however, they could eventually re-establish themselves after conditions stabilize.

AQUATIC FAUNA INHABITING AFFECTED AREAS

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 that formerly occupied the impoundment have disappeared. The Rio Lower Rio Trinidad project would also take part of Gatun Lake; therefore, the peacock bass and tilapia would already be present.

WETLANDS

The impacts to wetlands could be significant. As present wetlands are inundated, they could become aquatic habitat. Project activities may lead to increased 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 portion of Gatun Lake. Fish and other aquatic species use shallow water areas as spawning grounds as well as habitat for juvenile aquatic species. Juvenile aquatic species survive in shallow water wetland areas until they are large enough to venture out into deeper water. These areas are vital to the sustainability of this portion of Gatun Lake.

AIR QUALITY

During project implementation, emissions from construction equipment, along with local slash and burn activities, could cause deterioration of air quality in the project area. After project implementation, the air quality could improve because the Panamanian government currently discourages slash and burn activities.

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.

Additional Environmental Information Required

This section identifies the subject 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 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.
  - Recreational Resources.

TERRESTRIAL AND AQUATIC HABITAT

- Prepare site-specific habitat maps to ensure that the major aquatic habitat types 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.
- Provide 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 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

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 Section 35. Tables 16 - 12 through 16 - 14 present the evaluation of the proposed Lower Rio Trinidad project as related to developmental effects, environmental effects, and socio-economic effects.

Table 16 - 12 Developmental Effects

Evaluation Criteria	Function	Measure [1/]	Importance [2/]	Composite [3/]
Water Contribution (Water Yield)	Meets M&I Demands	5	10	50
	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	10	6	60
	Maintenance Requirements	5	2	10
	Operational Resources Required	8	2	16
Economic Feasibility	Net Benefits	1	9	9
	Total			169

[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 16 - 13 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	5	4	20
Air Quality	5	3	15
Cultural Resources and Historic Properties	5	10	50
Total			501

[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 - 14 Socio-Economic Effects

Item	Measure [1/]	Importance [2/]	Composite[3/]
Land Use	4	7	28
Relocation of People	5	10	50
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			452

[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 16 - 15 presents pertinent data for the proposed Lower Rio Trinidad project.

Table 16 - 15 Pertinent Data for Operating Option 1

GENERAL		
Dam Site, above Gatun Dam	10 km	
Drainage Area above Dam Site	741 km^2	
Average Annual Flow at Dam Site	32 CMS	
LAKE	**Option 1**	**Option 2**
Elevation of Normal Operating Lake Level	30 m MSL	30 m MSL
Elevation of Maximum Flood Lake Level	30.5 m MSL	30.5 m MSL
Elevation of Minimum Operating Lake Level	24.8 m MSL	25.9 m MSL
Useable Storage between Max and Min levels	798 MCM	655 MCM
Area at Normal Operating Lake Level	4,280 ha	4,280 ha
Area at Maximum Flood Lake Level	4,440 ha	4,440 ha
Area at Minimum Operating Lake Level	3,630 ha	2,360 ha
Top Clearing Elevation	30.5 m MSL	30.5 m MSL
Lower Clearing Elevation	26 m MSL	26 m MSL
EMBANKMENTS		
Dam		
Type of Dam	Rock Fill Embankment	
Top Elevation of Dam	31 m	
Fixed Crest Width	7 m	
Height	30 m	
Overall Length of Dam	4,473 m	
Saddle Dams (Caño Saddle Dam No. 4 and two additional)		
Type of Saddle Dam	Earth / Rock Fill Embankment	
Top Elevation of Saddle Dam (minimum)	31 m MSL	
SPILLWAY		
Type of Spillway	Gated Ogee	
Number of Gates	15	
Gate Width	18.33 m	
Total Length	323 m	
Elevation of Spillway	24.8 m MSL	
Maximum Discharge	250,000 CMS	
NAVIGATION LOCK		
Length	230 m	
Width	7.6 m	
Maximum Lift	5.4 m	
Minimum Depth Over Sills (Pool Elev.25 m)	3 m	

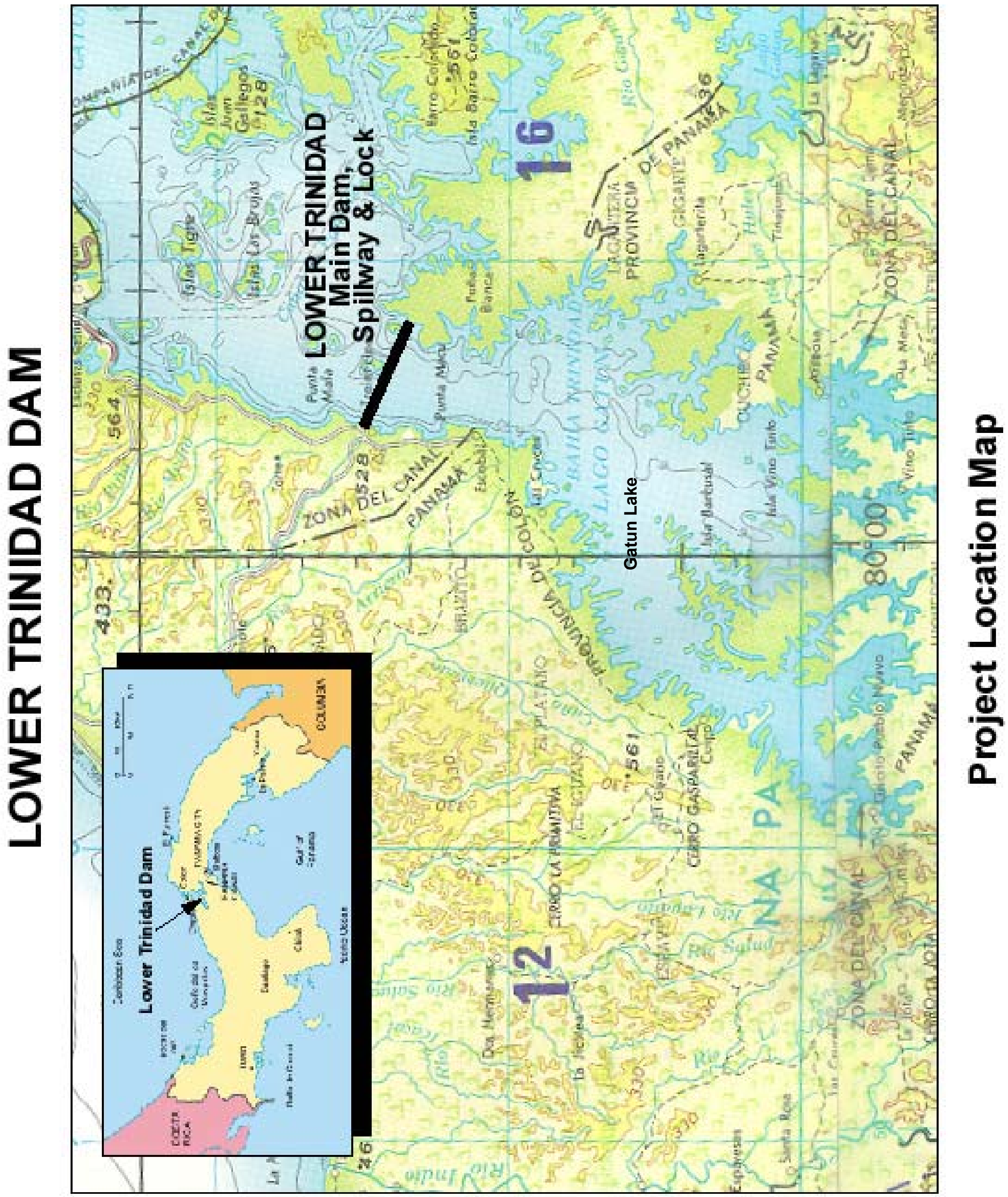
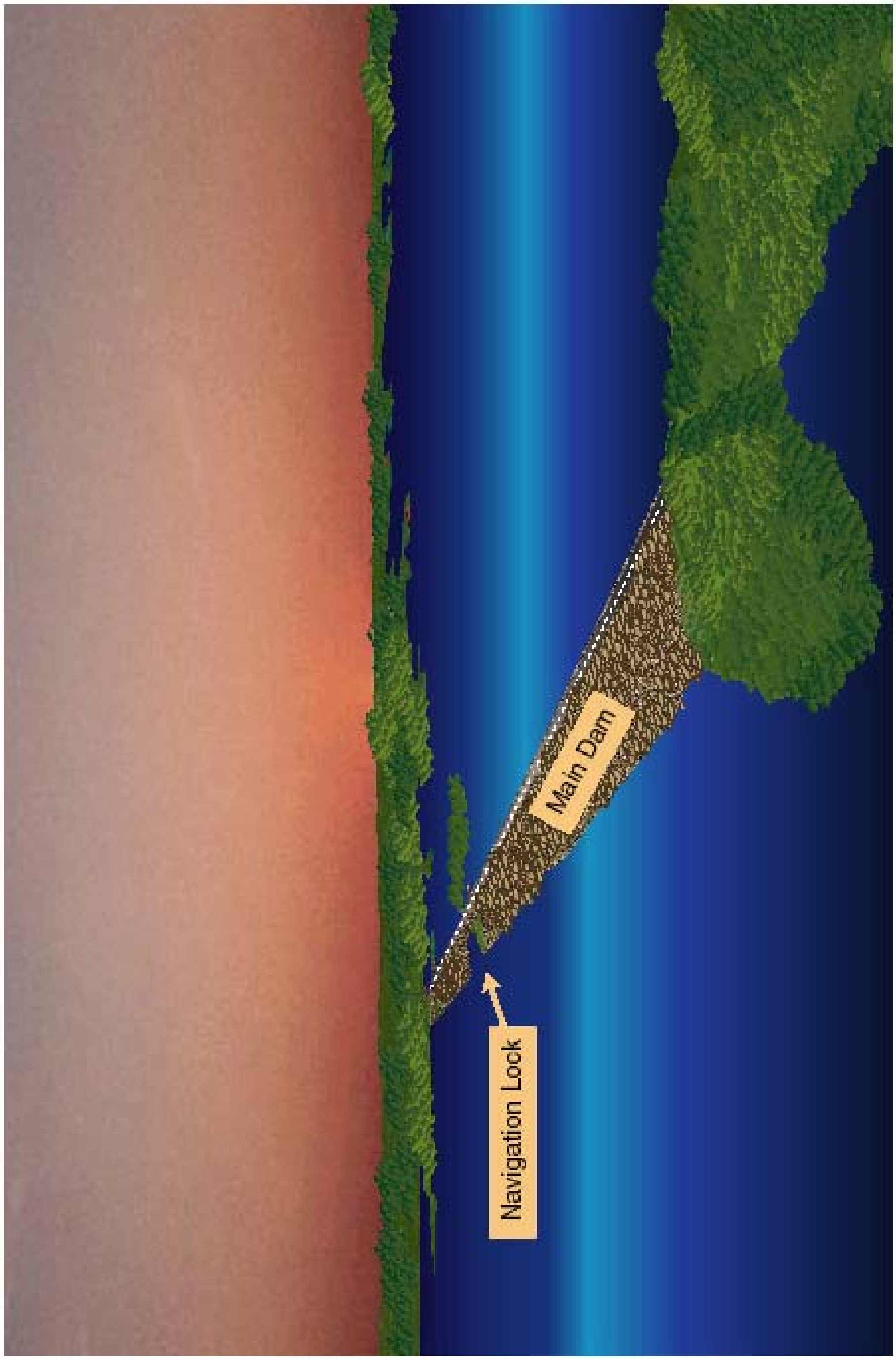


Plate 16 - 1   Project Location Map

LOWER TRINIDAD



Site Plan

Plate 16 - 2   Site Plan