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Autoridad Del Canal De Panama
Division de Proyectos de Capacidad del Canal

Work Order No.5 Feasibility Design For The Ríos Coclé Del Norte And Caño Sucio Water Supply Projects

Panama Canal

Contract Number CC-3-536

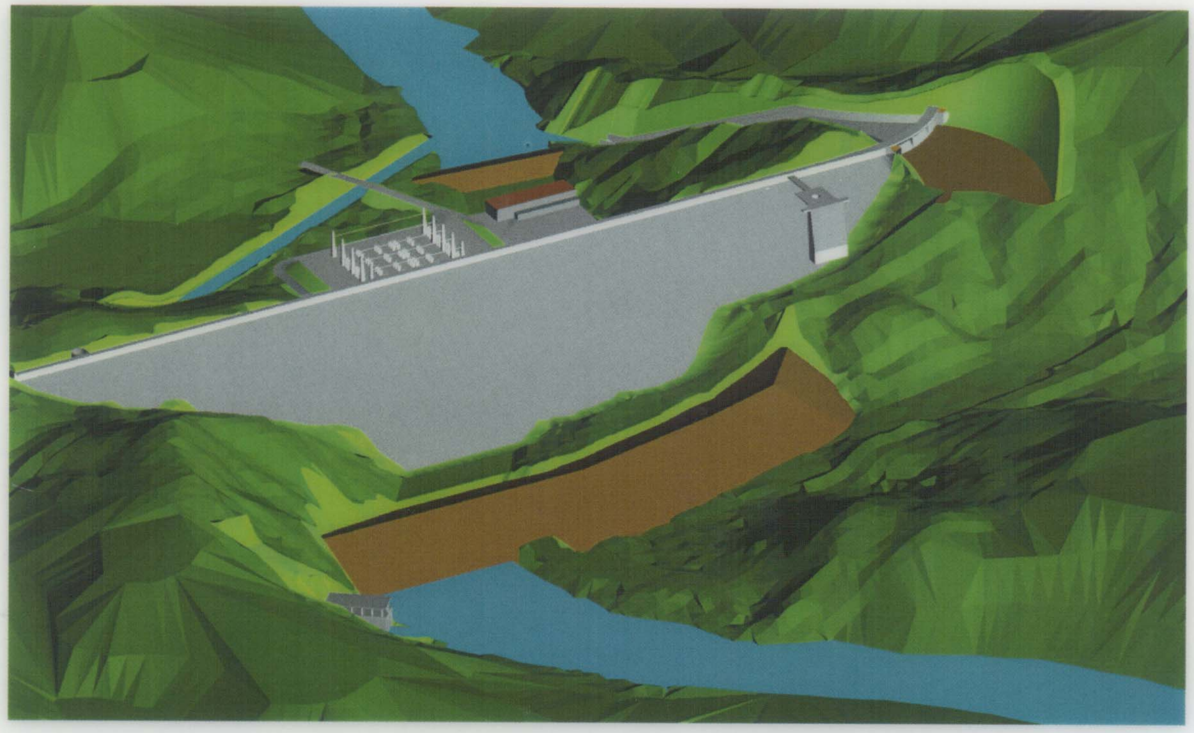
VOLUME 1: MAIN REPORT
Coclé Del Norte-Río Indio Project

MWH
In association with
TAMS
AN EARTH TECH COMPANY

December 2003

ACP

Coclé del Norte with Río Indio



MWH

FEASIBILITY DESIGN FOR THE RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS

Volume	Title
1	**Feasibility Study of the Río Coclé del Norte Reservoir Acting in Full Regulation with the Río Indio Reservoir**
2	Feasibility Study of the Río Coclé del Norte Reservoir Acting in Full Regulation with the Río Caño Sucio and Río Indio Reservoirs
3	Appendix A – Hydrology, Meteorology and River Hydraulics Appendix B – Geology, Geotechnical and Seismological Studies Appendix C – Operation Simulation Studies
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AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

THE PANAMA CANAL

ENGINEERING SERVICES

Work Order No. 5
The Ríos Coclé del Norte and Caño Sucio Water Supply Projects

Volume 1

Feasibility Study Of The
Río Coclé del Norte Reservoir Acting in Full Regulation With The Río Indio Reservoir

DECEMBER 2003

MWH
In association with
TAMS Consultants, Inc.
Ingenieria Avanzada, S.A.
Tecnilab, S.A

Executive Summary

EXECUTIVE SUMMARY

INTRODUCTION

The ACP is undertaking a Canal Capacity Study, which includes the evaluation of additional sources of water to augment Canal capacity. The transit of ships through the Panama Canal is dependent upon the availability of the fresh water stored in Madden and Gatun reservoirs. Water availability is limited and, even at present traffic levels, is not sufficient to meet traffic demand during prolonged dry periods. Therefore, new sources of water must be identified, defined, and evaluated.

The US Army Corps of Engineers (USACE) performed a reconnaissance study for the Panama Canal Commission to identify and evaluate potential water supply projects. A reservoir on the Río Coclé del Norte, operating in conjunction with a reservoir on the Río Indio, was recommended as a feasible alternative for further consideration to develop a long-term water supply plan.

The Autoridad del Canal de Panama (ACP), formerly the Panama Canal Commission, has authorized Montgomery Watson Harza, formerly Harza Engineering Company, to perform an engineering feasibility study of this project under Contract CC-3-536, Work Order 005, dated June 19, 2000.

OBJECTIVE OF THE STUDY

The original objective of this study was to determine the technical and economic feasibility of the project. An assessment of the environmental feasibility was to have been performed separately under the direction of the ACP.

During the course of the study, it was not possible to implement the subsurface investigation programs. Also, during the course of the study, the ACP decided to implement development in the Río Coclé del Norte basin only in conjunction with a plan to add new locks to the Panama Canal System. Under this condition, the demand for and benefits from developing the Río Coclé del Norte Project could not be assessed at this time. Therefore, a determination of economic feasibility was not possible. The objective of the study was changed to an assessment of technical feasibility, based on the available information.

HYDROLOGY AND RIVER HYDRAULICS

Studies were performed to confirm the long-term streamflow sequences for the Río Coclé del Norte at the damsite, to estimate the spillway design flood at the site, and to estimate the impact of reservoir sedimentation.

A long-term flow sequence (1948-1999) at the Río Coclé del Norte damsite was generated by adding the data from El Torno and Batatilla, adjusted for drainage area and rainfall. The flows at El Torno and Batatilla were completed using correlations with El Chorro, Los Canones and Boca de Uracillo. The mean annual flow at the Río Coclé del Norte damsite is estimated to be 107.5 m^3/s and the monthly distribution of flow is shown below.

MONTHLY MEAN STREAMFLOW AT THE RÍO COCLÉ DEL NORTE DAMSITE
(m^3/s)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
89.5	52.1	37.7	53.5	91.8	108.8	107.7	125.3	139.2	162.7	173.0	149.2	107.5

The probable maximum floods (PMF), based on probable maximum precipitation (PMP) were adopted as the spillway design flood. A PMP estimate of 714 mm was adopted for the Río Coclé del Norte basin based on information presented in the National Weather Service publication of PMP dated 1978. Using the HEC-1 computer model and allowing for a based flow estimated from an analysis of major historic floods, the PMF was estimated to have a peak inflow of 10,460 m^3/s and a 5-day volume of 988 MCM.

The impact of sediment deposition on storage in the reservoir was evaluated using data from the Río Coclé del Norte basin, Lake Madden and other sources. After 100 years, it is expected that sediment deposition will reduce the live storage of the Río Coclé del Norte reservoir by about 1 percent and, therefore, presents no problem.

GEOLOGIC CONDITIONS

The geologic conditions were established on the basis of geologic mapping, geomorphological analysis, photogeologic studies, a moderate subsurface investigation program, and construction materials investigations.

Río Coclé del Norte Damsite

Bedrock at the dam site is found to consist mostly of porphyritic basalt and, less commonly of basic agglomerate. Rock float and large boulder talus indicate the presence of *in situ* bedrock at relatively shallow depths, but extensive weathering is evident. Basalt float was observed all the way up the left abutment to above El. 100 m. Rock outcrop was observed at river level on the left side, at several other locations on the left abutment and is widespread on the right side.

Both abutments are heavily vegetated and are almost entirely covered with talus, colluvial, and residual soils. Small, scattered rock outcrops can be observed throughout the site area on both abutments, especially in gullies. Most of the dam site area is characterized by a moderately deep weathered profile with locally thick soil cover typical of the sub-tropical climate.

Based upon experience with geological investigations and construction in the Canal Area, it is likely that several small faults and shear zones could exist at the dam site. From regional geologic mapping and photogeologic studies, the presence of major faults, however, is not expected. Some photogeologic linears have been interpreted in the dam site area but these are not thought to be caused by significant faulting.

In general, the basaltic foundation bedrock at the site should provide a suitable foundation for all types of structures being considered.

Water Transfer Tunnel to Río Indio

Only one principal tunnel alignment was investigated for the tunnel from the Río Coclé del Norte Reservoir to the Río Indio Reservoir. This alignment has a total length of about 16,500 m, including the 0.7 km-long connection for a lake tap.

Existing geologic maps of the region show bedrock in the region as belonging to 'undifferentiated Tertiary volcanics' or alternatively as belonging to the Tertiary age Caimito Formation (tuffaceous sandstone, tuffaceous siltstone, tuffs, dacitic agglomerate, conglomerate, sandstone, and limestone). It is assumed that rock units that could be encountered in excavation of the tunnel alternative could include any of those identified during investigation of the Río Toabré and Río Indio sites and reservoir areas.

Observations indicated that the outlet works into the Río Indio reservoir would be constructed in rolling subdued topography with possibly little cover over tunnel grade and deeply weathered sedimentary units (sandstones and shales). Recommendations were made to locate the proposed outlet works sufficiently far back to ensure adequate rock cover and to attain relatively sound bedrock.

At the intake end, reconnaissance revealed that the topography in the portal area is complicated with deeply incised drainages. Nevertheless, it was considered that a favorable portal location could be found with a range of options for detailed design, i.e. flexibility in vertical and horizontal location.

It is probable that tunnel construction will encounter a wide range of rock types and tunneling conditions. Rock types could include sandstone and softer epiclastics of the Caimito Formation as well as hard, strong lavas (andesites, dacites, and basalts), limestones, and agglomerates.

Experience indicates that groundwater inflow should be expected at various points along the proposed tunnel alignment. The potential for encountering hazardous gases is considered remote. The tunnel is not likely to encounter stress-related problems (popping rock, slabbing rock, or rock burst in competent rock, squeezing ground in weak/fractured rock) because the rock cover is not that great.

Construction Materials

The types of required construction materials for the project are:

- Materials for cofferdams;
- Concrete aggregates;
- Filters and drains;
- Rock fill for the dam, backfill materials and other structural fills, and;
- Rock for riprap and slope protection.

The diversion cofferdams will consist of temporary dikes designed to divert the river, in combination with channel excavation. Currently, it is assumed that these could be constructed from locally available random fill obtained from the immediate area of the dam site.

The majority of the rockfill and all aggregates (including coarse and fine aggregates for concrete, filters, drains, and riprap) for the Río Coclé del Norte Project need to be manufactured from quarried sources. Coarse and fine aggregates for concrete will be processed from quarried igneous rock materials, i.e. basalt or andesite. Aggregates for filters and drains will be obtained by processing of the same quarry sources as exploited for concrete aggregates. The area one to three kilometers to the east of the damsite consists of high hills that could be stripped and opened as quarries.

Materials for backfill will come from the required excavations, including use of tunnel excavation spoil. A portion of the rockfill for the dam also could be obtained from required excavation, provided that it is not too decomposed.

It is anticipated that some mixing with imported sands and silts will be necessary.

DESCRIPTION OF THE PROJECT

Implementation of a project to result in the impoundment of the Río Coclé del Norte Reservoir that will operate in full regulation with the Río Indio Reservoir will require the construction of:

- A dam on the Río Coclé del Norte,
- A tunnel to transfer water from the Río Coclé del Norte Reservoir to the Río Indio Reservoir, and
- A second tunnel between the Río Indio Reservoir and Lake Gatun.

In addition, it has been determined that a power plant at the base of the Río Coclé del Norte dam is feasible. Commercial agriculture associated with the development of the project is not warranted at this time. A general plan of the project is shown on Exhibit 1.

Río Coclé del Norte Dam and Reservoir

The major elements that comprise the storage facility on the Río Coclé del Norte include:

- An 86-m high concrete-face rockfill dam with its crest at El. 74 and top-of-structure at El. 76,
- A 50-m wide spillway in the right abutment with a capacity at full surcharge of 800 m^3/s,
- An 8-m diameter, D-shaped tunnel in the left abutment sized to pass the 50-year flood and provide for drawdown in the case of emergency,
- A 60 MW powerplant at the base of the dam, incorporating a minimum release facility.

The dam will impound a reservoir with a gross storage capacity of 5,275 MCM and operate between El. 71, the full supply level, and El. 50. Live storage between El. 71 and El. 50 will be about 3,445 MCM. The reservoir area at the full supply level is 227 square kilometers.

The yield resulting from the addition of the Río Coclé del Norte reservoir to the system is 3,480 MCM/year or 45.4 lockages/day. The 60 MW powerplant will contain three equal-sized units and generate an average of 327 GWh/year ranging from 425 GWh/year in the initial years of operation to 120 GWh/year at the end of its economic life.

A general site plan of the Río Coclé del Norte Project, showing the location of the dam and appurtenant works is shown on Exhibit 2.

Water Transfer Tunnel to Río Indio Reservoir

To transfer water from the Río Coclé del Norte reservoir to the Río Indio basin, it is necessary to construct a 16,500-m long, 9.0-m diameter tunnel. The dimensions of the facilities are controlled by the requirement to pass about 185 m^3/s when the Río Coclé del Norte reservoir is at its minimum level (El. 50). A plan showing the tunnel alignment is presented on Exhibit 3.

Second Tunnel from Río Indio Reservoir to Lake Gatun

According to the present concept, the Río Indio Project will have been constructed about 20 to 30 years prior to any Río Coclé del Norte Project configuration. As described in the Río Indio Water Supply Project Report, a 4.5-m diameter tunnel is required to convey Río Indio water to Lake Gatun. With the connection of the Río Coclé del Norte Project to the system, a second tunnel, 8250-m long with a diameter of 6.5 m, will be required. The tunnel will be aligned parallel and next to the presumed existing tunnel. A plan of the alignment is shown on Exhibit 4.

COST OF THE PROJECT

The estimated cost of the Project has been developed on the basis of the present feasibility design and construction schedule, plus a compensation and mitigation cost estimated by the ACP. The construction cost estimates represent the prevailing rates and prices in January 2003 and are based on the assumption that an international contractor will construct the water supply and hydropower facilities without restriction on sources of supplies and equipment. The unit prices have been estimated at feasibility level.

A summary of the Project cost is shown below.

Item	Estimated Cost
Mitigation and Compensation Costs	**$140,000,000**
Access Roads and Construction Camp	$13,500,000
Río Coclé del Norte Storage and Hydro Facilities	$132,600,000
Water Transfer Tunnel	$176,400,000
Second Río Indio-Lake Gatun Tunnel	$85,900,000
Reservoir Clearing	$22,000,000
Subtotal Direct Cost	**$430,400,000**
Contingency	$83,500,000
Direct Cost	**$513,900,000**
Engineering and Administration	$77,100,000
Construction Cost (Jan 2003 price level)	**$591,000,000**
TOTAL COST	**$731,000,000**

The annual operating costs include the costs of operation and maintenance (O&M), for the various features, the cost of replacing short-life equipment, administration by the Owner, and insurance. In addition, an annual cost associated with watershed management, implementation of the environmental mitigation plan and the relocation activities is included. The annual operation and maintenance costs are summarized below:

Item	Annual Cost
O&M	$2,450,000
Replacement	$110,000
Admin and General Expenses	$700,000
Insurance	$589,000
Resettlement Administration	$150,000
Watershed Management	$150,000
Mitigation Plan Implementation	$100,000
Total (rounded)	**$4,250,000**

PROJECT IMPLEMENTATION

It is estimated that implementation of the Project could be achieved in about 12 years. However, it is likely that the project will not be required within that time frame assuming that the Río Indio Water Supply Project or some water saving device is in operation. Therefore, the implementation schedule assumes that additional studies such as finalization of the Master Plan, water demand assessment studies, and alternative water supply projects analyses will have been performed prior to project selection. If the project is selected, environmental studies, funding, design, contractor selection, can all be accommodated within this overall implementation schedule. The implementation schedule is shown on Exhibit 5.

The durations of the construction of each component are estimated as 32 months for the access roads, 50 months for the Río Coclé del Norte dam and power facilities, 67 months for the Coclé-Indio transfer tunnel, 34 months for the second Transfer Tunnel, and 33 months for reservoir clearing and mapping. Overall the construction, including the filling of the reservoirs to levels sufficient for the project to be fully operational will require about seven years.

CONCLUSIONS AND RECOMMENDATIONS

Without the information required to perform and economic and financial evaluations (for reasons given in Section 1.3.2), it is not possible to make a recommendation concerning the implementation of the project. The economic cost of water is higher than what might normally be expected for a commercial supply and approaches what might be expected for a municipal or industrial (M&I) supply. However, the current benefits accruing to water supply from the Panama Canal operation also are high and may continue at this level. Therefore, development of the project cannot be ruled out, but the recommendations, at this time, can relate only to the relative attractiveness of the possible alternative developments in the basin.

Conclusions

As a result of the studies described in this report and its appendices, it is concluded that:

- The Project is technically feasible.
- The dam sites selected in the Reconnaissance Report are suitable sites for the development of the water resources of the Río Coclé del Norte Basin.
- A concrete-faced rockfill dam at the Río Coclé del Norte site is the most appropriate types of dam for the site based on the available information, estimates of cost, and preferences of the ACP.
- It is our considered opinion that there are no geologic or geotechnical problems associated with the site that cannot be accommodated using conventional solutions although the lack of subsurface investigations has increased the potential for inaccuracies in the estimate of cost.
- The yield of the Panama Canal system will increase by about 3,480 MCM/yr (about 45.4 L/d) with the addition of the Project.
- The addition of a 60 MW hydropower plant at Río Coclé del Norte dam is economically attractive.
- The inclusion of a commercial agricultural endeavor is technically feasible, but is not economically viable at this time and development should not be initiated at this time.
- Construction of the project is estimated to cost about $591 million in 2003 dollars. An addition $140 million have been allowed for compensation and mitigation for a total cost of $731 million.
- The economic cost of the water is less than for the project with a full supply level at El. 100 and acting in full regulation with the Río Caño Sucio and Río Indio Reservoirs.

Recommendation

As a result of these conclusions, it is recommended that the project be favored over the Norte/Sucio/Indio Project (see Volume 2) if development in the Río Coclé del Norte basin is considered further.

TABLE OF SIGNIFICANT DATA

Project Setting

The project is located about 80 km to the west of Colon in the farthest west of the "Western Watersheds". The basin rises along the Continental Divide and drains into the Atlantic Ocean.

Hydrology		
Río Coclé del Norte		
Average Annual Precipitation	2,800	mm
Average Annual Streamflow	107.5	m^3/s
Río Coclé del Norte Storage Facilities		
Reservoir		
Drainage Area	1594	km^2
Normal Maximum Water Level	El. 71	msl
Volume	5,275	MCM
Surface Area	227	km^2
Minimum Pool Level	El. 50	msl
Volume	1,830	MCM
Surface Area	106	km^2
Live Storage	3,445	MCM
Dam		
Type of Dam	Concrete-face rockfill	
Parapet/Crest Elevation	76/74	m
Minimum Foundation Elevation	-10	m
Maximum Height	86	m
Crest Length	670	m
Upstream and Downstream Slope	1.4H:1.0V	
Fill Volume	2,920,000	m^3
Upstream and Downstream Slope	1.4H:1.0V	
Spillway		
Type of Spillway	Ungated ogee	
Spillway Crest Elevation	71	m
Crest width	50	m
Excavation Volume	367,000	m^3
Concrete volume	10,600	m^3
Spillway Design Flood		
Peak Inflow	10,460	m^3/s
5-day Volume	988	MCM
Peak Outflow	800	m^3/s
Surcharged Reservoir Level	El. 74.7	msl

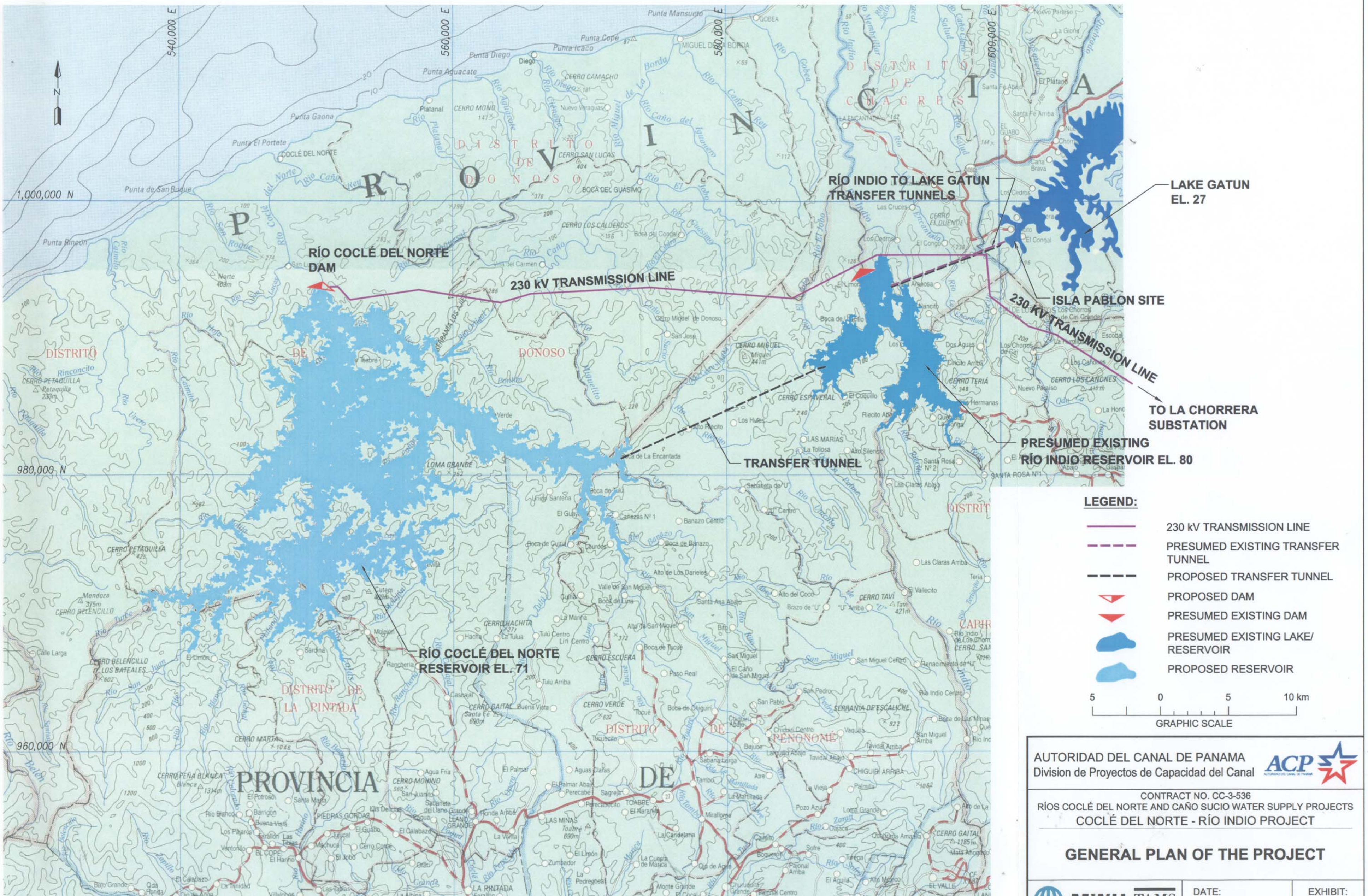
TABLE OF SIGNIFICANT DATA, cont.

Río Coclé del Norte Storage Facilities, cont.		
Diversion During Construction		
Section Shape	modified horseshoe; vertical sides; horizontal invert	
Diameter	8.0	m
Length	530	m
Diversion Flood	3,860	m^3/s
Discharge Capacity	640	m^3/s
Upstream Cofferdam Height (hydraulic)	29	m
Downstream Cofferdam Height (hydraulic)	7	m
Cofferdam fill Volume	529,000	m^3
Minimum Release Facility		
Type	Bypass in hydropower plant	
Capacity	10.7	m^3/s
Power Facilities		
Power and Energy		
Installed Capacity	60	MW
Firm Capacity	60	MW
Average Annual Energy Production	327	GWh/year
Peak Annual Energy Production	425	GWh/year
Minimum Annual Energy Production	120	GWh/year
Unit Information		
Number of Units and Capacity	3-20	MW
Design Head	68	m
Discharge	35	m^3/s
Rotational Speed	300	rpm
Generator Rating	22,250	kVA
Generator Frequency	60	Hz
Power Factor	0.9	
Physical Data		
Powerplant Type	Surface	
Power Tunnel Length	260	m
Power Tunnel Diameter	5.8	m

TABLE OF SIGNIFICANT DATA, cont.

Water Transfer Tunnel		
Coclé del Norte Reservoir to Río Indio Reservoir		
Excavation Method	TBM; Drill & Blast	
Section Shape	Circular; Modified horseshoe	
Length	16,500	m
TBM	15,600	m
Drill & Blast	900	m
Diameter	9.0	m
Capacity at Maximum Pool	300	m^3/s
Río Indio Reservoir to Lake Gatun		
Excavation Method	Drill & Blast	
Section Shape	Modified horseshoe	
Length	8,250	m
Diameter	6.5	m
Estimated Project Cost		
Construction Cost	$591,000,000	
Mitigation and Compensation Cost	$140,000,000	
Total Project Cost	$731,000,000	
Annual Cost	$4,250,000	
Estimated Project Schedule		
Implementation Period	12	years
Construction Period	7	years
Estimated Project Yield		
Volumetric Reliability	99.6	%
Yield L/d	45.4	L/d
Yield MCM/year	3,480	MCM/yr

EXHIBITS



AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

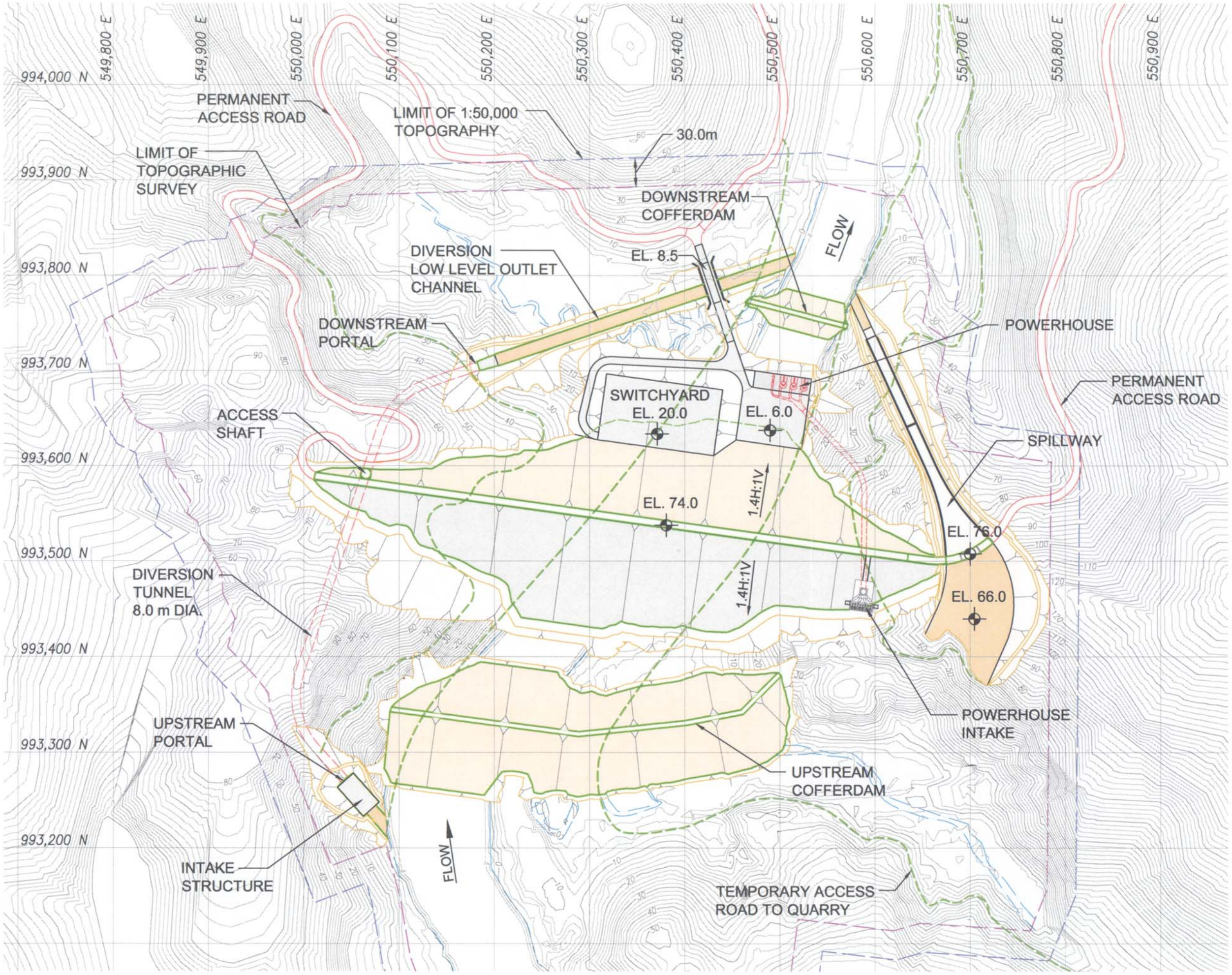
ACP

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

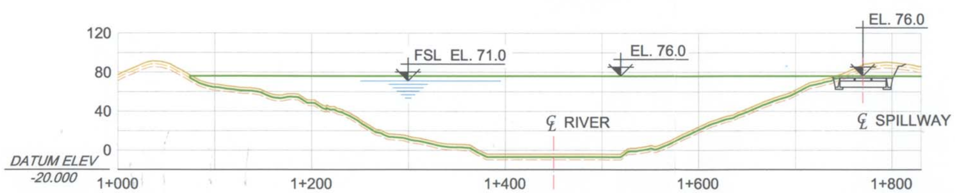
GENERAL PLAN OF THE PROJECT

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	1



SITE PLAN



UPSTREAM DAM ELEVATION

LEGEND:

- PERMANENT ACCESS ROAD
- CONSTRUCTION ACCESS ROAD

0 50 100 150 200 250 m
GRAPHIC SCALE

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

RÍO COCLÉ DEL NORTE PROJECT SITE PLAN

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 2

NOTE:

TOPOGRAPHY COMPILED FROM THE FOLLOWING SOURCES:

1. GROUND SURVEY (IASA, 2003)
2. AERIAL PHOTOGRAPHY (GEOCART - GRAFOS, 2002)
3. PUBLISHED 1:50,000 TOPOGRAPHIC MAPS (TOMMY GUARDIA)

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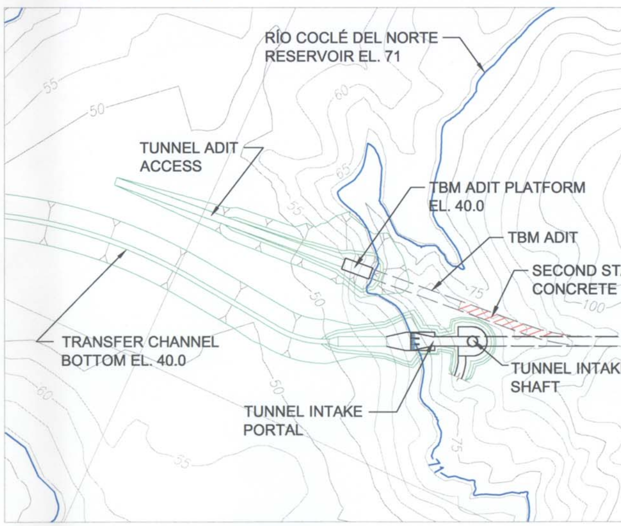
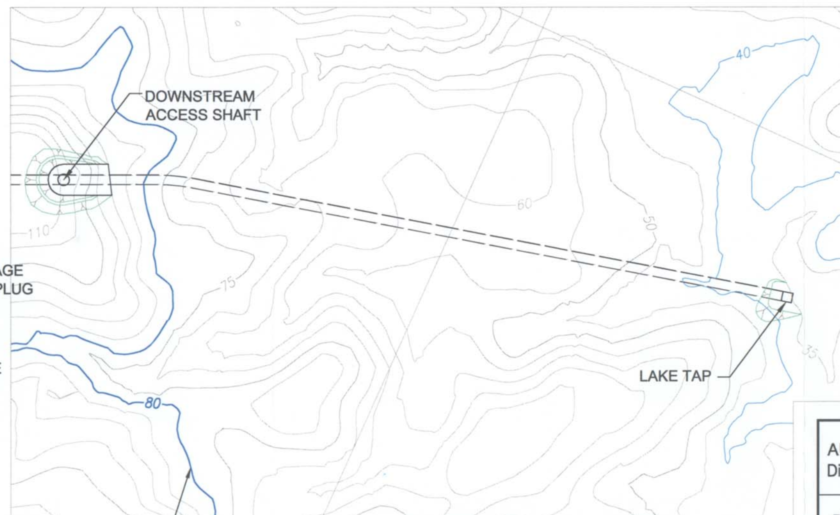


DETAIL 1
TRANSFER TUNNEL INTAKE AND TBM ADIT

0 50 100 m

GRAPHIC SCALE



PRESUMED EXISTING RÍO INDIO RESERVOIR EL. 80

DETAIL 2
TRANSFER TUNNEL OUTLET

0 50 100 m

GRAPHIC SCALE

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

ACP

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

RÍO COCLÉ DEL NORTE TO RÍO INDIO WATER TRANSFER TUNNEL PLAN AND DETAILS

MWH TAMS

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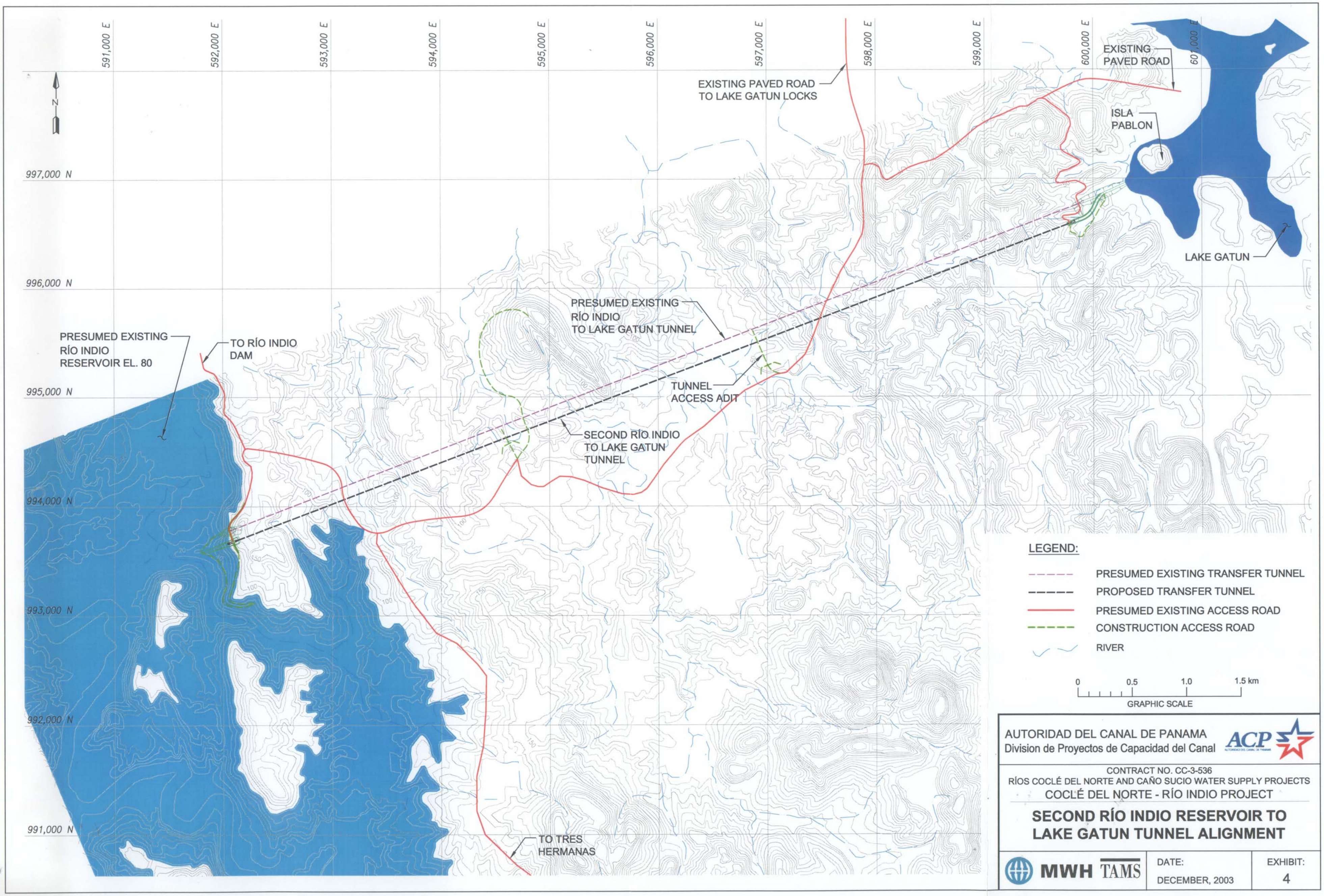
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EXISTING PAVED ROAD
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ISLA PABLON
LAKE GATUN
PRESUMED EXISTING RÍO INDIO TO LAKE GATUN TUNNEL
PRESUMED EXISTING RÍO INDIO RESERVOIR EL. 80
TO RÍO INDIO DAM
TUNNEL ACCESS ADIT
SECOND RÍO INDIO TO LAKE GATUN TUNNEL
TO TRES HERMANAS
LEGEND:
PRESUMED EXISTING TRANSFER TUNNEL
PROPOSED TRANSFER TUNNEL
PRESUMED EXISTING ACCESS ROAD
CONSTRUCTION ACCESS ROAD
RIVER
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0.5
1.0
1.5 km
GRAPHIC SCALE
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal
ACP
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT
SECOND RÍO INDIO RESERVOIR TO LAKE GATUN TUNNEL ALIGNMENT
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DATE:
DECEMBER, 2003
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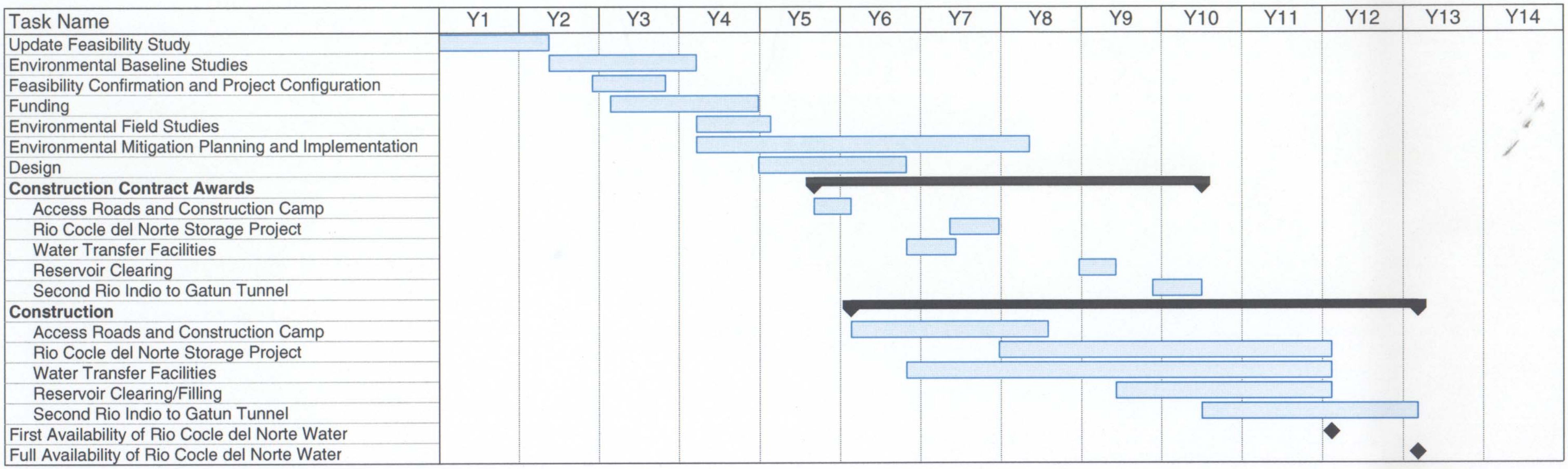
4

Cocle del Norte - Rio Indio Project

Implementation Schedule



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CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

IMPLEMENTATION SCHEDULE

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 5

Main Report

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EXHIBITS

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APPENDICES

1. INTRODUCTION

1.1 Authorization

The Autoridad del Canal de Panama (ACP), formerly the Panama Canal Commission, has authorized Montgomery Watson Harza, formerly Harza Engineering Company, to perform an engineering feasibility study of the Río Coclé del Norte and Río Caño Sucio Water Supply Project under Contract CC-3-536, Work Order 0005, dated June 19, 2000.

1.2 Background

In 1998, the ACP established the Canal Capacity Projects Office to study options for improving the Panama Canal (Canal) operating systems to provide efficient and competitive services for the next 50 years.

The ACP is undertaking a Canal Capacity Study, which includes the evaluation of additional sources of water to augment Canal capacity. The transit of ships through the Panama Canal is dependent upon the availability of the fresh water stored in Lake Gatun and *Lago Alajuela* (Lake Madden). Water availability is limited and, even at present traffic levels, is not sufficient to meet traffic demand during prolonged dry periods. Therefore, new sources of water must be identified, defined, and evaluated.

The US Army Corps of Engineers (USACE) performed a reconnaissance study to identify and evaluate potential water supply projects (1)[1]. A project in the Río Coclé del Norte basin was identified as having significant potential to augment the existing water supply to the Canal.

Two concepts were identified in the Reconnaissance Report for transferring water from the Río Coclé del Norte basin to the Canal:

- The Río Coclé del Norte Reservoir acting in full regulation with the Río Indio Reservoir (Norte/Indio Project), and
- The Río Coclé del Norte Reservoir acting in full regulation with the Caño Sucio and Río Indio Reservoirs (Norte/Sucio/Indio Project).

The Norte/Indio Project is the subject of this volume.

[1] Numbers in parentheses refer to the List of References in Section 11.

1.3 Objectives

1.3.1 Original Objective

The original objective of this study was to determine the technical and economic feasibility of the Project. An assessment of the environmental feasibility will be performed separately under the direction of the ACP.

1.3.2 Modified Objectives

During the course of the study, it was not possible to implement the subsurface investigation program or the refraction surveys. Therefore, a firm determination of technical feasibility was not possible. The objective was changed to an assessment of technical feasibility.

Also, during the course of the study, it was determined by the ACP that development in the Río Coclé del Norte basin would not be considered without a plan to add new locks to the Panama Canal System. Under this condition, the demand for and benefits from a project in the Río Coclé del Norte watershed could not be assessed at this time. The dam-height optimization and the economic analysis were, therefore, suspended pending the further study of the additional locks.

As a result of these events, the scope of the technical and economic feasibility study was modified to result in an engineering study that has, as its objectives, to:

- Assess the technical feasibility of the Project
- Estimate the economic cost of water for a range of developments at the site identified in the Reconnaissance Report.
- Evaluate the potential for adding hydropower to the water supply Project.
- Evaluate the potential for developing an agricultural component to the Project.

1.4 Original Scope of Services

Relying on readily available data, information, literature, mapping, photographs, *etc.*, and ground topographic surveys at each of the project features and geological/geotechnical investigations performed under separate contract actions by the ACP, the services are described as a series of 13 tasks, paraphrased from the Terms of Reference as follows:

<u>Task 1 Work Plan and Quality Control Plan.</u> Present final plans with milestones in Panama within two weeks of notification of award.

Task 2 Selection of Dam Location and Field Investigations. Visit both sites to provide preliminary confirmation of dam location, review ground survey, geology, and geotechnical field program proposals.

Task 3 Hydrology and Meteorology. Task 3 included a series of subtasks that apply to both basins:

- Develop a long-term streamflow sequence
- Using a HEC-5 simulation model provided by the ACP, operate the Canal water supply system to determine the contribution from the Río Coclé del Norte basin and to optimize the features of the Project.
- Estimate the probable maximum flood for spillway design and lower frequency floods for the determination of diversion facilities during construction for both damsites.
- Estimate evaporation and reservoir sediment deposition for both reservoirs.

Task 4 River Hydraulics. Assess the impact of construction on the water quality downstream from the reservoirs and the stability of the river channels as a result of the development of the reservoirs. If necessary, perform a feasibility-level assessment of required remedial works.

Task 5 Geology. Based on reports, field visits, and the geologic investigations being performed by the ACP, describe the regional, reservoir, and site geology, the nature of the foundation materials, and the location and characteristics of construction materials in both basins.

Task 6 Geotechnical and Seismological Studies. Using information supplied by the ACP and collected during field visits, characterize foundation conditions, estimate excavation slope requirements, assist in the location of construction materials, and assess seismotectonic movement and risk.

Task 7 Agricultural Development. Assess the potential for small-scale agricultural development in and around the Río Coclé del Norte Reservoir area and downstream of the reservoir area. Estimate water demand, costs, and benefits of potential irrigation systems.

Task 8 Power and Energy Studies. Using estimates of power generation from the HEC-5 simulation model, estimate the costs and benefits of installing hydro plants at the base of the Río Coclé del Norte dam and at the downstream end of the tunnel transferring water from Indio to Gatun Lakes. In addition, perform a power market study to determine the competitiveness of the project power production as it relates to the national power system.

Task 9 Design of Main Features. Select the most suitable type of dam at each site and provide feasibility-level designs and drawings for the Project features.

Task 10 Construction Planning. To support a detailed engineering and construction schedule, a construction plan will be developed that identifies construction and management components, construction methods, characteristics of the work force, access of materials and equipment, and a construction sequence.

Task 11 Cost Estimate. Prepare a detailed cost estimate to a feasibility-level of detail.

Task 12 Canal Operation Benefits. Define benefits for Canal operation, municipal and industrial water supply, hydropower generation, and agricultural development.

Task 13 Economic Evaluation. Define evaluation methods in coordination with the ACP and calculate the cost-benefit ratio for the project.

A draft feasibility report is to be presented 10 months after issuance of the Task Order. In addition, interim meetings will be held with the ACP to review work progress, hands-on training will be provided in the Consultants home office, and a series of seminars will be presented for the purpose of technology transfer.

1.5 Revised Scope of Services

Over the course of the investigation, there were two significant changes to the geologic/ geotechnical and economic tasks:

- It was determined to be inappropriate to perform the drilling program and the refraction surveys due to the concerns of the local inhabitants. As a result, these two subtasks were eliminated from the services.
- Mid-way through the studies, the ACP decided that the channel through Lake Gatun would be deepened and that a third and possibly a fourth set of locks would be constructed. As a result, the historic navigation demand, toll structure, and operating costs were not a suitable basis for the estimation of navigation benefits and the canal benefit and economic analysis subtasks were suspended.

1.6 Organization of Report

This volume titled "*Feasibility Study of the Río Coclé del Norte Reservoir Acting in Full Regulation with the Río Indio Reservoir*" is a stand-alone document and contains a summary of the studies done in connection with the project and the conclusions and recommendations. A similar report, Volume 2, presents the studies associated with the second concept identified in Section 1.2 –" *Feasibility Study of the Río Coclé del Norte*

Reservoir Acting in Full Regulation with the Río Caño Sucio and Río Indio Reservoirs". The details of the studies are presented in seven appendices that are contained in an additional three volumes. The appendices are written to cover both concepts. The report organization is shown below:

Volume	Title
1	Feasibility Study of the Río Coclé del Norte Reservoir Acting in Full Regulation with the Río Indio Reservoir
2	Feasibility Study of the Río Coclé del Norte Reservoir Acting in Full Regulation with the Río Caño Sucio and Río Indio Reservoirs
3	Appendix A – Hydrology, Meteorology and River Hydraulics Appendix B – Geology, Geotechnical and Seismological Studies Appendix C – Operation Simulation Studies
4	Appendix D – Project Facilities Studies Appendix E – Power and Energy Studies
5	Appendix F – Agriculture and Irrigation Potential Appendix G – Cost Estimates

1.7 Acknowledgements

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- John Gribar, Special Consultant
- The Supporting Staff of the Canal Capacity Projects Division;
- The Environmental and Safety Group;
- The Department of Meteorology and Hydrology, Autoridad del Canal de Panama, and;
- The Electrical Division, Autoridad del Canal de Panama.

1.8 Subcontracts

The Río Coclé del Norte and Río Caño Sucio Water Supply Project studies were performed by MWH in association with:

TAMS Consultants, Inc., New York USA, an Earth Tech Company

In addition, assistance was provided for data collection in support of this study by:

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Tecnilab, S.A., Panama.

2. PROJECT SETTING

The Norte/Indio Water Supply Project consists of a storage facility in the Río Coclé del Norte basin, a tunnel between the storage facility in the Río Coclé del Norte basin and the presumed existing Río Indio Reservoir, an a second tunnel between the Río Indio Reservoir and Lake Gatun. It is located essentially in the middle of the Republic of Panama, in two watersheds immediately to the west of the Panama Canal Watershed. A location map is presented on Exhibit 2-1. Descriptive information for the Río Indio Basin is contained in the Feasibility Study of the Río Indio Water Supply Project (2). The production from the Project will be used to augment the existing supply of water to the Canal, provide for increases in municipal and industrial water in and around the Panama Canal Watershed, and possibly as a source of electricity in the local and regional market.

2.1 Climate

The general climate of Panama is tropical with distinct wet and dry seasons induced by the movement of the inter-tropical convergence zone (ITCZ). When the ITCZ is located to the south of Panama, the effect is to cause a dry season; when it travels over Panama either moving northward or southward, its passage results in heavy rainfall; and when it is to the north, the strength of the rainy season decreases somewhat. This movement results in a dry season from January through April, a moderated wet season from mid-June to mid-September, and a wet season for the rest of the year.

The average annual rainfall over the Río Coclé del Norte basin above the damsite is estimated to be 2,800 mm. Exhibit 2-2 shows a mean annual rainfall map taken from *Atlas Nacional de la Republica de Panama* (3). The map shows that mean annual rainfall is higher in the coastal area and decreases inland.

Based on extended records for the Coclecito station, the mean monthly rainfall over the Río Coclé del Norte basin is computed as a ratio of the basin annual rainfall and the station annual rainfall times the station monthly rainfall. Mean monthly rainfall values are shown in Table 2-1

TABLE 2-1 MEAN MONTHLY RAINFALL, RÍO COCLÉ DEL NORTE BASIN (mm)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
192	128	119	203	287	258	215	279	241	303	265	310	2,800

The mean monthly rainfall varies from a low of 119 mm in March to a high of 310 mm in December.

Literature studies and discussions with ACP staff indicate that the occurrence of the El Niño phenomenon causes below normal rainfall in almost all regions of Panama. The studies indicated that the average annual rainfall anomaly based on the El Niño episodes was about 8 % below normal. In the case of the strong episodes of 1976 and 1982, the corresponding anomalies were about 28% and 24%.

Mean monthly temperatures vary about 2° C throughout the year around 26° C near the dam to about 24° C in the head reach. The lowest temperature occurs in September and October, and the highest occurs in March and April at lower altitudes and in June at higher altitudes.

2.2 Location and Description of the Río Coclé del Norte Basin

The Río Coclé del Norte is formed downstream from the confluence of the Río San Juan, Río Coclecito, Río Cascajal near the town of Coclecito. The three rivers drain the northern slopes of the Cordillera Central (Continental Divide) and flow northward to the Atlantic Ocean. About half-way to the damsite, the Río Coclé del Norte is joined by the major basin tributary, the Río Toabré. The drainage configuration of the basin is shown on Exhibit 2-3. At the mouth, the drainage area of the Río Coclé del Norte is about 1,730 km^2. The damsite is located about 15 km upstream from the Atlantic Ocean. Above the damsite, the river drains an area of about 1,594 km^2. The river basin is fan-shaped with a maximum length of about 58 km and a width of about 55 km.

The Río Toabré drains an area of about 810 km^2 at the confluence. The Toabré system is comprised of the main stem of the Río Toabré, the Río San Miguel and the Río de U on the right bank, and the Río Lura and Río Tulu on the left bank. The Río San Miguel is the major and longest tributary of the Río Toabré. It rises at about El. 900 and flows in a general north-westerly direction to join the Río Toabré. The slope of the Río San Miguel/Río Toabré is about 10 percent in the 4-km long head reach, decreases to 3.3 percent in the next 6 km, and flattens to about 0.06 percent near the confluence.

The three rivers above Coclecito drain an area of about 520 km^2. The Río San Juan is the larger and longer of the three rivers. It drains an area of 270 km^2, and rises at an elevation of 1,300 meters above mean sea level (El. 1300). The river is very steep in the head reach, dropping about 900 meters in a distance of about 5 km (about 18 percent slope). The slope decreases downstream to about 6 percent in about 4 km. From Coclecito, the Río Coclé del Norte flattens to a slope of 0.3 percent to the damsite.

The Río Cuatro Calles is another right bank tributary, joining the Río Coclé del Norte about 2 km upstream from the dam site. The drainage area is about 140 km^2. Except for the last 1,200 m, the river slope is about 0.3 percent.

Profiles of the mainstream and main tributaries are presented in Appendix A. The drainage areas of the basins are presented below:

Basin	**Drainage Area (km^2)**	**Accumulated Drainage Area (km^2)**
Río San Juan	270	
Río Coclecito	110	
Río Cascajal	140	
Area above Coclecito		*520*
Intervening local drainage	260	
Río Cuatro Calles	140	
RioToabré	700	
Area above damsite		*1,600*
Intervening local drainage	130	
Total Basin Area		**1,730**

There is no access to the basin in the vicinity of the dam.

Slightly less than 40% of the basin is in forest. The remaining area has been deforested and is now comprised of shrubs, pasture, and annual crops. Within the inundated area, there are about 160 towns and about 6,200 persons. Agriculture and cattle ranching are the main economic activities. There are also mineral and ore resources reported in the area.

2.3 Panama Canal Operations

The Panama Canal operation is dynamic and has a significant macroeconomic impact. Panama has transformed the Canal from a government-run entity into a commercial venture. The Canal has been transformed from a transport route for ships into a commercial supplier of a broad range of services (4). Although these services have been provided in the past, treaty limitations curtailed the full exploitations of this potential. Currently, the government plan is to make the Canal an autonomous enterprise and to permit increased activity in the areas of electricity generation, municipal and industrial (M&I) water supply, and the provision of marine services.

The United States is the most important user in terms of cargo tonnage. The US East Coast to Asia is the dominant trade route for the Canal and the US West Coast and

Canada comprise the second major trade route of the waterway. Trade along the north-south axis is also increasing especially between the west coast of South America and the east coast of the United States (4). Ships carrying coal from the east coast of the United States to Japan save 3,000 miles versus the shortest alternative all-water route and ships sailing from Ecuador to Europe save 5,000 miles. Grain is the largest commodity (by tonnage) shipped through the Canal followed by crude oil and petroleum products, and phosphates and fertilizers. There is significant variation in direction – over 90 percent of the grain and phosphates and fertilizers, and over 62 percent of the crude oil and petroleum are shipped from the Atlantic to the Pacific. The largest commodity shipped through the Canal from the Pacific to the Atlantic is mining products and specifically coal or ores and metal (5).

2.3.1 Description of the Canal Facilities

As reported in the Reconnaissance Report (1), the principal features of the 80-km long Canal system, from the Atlantic Ocean to the Pacific Ocean, are:

- The Cristobal Terminal in Colon
- A short section of sea-level channel
- The Gatun Locks, which can raise or lower a ship 26 meters in three steps
- Gatun Lake, which develops 37.6 km of the Canal passage
- The Gaillard Cut, which is 13.7 km long
- The Pedro Miguel Lock, which can raise or lower a ship 9.4 meters
- Miraflores Lake
- The Miraflores Locks, which can raise or lower a ship up to 16.6 meters
- A 9.6-km long sea level channel
- The Balboa Terminal in Panama City
- Madden Lake, which serves as a source of water for the Canal

Gatun Lake is impounded by the Gatun Dam, an earth embankment with a gated spillway across the Río Chagres. Madden Lake is impounded by Madden Dam, a concrete structure also on the Río Chagres about 19 km east of the Canal. Miraflores Lake is formed by an earthfill dam located on either side of the high end of Miraflores Locks. Electricity is generated at both Gatun and Madden dams, and municipal and industrial water is supplied from both Gatun and Madden Lakes.

The ACP is currently improving the efficiency of the Canal through the purchase of new locomotives and tugboats, installing a traffic management system, improving lock chamber door operating machinery, and widening the Gaillard Cut. The Cut is being widened from 152 meters to about 192 meters in the straight sections and 222 meters in the curves. The improvements will shorten the time needed to move vessels through the locks and allow larger ships to use the Canal at the same time.

In addition, the ACP is currently deepening the navigation channel through Lake Gatun by three feet (0.91 m).

2.3.2 Canal Traffic

The ACP operates the twin-lane locks continuously on a 24-hour per day, 365 days per year basis. In 1997 and 1998, oceangoing vessel transits totaled slightly more than 13,000 or an average of just less than 36 vessels per day. In 1997, more than 29 percent of the vessels were classified as PANAMAX vessels (beams of 30.5 m) and this percentage was estimated to increase to about 33 percent by Year 2010 (6). Actual use of the canal by PANAMAX ships is already at 40 percent according to the ACP. At the completion of the improvements described above, the APC estimates that the sustainable transit capacity of the Canal will increase to 43 vessels per day or 15,695 per year.

In 1993, the following actual and projected estimates of traffic were reported (7):

Maximum Design Vessel Size	Cargo Tonnage			Vessel Transits		
	1990	2020	2060	1990	2020	2060
Present Canal (65,000 dwt)	157,472	265,962	276,529	11,162	17,359	18,078
150,000 dwt	NA	360,990	490,647	NA	17,796	23,934
200,000 dwt	NA	363,312	494,726	NA	17,844	24,074
250,000 dwt	NA	369,883	508,527	NA	17,856	24,053

With the currently anticipated limit of about 16,000 vessel transits per year, it becomes apparent that significant improvements to the Canal will be required to meet the anticipated demand.

2.3.3 Water Availability

Currently, the supply of water for the operation of the Canal and the provision of M&I water comes from regulation provided on the Río Chagres. Historically, the supply of water has been adequate to provide a reliable operation of the Canal. The reliability of supply, measured as the ratio of the volume of water provided and the volume of water required, was computed to be 99.6% for a demand equal to the average of the lockage and M&I demands from 1993 to 1997. This value has been used as an indicator of the systems' reliability and, currently, as a goal to which all future developments are compared.

The impact of providing less than the required water supply is severe. At the current time, there are no auxiliary sources of water for M&I supply and, therefore, the entire impact of any shortage is absorbed by the canal operation. There are two actions that can be taken during water shortages: 1) maintain the level of Gatun Lake but restrict the transits, or 2) allow the lake level to drop and impose draft restrictions. The ACP has taken the option of allowing passage to all requesting vessels and imposing draft restrictions on large vessels.

Using the 50-year period of hydrologic data and simulating the operation of the Canal system for multiples of the current demand (taken as the average demand from 1993 to 1998), the reliability of the system as reported in the Reconnaissance Report (1) would have been:

Demand Multiple	Reliability
Current Demand	99.6 %
1.2	98.8 %
1.4	96.4 %
1.6	92.0%
1.8	86.3%

These reliability values indicate that, on the average, current shortages amount to about 11 MCM/yr and shortages for the increased multiples range from 44 MCM/yr for 1.2 times the current demand to 725 MCM/yr for the 1.8 multiple. The situation is worse than suggested by the averages. For the 1.2 multiple, shortages occur in only 20 of the 50 years, which indicates a shortage that averages about 100 MCM/yr in the short years, but as many of the years have only minimal shortages, the shortage in the most severe year would be much larger than the average.

2.3.4 Municipal and Industrial Water Supply

Historically, the Panama Canal Authority has provided municipal and industrial (M&I) water to the Panama Canal Watershed and the immediate vicinity. In year 2000, that supply equaled about 244 million gallons per day (mgd), which is equivalent to about 4.4 lockages per day in the Canal operations. Based on a study performed in 2000 (8), the M&I demand is forecast to increase from 244 mgd to about 500 mgd (about 9.1 lockages per day) in year 2060. It is anticipated that the ACP will retain the responsibility to supply this water.

2.4 Socio-Economic Conditions

The population of the Río Coclé del Norte basin was estimated in year 2000 to be about 26,350 persons. However, there are no indigenous populations reported in the area.

Agriculture and cattle ranching are the main economic activities, but per capita income falls below the extreme poverty level. Cattle ranching occupies about 22% of the Río Coclé del Norte basin respectively and, based on a count of animals, low productivity and mismanagement is indicated. Basic crops are rice, corn, and beans, and production rates of these staples is considered to be low when compared to national averages. There are mining metallic concession contracts and requests in both reservoir areas according to the Ministry of Industry and Commerce.

The literacy rate is around 90 percent, although this is slightly lower than the national average. Most homes do not have access to potable water and over 90 percent of the homes do not have electricity. Except for the roads into Coclecito, there is a lack of infrastructure. Medical services are more than an hour away for a high percentage of the population.

About 6,200 persons resided in the Río Coclé del Norte basin below El. 80 in about 160 towns. The average family size is estimated to be about 4.7 persons. The six largest towns in the Río Coclé del Norte Reservoir are Coclecito (population 683), Villa de Carmen (495), Cutevilla (372), Valle de San Miguel (256), Boca de la Encantada (193), and Sabanita Verde (193) and they contain 30 % of the directly impacted population.

According to the Reconnaissance Report (1) there are few public services. The town of Coclecito is the most developed and the largest of the towns. It has several schools and a hospital as well as access by road to La Pintada and Penonome. There is essentially no power except from small, local generating sources and telephone coverage is limited. All of the towns obtain water from the rivers or from groundwater. There is no treatment of community waste and most finds its way into the environment. As a result, there are known health problems such as hepatitis, dysentery, dermatitis, intestinal parasites, and respiratory illnesses associated with the waste disposal methods. A lack of good quality all-weather roads is probably one of the most pressing needs. The only roads are rarely graded and receive little attention from the Ministry of Public Works or local government.

2.5 Power Sector

In 1998, the power sector of Panama was restructured. Prior to 1998, the Panama National Integrated System (PNIS) was operated by the *Instituto de Recursos Hidraulicos y Electrification* (IRHE), responsible for generation, transmission, distribution, and sales. As a part of the restructuring, the generation and distribution facilities were privatized while the transmission system was assigned to a new government agency, the *Empresa de Transmission Electrica, S. A.* (ETESA).

After the restructuring, there were ten generation companies and three distribution companies providing electricity to the national grid. Currently, there are six companies generating a total of 1,060 MW that are providing the bulk of the electricity to Panama. (9).

Two of the original ten companies, EGE Bayano and EGE Chiriqui were bought by the AES Corporation and merged into AES Panama. As reported in a 1999 plan of expansion (10), two additional generation companies, Petroterminales and Hidro Panama operated 15 MW and 1.5 MW respectively. It is not known whether these units were retired or just not considered as major producers for the 2002 operation plan (11).

In the 1999 expansion plan, it was also reported that the distribution companies operated a series of thermal plants. EDE Metro Oeste operated five plants totaling 35 MW that were connected to the Panama National Integrated System (PNIS) and 3.4 MW that were isolated from the grid. EDE Elektra Noreste operated 14 plants with a total capacity of 10.8 MW that were also isolated from the grid.

The Panama Canal Authority owns and operates three power plants: the Gatun and Madden Hydroelectric plants and the Miraflores Thermal Plant. The three plants have installed capacities of 24 MW, 36 MW, and 115 MW respectively for a total of 175 MW. The generation is used to meet the electricity needs of Canal operation. The ACP load is estimated by the Electricity Department of the ACP to be about 60 MW. The Miraflores plant serves as a backup to the hydro plants when there is sufficient water in the Canal System to generate hydropower and supplies electricity when there is not sufficient water. The ACP can sell surplus energy in the energy spot market of the PNIS.

The 2002 Operation Plan indicates that an additional installed capacity of 344 MW will be on line by the end of 2003, consisting of 224 MW of hydro and 120 MW of thermal (although the tabulated expansion plan only shows 206 MW of hydro). Therefore, the major generation companies will have an installed capacity of about 1,404 MW by the end of 2003.

The total installed capacity and distribution between thermal and hydro is presented in Table 2-2

TABLE 2-2 GENERATION FACILITIES
(MW)

Company	Hydro Capacity	Thermal Capacity	Total Capacity	Connected to PNIS
Major Generation Companies				
AES Panama	240.0	40.0	280.0	Yes
EGE Fortuna	300.0	0.0	300.0	Yes
EGE Bahia Las Minas	0.0	280.0	280.0	Yes
Petroelectrica de Panama	0.0	60.0	60.0	Yes
COPESA	0.0	44.0	44.0	Yes
PanAm	0.0	96.0	96.0	Yes
Subtotal	540.0	520.0	1,060	
Planned Expansion				
2002	86.0	0.0	86.0	Yes
2003	120.0	120.0	240.0	Yes
Other Generation (may or may not be still available)				
ACP	60.0	93.0	153.0	Yes
Petroterminales	0.0	15.0	15.0	Yes
Hidro Panama	1.5	0.0	1.5	Yes
EDE Metro Oeste	0.0	34.9	34.9	Yes
EDE Metro Oeste	0.0	3.4	3.4	No
EDE Elektra Noreste	0.0	10.8	10.8	No

The major generation companies, including their planned expansions, have a total installed capacity of 1,386 MW.

In 1998, 2000, and 2002, the total net energy production, which is defined as gross generation less station use, amounted to about 4,192 GWh, 4,511 GWh, and 4,686 GWh respectively.

The existing transmission system consists of 578 km of 230 kV lines, 134 km of 115 kV lines, and ten 230-kV substations with a total capacity of 885 MVA (11). Transmission line losses were estimated at about 3.4 percent of the total energy supply and distribution system losses were estimated at about 17.6 percent of purchased energy. In 1998, energy consumption, as reported by the distribution companies, amounted to about 3,393 GWh to about 452,000 consumers. Aggregate distribution by consumer category for 1998 is shown in Table 2-3.

TABLE 2-3 1998 ENERGY CONSUMPTION BY CONSUMER CATEGORY

Consumer Category	Energy Consumption (GWh)	Percent of Total
Residential	1,005	30
Commercial	1,342	40
Industrial	488	14
Governmental	477	14
Public Lighting	64	2
Own Uses	17	<1
Total	**3,393**	**100**

In 1999, the energy consumption was 3,521 GWH, an increase of 5.8%. The customer base increased by 5.2% to about 476,000 consumers.

Each of the three distribution companies has established a tariff structure including capacity and energy charges for the various types of consumers. The average unit energy sale price in 1998 for each of the consumer categories is presented in Table 2-4.

TABLE 2-4 AVERAGE UNIT ENERGY SALES PRICE IN 1988 ($/MWh)

Sector	Residential	Commercial	Industrial	Government	System
Sale Price	119.00	115.60	97.40	111.20	111.20

The unit energy sales prices in Panama have been decreasing slightly over the last decade. Including the estimated unit sales price of $103/MWh for 1999, the sales price has decreased at an average rate of 1.6 %/year.

2.6 Agricultural Sector

The Río Coclé del Norte basin is largely undeveloped. The vegetation consists mostly of shrubs, forest, and pasture. Croplands are included within the shrub category, mostly because of the nature of the area under cultivation, the landscape position, and the size of the farm holdings. The distribution of vegetation is shown in Table 2-5:

TABLE 2-5 VEGETATION DISTRIBUTION

Habitat	Río Coclé del Norte Basin	
	Ha (rounded)	% of Total
Shrub	65,000	40
Forest	63,000	39
Pasture	35,000	21
Total	**163,000**	**100**

Farms and ranches of various sizes occupy approximately 60% of the land in the project area. 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 (1).

2.7 Geologic Setting

A regional geologic map for the basin is presented as Exhibits 2-4. The general pattern and distribution of major faulting in Panama is depicted on Exhibit 2-5.

2.7.1 Regional Geology

Bedrock in the region of the proposed Río Coclé del Norte project consists mostly of volcanic igneous rocks belonging to the Tucue Formation. These include basic and intermediate (basaltic and andesitic) lava flows, breccias, tuffs, and agglomerates. Reportedly, other rock types are intrusive igneous rocks classified as granodiorites, quartz monzonites, gabrodiorites, diorites, or dacites. The published regional geologic map indicates bedrock in the site area to be of an intrusive igneous nature, possibly granodiorite or quartz monzonite (Tertiary age Petaquilla Formation). These rock types were not found during reconnaissance visits to the dam site and surrounding areas.

Although little information on the engineering characteristics of these rocks exists, it is anticipated that they may exhibit a wide variety in quality (ranging from high quality intrusive rocks and extrusive lava flows to weathered and lesser quality volcanic tuffs and epiclastics).

2.7.2 Regional Tectonics

The tectonics in the Central American region are predominantly governed by the interaction of the Nazca, Cocos, South American, and Caribbean Plates. Geologic processes in the Republic of Panama, including tectonics, sedimentation, volcanism, seismicity, and epeirogenesis, are all strongly influenced by the relative movements of these plates, the boundaries of which are shown on Exhibit 2-6. Although the country is located on the southwest edge of the Caribbean Plate, Panama itself is located on a tectonic microplate called the Panama Block, which is a fairly rigid, yet seismically active segment of crust.

Plate movement in Central America is typically generalized as subduction zone tectonics. However, based on a review of the tectonics, the limit of the strongest influence of the subduction zone appears to cease near the border between Panama and Costa Rica and begins again on the eastern side of Panama and runs along the west coast of South America (13).

The Panama Block was formed over a period of 12 million years, largely as a result of the north to south spreading at the Galapagos Rift boundary between the Cocos and Nazca plates. Newly created crust at this boundary is being subducted beneath Costa Rica and regions further north. This action contributes to seismic activity extending from Costa Rica all the way to the western coast of Mexico. Four major tectonic regions define the boundaries of the Panama Block (14):

- Panama Block-Caribbean Plate Boundary,
- Panama Block-Nazca Plate Boundary,
- Eastern Panama-Columbia Collision Zone, and
- Panama Block-Cocos Plate Boundary.

Most historical seismicity within a 400-km-radius of the Panama Canal area can be attributed to collision and shear deformation at each of these neighboring plate boundaries (15). The junction of the Cocos, Nazca, and Caribbean Plates occurs near what is termed Punta Burica, or Burica Peninsula. The junction of the Cocos and Nazca Plates is termed the Panama Fracture Zone (16).

The north edge of the Cocos Plate is being subducted under the Caribbean Plate resulting in a reverse fault structure termed the Middle American Trench. The Nazca plate is being subducted obliquely in the northeast direction beneath the southwest margin of Panama creating the Eastern Panama-Columbia Collision Zone, while the eastern portion of the Nazca plate is being subducted under South America (15). The thrust of the Caribbean Plate beneath the northern margin of the Panama Block has produced some large earthquakes in the past. The provinces and adjoining offshore regions of Bocas del Toro, Chiriqui, Los Santos in western and southern Panama, and San Blas and Darien in the east are also seismically active regions of Panama located along the margins of the Panama Block (15).

A detailed description of the significant tectonic features of Panama is presented in Appendix B.

2.8 Environmental Setting

The information presented has been supplied by the ACP or was taken from the Reconnaissance Report (1).

2.8.1 Terrestrial Habitat

Forests cover about 39% of the land and about 40% of the reservoir area. The remaining areas are categorized as shrub and pasture.

2.8.2 Fish and Wildlife

The Río Coclé del Norte are typical of streams in mountainous country. The water is clear and cool and the river bottom ranges from sand to boulders with numerous riffles, rapids, and pools. The river and its tributaries support some fish and benthic communities. Currently, no fish species information is available. The snail *Melanoides tuburculata* is present and is considered a vector of some parasites. *Corbicula fluminea* (clam) are abundant.

The biological diversity of the Río Coclé del Norte basin includes 317 species of birds, 71 species of amphibians, 46 species of reptiles, and 75 species of mammals. The endangered species include 143 species of birds, 32 species of amphibians, 22 species of reptiles, and 35 species of mammals or about one-half of all species.

2.8.3 Wetlands

According to the Reconnaissance Report (1), the wetlands in the project area consist of forested riparian habitat along the immediate stream bank area. The width of the riparian habitat within the impoundment varies from 10 m to 75 m. About 80% to 90% of the streams above the dam site are bordered by forested riparian habitat.

2.8.4 Air Quality

Air quality in the project area is generally good except during the slash and burn period. At the end of the dry season, during March and early April, sizable areas of forest and secondary growth are burned and cleared to prepare the land for agricultural use.

2.8.5 Cultural and Historic Resources

There are more than 80 reported archaeological sites in the impoundment area. These sites are located and consist of indigenous villages, hamlets, funeral sites, mines, and miscellaneous sites.

3. DESCRIPTION OF THE NORTE/INDIO PROJECT

Implementation of a project to result in the impoundment of the Río Coclé del Norte Reservoir that will operate in conjunction with the Río Indio Reservoirs will require the construction of:

- A dam on the Río Coclé del Norte,
- A tunnel to transfer water from the Río Coclé del Norte Reservoir to the Río Indio Reservoir, and
- A second tunnel between the Río Indio Reservoir and Lake Gatun.

In addition, it has been determined that a power plant at the base of the Río Coclé del Norte dam is feasible. Commercial agriculture associated with the development of the project is not warranted at this time. A general plan of the project is shown on Exhibit 3-1.

3.1 Río Coclé del Norte Dam and Reservoir

The major elements that comprise the storage facility of the Río Coclé del Norte include:

- An 86-m high concrete-face rockfill dam with its crest at El. 74 and top-of-structure at El. 76,
- A 50-m wide spillway in the right abutment with a capacity at full surcharge of 800 m^3/s,
- An 8-m diameter, D-shaped tunnel in the left abutment sized to pass the 50-year flood and provide for drawdown in the case of emergency,
- A 60 MW powerplant at the base of the dam incorporating a minimum release facility.

The dam will impound a reservoir with a gross storage capacity of 5,275 MCM and operate between El. 71, the full supply level, and El. 50. Live storage between El. 71 and El. 50 will be about 3,445 MCM. The reservoir area at the full supply level is 227 square kilometers.

The yield resulting from the addition of the Río Coclé del Norte reservoir is 3,480 MCM/year or 45.4 lockages/day. The 60 MW powerplant will contain three equal-sized units and generate an average of 327 GWh/year ranging from 425 GWh/year in the initial years of operation to 120 GWh/year at the end of the economic life.

A general site plan of the Río Coclé del Norte Project, showing the location of the dam and appurtenant works is shown on Exhibit 3-2.

3.2 Water Transfer Tunnel to Río Indio

To transfer water from the Río Coclé del Norte reservoir to the Río Indio basin, it is necessary to construct:

- A 1,500-m long approach channel in the reservoir to convey water to the tunnel intake,
- A 16,500-m long, 9.0-m diameter tunnel from the reservoir to the Río Indio Reservoir, and
- A TBM adit, intake protection, an access/gate shaft and a lake-tap outlet.

The dimensions of the facilities are controlled by the requirement to pass about 185 m^3/s when the Río Coclé del Norte reservoir is at its minimum level (El. 50). A plan showing the tunnel alignment is presented on Exhibit 3-3.

3.3 Second Water Transfer Tunnel from Río Indio to Lake Gatun

According to the present concept, the Río Indio Project will have been constructed about 20 to 30 years prior to any Río Coclé del Norte Project configuration. As described in the Río Indio Water Supply Project Report (2), a 4.5-m diameter tunnel is required to convey Río Indio water to Lake Gatun. With the connection of the Río Coclé del Norte Project to the system, a second tunnel, 8,250-m long with a diameter of 6.5 m, will be required. The tunnel will be aligned parallel and next to the presumed existing tunnel. A plan of the alignment is shown on Exhibit 3-4.

3.4 Estimate Cost of the Project

The Norte/Indio Project is estimated to cost $514 million as shown in Table 3-1.

TABLE 3-1 SUMMARY COST OF THE PROJECT

Feature	Project Cost ($ million)
Access Roads and Construction Camp	13.5
Río Coclé del Norte Project	132.6
Water Transfer Tunnel to Río Indio Reservoir	176.4
Second Tunnel from Río Indio Reservoir to Lake Gatun	85.9
Reservoir Clearing	22.0
Contingency	83.5
Total Cost	**513.9**

4. PROJECT SUPPORT STUDIES

The project support studies are the basic studies that support the selection of the project facilities and the final project arrangement. These studies include topography, hydrology, geology and geotechnical investigations, and project operation studies.

4.1 Topography

Ingenieria Avanzada, S.A. prepared topographic mapping of the proposed dam site areas and the water transfer tunnel portals under subcontract to MWH. The services were completed and submitted to the ACP under Contract CC-3-536, Task Orders 2 and 8. The extent of the topographic coverage is shown on the plan views of the proposed project facilities. In some instances, there are project features that are not totally covered by the large-scale mapping. For these features, and for other data requirements such as the area and volume curves, additional topographic mapping of the dam site and basin were developed by digitizing 1:50,000 scale maps obtained from Instituto Geografico Nacional (Tommy Guardia).

4.2 Hydrology Studies

Hydrologic analyses were performed to estimate reservoir evaporation, to confirm the long-term streamflow sequence adopted for the Reconnaissance Study (1), and to estimate construction-period floods, the spillway design flood, and sediment deposition in the reservoir. The studies and their results are presented in more detail in Appendix A, Hydrology and River Hydraulics.

4.2.1 Net Reservoir Evaporation

Net reservoir evaporation is estimated to total 1,134 mm/year and is based on historic reservoir evaporation data from Gatun Lake over the period 1993 to 1998. The estimate, developed by the ACP, was judged to be reasonable and was used for both reservoirs in this study. The monthly distribution of net reservoir evaporation is presented in Table 4-1.

TABLE 4-1 MEAN MONTHLY NET RESERVOIR EVAPORATION (MM)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
112	117	133	123	91	80	84	80	78	80	72	84	1,134

4.2.2 Long-Term Streamflow at the Río Coclé del Norte Damsite

The long-term flow sequence was developed by the APC and reviewed by Harza. There are three gages located in the Río Coclé del Norte basin. Two stations, Batatilla and El Torno were used with three other gages located outside the basin to derive the long-term streamflow. Pertinent data for each gage is presented in Table 4-2.

TABLE 4-2 STREAM GAGES USED IN ANALYSIS OF LONG TERM FLOW RECORD

Station	Watershed	Location	Period of Record	Drainage Area
Río Coclé del Norte at Canoas	Río Coclé del Norte	Half-way between Coclecito and the Río Toabré	1983-date	571 km^2
Río Coclé del Norte at El Torno	Río Coclé del Norte	Slightly upstream from Río Toabré confluence	1958-1986	672 km^2
Río Toabré at Batatilla	Río Coclé del Norte	5 km upstream from the mouth	1958-date	788 km^2
Río Trinidad at El Chorro	Gatun	3 km upstream from Lake Gatun	1948-date	172 km^2
Río Ciri Grande at Los Canones	Gatun	9 km upstream from Lake Gatun	1948-date	186 km^2
Boca de Uracillo	Río Indio	5 km upstream from Río Indio damsite	1979-date	376 km^2

The long-term flow sequence (1948-1999) at the damsite was generated by adding the data from El Torno and Batatilla, adjusted for drainage area and rainfall. The flows at El Torno and Batatilla were completed using correlations with El Chorro, Los Canones and Boca de Uracillo. MWH reviewed the correlation and double mass curve analyses and determined that the approach is logical and results are acceptable.

The mean annual flow at the Río Coclé del Norte damsite is estimated to be 107.5 m^3/s and the monthly distribution of flow is shown in Table 4-3. The complete monthly flow at the damsite is presented in Table 1 (note tables numbered without the section number are located at the end of the report text).

TABLE 4-3 MONTHLY MEAN STREAMFLOW AT THE RÍO COCLÉ DEL NORTE DAMSITE (m^3/s)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
89.5	52.1	37.7	53.5	91.8	108.8	107.7	125.3	139.2	162.7	173.0	149.2	107.5

Mass curve and time series analyses indicate that the annual flows are consistent, homogeneous, and that there are no apparent trends. The annual flows exhibit significant variations in flow from year to year. The highest mean annual flow, 188 m^3/s, occurred in 1970 and the lowest, 72 m^3/s occurred in 1997.

On an annual basis, the lowest 1, 2, 3, and 4 calendar year flow sequences occurred in 1997, 1976-77, 1976-1978, and 1976-79, respectively. The 2, 3, and 4-year flows over the period including 1997 and 1998 were very close. The average runoff in these periods amounted to 67%, 72%, 82%, and 85% of normal, respectively. This would suggest that carryover storage of about one-half year would permit a yield on the order of the mean annual flow. For reference, drought-frequency curves for sequential 6-month, 12-month, 18-month and 24-month periods are presented Appendix A.

4.2.3 Construction Period Floods

Construction period floods were evaluated using both available regional flood frequency data and annual maximum instantaneous flood peaks at representative stations. For both sites, use of the site-specific instantaneous peak data was considered more appropriate than using the regional analysis.

Instantaneous flood peak data are available at the three gages in the Río Coclé del Norte basin, at Canoas, at El Tomo, and on the Río Toabré at Batatilla. Both Canoas and El Torno measure essentially the same contributing watershed and, since the record at El Torno is longer, the flood peak data for El Torno was used to represent the Río Coclé del Norte basin above Río Toabré. The Generalized Extreme Value (GEV) distribution was adopted to estimate the relationship between return period and flood peak for the two stations.

A general procedure for transposition of flood peaks from a gaged location to an ungaged location is to use coefficients of empirical relationships assuming that these coefficients remain constant for hydrologically and meteorologically similar drainage basins.

The adopted relationship is given below.

Rodier's Formula

$$K = 10 * (1- ((\log^{Q} -6) / (\log^{A} -8))) \quad (17)$$

'K' is a coefficient, A is the drainage area in km^2 and Q is flood peak in m^3/s.

The values of K were computed for the flood peaks of selected return periods for El Torno, Batatilla, and Boca de Uracillo. For the Río Coclé del Norte damsite, the mean of the K values for El Torn and Batatilla were used with the drainage area behind the dam to estimate flood peaks for selected return periods. The flood peaks are presented in Table 4-4.

TABLE 4-4 FLOOD PEAKS FOR SELECTED RETURN PERIODS

	Río Coclé del Norte	
Return Period (years)	**Flood Peak (m^3/s)**	**Dry Period Flood Peak (m^3/s)**
5	1,925	288
10	2,430	458
20	2,995	697
50	3,860	1,171
100	4,610	1,705

4.2.4 Spillway Design Flood

The probable maximum flood (PMF), based on probable maximum precipitation (PMP), was adopted as the spillway design flood for the both the Río Coclé del Norte and Río Caño Sucio dams.

4.2.4.1 Probable Maximum Precipitation

Three procedures were used to evaluate and select the PMP.

1. The first consisted of transposing the most severe storms listed in the 1965 US Weather Bureau (WB1965) and 1978 National Weather Service (1978NWS) reports (18, 19). These reports covered storms up to 1976.
2. The second procedure was to develop and evaluate storm isohyetal patterns of major storms that occurred over the basins since 1976, and

3. The third was to use the PMP estimates and depth-area duration curves developed as a part of the NWS1978 and WB1965 reports.

A total of 15 storms were evaluated under the first and second procedures, and the storm of November 7-9, 1931 was judged to be critical in terms of rainfall amount and aerial extent over the Río Coclé del Norte Basin. This storm was maximized in-place, and transposed to the basin using a factor based on a ratio of October-December rainfall for the Río Indio basin and the place of occurrence of the storm. This resulted in a maximized and transposed storm with a 48-hour rainfall of 610 mm. For the third procedure, the PMP was estimated to be 714 mm. The higher value was adopted for the Río Coclé del Norte basin.

4.2.4.2 Probable Maximum Flood

The PMP was transformed to a PMF using the HEC-1 computer model. The PMP was distributed into one-hour increments using the depth duration curve of the US Weather Bureau (WB1964) extended for durations of less than 6 hours using hourly rainfall data recorded at El Chorro. The one-hour increments were arranged sequentially using the "alternating block method" (20), adjusted for retention losses, and applied to a unit hydrograph developed using the Clark Method (21).

The total excess rainfall amounted to 590 mm and the maximum one-hour increment was 97 mm. For a base flow of 110 m^3/s, estimated from an analysis of major historic floods, the probable maximum flood hydrograph has a peak of 10,460 m^3/s and a 5-day volume of 988 MCM. The PMF inflow hydrograph is shown on Exhibit 4-1.

4.2.5 Tailwater Rating

A tailwater rating curve was developed for the Río Coclé del Norte at the damsite. The analysis was based on 10 river sections located from 200 to 13,000 m downstream from the dam. The analysis was performed using the Full Equations (FEQ) modeling system developed by Delbert Franz of Linsley, Kraiger Associates Ltd. The resulting tailwater data at the damsite are shown in Table 4-5.

TABLE 4-5 TAILWATER RATING, RÍO COCLÉ DEL NORTE

Flow Rate (m^3/s)	Tailwater Elevation (m)
0	0.0
200	1.1
500	2.9
1,000	5.0
2,000	7.8
3,000	9.8
4,000	11.4

4.2.6 Reservoir Sedimentation

The analysis of reservoir sedimentation consisted of the collection of available data, a review of existing analyses, and estimation of the anticipated sediment yield, storage depletion in the reservoirs after periods up to 100 years, and sediment level at the dam after 100 years.

ETESA collected 46 samples on the Río Coclé del Norte at Canoas and 56 samples from the Río Toabré at Batatilla and developed a suspended sediment rating curve, which was limited to a maximum concentration equivalent to the observed maximum. The suspended sediment rating curves for Río Coclé del Norte and Toabré fitted by ETESA were revised upward by MWH to reflect a limiting concentration of 10,000 mg/l rather than the maximum observed concentration. This increase was based on a field visit to the basin and MWH experience. As a result, the unit yields of the Río Coclé del Norte and Toabré basins areas above the sampling locations were estimated to be 1.3 mm/yr and 1.2 mm/yr, including 15% for base load, respectively.

The ACP has collected samples at three stations on streams flowing to Lake Madden and three stations on steams flowing to Lake Gatun. The ACP has also conducted a sediment survey of Lake Madden in 1983, which was revised in 1990. The sediment survey of Lake Madden indicated a sediment yield of about 1.4 mm per year.

These analyses indicate that the sediment yield, including base load, could vary from 1.2 mm/yr to 1.4 mm. For a conservative estimate of the reservoir sedimentation, a unit yield of 1.4 mm/yr was adopted. This yield is considered to be indicative of the current land use and could increase significantly in the future if deforestation and agricultural development continue to expand.

Sediment distribution in the Río Coclé del Norte reservoir was estimated using the US Bureau of Reclamation's alternate area increment method. The method is used to estimate the new zero capacity elevation at the dam as well as sediment distribution in the reservoir. The analysis indicates that reservoir sedimentation will not be a problem for the project. After 100 years, it is estimated that less than 1 percent of the live storage will be lost to deposition. Using the same model, the deposition at the face of the Río Coclé del Norte dam is estimated to reach to about El 3.

4.2.7 Stability of the River Channel Downstream from the Dam

Studies were performed to assess the stability of the Río Coclé del Norte channel downstream from the dam to determine if channel-stabilizing measures would be needed to maintain the system in its pre-project condition.

The analysis consisted of an estimation of flood peaks in the channel downstream from the dam under pre- and post-project conditions, a determination of the hydraulic and bed material characteristics of the channel, and an evaluation of channel stability.

4.2.7.1 Flood Regime Downstream from the Dam

Pre-project floods were based on the flood frequency data presented in Section 4.2.3, 1 and 2-day volumes for the selected return periods, and a hydrograph shape based on the December 1955 flood on the Río Toabré. The post-project floods were estimated by routing the pre-project floods through the reservoir. The flood peaks are shown in Table 4-6.

TABLE 4-6 FLOOD FREQUENCY DATA IN RÍO COCLÉ DEL NORTE CHANNEL DOWNSTREAM FROM THE DAM

Return Period (years)	Pre-Project Flood Peak (m^3/s)	Post-Project Flood Peak (m^3/s)
2	1,295	17
5	1,925	25
10	2,430	34
25	2,995	50
50	3,860	75
100	4,610	98

4.2.7.2 Hydraulic and Bed Material Characteristics

The hydraulic characteristics of the channel downstream from the dam were based on 9 cross sections. It was determined that a representative cross section could be used, which was sketched visually from an overlay of all six sections. The bed load characteristics were based on six bed material samples taken at four of the cross sections. These characteristics are presented in Table 4-7.

TABLE 4-7 CHARACTERISTICS OF THE RÍO COCLÉ DEL NORTE BED MATERIAL

Size Designation	Particle Size (mm)
D35	0.45
D50	0.65
D65	3.50
D90	29.0
Median D	**0.7**

4.2.7.3 Channel Stability

Channel stability was assessed on the basis of an evaluation of degradation potential and the availability of sufficient armoring in the existing bed material. A reduction in the sediment load occurs as the sediment is trapped in the reservoir. The downstream effects are generally an increase in degradation of the channel and banks as the sediment-free reservoir releases pick up sediment from the bed. The degradation continues until a stable, gravel-armored bed is formed or until the slope of the channel is reduced to a value that prevents further removal of sediment from the bed.

It was determined that under pre-project conditions, degradation will (and does) occur. Under post-project conditions, the required armoring size is less than the size of the existing bed material. Therefore, no stabilizing measures will be needed. Further, aggradations will likely occur at the mouths of the tributaries because the reduced flood peaks will not be able to transport the bed load material deposited by the tributaries.

4.3 Engineering Geology

This section summarizes the significant results and conclusions of the site investigation program, laboratory tests, and other analyses. More detail is presented in Appendix B, Geology, Geotechnical & Seismological Studies.

4.3.1 Geologic and Geotechnical Investigations

Geologic and geotechnical information was obtained during two visits to the proposed dam sites, one in September 1999 and another in December 2001. Investigations were limited to general reconnaissance of the project area, and descriptions of site geology provided here are taken from observations made during the reconnaissance site visits and literature studies conducted by the USACE for development of the August 1999 Reconnaissance Report.

The original scope of the feasibility investigation program was quite extensive and also included core drilling at locations of principal project elements and geophysical surveys. Because there were problems in obtaining access to the project site, the drilling program and associated activities (sampling, permeability testing) and the seismic refraction program have been indefinitely postponed.

The final program incorporated the following activities:

- Reconnaissance of dam and powerhouse sites; establish exploration program and investigation requirements,
- Reconnaissance geologic mapping, including geomorphological analysis and photo-geologic studies,
- Outcrop geologic mapping at the dam site,
- Construction materials investigation,
- Identification of principal geologic factors governing alternative tunnel routes,
- Development of preliminary geologic and geotechnical criteria for use in the selection of recommended project concepts and features/structures,
- Seismic hazard assessment of project region,
- Laboratory testing and analyses of test pit samples, and
- Development of geologic and geotechnical parameters for use in design of selected project and estimation of construction costs.

The objectives of geologic mapping performed during these investigations included identifying, interpreting, and documenting the following aspects:

- Geomorphic conditions at the project sites,
- Occurrence and general nature of overburden units,
- Location and conditions of rock outcrops,
- Lithologic and surficial properties of rock units,
- Surficial extent and characteristics of rock weathering, and
- Orientation and condition of joints, shears, and faults.

Reconnaissance geologic mapping was performed along the Río Coclé del Norte from the reservoir area to immediately downstream of the dam site. Geologic reconnaissance was also carried out at selected locations to help identify conditions along prospective tunnel alignments, tunnel portals and intake locations. A general reconnaissance of some of the proposed reservoir area (up to the confluence with the Río Toabré) was performed by helicopter to identify and evaluate any geologic features relevant to reservoir rim stability and watertightness.

Available aerial photographic coverage was obtained from *Instituto Geográfico Nacional*. The quality, age, and scale of the basin coverage was a limiting factor in performing detailed examination of key areas and accurate studies for photogeologic interpretations. Conventional photogeologic methods were followed using a mirror stereoscope and photo-comparator.

Samples of rock and soil samples from test pits were collected for subsequent laboratory testing and analysis through the services of Tecnilab in Panama City. The testing included:

- Laboratory tests for gradation, specific gravity, absorption, soundness, and abrasion resistance were performed on samples collected from test pits in order to establish their potential use as construction materials, and
- Preliminary petrologic determinations were made from hand samples collected during geologic mapping.

4.3.2 Geology of the Damsite

The Río Coclé del Norte dam site is about 15 km from the mouth of the river on the Atlantic coast and about 7 km downstream from the confluence of the Río Coclé del Norte and Río Toabré, its main tributary.

Bedrock at the dam site is found to consist mostly of porphyritic basalt and, less commonly of basic agglomerate. Regional geologic maps indicate bedrock at the site to be of an intrusive igneous nature, possibly granodiorite or quartz monzonite (Tertiary age Petaquilla formation). Such rock types were not observed in the site area. Rock float and large boulder talus indicate the presence of *in situ* bedrock at relatively shallow depths, but severe weathering is evident. Basalt float was observed all the way up the left abutment to above el. 100 m. Rock outcrop was observed at river level on the left side, at several other locations on the left abutment and is widespread on the right side.

River terrace deposits are found along the valley at many locations, mostly at about 5-10 m above present river level, on the inside of meanders, and at the confluence of tributaries. The terrace deposits appear to be largely silty-sand and clayey-silt. No significant gravel deposits have been found.

At the dam site, the Río Coclé del Norte flows north forming an asymmetrical, relatively steep-sided valley. The river is only slightly above sea level at the site and minor tidal fluctuations (reportedly up to 30 cm) are evident. The sides of the river rise steeply to a little over 100 m on the left side and to above 140 m on the right side. The width of the valley bottom at the site varies, but averages about 100 m with the streambed occupying about 50-80 m.

Both abutments are heavily vegetated and are almost entirely covered with talus, colluvial, and residual soils. Small, scattered rock outcrops can be observed throughout the site area on both abutments, especially in gullies. Most of the dam site area is characterized by a moderately deep weathered profile with locally thick soil cover typical of the sub-tropical climate.

The principal geologic structures at the Río Coclé del Norte dam site are joints and bedding. Until subsurface investigations are performed, the existence and extent of other features, such as shear zones and faults, are unknown.

Based upon experience with geological investigations and construction in the Canal Area, it is likely that several small faults and shear zones could exist at the dam site. From regional geologic mapping and photogeologic studies, the presence of major faults, however, is not expected. Some photogeologic linears, shown on Exhibit 2-4, have been interpreted in the dam site area but these are not thought to be caused by significant faulting.

4.3.3 Engineering Geology

In general, the basaltic foundation bedrock at the site should provide a suitable foundation for all types of structures being considered. This type of foundation material is not expected to present any significant constraints on project development that cannot be taken care of with appropriate design details and construction practices. This is in contrast to some sedimentary rock units and geotechnical conditions known from the Panama Canal (e.g. Cucaracha Formation), where sliding and foundation failures have been common and presented serious problems. Rather, the bedrock geology should be closer to what has been encountered in the basalt formations in the Miraflores Locks area.

4.3.3.1 Geotechnical Design Parameters

Geotechnical design parameters and criteria used for developing project layouts and cost estimates are presented in Table 4-8.

TABLE 4-8 SUMMARY OF GEOTECHNICAL DESIGN PARAMETERS FOR RÍO COCLÉ DEL NORTE DAM

Parameter	Selected Design Criteria
Depth to top of weathered rock (dam/tunnel)	3 m / 5 m
Depth to top of competent rock (dam/tunnel)	6 m / 10 m
Excavation depth under plinth and 25 m downstream of main dam body	6 m
Excavation depth under main dam body	3 m
Excavation depth under spillway headworks and chute	6 m
Rock Excavation Slopes	1H:5V, 3-m-wide benches every 10 m vertically
Soil Excavation Slopes, Permanent	2H:1V, 3-m-wide benches every 10 m vertically. Bench at soil-rock contact
Soil Excavation Slopes, Temporary	1.5H:1V, 3-m-wide benches every 10 m vertically. Bench at soil-rock contact

4.3.3.2 Foundation Treatment

Dental excavation and concrete will be used to treat local zones of highly weathered, sheared, or otherwise unacceptable rock encountered in the foundation under the plinth slab and under the spillway headworks. Required dental treatment should be nominal and only local. Consolidation grouting is not envisaged except in limited areas (e.g. fault or fracture zones) should they become exposed during excavation.

Curtain grouting will be used to reduce seepage through joints and fractures under the dam and in the abutments. For estimating purposes, a single row, staged grout curtain constructed by the split-spacing method is assumed.

4.3.3.3 Diversion and Cofferdams

River diversion during construction will be accomplished through a diversion tunnel and the work site will be protected by cofferdams. The diversion tunnel will be excavated entirely in basalt. Basalt should provide favorable tunneling conditions using conventional drill and blast methods. Poor conditions may be encountered locally. Geologic data currently available for the diversion cofferdam areas are limited to surface mapping and the foundation areas are underlain by an unknown thickness of overburden. Construction of the upstream cofferdam may present some problems. The structure will be founded only partly on bedrock; the majority will be on channel fill and terrace deposits. Cut-off will involve excavation through varied overburden materials of unknown thickness (possibly 3-6 m to top of rock).

4.3.4 Seismicity

As indicated on Exhibit 4-2 several major historical earthquakes have occurred in the study region. Most notably, earthquakes occurred in 1822 and 1916 in Northwest Panama along the border of the North Panama Deformed Belt, while two earthquakes occurred nearly 25 km off the northern coast near Colon in 1621 and 1882. An additional earthquake event is noted in 1914 on the northeastern coast in the San Blas region. The Global Hypocenter Database prepared by the U.S. Geological Survey/National Earthquake Information Center (USGS/NEIC) of Denver, CO, was used to search for all historical (non-instrumented) and modern (instrumented) seismicity data within the region bounded by latitudes 5°N and 11°N and longitudes 75°W and 85°W. The database contains over 900,000 earthquakes from 2100 B.C. through 2002 and draws on information from 53 separate regional and worldwide catalogs. Within the defined region, nearly 2,150 earthquakes were identified. The general distribution of these earthquakes plotted as function of their depth below the surface is also presented on Exhibit 4-2.

An evaluation of the project seismicity as well as the economic and life-safety issues associated with the western watershed projects indicates that these projects can most likely be classified as significant rather than high hazard projects. No fault movement, or ground breakage due to tectonic offset, has been recorded in the area over the last 10,000 years and the project region has no potential for the development of seiches or earthquake-triggered tsunamis.

Because the projects will be newly designed and constructed, the most up-to-date seismic design guidelines will be used and seismic resistant design features adopted where needed. The projects will not be constructed of or founded on liquefiable or potentially liquefiable materials and the projects will not be constructed on any known active or potentially active faults.

Based on the density plot of earthquakes (Exhibit 4-2), it is apparent that the greater percentage of earthquakes occurs on the borders of the Panama Block, away from the location of the projects. Although the occurrence of a large event affecting the project area is possible, it is more likely to affect the plate boundaries.

On the basis of the above, therefore, it is recommended to analyze the projects with a return period near 2,000 years, *i.e.*, a five percent probability of exceedance over a project life of 100 years. In this respect, it is suggested that a level of motion less than the controlling maximum credible earthquake (MCE) can be acceptable to represent the maximum design earthquake (MDE), when using probabilistic methods.

The recommended operating basis earthquake (OBE) for the projects shall be as recommended by USCOLD at 50 percent probability of exceedance over a project life of 100 years, or a return period of 144 years.

The recommended seismic design parameters for the Río Coclé del Norte Project are as follows:

- Maximum Design Earthquake (MDE) = 0.27 g
- Operating Basis Earthquake (OBE) = 0.14 g

The Río Coclé del Norte Dam was analyzed for stability under MDE conditions.

4.3.5 Geology of the Water Transfer Tunnel

Only one principal tunnel alignment was investigated for the tunnel from the Río Coclé del Norte Reservoir to the Río Indio Reservoir. This alignment, which is indicated on Exhibit 3-3, has a total length of about 16,500 m, including the 0.7 km-long connection for a lake tap.

Existing geologic maps of the region show bedrock in the region as belonging to 'undifferentiated Tertiary volcanics' or alternatively as belonging to the Tertiary age Caimito Formation (tuffaceous sandstone, tuffaceous siltstone, tuffs, dacitic agglomerate, conglomerate, sandstone, and limestone). It is assumed that rock units that could be encountered in excavation of the tunnel alternative could include any of those identified during investigation of the Río Toabré and Río Indio sites and reservoir areas.

Observations indicated that the outlet works into the Río Indio reservoir would be constructed in rolling subdued topography with possibly little cover over tunnel grade and deeply weathered sedimentary units (sandstones and shales). Recommendations were made to locate the proposed outlet works sufficiently far back to ensure adequate rock cover and to attain relatively sound bedrock.

At the intake end, reconnaissance revealed that the topography in the portal area is complicated with deeply incised drainages. Nevertheless, it was considered that a favorable portal location could be found with a range of options for detailed design, i.e. flexibility in vertical and horizontal location. The bedrock geology in this area (possibly Cañazas Formation) consists of a variable sedimentary sequence of thick-bedded calcareous pebbly sandstone units (conglomerates), calcareous sandstone and siltstone (calcilutes), sandy tuffaceous limestone, and hard cherty limestone (calcarenite). Based on the presence of abundant basalt float in the area, an igneous unit could also occur in the area, possibly a local dike, sill, or isolated lava flow, but its exact location with respect to the portal is not known.

It is probable that tunnel construction will encounter a wide range of rock types and tunneling conditions. The range and relative persistence of various conditions will depend on final alignment selection. Rock types could include sandstone and softer epiclastics of the Caimito Formation as well as hard, strong lavas (andesites, dacites, and basalts), limestones, and agglomerates. Based on air-photo interpretation and map studies, there is a strong probability of encountering karstic limestone conditions within the first third of the tunnel length – as evidenced by enclosed surface depressions and doline-like features. Associated with karstic conditions could be the potential for significant water inflows and poor tunneling conditions. There will also be transition over short distances from very hard strong rock (such as andesite or basalt) to soft, weak almost clay-like materials. Such aspects would need to be examined in more detail to establish their impact on construction method as well as cost parameters, including support and lining requirements.

The tunnel cover criterion (the minimum vertical distance between the ground surface and the crown of the tunnel excavation) used in developing a potential alignment was:

$$H = 2D + 10 \text{ meters}$$

Where H equals the distance between the ground surface and the crown of the excavated tunnel and D equals the tunnel diameter. Ten meters was added to this value to account for topographic uncertainty.

For costing and scheduling purposes, it was assumed that tunnel construction would utilize a tunnel boring machine (TBM) for the bulk of excavation with drill-and-blast techniques in limited lengths at the main portals.

Experience indicates that groundwater inflow should be expected at various points along the proposed tunnel alignment. However, the location and quantity of water inflow are not known and cannot be predicted with any certainty. The potential for encountering hazardous gases is considered remote. Ventilation and shotcrete have been used successfully to control gas occurrences, should they occur. The tunnel is not likely to encounter stress-related problems (popping rock, slabbing rock, or rock burst in competent rock, squeezing ground in weak/fractured rock) because the rock cover is not that great.

Anticipated rock condition type and support requirements for the water transfer tunnel during construction are listed in Table 4-9. Tunnel lengths associated with the rock support classes were estimated on the basis of general knowledge of the geology of the area, geologic mapping, and experience.

TABLE 4-9 ESTIMATED ROCK SUPPORT CLASSES FOR RÍO COCLÉ DEL NORTE-RÍO INDIO TRANSFER TUNNEL

Rock Support Class	TBM*	Tunnel Length
Excellent	No systematic support required	20 %
Good to Fair	One pass shotcrete locally, split sets, mine straps as required.*	30 %
Fair to Poor	One pass shotcrete, locally, systematic split sets, mine straps as required.*	40 %
Very Poor	Shotcrete with mesh, systematic split sets, mine straps as required.*	10 %

* Note: It is assumed that if a segmental liner system is used in combination with TBM excavation method that temporary rock support requirements would be minimal provided prompt installation of the liner takes place. It is also assumed that probe drilling ahead of the face will be carried out with provisions for pre-excavation grouting.

It is assumed that the tunnel will be fully lined from portal to portal. The lining will be required to control water loss in low cover zones and areas of severely fractured rock, to prevent erosion and deterioration of the rock in areas of soft or highly fractured rock, and for hydraulic reasons.

A pre-cast concrete, segmental lining has been assumed in all rock conditions (I-IV) described above. The thickness of the liner is expected to be between 0.3 and 0.5 m. A thickness of 0.4 m has been assumed for estimating purposes.

The anticipated geologic and tunneling conditions strongly influenced the estimate of excavation advance rate and construction cost. In general, it is estimated that the mining advance rate could be in the range of 12-15 m per day (net penetration rate of about 1.75 m/h and 42% utilization).

4.3.6 Construction Materials

For the Río Coclé del Norte Project, the types of required construction materials for the project are:

- Materials for cofferdams;
- Concrete aggregates;
- Filters and drains;
- Rock fill for the dam, backfill materials and other structural fills, and;
- Rock for riprap and slope protection.

The diversion cofferdams will consist of temporary dikes designed to divert the river, in combination with channel excavation. Currently, it is assumed that these could be constructed from locally available random fill obtained from the immediate area of the dam site.

The majority of the rockfill and all aggregates (including coarse and fine aggregates for concrete, filters, drains, and riprap) need to be manufactured from quarried sources. Coarse and fine aggregates for concrete will be processed from quarried igneous rock materials, i.e. basalt or andesite. Aggregates for filters and drains will be obtained by processing of the same quarry sources as exploited for concrete aggregates. The area downstream from the damsite on the right side of the river consists of high hills that could be stripped and opened as quarries. The location of these sources is shown on Exhibit 4-3.

Materials for backfill will come from the required excavations, including use of tunnel excavation spoil A portion of the rockfill for the dam also could be obtained from required excavation, provided that it is not too decomposed.

4.4 Dam Site and Dam Type Selection Studies

A consideration of alternative damsites was made and no better site was identified. Studies were then performed to select the type of dam most appropriate for the selected site. A concrete-face rockfill dam (CFRD) was selected.

4.4.1 Dam Site Selection

In their Reconnaissance Report (1), the USACE selected a dam site with a view toward maximizing the water development potential at a minimum cost.

Selection of a site was fairly straightforward. To maximize the water development potential in the basin, it is necessary to regulate the flow of the Río Toabré, which accounts for about one-half of the catchment area. It is desirable to locate the dam as far upstream as possible below the confluence to limit the height of dam without sacrificing any significant drainage area. The selected site regulates about 92% of the drainage and is considered to be an acceptable alternative.

The dam site is located about 1 km downstream of Cerro Pelado, and approximately 4km upstream of the village of San Lucas. It is about 6 km downstream of the confluence with the Río Toabré, and 15 km from the mouth of the Río Coclé del Norte with the Atlantic Ocean. The axis used for this study was selected primarily to maximize storage and for topographical considerations. It takes advantage of a relatively narrow reach of river valley to reduce the volume of fill, provides adequate space for cofferdam and diversion facilities, and does not present any adverse access difficulties. The final alignment of the dam will be confirmed following the site investigation program during final design.

4.4.2 Dam Type Selection

The detailed studies of the selection of the type of dam for the Río Coclé del Norte Project are presented in Appendix D, Part 1.

The dam type selected in the Reconnaissance Study (1) was a center core rockfill dam. An ungated spillway was located on the right abutment. The proposed spillway had a crest width of 346 m and the spillway chute was proposed as a sloped and stepped natural rock cut channel.

Four types of dam were identified for evaluation as a part of the current dam type study:

Alternative	Dam Types	Abbreviation
1	Concrete Faced Rockfill Dam	CFRD
2	Roller Compacted Concrete Dam	RCC
3	Conventional Gravity Concrete Dam	CGCD
4	Earth Core Rockfill Dam	ECRD

Alternatives 3 and 4 were rejected in the preliminary screening. The CGCD was rejected because it will be more expensive than the RCC dam primarily owing to the higher cement content (and therefore cost), the need for more formwork, and the longer construction period. The ECRD was rejected because suitable quantities of impervious material were not located in the vicinity of the dam site and the wet climate is less favorable for the construction of an ECRD.

4.4.2.1 Concrete Face Rockfill Dam

For the dam type selection study, the slopes of both the upstream and downstream faces of the CFRD were 1.4H:1.0V. The dam would be constructed of selected rockfill obtained from adjacent or nearby rock quarries. An upstream parapet wall extending 2 m above the fill, and a downstream retaining wall of 1 m, would form the top-of-structure.

An 8-m diameter 530-m long diversion tunnel would be located in the left abutment. It was sized to pass the 50-year event.

An ungated spillway will be located in the right abutment. As configured, the spillway would have a crest width of 50 m and a 250-m long tapered chute.

4.4.2.2 Roller Compacted Concrete Dam

The RCC dam was configured for a vertical upstream face and a downstream slope of 0.75H:1V. The crest would be 8-m-wide and a parapet wall would be constructed to two meters above the crest.

The diversion was also sized for a 50-year flood. The tunnel would be about 450 m long and have a diameter of 8 m.

An ungated spillway was adopted for the dam-type studies with the same hydraulic capacity as the CFRD ungated spillway. It was be located on the RCC dam to discharge directly by means of a chute and flip bucket into the existing Río Coclé del Norte channel. The spillway would be constructed of conventional reinforced concrete.

4.4.2.3 Dam-Type Selection

The two alternatives were evaluated on the basis of cost and construction, foundation, and operation and maintenance considerations.

The CFRD alternative resulted in a cost about 9% lower than the RCC alternative.

Construction considerations do not necessarily favor either type of dam. The RCC dam can be constructed in a shorter time, but the CFRD takes more advantage of local materials.

The known foundation characteristics are equally suitable for either dam type. The rock formation found in outcrop, and found to extend throughout the site is suitable for both types of dam.

Operation and maintenance considerations tend to favor the RCC dam. Leakage through either type of dam should be minimal.

As a result of the analysis, an ungated concrete-face rockfill dam was selected for further study for the following reasons:

1. Changes to the current available foundation information would have less impact on this dam type and cost;
2. The CFRD cost estimate is less sensitive to variation in unit cost, and;

3. The total cost of the CFRD alternative is projected to be lower than the total cost of the RCC alternative.

The selection of the CFRD alternative should be confirmed following the completion of site investigation programs if the investigations show foundation conditions that are highly favorable for RCC dams.

4.5 Project Operation Studies

The HEC-5 Reservoir System Model, developed by the U.S. Army Corps of Engineers' Hydrologic Engineering Center in Davis, California was used to evaluate the capability of the present ACP system and to evaluate the effectiveness of proposed alternatives to improve the system capability and reliability.

This model performs a sequential simulation of reservoir operations given a time-series of flow. The reservoirs are defined by their storage and outflow capability. The reservoir storage is allocated to operational zones (levels) that define their usage (rule curves). Water demands include 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 connecting routing reaches then define the reservoir model system.

4.5.1 Area/Volume Relationships

Area and volume data versus elevation were developed for the Río Coclé del Norte Reservoir based on the 1:50,000 scale maps. The "zero" area and volume point was taken from topographic mapping of the dam site. A curve of area and volume versus elevation is shown on Exhibit 4-4.

4.5.2 Reservoir Operating Level

The minimum operating level at Río Coclé del Norte was selected to provide for acceptable hydraulic conditions in the operation of the transfer tunnel. El. 50 was adopted as a suitable minimum level.

A series of operation studies were performed to assess the variability of yield versus active storage at various levels in the operating range. Although no economic studies were possible, based on experience and a storage/yield curve, discussed and presented in Appendix D, it was determined that an active storage between 3,000 MCM and 4,000 MCM provides a development level near to the optimum. The active storage available between El. 50 and El. 71 in the Río Coclé del Norte Reservoir is about 3,445 MCM and, therefore, this operating range was adopted.

4.5.3 System and Project Yield

Operation simulations were made for a demand identified in terms of daily lockage requirements (Lockages per day, L/d) using the live storage in the reservoir between El. 50 and El. 71. One lockage was assumed to equal 55 million gallons or 208,000 m^3. The yield allocated to the Project was estimated as the total yield of the existing system, (Gatun after deepening, Madden, Río Indio) plus Norte/Sucio less the yield of the system without Norte/Sucio. The yields are presented in terms of a hydrologic reliability, which is computed as the total water delivered divided by the total requirement. The target reliability, based on historic records, is 99.6%.

The yield of the Norte/Indio Project under these conditions is estimated to be 3,480 MCM/year or 45.4 L/d as shown in Table 4-10.

TABLE 4-10 PROJECT YIELD

	Yield		
	L/d	**Mgd**	**MCM/yr (rounded)**
Existing System Yield (as defined) at reliability of 99.6%	60.3	3,315	4,580
System Yield w/ Coclé del Norte Reservoir (71-50)	106.1	5,835	8,060
Yield allocated to Río Coclé del Norte Reservoir (71-50)	45.4	2,520	3,480

Additional information on the operation studies is presented in Appendix C.

4.6 Project Configuration Studies

The project configuration studies addressed the selection of design floods, the diversion arrangement and the emergency drawdown arrangement.

4.6.1 Spillway and Diversion Flood

The spillway is designed to pass the probable maximum flood without overtopping the dam or causing any damage to the spillway facilities. For a project whose failure could result in loss of human life and economic endeavor, such as the Río Coclé del Norte Project, it is customary to design the project for the worst conditions that could reasonably be postulated. The maximum peak inflow of the PMF is estimated to be 10,460 m^3/s and the 5-day volume is about 988 MCM.

A flood with a return period of 50 years was selected for the construction diversion flood. This flood would have a peak discharge of 3,860 m^3/s and a 1-day volume of about 167 MCM.

4.6.2 Diversion and Emergency Drawdown Facilities

The dimensions of the diversion facilities were selected in a two-step study. In the first step, the lease cost total of the diversion tunnel and cofferdams, both upstream and downstream, was estimated. The second step consisted of evaluating the diversion tunnel diameter needed to meet the adopted emergency drawdown criteria. It was assumed that the tunnel would be about 550 m long, and that the velocity in the tunnel would be limited to 20 m/s.

The 50-year flood was routed through the reservoir for three sizes of tunnel to determine the upstream and downstream water surface elevations. The results are shown below:

Tunnel Diameter (m)	Upsteam Water Surface Elevation (m)	Downstream Water Surface Elevation (m)
6	24.0	0.7
8	22.1	3.5
10	20.6	4.8

Based on the relative cost of cofferdams for the indicated water surface elevations and the tunnel cost for a 550-m long tunnel, the smallest diameter tunnel resulted in the least cost.

The 6-m diameter and 8-m diameter diversion tunnel arrangements were evaluated against emergency drawdown requirements of the USBR in their guidelines "ACER Technical Memorandum No. 3 dated January 1982 entitled Criteria and Guidelines for Evacuating Storage Reservoirs and Sizing Low-level Outlet Works". In summary, the guidelines are as follows:

Drawdown in percent of the Hydraulic Height of Dam	Allowable Time (days)
75	30-40
50	50-60
25	80-100

Preliminary hydraulic analysis showed that the time to empty the reservoir to the required levels can be accomplished within the guidelines assuming an 8-m diameter tunnel and a constant inflow equal to the mean annual runoff.

Drawdown times with this the 8-m diameter tunnel are:

TABLE 4-11 DRAWDOWN TIME FOR AN 8-M DIVERSION TUNNEL

Drawdown Elevation (and % of hydraulic head)	Time, days
El. 71 (100%)	0
El. 53 (75%)	34
El. 35 (50%)	54
El. 18 (25%)	65

The 8-m diameter tunnel was adopted for diversion and emergency drawdown.

4.6.3 Spillway Arrangement

The least-cost approach to protecting the dam against the PMF is to provide enough storage in the reservoir to contain the flood. This unconventional solution was not adopted and, instead, a 50-m wide spillway was selected. Based on studies performed for the dam at El. 100 (Appendix D, Part 4), the selected spillway arrangement consists of a curved ogee control structure, a tapered chute, and a flip bucket. The chute alignment was selected to be as short as possible and still form a plunge pool in the middle of the channel downstream and away from the other project structures. The chute profile was configured to accommodate the taper and the assumed top of sound rock.

4.6.4 Water Transfer Tunnel Size and Alignment

As a part of the operation studies, it was determined that the operating range will be between El. 51 and El. 70 and that the system yield would be about 46 L/d. The HEC-5 runs were performed assuming a 9.0-m diameter tunnel from Río Coclé del Norte to Río Indio Reservoir. Additional HEC-5 runs were performed for other diameter tunnels to determine the minimum diameter required to provide the yield. It was concluded that a 9.0-m diameter is the appropriate diameter.

The shortest tunnel alignment between the Río Coclé del Norte Reservoir and the Río Indio Reservoir was selected for the purposes of this study. It is aligned from the area near the confluence of the Río de U and the Río Toabré to the Río Indio Reservoir near Isla Pablon. Based on preliminary inspections, the intake and outlet areas are suitable and adequate cover is provided throughout the alignment.

5. PRELIMINARY DESIGN OF THE PROJECT FEATURES

This section presents a more complete description of the project features and the design assumptions that were adopted. The project hydrology, engineering geology, and geotechnical assumptions have been summarized in Section 4 and are presented in detail in Appendixes A and B.

5.1 Río Coclé del Norte Dam and its Appurtenant Features

These features include the dam, spillway, diversion, emergency drawdown, and the minimum release facility.

5.1.1 Río Coclé del Norte Dam

Río Coclé del Norte Dam will be a concrete-face rockfill dam (CFRD) constructed of durable, free-draining compacted rockfill obtained from nearby quarries. The slopes of the upstream and downstream faces will be conservatively set at 1.4H:1.0V based on precedent for this dam type, foundation, and the seismicity of the region. The main body of the dam will be comprised of rockfill and the downstream shell will be coarse rockfill. The rockfill shells and filters of the dam have an in-place volume of about 3.1 million cubic meters.

The axis of the dam will be slightly off of perpendicular to the river and will cross the main channel of the Río Coclé del Norte at about 993540N, 550430E (UTM Coordinate System). The crest of the dam will be at El. 74 and the width of the crest will be 8.0 m. A 5-m high parapet wall will extend 2 m above the crest to El. 76. The dam will be about 86 m high from the deepest foundation excavation to the top of the parapet wall. A plan of the dam is shown on Exhibit 3-2 and a section, and details of the dam are shown on Exhibit 5-1.

A reinforced concrete facing will act as the impermeable membrane. It will be designed to have low permeability, durability against weathering, and sufficient flexibility to tolerate small, expected embankment settling. A 3-m wide zone of filter material and a 3-m wide zone of fine rockfill will underlay the concrete face to provide continuous support. The filter material will be manufactured from the igneous quarry material. The average thickness of the concrete face will be 0.4 m. Reinforcing steel will be included at a rate of 30 kg/m^3. The facing will be placed in individual slabs, up to 15 m wide, and horizontal joints will be inserted as needed.

The proposed treatment programs for the dam foundation will include surface treatment, shallow foundation grouting, curtain grouting, and drainage.

For the plinth slab excavation at the dam toe and under the spillway headworks, dental excavation and concrete will be used to treat local zones of highly weathered, sheared, or otherwise unacceptable rock encountered in the foundation. Required dental treatment should be nominal and only local.

Consolidation grouting is not envisaged except in limited areas (e.g. fault or fracture zones) should they become exposed during excavation for the plinth slab and under the spillway headworks. Low pressure cement grouting will be used in such limited zones to fill open cracks or joints in the rock zone immediately beneath the dam foundation. In general, grout takes should be low.

Curtain grouting will be performed from the toe slab of the CFRD and through the spillway concrete (or from a grout slab prior to placing first stage spillway concrete). It is assumed that the spacing of the primary grout holes will be 10 m and it is further assumed that procedures will entail split-spacing down to 2.5 m (tertiary holes) over the entire curtain, and to 1.25 m (quaternary holes) over 75% of the curtain. The grouting will be to a depth of one-half the height of the PMF above the dam foundation or to a maximum depth of about 38 m below the structural foundation level. Final design might require grout holes to be inclined to intercept the maximum number of open joints, fractures, and faults. The average grout consumption was assumed for estimating purposes to be about 30 kg/m.

5.1.2 Spillway

An ungated chute spillway will be located in the right abutment. The spillway has been designed to pass the PMF without overtopping the dam. The discharge under PMF conditions will be 800 m^3/s using a surcharge of 3.7 m above the full supply level. An outflow hydrograph is shown on Exhibit 4-1. The resulting freeboard under this flooding condition will be 1.3 m.

The spillway will consist of an approach channel, an ogee control section, a tapered chute, a flip bucket, and a short excavated channel to direct the water back to the natural river channel. A plan and sections of the spillway are shown on Exhibit 5-2 and 5-3.

The approach channel will be about 100 m long and will be excavated to El. 66. The channel will be curved and widen from about 55 m at the control structure to about 80 m at the end of the channel.

The ogee-type control section will be concave downstream and consist of three bays with a total clear opening of 50 m. Two piers will support an 8-m wide bridge to connect the dam crest to the right abutment access road.

The chute will be about 225 m long from the downstream end of the control structure to the beginning of the flip bucket. The width of the spillway chute will taper from 52 m to 10 m about 100 m downstream from the control structure and remain at 10 m to the upstream end of the flip bucket. An aeration ramp will be installed about two-thirds of the way down the chute at El. 60. The chute essentially is configured to follow the rock line. The maximum water depth will vary from 3.7 m at the crest to 1.5 m at the bottom of the control structure, to a maximum of 5.0 m at the break in the slope of the chute, to 2.3 m at the upstream end of the flip bucket. A constant wall height of 6.0 m was adopted.

The flip bucket is located so that the plunge pool will be located in the main channel and the spillway discharge will not impact on any of the proposed project structures. The lip of the bucket will be 10 m wide and will be at El. 6 about 2.0 m above the anticipated tailwater elevation under PMF conditions. A reinforced concrete slab about 10.0 m long will extend downstream from the bucket to provide foundation protection for small discharges.

Foundation drainage will be provided under the control structure and along the chute. to control seepage to reduce pore pressures in the rock mass, and hence uplift.

5.1.3 River Diversion During Construction

The facilities for the temporary diversion of the Río Coclé del Norte during construction consist of cofferdams upstream and downstream from the damsite and a tunnel in the left abutment. The river diversion facilities plan, profile, sections, and details are presented on Exhibit 5-4. The tunnel will serve to:

- Pass the 50-year flood;
- Control the rate of initial reservoir filling, and;
- Assist in the evacuation the reservoir.

The criteria presented in Section 4.6.2 were adopted for determining the drawdown capability. It was determined that controlling the rate of filling determines the selection of the capacity of the diversion tunnel. Provision of drawdown capability will be achieved by a combination of converting the diversion tunnel to a low-level outlet and utilizing the water transfer tunnel.

The diversion tunnel will be an 8.0-m diameter, modified horseshoe with vertical sides and a horizontal invert, approximately 530 m long. The diversion tunnel will be constructed entirely in basalt. Under the 50-year flood event, the tunnel will discharge about 640 m^3/s with the upstream water surface at El. 22.1 and the downstream water surface at about El. 3.

An approach channel 70 m long will lead to the intake portal. The approach channel will be horizontal and approximately at El. 0. The upstream portal will be excavated into a rock face to provide cover of about 20 m at the beginning of the tunnel. The excavation will be at a slope of 1H:5V in the rock and 2H:1V in the overburden. Rockbolts and shotcrete will be applied as needed. A 350-m long discharge channel will extend from the downstream portal to the river channel.

The upstream and downstream cofferdams will be approximately 29 m high and 7 m high respectively. The wet-side slopes will be 2.5H:1V and the dry-side slopes will be 2H:1V. The upstream cofferdam will have its crest at El. 22.5 and is proposed as a zoned-fill structure constructed with materials excavated at the damsite. The structure will only be partially founded on rock and a cutoff of 3 m to 6 m may be required. The downstream cofferdam will have its crest at El. 4 and will be constructed of random fill excavated from the site. The total volume of both cofferdams will be about 530,000 m^3.

5.1.4 Emergency Drawdown

Emergency drawdown will be through the diversion tunnel. The emergency drawdown facilities will consist of a low-level intake structure constructed at the intake portal, a gate shaft constructed under the crest of the dam to facilitate its use for reservoir evacuation and passing the minimum release, high-strength concrete lining, and hydro-mechanical equipment. Profiles and sections of these facilities are shown on Exhibit 5-5.

The intake structure will be constructed to El. 14 to permit continuous operation over the life of the project without interference from sediment buildup. The gate shaft will house two 3.6-m wide by 6-m high wheel gates and two similar sized bulkhead gates. The diversion tunnel opening in the low-level intake will be plugged when the gate shaft is completed. Water can then rise to El. 14 and flow through the low-level intake and be controlled at the gate shaft.

Drawdown times are presented in Section 4.2.6. At high reservoir elevations, flow through the diversion tunnel will be controlled by the wheel gates. Control is required to limit the velocity in the tunnel to 20 m/s, to prevent cavitation damage to the tunnel lining by providing aeration, and to control the downstream tailwater elevations. The tunnel lining will be constructed using high strength concrete, and a 20 m long anchored apron will be constructed downstream of the tunnel outlet portal to prevent foundation erosion. At high discharge flows, some erosion damage can be expected in the downstream channel.

5.1.5 Minimum Release Facility

The minimum release has been assumed to equal 10% of the average flow or about 10.7 m^3/s. The minimum release will be discharged through the powerhouse or through a bypass valve in the powerhouse, if required.

5.2 The Water Transfer Tunnel to Río Indio Reservoir

The water transfer tunnel will convey water from the Río Coclé del Norte Reservoir to the Río Indio Reservoir. The alignment was selected from a map study as the shortest route with adequate cover and suitable portal locations. The portal locations were visited to confirm their suitability.

5.2.1 Tunnel Alignment and Facilities

The size of the water transfer facilities is based on operation data provided by the ACP. The design flows for the tunnel from the Río Coclé del Norte Reservoir to the Río Indio Reservoir are estimated to be 185 m^3/s when the Río Coclé del Norte Project is at El. 50 and 220 m^3/s at El. 61. The maximum capacity is estimated to be 300 m^3/s.

From an inspection of the 1:50,000 maps, it was determined that shortest route between the Río Coclé del Norte Reservoir and the Río Indio Reservoir with adequate cover begins approximately at the confluence of the Río Toabré and the Río de U and ends in the Río Indio Reservoir near Isla Pablon.

Based on the analysis of cover, it was determined that intermediate access to the tunnel is not feasible because the adits would be very long. Therefore, it was decided to assume that excavation would be accomplished using a single tunnel-boring machine (TBM).

The water transfer tunnel consists of an approach channel, intake facilities, a TBM adit, the tunnel, and a lake-tap outlet. A plan of the alignment, intake area, and outlet area is shown on Exhibit 5-6. A profile is shown on Exhibit 5-7, and sections of the intake and outlet are shown on Exhibits 5-8 and 5-9.

The approach channel is about 1,500 m long and has its invert at El. 40. The channel is excavated as a trapezoidal section with a bottom width of 5 m and side slopes of 2H:1V.

The intake is a reinforced concrete structure with an opening 15 m wide by 10 m high. Trash racks protect the openings. Intake flow velocities through the trash racks at maximum discharge are limited to 1.5 m/s to permit raking. The invert of the intake is at El. 40 to allow for proper hydraulic conditions at minimum pool operation. The intake structure extends up to El. 75, slightly above the design flood elevation to provide access to the trash racks. A trash rake is provided to clean the trash racks.

A TBM adit will be located at the upstream end so that the tunnel and intake can be constructed at the same time. The adit will consist of a 250-m long approach, a 30-m long TBM platform, and a 220-m long tunnel segment.

The 16,500-m long, 9-m diameter tunnel consists of a 200-m long drill and blast segment at the upstream end from the intake to the tunnel adit, the main tunnel segment, which is about 15,600 m long, and a second drill and blast reach, 700 m long to the lake tap. The TBM segments will be circular-shaped and the drill and blast segments will take the shape of a modified horseshoe with vertical sides and a horizontal invert.

It was assumed that the tunnel construction would be from the upstream portal. It is also assumed that the tunnel will be fully lined throughout to control water loss in low cover zones and areas of severely fractured rock, to prevent erosion and deterioration of the rock in areas on soft or highly fractured rock, and for hydraulic reasons. A pre-cast concrete, segmental lining has been assumed in all rock conditions. A thickness of 0.4 m has been assumed for estimating purposes.

A gate shaft and gates will be provided at the upstream end of the tunnel for dewatering. It will be part of the intake structure and located about 60 m from the intake. The gate will consist of two side-by-side 4 m wide by 8 m high wheel gates. The gate will be raised and lowered by means of a hydraulic cylinder hoist that will be powered and operated from a surface control structure.

At the downstream end of the TBM segment, a gate/access shaft will house two 4-m wide by 7-m high, bonneted guard gates, and two equal-sized bonneted control gates in series. This will provide redundancy for reliable operation and maintenance, and additional flow control. The outlet structure will be founded on sound rock. Power and control equipment will be housed in a small structure adjacent to the gates. A road will be provided for a mobile crane to access the gates when maintenance is required.

5.2.2 Lake-tap Outlet

A lake tap has been adopted to connect the transfer tunnel to Indio Reservoir to minimize the time when the operation of the water supply system could be impacted. Using drill and blast techniques, a 700-m, modified horseshoe section tunnel will be excavated from the gate shaft to a lake tap structure at the end of the tunnel. A section through the lake tap is shown on Exhibit 5-9).

5.3 Second Water Transfer Tunnel from Río Indio Reservoir to Lake Gatun

The second tunnel from Indio to Lake Gatun will be adjacent and parallel to the presumed existing tunnel. It will consist of an approach channel, an intake structure, the tunnel, and an outlet structure. For the estimate, it has been assumed that the tunnel will be excavated using drill and blast techniques. The alignment is shown on Exhibit 5-10 and a plan and profile is shown on Exhibit 5-11. More detail on the selection of the alignment is given in the Río Indio Feasibility Report (2)

The approach channel will be 100 m long and will have its invert at El. 30. The channel will be excavated as a trapezoidal section with a bottom width of 20 m and side slopes of 2H:1V. The intake structure will be a reinforced concrete structure with an opening of 5 m by 10 m. Trash racks will protect the openings. Intake flow velocities at maximum discharge are limited to 1.5 m/s. The invert of the intake will be at El. 32 to allow for proper hydraulic conditions at minimum pool operation. The intake structure will extend up to El. 85, 1 m above the design flood elevation to provide access to the trash racks. A trash rake will be provided to clean the trash racks. A section of the intake is shown on Exhibit 5-12

The intake will transition to the tunnel, which will be an 8,250-m long modified horseshoe shaped tunnel with vertical sides and a horizontal invert. The finished diameter of the tunnel will be 6.5 m and the capacity is 277 m^3/s and 137 m^3/s at the full supply level, El. 80, and the minimum pool level, El. 40, respectively.

A gate and access shaft, housing two side-by-side wheel gates, will be located at the upstream end of the tunnel for dewatering. It will be located about 70 m from the intake structure trashracks. The gate will be 3.4 m wide by 6 m high. The gate will be raised and lowered by means of a hydraulic cylinder hoist that will be powered and operated from a surface control structure.

At the downstream end of the tunnel, an outlet structure will house two 3.5 m wide by 5.4 m high, bonneted guard gates and bonneted control gates in series. This will provide redundancy for reliable operation and maintenance, and additional flow control. The outlet structure will be founded on sound rock.. Power and control equipment will be housed in a small structure adjacent to the gates. A road is provided for a mobile crane to access the gates when maintenance is required. A profile through the outlet facility is shown on Exhibit 5-13.

The outlet will discharge at El. 27, slightly above the maximum water surface elevation for Lake Gatun, onto a concrete sill about 35 m long. The sill will end at El. 20, slightly below the minimum level of Lake Gatun. The sill will widen from 9 m wide at the outlet structure to 19 m wide at the downstream channel.

The outlet structure will discharge into a 240 m long channel. The channel will be excavated as a trapezoidal section with a bottom width of 20 m and side slopes of 2H:1V. It will direct the flow from the Río Indio transfer tunnel into Lake Gatun adjacent to Isla Pablon.

6. POWER DEVELOPMENT

The ACP owns and operates three powerplants; two hydro plants at Lake Gatun and Lake Madden, and a thermal powerplant at Miraflores that includes 3 diesel-burning gas turbines and 2 steam units that are fired with Bunker C oil. The ACP system is shown in Table 4-12.

TABLE 6-1 ACP ELECTRIC GENERATING SYSTEM

Plant	No. of Units	On-line Date	Actual/Planned Installed Capacity (MW)
Gatun	6	1916(3), '18,'46, '47	24
Madden	3	1935(2), '42	36
Miraflores	6	1963(2),'66,'71(2)	115

As a part of the reconnaissance studies performed by the USACE (1), the potential for adding hydropower to the Río Coclé del Norte Project was considered. The analysis indicated that, at a benefit of $0.07/kWh, the addition of hydropower was very attractive. The USACE went on to say that the estimated value of energy might understate its true value and that modifications to the operating regime of the system might improve the production of energy over that reported in the Reconnaissance Report. It was recommended that additional effort should be expended in any future planning studies to determine the economic value of added hydroelectric power generation and that further study be performed to optimize the (hydro) operation of the project.

As reported by the USACE, the power features of the Río Coclé del Norte Project consisted of a 21.3 MW installation at the base of the dam, 6.2 MW at the end of the Caño Sucio-Río Indio Tunnel, and 9.7 MW at the end of the Río Indio-Lake Gatun tunnel.

A power market study was performed to confirm the need for additional generation in Panama, and the potential for adding hydro to the Río Coclé del Norte Project was evaluated. The results of these studies are summarized below and are presented in detail in Appendix E.

6.1.1 Existing Power Market

The power generated at the Gatun and Madden power plants is used to meet the electricity needs of the canal operation, and the commercial, residential, and governmental sectors in the ACP area. Any surplus can be sold into the Panama national electrical system. A power market survey of Panama was conducted to determine the future power needs of the national system to evaluate the opportunities for such a sale.

6.1.1.1 ACP Internal Market

Over the period from 1992 to 1999, the overall trend in sales by the ACP has been down reflecting a downward trend in sales to its internal customers and a varying but relatively constant sale to IRHE. Historically, the largest user of ACP electricity, accounting for about 65% of the total usage, has been the industrial components of the U.S. Army, Air force, and Navy. This use held constant through 1995 and then began a rapid decline as the plans for the turnover of the Canal progressed. In 1999, the demand had dropped 40 percent from the average 4-year usage between 1992 and 1995. The second largest group of users, accounting for 25% to 35% of the sales, consisted of the lock operation, drinking and cooling water, and other miscellaneous uses. This use group has shown an upward trend over the 8-year period of slightly more than one percent per year. The final user group consists of various agencies, employees of the ACP, and other residential and commercial users in the Canal Area. This group, accounting for about 10% of the sales, has generally trended downwards. The sales to IRHE averaged about 70 GWh/year and have varied from a low of 8 GWh in 1997 to a high of 104 in 1992. These historic data are presented in Table 4-14. Generation has generally been about five percent higher than usage and the average peak load over the period has been 80 MW and trending downward.

TABLE 6-2 HISTORIC SALES AND GENERATION OF ELECTRICITY BY THE ACP
(GWh)

Year	U.S. Military	Locks, Water, etc.	Other Agencies	IRHE	Total Sales	Generation
1992	342	117	52	104	615	643
1993	342	117	51	84	593	624
1994	343	119	50	50	562	599
1995	341	120	49	89	599	635
1996	316	119	44	58	536	570
1997	318	120	43	8	488	502
1998	257	127	36	94	514	548
1999	206	129	26	71	431	450
Avg.	**308**	**121**	**44**	**71**	**544**	**571**

It is difficult to forecast the firm generation demand on the ACP system, especially over the near-term. It is assumed that the industrial demand formerly required by the U.S.

military will recur as the facilities are taken over by others. What is not sure is whether or not the required demand will be purchased from the ACP or another generation company. Therefore, it is assumed that the ACP will have an internal demand of about 180 GWh in the first year of operation of Project and that all other demands occurring in the Panama Canal Watershed will be subject to competition.

6.1.1.2 National Market

Historic energy demand and peak load for the Panama National Integrated System (PNIS) is presented in Table 4-15.

TABLE 6-3 ENERGY DEMAND AND PEAK LOAD IN THE PNIS

Year	Energy Demand (GWh)	Peak Load (MW)	Load Factor (%)
1990	2746.1	464	68
1991	2896.6	488	68
1992	3011.6	518	66
1993	3199.1	541	68
1994	3400.0	592	66
1995	3619.4	619	67
1996	3795.8	640	68
1997	4254.4	707	69
1998	4295.8	726	68
1999	4456.8	754	67
2002[1]	4998.5	857	67

[1] Source: ETESA's web page

Energy demand and peak load grew at a rate of about 5% per year over the 12-year period from 1990 to 2002. The annual system load factor has been constant at about 68%. There are only minor variations among monthly energy demands and peak loads, as monthly temperatures remain relatively constant throughout the year. The monthly peak loads in terms of percent of annual peak load and the monthly energy demand in terms of percentage of total annual energy demand for year 2002 are shown in Table 4-16.

TABLE 6-4 MONTHLY PEAK LOADS AND ENERGY DEMANDS OF THE PNIS FOR 2002

Month	Peak Load (% of Annual Peak Load)	Energy Demands (% of Total Demand)
January	93.2	8.1
February	94.2	7.5
March	96.8	8.6
April	97.9	8.5
May	100.0	8.9
June	96.2	8.3
July	99.2	8.5
August	96.2	8.3
September	97.4	8.1
October	96.6	8.4
November	98.6	8.0
December	99.7	8.8
Total	-	**100.00**

Daily peak loads of the PNIS occur during the period from 11 AM to 3 PM on weekdays and Saturdays and at 7 PM or 8 PM on Sundays. The distribution of typical hourly loads is presented in the Appendix E, Part 1, Power Market Study.

6.1.2 Power Market Forecast

Three demand forecasts are available for each of two economic assumptions, moderate growth and high growth. One forecast was developed in 1998, one in 1999, and the third in November 2000. The earlier estimates were developed using a multiple regression analysis to define the relationship between energy consumption and economic parameters for each consumer sector including residential, commercial, industrial, government, and public lighting. A regression equation was defined for each sector. The economic parameters included population, Gross Domestic Product (GDP) per capita, unit energy sale price for each sector, and energy efficiency. The energy efficiency is the unit energy consumption rate for producing the GDP of the industry sector, and is computed by dividing the GDP by total energy consumption of the sector. The peak load demands were estimated on the basis of the forecasted energy demand and a system load factor at 67.9 %.

The more recent demand estimate was developed using a simplified relation of total energy sales as a function of gross national product (GNP). The coefficient of determination for the two samples (total energy and GNP) was highest using a polynomial function. The simplified approach was used for the recent estimate due to the difficulty in obtaining accurate economic information needed for the earlier estimates.

The estimated energy losses of the transmission and distribution systems, in terms of percentage of the total energy consumption, for the two scenarios was estimated to decrease from about 22% in 1997 to about 14% in 2015. The most recent estimated total energy demands of the PNIS developed in 2000 for the medium and high growth scenarios are shown in Table 6-5.

TABLE 6-5 DEMAND FORECAST DEVELOPED IN 2000 FOR THE PNIS

Year	Medium Growth Scenario		High Growth Scenario	
	Capacity (MW)	Energy (GWh)	Capacity (MW)	Energy (GWh)
2000(Actual)	790	4,732		
2002(Actual)	857	4,998		
2005	1,107	5,304	1,777	5,655
2010	1,608	7,616	1,832	8,691

For comparison, the energy production estimates for the medium growth scenario are shown below for all three estimates:

Year	Medium Growth Scenario – GWh			
	1998 Estimate	1999 Estimate	2000 Estimate	Actual
2001	4,981	4,907	4,028	4,823
2005	6,280	6,431	5,304	
2010	8,154	8,435	7,616	

Average annual growth rates of the most recent forecasted energy demands of the PNIS for the period of 2001-2010 were 7.3 % for the medium scenario forecast, and 8.8 % for the high scenario. These compare with the historical average annual growth rate of the energy demand at 5.5 % for the period of 1990-1999 and 5.6% and 7.0% for the corresponding period and scenario of the 1998 estimate. The comparison indicates a reduction in the forecast of about 18% in the early years and about 10% in 2010.

The average annual load factor of the PNIS was 67.2 % for the period of 1990-1999. In recent years, the system load factor has increased from 65.6 % in 1994 to 68.5 % in 1997, and decreased to 67.4% in 1999. The PNIS has forecasted that the annual system factor will be in the low 50th percentile through year 2010.

6.1.3 Market Opportunity for Río Coclé del Norte Generation

The existing PNIS had an installed capacity of 1,058 MW in 2000. The total generation from the PNIS facilities in 1999 was 4,457 GWh. It appears that the Esti Hydropower project, consisting of two plants, Guasquitas and Canjilones, are committed and will be on line prior to the Río Coclé del Norte project. These two plants have an aggregate capacity of 119 MW and are expected to generate an average of 627 GWh each year. However, from the 1999 expansion plan (10), there are plans to retire two plants by January 1, 2010, which currently have an aggregate capacity of 80 MW.

On the basis of the peak load and energy requirements, the existing, committed, and scheduled retirement available from the 1999 expansion plan, the power balance in year 2010 should be about as follows:

TABLE 6-6 POWER BALANCE IN 2010

	Capacity Demand
Year 2010	1,608 MW
Available Capacity (2000)	1,058 MW
Committed Capacity	119 MW
Planned Retirement	80 MW
Net Capacity	1,097 MW
Required Capacity	>500 MW

According to ETESA's web site, the PNIS installed capacity in 2002 was 1,079 MW and the total generation was 4,998.5 GWh, which is within the range of the estimate for 2010. Therefore, it can be concluded that there is a substantial market for additional power in the future and that the Río Coclé del Norte hydropower project will be easily absorbed into the PNIS.

6.2 Potential for Adding Hydropower to the Río Coclé del Norte – Río Indio Project

Studies were performed to determine if the addition of hydropower to the Río Coclé del Norte Water Supply 71-50 Project was viable. The studies consisted of estimating the potential energy production under a variety of conditions that nearly reflect the water supply operation and that reflect significant changes to that operation.

The water supply system for the Canal, including the Río Coclé del Norte Project, will not be required to supply its full yield for a long period after the completion of the Project. To estimate the duration of the period during which the system yield is more than what is required, the projection for unconstrained water demand for navigation presented in the Reconnaissance Study (1) plus the municipal, industrial (M&I) and tourism water demand presented in the report entitled "Long Term Forecast for M&I Demand" (8) prepared by MWH, January 2001. Due to anticipated future development at the Canal, the navigation demand is not considered to be accurate enough to be used in economic studies of the Río Coclé del Norte Project; however, it is the only estimate available at this time and was used for this analysis. First, the total demand was used as a basis for an assumption that the Río Coclé del Norte Project would be required in 2028 based on a comparison of the demand and the yield of the Gatun/Madden/Indio system. A comparison between the system yield with Río Coclé del Norte and the total navigation and M&I demand, extrapolated from 2060 to 2090 on a straight-line basis, indicates that the total yield of the system including Río Coclé del Norte will not be utilized until about 2082. The details of the power and energy studies are presented in Appendix E Part 2 and are summarized below.

In the period prior to the need for the full yield of the system including Río Coclé del Norte, operating the system for hydropower results in more favorable hydropower developments, even if these potential developments had a limited economic life. For the purpose of selecting the best hydropower development associated with the reservoir scheme, three strategies were investigated:

- Strategy 1 would consist in discharging the maximum possible flow into the Río Coclé del Norte to favor hydropower development at that site.
- Strategy 2 would consist in discharging the maximum flow into the Río Indio to favor hydropower development at that site.
- Strategy 3 would consist in discharging the maximum flow through the transfer tunnel between Indio and Lake Gatun to favor the development of a power plant at the Isla Pablon site.

Strategy 3 would also favor energy production at the Gatun 24-MW hydroelectric plant.

The yield of the system under water supply conditions (Base Case) and under conditions that favor hydropower operations, and the estimated year when the water demand will reach that yield are shown in Table 6-7.

TABLE 6-7 RESERVOIR SYSTEM YIELD MODIFIED FOR HYDRO OPERATION

	Coclé Constant Release (m^3/s)	Coclé Operating Range	Indio Constant Release (m^3/s)	Indio Operating Range	Constant Transferred Discharge into Gatun (m^3/s)	System Yield (L/d)	Year
Base Case	10.9	50 – 71	2.6	40 – 80	No Rule	106.1	2081
Strategy 1A	20.0	50 – 71	2.6	40 – 80	No Rule	102.7	2078
	40.0	50 – 71	2.6	40 – 80	No Rule	95.1	2070
	60.0	50 – 71	2.6	40 – 80	No Rule	86.8	2062
Strategy 1B	10.9	50 - 71	2.6	50 - 80	No Rule	99.8	2075
	20.0	50 –71	2.6	50 – 80	No Rule	97.0	2072
	40.0	50 – 71	2.6	50 – 80	No Rule	89.9	2065
	60.0	50 – 71	2.6	50 – 80	No Rule	82.0	2055
	80.0	50 – 71	2.6	50 – 80	No Rule	74.1	2044
Strategy 1C	20.0	60 –71	2.6	40 – 80	No Rule	91.1	2066
	40.0	60 – 71	2.6	40 – 80	No Rule	83.5	2057
	60.0	60 – 71	2.6	40 – 80	No Rule	76.2	2046
Strategy 1D	20.0	60 –71	2.6	50 – 80	No Rule	89.0	2064
	40.0	60 – 71	2.6	50 – 80	No Rule	81.4	2054
	60.0	60 – 71	2.6	50 – 80	No Rule	73.9	2044
Strategy 1E	10.9	60 – 71	2.6	60 – 80	No Rule	87.7	2063
	20.0	60 – 71	2.6	60 – 80	No Rule	84.5	2059
	40.0	60 –71	2.6	60 – 80	No Rule	77.0	2047
	60.0	60 – 71	2.6	60 – 80	No Rule	69.4	2038
	80.0	60 – 71	2.6	60 – 80	No Rule	61.5	2030
Strategy 2	10.9	50 – 71	20.0	50 – 80	No Rule	91.7	2067
	10.9	50 – 71	40.0	50 – 80	No Rule	81.6	2054
	10.9	50 – 71	60.0	50 – 80	No Rule	71.6	2041
	10.9	50 – 71	80.0	50 – 80	No Rule	62.5	2031
	10.9	60 – 71	60.0	60 – 80	No Rule	60.5	2029
	10.9	60 - 71	80.0	60 – 80	No Rule	52.2	-
Strategy 3	10.9	50 – 71	2.6	50 – 80	60.0	97.3	2073
	10.9	50 – 71	2.6	50 – 80	80.0	97.5	2073
	10.9	60 – 71	2.6	60 – 80	60.0	86.4	2061
	10.9	60 - 71	2.6	60 – 80	80.0	87.2	2061

The operating rules for all three strategies would significantly reduce the overall yield of system, and therefore they would have a limited life.

For all three strategies, energy production and firm capacity were estimated for a range of hydropower plant capacities at the three potential hydropower sites, the dam site, the Río Indio Dam, and at the end of the Indio to Lake Gatun tunnel. In order to estimate the energy production for any given scheme, it was assumed that operating rules would apply until the water demand reaches the yield achieved under these conditions. Rules would be progressively relaxed to increase the yield of the system. For example under Strategy 1, the Río Coclé del Norte reservoir would release a constant 60 m^3/s downstream of the dam through a power plant until 2062; this discharge would be progressively reduced to 40 m^3/s in 2070, and 20 m^3/s in 2078, and so on, until the full yield of the system is reached and only the minimum release is discharged through the Río Coclé del Norte power plant. Similar rationale was applied to Strategy 2 and Strategy 3.

6.2.1 Evaluation of Power Plant Locations

For the purpose of calculating the energy production and firm capacity of the individual powerplants, a spreadsheet-type model was developed: the model uses the weekly output of the HEC-5 simulation performed by the ACP. The project water released were those determined by the HEC-5 simulation. The tailwater rating curve established under the hydraulics studies was used for the purpose of calculating the gross head on the project at the Río Coclé and Río Indio dam sites.

The energy production at each potential plant was calculated for a range of installed capacity depending on the strategy contemplated:

- At Río Coclé del Norte from 20 MW to 75 MW;
- At Río Indio from 2.5 MW to 40 MW;
- At Isla Pablon from 15 MW to 40 MW.

The input parameters of the computation and the results are presented in Attachment 3 of Part 2 of Appendix E.

Cost estimates were developed for representative powerplant developments at each of the sites and compared with the present value of the revenue from the site. The size of the powerplant selected for estimating costs was varied depending on the strategy. Table 6-8 presents the results of these studies. In Table 6-8:

- Plant size range is the range of installed capacities considered to be reasonable for the type of strategy adopted

- Present value of revenue is shown for the lower and upper plant size and consists of the value of energy generated, which varies over the life of the installation, estimated at \$45/MWh; and the value of firm capacity, estimated at \$60/kW-year. In strategy 3A, the firm capacity is greatly increased by operating the Río Indio reservoir between El. 60 and El. 80 rather than between El. 40 and El. 80.
- The representative powerplant size was selected to be appropriate for the plant and the strategy.
- The energy range is the estimated energy at year 1 of the operating period and year and at the end of the plants economic life.
- The cost of the representative powerplant is the economic cost at the beginning of construction.

TABLE 6-8 EVALUATION OF POWER PLANT SITES

	Plant Size Range (MW)	PV of Revenues (\$million)	Representative Powerplant Size (MW)	Energy Range Representative Project (GWh)	Cost of Representative Powerplant (\$million)
Strategy 1					
Coclé del Norte	20-75	71-197	60	424-118	77.3
Isla Pablon	20-40	15-18	30		37.2
Strategy 2					
Coclé del Norte	20-40	41-56	30		32.1
Río Indio	15-35	55-103	30		53.7
Isla Pablon	15-30	14-19	30		55.2
Strategy 3					
Coclé del Norte	20-60	41-68	30		32.1
Isla Pablon	20-40	75-105	30		55.2

From an inspection of the table, it can be concluded that a plant at Río Coclé del Norte is viable for any of the strategies. A plant at Isla Pablon is only viable for Strategy 3 (for all other strategies, the cost of the plant is more than the maximum of the revenues). Finally, a plant at Río Indio is viable under Strategy 2.

6.2.2 Selection of Strategy

Viable installations exist in all three strategies. The three strategies were compared utilizing the viable options from Table 6-8 plus the incremental impact on generation at Madden and Gatun, which vary according to the adopted strategy. The results of this comparison are shown in Table 6-9 and the details of the costs and revenue are presented in Appendix E, Part 2.

TABLE 6-9 COMPARISON OF HYDROPOWER STRATEGIES

	Installed Capacity (MW)	Construction Cost ($1000)	O&M Cost ($1000/year)	Annualized PV (12%) of Revenue ($1000)	Rate of Return
Strategy 1					
Coclé del Norte	60	77,300	1,395	21,750	
Río Indio	2.5	Assumed Exist.	No change	510	
Gatun	24	Existing	No change	1,260	
Madden	36	Existing	No change	7,900	
Total		**77,300**	**1,395**	**31,420**	**23 %**
Strategy 2					
Río Indio	30	53,700	931	12,070	
Coclé del Norte	30	32,100	595	5,880	
Gatun	24	Existing	No change	1,470	
Madden	36	Existing	No change	7,720	
Total		**85,800**	**1,526**	**27,140**	**17 %**
Strategy 3A					
Coclé del Norte	30	32,100	595	5,880	
Río Indio	2.5	Assumed Exist.	No change	680	
Isla Pablon	40	55,200	914	12,000	
Gatun	24	Existing	No change	4,540	
Madden	36	Existing	No change	7,920	
Total		**87,300**	**1,509**	**31,020**	**20 %**

From Table 6-9, it is apparent that all strategies are viable and that Strategy 1 results in the best rate of return. The advantages of Strategy 1 are that it will produce significant funds during the early years of the project that can be used to offset the cost of the water supply project, it will help to stabilize the national grid, and it will provide a major source of firm electricity in an underdeveloped region. Its disadvantage is that 50 years after construction, it will only be generating with the minimum release. Strategy 3A also produces a significant but slightly lower return. Its advantages are that it will continue to produce the revenue even after the economic life of the project, it will provide a small but significant source of firm power for the Río Coclé del Norte basin area, and its revenue, once built, does not depend on an arbitrary demand. For the purpose of this study, Strategy 1 was selected.

6.2.3 Hydropower Level of Development

Estimates of cost and energy generation were developed for a plant at the Río Coclé del Norte dam to select the level of development. The capacity of the plants evaluated and the rate of return based on the estimated costs and benefits are shown in Table 6-10.

TABLE 6-10 LEVEL OF HYDROPOWER DEVELOPMENT AT RÍO COCLÉ DEL NORTE

Plant Capacity	3 x 15-MW units	3 x 20-MW Units	3 x 25-MW Units
Internal Rate of Return	23.2 %	24.2 %	23.5 %

On the basis of this analysis, an installed capacity of 60 MW was selected for the hydropower installation at the Río Coclé del Norte dam although a 75 MW plant could also be selected.

6.3 Preliminary Design of the Hydro Facilities

The proposed hydroelectric development associated with the Río Coclé del Norte reservoir operating between El. 50 and El. 71 consists of a 60-MW power plant located at the toe of the dam. The plant will contain 3 20-MW units and will generate an average of 327 GWh/year over the first 50 years of operation, varying from 425 GWh/year in the first years to 120 GWh/year at the end of the period. A plan of the power facilities is shown on Exhibit 3-2. A profile of the hydroelectric scheme is shown on Exhibit 6-1.

6.3.1 Intake and Powerhouse

The power intake will be located on the right abutment approximately 40 meters west of the spillway. It will consist of a reinforced concrete tower, 35 meters high with foundation at approximately El. 35 and the access platform level with the crest of the dam. A plan and section of the intake are shown on Exhibit 6-2. A 6-m wide bridge will be built to access the intake tower. The invert of the intake will be located at El.43. The intake will have three openings, each 7-m wide by 8-m high. The openings will be protected by a trashrack, and controlled by a 2.5-m wide by 3.8-m high wheel gate. One set of stoplogs, sufficient to close one bay under a balanced head also will be provided. The intake openings join and transition into the 5-m diameter vertical shaft. The vertical shaft extends in the tower all the way up to the crest of the dam. A trash rake will be provided to clean the trash racks.

The vertical shaft will be excavated 30 m deep in rock, and concrete lined. It will connect the power intake with the 260-m long, 5.8-m diameter steel-lined tunnel. The tunnel diameter will be reduced to 5.2 m immediately upstream of a four-branch manifold. The manifold, located in the back of the powerhouse, consists of three 2.8-m diameter steel branches and one 1.7-m diameter steel branch. A spherical valve will be provided at the end of each manifold branch to permit isolation of one unit for maintenance or in case of emergency without interfering with the operation of the other units.

The powerhouse will be a conventional 52-m long by 15-m wide reinforced concrete structure located on the right bank of the Río Coclé del Norte. It will contain three unit bays and one service bay. The foundation will be excavated in sound rock to El. –10 approximately 15 m to 20 m below ground surface. The centerline of the units will be at El. –3, below the minimum tailwater level. The powerhouse downstream deck and surrounding ground and access will be at El. 5 to protect the area against flooding during the probable maximum flood. The superstructure will be structural steel with metal cladding. A plan and section of the powerhouse is shown on Exhibits 6-3 and 6-4.

To serve the power intake area equipment, lighting, and dam roadway lighting a 480-V line from the powerhouse will be provided. Provision will also be made for easy connection of a portable emergency generator for use during power outage.

The turbines will be vertical-shaft Francis units with steel spiral cases. The turbines will be direct connected to synchronous generators. The general characteristics of the 20 MW units are described below.

Turbine

Runner diameter:	1.98 meters
Design net head:	68 meters
Discharge:	35 m^3/s
Rated output:	28,000 HP
Setting:	3 meters below minimum tailwater level
Speed:	300 RPM

Generator

Type:	Synchronous / direct coupled
Rated output:	22,250 kVA
Terminal voltage:	13.8 kV
Frequency:	60 Hz
Power factor:	0.90

Each unit will be provided with the necessary auxiliaries such as bearings, servomotor, hydraulic power unit, digital governor, cooling water system for turbine bearing, shaft seal and generator bearings and coolers, lubricating oil system, excitation system, voltage regulator, automatic synchronizer, brakes, SCADA and protection system.

Each unit will have two welded-steel slide gates, 3.1-m wide by 2.0-m high gates to allow for unit and tunnel dewatering. An 80-ton semi-gantry crane spanning the powerhouse and the draft tube deck will be provided to handle turbine and generator components, inlet valves and draft tube gates during erection and maintenance.

The minimum release will be made through the one of the units or through a bypass line. A polyjet valve will be provided to control the flow releases through the bypass.

The generating voltage will be 13.8-kV. Generators will have individual main power transformers directly connected to the generators. Generator breakers will be on the 230 kV side of the transformers and will be located in the switchyard.

A 480/277-V station service power distribution switchboard will be provided to feed the outlying areas, the station auxiliaries and the three unit auxiliary motor control centers (MCC). Each unit MCC will also be fed from the unit auxiliary transformer providing power for its own auxiliaries when the unit is in operation.

A Class OA (liquid immersed air-cooled, self cooled) three-phase, oil-filled, 13.8/230 kV step up transformer rated at 25 MVA and 60 Hz will be connected to each generator.

Station service power will be provided at 480/277-V thru service power and station service transformers. A Service Power Transformer with standard rating of 5MVA, Class OA, located in the switchyard, will be used to step down the voltage from 230-kV to 13.8-kV. A Station Service Transformer, located at the powerhouse, will serve all utilization level power requirements at the site. This transformer will be a three phase, oil filled step down transformer from 13.8-kV to 480-V, 60-Hz rated 2 MVA, Class OA. The station service transformer will be fed from the service power transformer by an overhead 15kV line. Each unit will have a 150kVA dry type transformer directly connected to the generator terminals stepping down the voltage from 13.8-kV to 480/277-V to feed the unit auxiliary MCC.

Other station auxiliaries will include a 500-kW stand-by diesel generator, station battery, lighting system, heating, ventilation and air conditioning, fire alarm and protection system, communication system, and grounding and lightning protection.

6.3.2 Switchyard and Transmission

A 230-kV switchyard will be located at approximately El. 20 on a 130-m by 65-m leveled area about 100 m west of the powerhouse at the toe of the dam. The location of the switchyard is shown on Exhibit 3-2 and a plan is shown on Exhibit 6-5. Connection from the powerhouse to the switchyard will be by high voltage cables in conduits. The switchyard will be a conventional open air design yard utilizing the 'breaker and a half' switching scheme. The switchyard will have three fully equipped bays serving the three generator units, a single circuit 230-kV transmission line and the service power transformer. It will be fenced in and served by access and boundary roads. A suitably sized control building will also be provided to house the control, protection, metering and communication equipment.

A 109-km long, single circuit 230-kV transmission line will connect to national grid at ETESA's La Chorrera Substation. The transmission line will be conveyed on steel towers and have three 750 kcmil ACAR conductors. The proposed line will cross the Río Coclé del Norte near the project site, proceed in an easterly direction, and pass the Río Indio Dam to the vicinity of Isla Pablon. It will then continue in the east-southeast direction to La Chorrera Substation. The general alignment of the transmission line from the Coclé del Norte dam to the Río Indio Dam is shown on Exhibit 3-1 and a more detailed alignment of the transmission line from the dam to the substation is presented in Appendix E, Part 2. One of the two empty 230-kV bays at La Chorrera Substation will be fully equipped to handle the new incoming line from Río Coclé del Norte project.

A simplified one-line diagram of the powerhouse, including station services, substation, and transmission-line interconnection is depicted on Exhibit 6-6.

7. AGRICULTURAL DEVELOPMENT

A study was performed to assess the potential for commercial irrigated agriculture on the lands around the reservoir. The details of this study are presented in Appendix F and summarized below. The major components of the study consisted of:

- A land use survey;
- A land capability determination;
- The identification of potentially irrigable areas in the basin;
- The definition of potential crop patterns and their water requirements, and;
- An economic analysis to assess feasibility.

The study area was generally limited to the lands around the reservoir areas and to the east of the Río Coclé del Norte. In an initial study, the area was further limited to seven areas that appeared to provide the best opportunity for agricultural development. These seven areas are shown on Exhibit 7-1.

7.1 Land Use

The land use was identified initially by reviewing available aerial photographs, information provided by the Remote Sensing Unit, and the existing soils map, and verified by a field reconnaissance. The aerial photographs were dated June 1983. The land use categories adopted for this study were forest, slash and burn lands, bush/thicket lands, pasture lands, and miscellaneous, which includes stubble, small sparse farm lands,, villages, marshland, and wetlands. The field adjustments were based on transects and random observations. A land use map of the area is shown on Exhibit 7-2.

The land use in the 7 main areas within the study area, which totals about 95,000 hectares consists of 47% forest, 2% slash and burn, 26% bush/thicket, 16% pasture, and 9% miscellaneous lands. According to the 2001 Agricultural Census, almost 100% of the farms exceed one hectare and, based on conversations with farmers in the field, the average size is on the order of 4-5 hectares.

The main annual crops grown in the Project Area are rice, maize, beans, cassava, vegetables, melon, watermelon, cucumber, name, otoe, squash and sugar cane. The perennial crops are coffee, cocoa, fruit trees including avocado, guava, mango, maracuya, marañon, papaya, orange, grapefruit, lime, anona, plantains, banana, pineapple, and coconut.

7.2 Land Capability and Potentially Irrigable Areas

Land capability for irrigation in the basin was based on a semi-detailed soil study accomplished as a part of a National Rural Cadastre Project in 1970 and supplementary field observations and soil sampling. From a land capability map of the seven areas, shown in Appendix F, it was determined that about there are about 30,000 ha of arable land in the seven areas and, referencing the US Bureau of Reclamation Land Classification Specifications for Irrigated Land Use, 17,000 has are Class 2 lands and 13,000 ha are Class 3 lands. Class 1 lands were not found in the areas. The soils are clayey and clayey loams, acidic, high in calcium and magnesium, medium in organic matter and potassium, medium to low in nitrogen, and low in phosphorous, aluminum, copper, and zinc. The results from three water sample analyses suggest that the surface waters can be used for irrigation with little risk of salt accumulation that cannot be mitigated.

7.3 Potential Development Areas

Thirteen areas were identified as being potential development areas in the seven main areas. Based on the land classification, position with respect to potential water sources, and the potential for using the water sources economically, the thirteen areas were reduced to nine. The areas, arable areas based on amount of Class 2 and Class 3 land, and gross and net areas that practically can be developed for irrigated agriculture are presented in Table 7-1 as follows:

TABLE 7-1 POTENTIAL DEVELOPMENT AREAS

Main Area	Development Area	Arable Lands (ha)	Area Suitable for Development	
			Gross Area (ha)	Net Area (ha)
Lower Río Coclé del Norte Valley	Lower Río Coclé del Norte Valley	8,300	2,760	2,200
Costa Platanal – Punta Diego	Costa Platanal – Punta Diego	2,500	1,400	900
Lower Río Miguel de la Borda Valley	Lower Río Miguel de la Borda Valley	6,000	3,600	2,220
Río Caño Sucio Valley	Río Miguelito Valley	500	-0-	-0-
	Río Caño Sucio Valley at El Cedro	1,200	-0-	-0-
	Río Caño Sucio Valley at Las Maravillas	4,000	800	500

Main Area	Development Area	Arable Lands (ha)	Area Suitable for Development	
			Gross Area (ha)	Net Area (ha)
Valleys of the Rios Tulu and Curia	Río Curia Valley	200	-0-	-0-
	Río Tulu Valley	1,100	740	580
Valleys of the Rios Lura and Tucue	Río Lura Valley	550	200	160
Valleys of the Rios San Miguel and Chiguiri	Río San Miguel Valley	2,900	1,040	830
	Río Chiguiri Valley	2,200	640	500
TOTAL				**8,490**

The net areas are estimated as the gross area less allowances for off-farm hydraulic and other infrastructure, on-farm infrastructure, unusable land, unusable micro relief, and areas with poor drainage or soils conditions.

Water availability for the potential areas was estimated from data available at four gages in the Río Coclé del Norte basin; the Río Coclé del Norte at Canoas, and El Torno, the Río Toabré at Batatilla, and the Río San Juan at Los Higuerones. The available water is estimated as the monthly flow exceeded 80% of the time, on streams other than those regulated by the reservoir, converted to monthly discharge per unit of area. Flows were transposed to ungaged locations using drainage area. The minimum flows available at the streams supplying the potential areas, after deduction a minimum flow, were estimated to be 7-8 liters per second.

The source and estimated available flows for all of the areas are shown in Table 7-2:

TABLE 7-2 WATER AVAILABLE FOR IRRIGATION

Area	Source of Water	Catchment Area (km^2)	Available Minimum Flow (l/s)
Lower Río Coclé del Norte Valley	Río Coclé del Norte at El. 0	1,600	12,800
Costa Platanal – Punta Diego	Platanal, Majagual, Aguacate and Diego Rivers at El. 40	60	450
Lower Río Miguel de la Borda Valley	Miguel de la Borda River	520	4,200
Río Caño Sucio Valley at Las Maravillas	Riecito river at el. 100	42	300

Area	Source of Water	Catchment Area (km^2)	Available Minimum Flow (l/s)
Río Tulu Valley	Tulu River at El. 140	23	160
	Tulu River at El. 100	75	600
	proposed reservoir	75	600
Río Lura Valley	Lura River At El. 120	20	150
Río Tucue and Toabré Valleys	Toabré River at El. 110	26	110
	Toabré River at El. 110	174	1,200
Río San Miguel Valley	San Miguel River at El. 300	32	250
	San Miguel River at El110	40	320
	San Miguel River at El.100	92	700
Río Chiguiri Valley	Chiguiri River at El. 160	50 54	350 380

7.4 Cropping Patterns and Water Requirements

Cropping patterns were selected on the basis of monthly rainfall distribution, potential evapotranspiration, radiation, mean temperature, land capability, and predominant production environments. The crops included in the suggested pattern are dry-seeded and transplanted rice, maize, plantain, cassava, vegetables, yams, pasture, and nursery crops.

The proposed crops are based on the presently cultivated annual and perennial crops. Cropping patterns were developed for the coastal and inland areas. Generally, the cropping pattern calls for double cropping rice and maize and planting single crops of vegetables. The perennial crops were applied on about 45% of the land. The resultant cropping intensity was computed at 130%. Details of the cropping pattern and schedule are provided in Appendix F, Agricultural Development.

Supplementary irrigation requirements for the food crops, pasture, and perennials were estimated from potential evapotranspiration adjusted by an appropriate crop coefficient, dependable rainfall, and appropriate irrigation-system efficiency. The system efficiencies were estimated to be 50%. The water requirements varied widely depending on the potential area under consideration. Detailed estimates of the water requirements are presented as an attachment to Appendix F.

A rigorous analysis was performed in an attempt to identify the design flows for irrigation of the potential areas. A series of up to three crop conditions were considered for each of the landscape positions to provide a system capacity that would allow the farmer some flexibility in his choice of crops or system operation. The design flow rates varied from a low of 0.2 l/s/ha in the lower Río Coclé del Norte Valley to 0.9 l/s/ha in the Tucue Valley. All of the other areas were either 0.5 or 0.6 l/s/ha.

7.5 Potential for Economically Feasible Development

The assessment of feasible development consisted of developing irrigation schemes for each of the areas capable of delivering the design flow, estimating the construction and annual operating cost of the system, estimating the net benefits, and assessing economic viability of each area.

Each irrigation scheme consists of a main hydraulic system consisting of a water intake, a pumping station if required, a main canal, one or more branch canals, canal structures, a water distribution system between the canal and the farm gate, off farm drainage and roads, and on-farm irrigation and drainage systems. Layouts of each of the irrigation systems are presented in Appendix F.

Based on cropping pattern options for each area, average net benefits were estimated by hectare and for each potential area as the difference between net incomes without and with the reservoir development. The net benefits were computed using data from the Ministry of Agriculture Extension Service and consist of a cost for transport, materials, and labor subtracted from revenue estimated as yield times current price. The costs, benefits, and returns for each area are presented in Table 7-3.

TABLE 7-3 ECONOMIC ANALYSIS OF AGRICULTURAL DEVELOPMENT IN POTENTIAL AREAS

Potential Area	Construction Cost ($1,000)	Annual Cost ($1,000)	Benefits ($1,000)	Rate of Return
Lower Río Coclé del Norte Valley	19,086	251	1,842	8%
Costa Platanal – Punta Diego	11,644	110	754	5%
Lower Río Miguel de la Borda Valley	20,579	311	1,859	7%
Río Caño Sucio Valley at Las Maravillas	4,057	49	521	11%
Río Tulu Valley	7,222	117	604	6%
Río Lura Valley	1,580	29	167	8%
Río Tucue and Toabré Valleys	5,835	103	625	8%

Potential Area	Construction Cost ($1,000)	Annual Cost ($1,000)	Benefits ($1,000)	Rate of Return
Río San Miguel Valley	9,698	133	865	7%
Río Chiguiri Valley	5,849	94	521	7%

To assess the viability of a commercial development, all of the areas were considered as one development. If all potential areas are considered as one development, the rate of return will be about seven percent.

Therefore, it is concluded that the potential for irrigated agriculture marginal, and implementation of the development should not be initiated at this time.

8. CONSTRUCTION PLAN AND ESTIMATE OF COST

As a result of the analyses of the potential for adding hydropower and irrigated agriculture to the project, it is concluded that water supply and hydropower facilities are warranted. A project implementation schedule, a detailed construction schedule, and cost estimate have been prepared for the project as described in Section 3. Additional details of the construction cost estimate are presented in Appendix G.

8.1 Implementation

It is estimated that implementation of the Project could be achieved in about 12 years. However, it is likely that the project will not be required within that time frame assuming that the Río Indio Water Supply Project or some water saving device is in operation. Therefore, the implementation schedule assumed that additional studies would have been performed prior to project selection. The major steps required for project implementation following this engineering study are as follows:

- Master Plan
- Water Demand Assessments
- Environmental Studies
- Feasibility Confirmation and Project Configuration
- Funding
- Environmental Mitigation Planning and Implementation
- Environmental Field Studies
- Design and Contractor Procurement
- Construction Contract Awards
- Construction

The implementation schedule following project selection is presented on Exhibit 8-1.

ACP is preparing a Master Plan for the development of the Panama Canal. This will examine a wide range of options, including improvements to the existing facilities, new locks of various configurations, water management plans and alternative water supply projects. The Master Plan will also include shipping forecasts under various scenarios and toll structures. Therefore, the decision to implement the Project will not be made until the conclusion of studies for the Master Plan, and likely will not be made until some time in the future when other higher priority projects are in place that will impact the need for and benefit of this project. If this project is considered for implementation, it will be the subject of a series of updated assessments on the need for additional water and the timing for commencing this project.

These studies are assumed to take place in the years prior to the earliest projected need for this project to meet water demands. If the project is selected, environmental studies, funding, design, contractor selection, can all be accommodated within this overall implementation schedule. Some limited basic environmental studies have been performed in the Río Coclé del Norte watershed; however, if the project moves forward, substantial additional environmental base-line studies will be required. In addition, prior to seeking funding, it will be necessary to confirm the feasibility of the project, which will include subsurface investigations to evaluate the foundation conditions, confirm the dam type, perform economic studies to optimize the project facilities and establish the economic justification, and complete a financial analyses to determine the viability of the project and the cost of water

Once the decision to obtain funding has been taken, a mitigation plan will be required. This can be prepared while funding is being secured. This plan may cover resettlement of people, habitat mitigation, evaluation of cultural resources, development of a construction plan, and any other mitigation activities identified during the base-line studies. The field studies may include protection or removal of significant archaeological sites, habitat replacement, or additional detailed studies of the flora and fauna in the reservoir area.

With funding in place, the design-level investigation program and final designs can commence along with the procurement of contactors.

Construction of the project is envisaged to consist of five general contracts as follows:

1. Access Roads and the Construction Camp (national contractor),
2. The Río Coclé del Norte Storage and Hydropower Facilities (international contractor),
3. The Water Transfer Facilities (international contractor),
4. The Second Río Indio to Gatun Tunnel (international contractor) and,
5. Reservoir Clearing (national contractor).

The operation facilities might be a part of each of the contracts or the responsibility of the contractor for the Río Coclé del Norte Storage Facilities. ACP has also identified substantial compensation and mitigation costs, and implementation of the required mitigation plans could be managed by ACP internally, or also contracted out.

It is assumed that the ACP will develop the capability to manage the construction contracts and also to perform the operation and maintenance. Although it will be a complicated and difficult task, the experience the ACP will get implementing the third set of locks should put them in good stead to manage the development of this water source. It is expected that the ACP will hire a Project Management Team responsible for the consulting engineering services relating to the works required for implementation. Operation and maintenance of the development can be accomplished by adding staff to the ACP's existing organization. Operation and maintenance of the facilities required for the water supply project, including the hydro facilities, are well within the existing capability of the current O&M organization.

8.2 Construction Plan

A detailed construction schedule has been developed for the implementation of the Río Coclé del Norte/Indio Water Supply Project with the Río Coclé del Norte Reservoir at El 71 and is shown on Exhibit 8-2. The schedule has been divided into the contract components.

The durations of the construction of each component are estimated as 32 months for the access roads, 50 months for the Río Coclé del Norte dam and power facilities, 67 months for the Coclé-Indio transfer tunnel, 34 months for the second Transfer Tunnel, and 33 months for reservoir clearing and mapping. Overall the construction, including the filling of the reservoirs to levels sufficient for the project to be operational will require slightly more than seven years.

Electrical power needs for construction at the Río Coclé del Norte dam site is estimated to be approximately 1.5 MW. There is no source for such demand currently available at a reasonable distance from the dam site. The contractor will also generate the required power by providing small size diesel generators (300-kW to 500-kW) at appropriate locations. The electricity supply for the TBM operation, including an amount to maintain stability in the supply system plus an allowance for ventilation, water supply, and the conveyor, will be about 5.1 MW (the cost for this power has been included in the unit cost for TBM tunneling).

As the power needs at the construction sites are specifically related to the construction methods and the equipment, it does not appear that it would efficient to anticipate the Contractors needs prior to awarding the contract. Therefore the responsibility of the power supply should be left with the main contractors.

The following sections present a description of the major construction activities and their sequencing constraints.

8.3 Contract 1 - Access Roads and Main Construction Camp at the Damsite

Contract 1 will include the construction of about 72 km of permanent access road, the main construction camp at the dam, a major bridge across the Río Coclé del Norte and various other river crossings and drainage structures. The location of the access roads, camp, and bridge are shown on Exhibit 8-3 and 3-2.

The construction of access roads is on the critical path of the project schedule. For the purpose of scheduling, it is estimated that the rate of construction will be about 3 km/month and that construction will start from the Río Indio Dam. This is considered to be conservative because of the assumption of a single front. Construction of the roads and bridge will take about 32 months and the camp will also be completed in that time.

As a part of the project, 15 km of temporary construction roads also will be required. These roads will be constructed as a part of the individual contracts and will be included in the site preparation item. In addition, the camps at both ends of the water transfer tunnel will be a part of that contract.

8.3.1 Permanent Access

Access to the Río Coclé del Norte Dam will be start from the Indio dam site. The main access road from Indio Dam to the east end of the Río Coclé del Norte Dam will be about 63 km long including a spur to the construction camp. In addition, short segments of road will connect from the main access road to the shaft at the outlet and the intake, from the dam to the powerhouse, and from the powerhouse to the west end of the dam. The total length of permanent roads is estimated to be about 72 km.

A bridge, approximately 800 meters downstream of the dam axis, is considered necessary to provide access to the left bank of the Río Coclé del Norte for the construction of the diversion tunnel and cofferdam. The bridge construction will be initiated as soon as possible and will be finished about 5 months after the roads.

Access to the second Indio-Gatun transfer tunnel will be accomplished using the access constructed for the first transfer tunnel. It is also anticipated that the same access adits will be used for construction. No new road is anticipated for that purpose.

8.3.2 Construction Camp

The camp for the Río Coclé del Norte Project will be located in an area of 10 hectares approximately 3 kilometers east of the dam site, off the main access road. The construction will be started so that its substantial completion coincides with the completion of the main access and the beginning of the construction of the main features of the project. About six months of construction will be sufficient to provide housing for the initial crews working at the dam site.

No new construction camp is anticipated for the construction of the second transfer tunnel as part of the camp built for the construction of the Río Indio project could be refurbished for that purpose.

It is anticipated that the implementation of the construction camp will be contracted with the access road construction.

8.4 Contract 2 - Río Coclé del Norte Storage and Hydropower Facilities

8.4.1 Mobilization and Site Preparation

This activity is estimated to require about 3 months and will include moving the required equipment and personnel to the site, construction of about 7 km of construction access (including the road to the quarry) and clearing the site.

8.4.2 Rockfill and Aggregate Quarries

The quarry areas are located less than 3 km from the dam site. The quarry will be used to produce approximately 2,700,000 m^3 of rockfill, 220,000 m^3 of drain and filter material and 90,000 m^3 of aggregate. The establishment of the quarries is anticipated to take approximately 6 months including geotechnical investigations and construction of the access road. This activity is not on the schedule critical path as investigations can be initiated at any time during the first year of activities before aggregates are needed.

8.4.3 Diversion

A diversion tunnel approximately 530 meters long will be used to pass the river flows during the dam construction. As this tunnel will be ultimately used for emergency drawdown of the reservoir, its construction will need to be completed including concrete lining, intake works, gates and operating equipment, prior to start the construction of the cofferdam. Based on the river diversion requirements and the selected cofferdam height, the tunnel will have a diameter of 8 m. As the construction of the feature is one of the critical activities, the tunnel excavation will be initiated at both ends of the tunnel, followed immediately by the gate shaft excavation and concreting. Construction is estimated to take approximately 9 months including gate installation and testing, and outlet channel excavation.

Clearing and preparation of the cofferdam foundation will be initiated prior to completion of the low-level outlet. Materials for construction of cofferdam will be obtained from the overburden excavation of the dam foundation. Overall construction of the cofferdam is estimated to take about 6 months.

8.4.4 Main Dam and Spillway

The dam construction requires the placement of approximately 3,100,000 m^3 of materials including 2,700,000 m^3 of rockfill. Approximately 540,000 m^3 of rockfill are expected to be obtained from the spillway and dam rock excavation; the remaining rockfill will be extracted from two possible quarry areas located less than 3.0 km east of the dam site.

Excavations for the dam and foundation preparation are expected to take 11 months. Priority will be given to the grout curtain and consolidation grouting, to enable parallel operation as necessary to minimize the overall construction period as the dam construction represents the bulk of the critical path of the project construction.

Placement of the rockfill is expected to take 14 months; and another 7 months are anticipated to complete the construction of the embankment, the concrete face, the parapet wall, and the crest road.

The excavation for the spillway will be performed at a time when the materials can be directly placed in the dam. Concrete construction will be coordinated with the construction of the face of the dam to make efficient use of the concrete plant capacity.

8.4.5 Hydroelectric Power Plant

The hydropower plant will consist of an intake tower located in the dam right abutment approximately 50 meters west of spillway, a 35-meter long bridge to provide access from the crest of the dam, a 5.8-m diameter, 40-m deep vertical shaft and 260-m long horizontal tunnel, the power house, a switchyard, and a 109-km long, 230 kV transmission line.

The construction of the hydropower component will start with the excavation of the powerhouse followed by the tunnel portal and tunnel excavation. The vertical shaft will then be excavated, immediately followed by concreting. Upon completion of the shaft, the tunnel steel liner will be installed and backfilled with concrete. Field fabrication of the steel liner may be performed at the location of the proposed switchyard, between the toe of the dam and the low-level outlet tailrace channel, approximately 200 meter from the portal. Overall the tunnel and shaft construction will take approximately 10 months.

The powerhouse construction will take approximately 2 years after completion of the tunnel liner. The first twelve months will be essentially dedicated to the civil work while the second will the installation of the three units and the ancillary mechanical and electrical equipment.

The engineering and construction of the 230-kV switchyard at the toe of the Río Coclé del Norte Dam, the transmission line, and the connection to La Chorrera substation are not critical activities of the project schedule. They will be scheduled in parallel with other construction activities. The duration of this activity is estimated at 4 years beginning with preliminary engineering and route survey, followed by detailed design, material procurement and construction.

8.5 Contract 3 - The Río Coclé del Norte Reservoir to Río Indio Reservoir Water Transfer Tunnel

The water transfer tunnel will be about 16,500-m long and have a finished diameter of 9.0 m. Its capacity at maximum pool will be about 300 m^3/s.

8.5.1 Camps and Access Roads

A construction camp will be located in the immediate vicinity of both the intake portal and the downstream access shaft. Construction access roads totaling about 5 km will be required in the vicinity of the upstream and downstream ends of the tunnel and to the disposal areas. These activities will be accomplished during mobilization and site preparation.

8.5.2 Excavation Methods

It was assumed that the tunnel construction will be accomplished using a tunnel boring machine (TBM) for the bulk of the excavation and drill-and-blast techniques over limited reaches at the main portals. The excavated shape and the final section of the TBM segments of the tunnel will be circular and the drill a blast segments will be a modified horseshoe shape.

The TBM method of excavation was selected due to the length of the tunnel and the lack of intermediate access locations needed with a drill-and-blast approach to have a reasonable construction duration. The construction schedule is based on a single TBM operating from one face.

It is estimated that the average mining advance rate, including placement of the segmental lining will be in the range of 12-15 m per day, and 13 m/day was assumed for the schedule.

The daily advance rate estimates per excavation face for drill-and-blast excavation sections of the headrace tunnel range from about 1 m/day in the Type IV ground to about 5 m/day in the best ground. An average advance of 3 m/day has been assumed for the schedule.

8.5.3 Tunnel Construction

A 9-meter finished diameter has been selected for the 16-km long tunnel. It is assumed that the tunnel will be fully lined from portal to portal. A pre-cast concrete, segmental lining has been assumed in all rock conditions. A thickness of 0.4 m has been assumed for estimating purposes. A segmental lining system typically has significant scheduling and production advantages in that rock support and tunnel lining are installed in one pass. The invert will be designed to withstand the load from the transport of muck and other equipment and material.

A cast-in-place concrete lining (reinforced as required) will be included in the drill-and-blast sections of the tunnel, such as at the portals, and in other areas as needed.

It is estimated that about 1,250,000 m^3 of excavated material (un-bulked tunnel muck; approximately 1.94 million m^3 bulked) will be removed from the underground works. Initially, some of the material (such as the muck from excavation of the portals and starter tunnels) might be used immediately for other construction purposes (e.g. road bedding, fills, etc.) though the majority will probably be hauled to disposal areas, which are located about 1 km away from the portals.

8.6 Contract 4 - Second Transfer Tunnel from Indio Reservoir to Lake Gatun

The 8,250-m long 6.5-m diameter second tunnel will be installed immediately next to the presumed existing 4.5-m diameter tunnel, which is a part of the Río Indio development.

8.6.1 Excavation Methods

Based on the available geologic information and the relatively shallow topography along the alignment of the transfer tunnel it is anticipated that the tunnel construction will meet a broad range of working conditions and required supports. It is also probable that rock type changes from hard volcanic rock to weaker sedimentary rock may be frequent, resulting in numerous difficult transition zones. On that basis, the drill-and-blast method was selected for the purpose of scheduling.

An advance rate of excavation of 3 meters per day has been adopted as a realistic estimate for the second Río Indio transfer tunnel.

8.6.2 Tunnel Construction

It is estimated that a minimum of 445,000 m^3 of material will be excavated from the tunnel. The two adits excavated for the construction of the first transfer tunnel will be used as intermediate access. Based on the excavation rate of 3 meters per day and the six excavation fronts anticipated, it is estimated that the excavation of the tunnel will take approximately 75 weeks. For that purpose, the most western excavation front will be started from a vertical shaft, to be used as the intake gate shaft.

The upstream end of the tunnel is lower than the Río Indio minimum operating pool, and therefore the construction of the intake will require a cofferdam. As the Río Indio reservoir needs to remain operational during the construction, the level will be maintained at approximately El. 40. A cellular cofferdam 15 to 20 meters high, 200 meters long, will be built around the tunnel intake area.

The proposed schedule shows the sequencing of the activities including the excavation of the gate shaft at the intake and the outlet work. Overall the tunnel construction, including the intake and outlet works is expected to take 33 months. The last activity to be completed prior to the filling of the reservoir is the installation and testing of the intake gate at the upstream end of the tunnel. This is anticipated to take place prior to the completion of the outlet work.

The tunnel excavation can be initiated prior to the completion of the Río Coclé del Norte dam and reservoir; however, as the system of reservoir must remain operational, the Indio reservoir will only be lowered to El 40 after the Río Coclé del Norte reservoir is filled and can supply the needed water to maintain the required yield. The Río Coclé del Norte reservoir at El.60 will have sufficient storage to substitute for Río Indio. It is only when Río Coclé del Norte reaches this level that the cofferdam can be built and the intake construction can be initiated.

8.7 Contract 5 - Reservoir Clearing

Reservoir clearing will be done on all forested lands within the reservoir below El. 75. The surface area at this elevation is approximately 250 km^2. Based on the environmental studies for the Río Coclé del Norte basin, lowland forest is estimated to cover about 10,000 ha or about 40% of the reservoir area.

The reservoir area will also need to be surveyed to determine the initial reservoir volume and to be used as the base survey to monitor sedimentation. The vegetation clearing is expected to take about three and will be started from the lower level working towards the higher elevations.

8.8 Reservoir Filling

The project will only be operational when it is capable of delivering water into the Río Indio reservoir, i.e., with Río Coclé del Norte level above El.50. For this reason, it is recommended to start filling the reservoir prior to completion of the project. When the dam construction reaches a reasonable height, it is anticipated that the low level outlet will be used to control the release from the reservoir.

For the purpose of determining the required time to fill the reservoir, the monthly flow sequence of 52 years from 1948 to 1999 were analyzed. It was also assumed that a minimum release of 10.8 m^3/sec would be continuously released during the filling period. The results of this analysis are presented in Table 8-1.

TABLE 8-1 RESERVOIR FILLING

Filling Period	Reached Levels		
	At 90% Probability	At 50% Probability	At 10% Probability
6-mth Jul – Dec	El.47	El.51	El.57
1 year	El.53	El.59	El.64
18-mth Jul – Dec	El.67	El.70	El.71
2 years	El.71	El.71	El.71

Based on the results presented above, it is recommended that the reservoir filling be started one year prior to completion. Based on the median hydrologic conditions, the reservoir would reach El.60 in approximately one year. This level is sufficient for the Río Coclé del Norte reservoir to substitute the Río Indio reservoir and therefore would allow the reservoir system, without the Río Indio active storage, to operate and meet the Canal demand while the Río Indio reservoir is maintained at El.40. From this table it can also be seen that at least two rainy seasons are needed to fill the reservoir to its maximum operating level.

8.9 Cost Estimate

The cost estimate for the construction of the Project has been developed on the basis of the present design and the construction schedule presented in Section 8.2. This estimate includes the direct costs of labor, equipment and material, the Contractor indirect costs and engineering and administration costs. The costs were estimated in US Dollars at a January 2003 level. It is assumed that the project will be implemented with five contracts. National contractors will construct the access roads and construction camp, the Río Caño Sucio dam, and clear the forest lands in the reservoir. International contractors will perform the work associated with the Río Coclé del Norte dam, and the water transfer tunnel, and the second Río Indio to Lake Gatun tunnel. All contracts would be awarded on the basis of competitive bidding.

For each project feature, quantities were calculated from the feasibility-level design drawings and exhibits. The unit costs for major items of dam, appurtenant work and tunnel construction were developed using cost of labor, equipment and material. These items include: excavation (common and rock), fill placement, quarrying, concrete fabrication and placement, formwork, steel reinforcement and tunnel excavation and lining. Other unit costs were estimated from experience on other projects of similar nature.

8.9.1 Cost of Labor and Materials

The cost of local labor was estimated based on the "Convención Colectiva de Trabajo de Panamá" dated July 1998. This document indicates the minimum applicable wages to be paid to workers in the construction industry by profession and region, for every year from July 1998 to June 2002. Beyond that date, labor rates were adjusted according to the local CPI. These rates were increased by 30% to reflect the fact they are mandatory minimum wages. An average across the professions was taken to derive four main categories: unskilled labor, skilled labor, equipment operator and truck driver. The wages were also increased to reflect the expected 60-hour workweek: an overtime premium of 16.7% was assumed. Labor rates were then calculated by adding 50% for social costs. This resulted in the following hourly cost of salary.

TABLE 8-2 LOCAL LABOR COST OF SALARY

Category	Labor Rate
Unskilled labor	$5.60/hr
Skilled labor	$6.70/hr
Equipment operator	$8.00/hr
Truck driver	$6.30/hr

In addition to the local labor a crew leader was generally included at the rate of $10.00/hr.

Equipment rates were generally obtained from the publication of the US Army Corps of Engineers entitled "Construction Equipment Ownership and Operating Expense" (EP 1110-1-8), dated August 31, 2001. These rates have been increased at a 0.8% p.a. factor, reflecting the construction equipment cost escalation for the period. Equipment requirements and production rates were developed based on experience in similar type of project in tropical countries.

It is anticipated that materials including explosives, cement, and reinforcement steel will be imported for the most part. International unit prices were used: Table 8-3 below shows estimated unit costs of materials delivered at the site.

TABLE 8-3 MATERIAL UNIT COST

Material	Unit	Cost
Cement	MT	$122
Explosive	Kg	$1.50
Reinforcing Steel	MT	$725

The operational costs for the international contractor were also itemized for the purpose of this estimate. These costs include a management and engineering crew of eight, including a project manager, a superintendent, three staff engineers, a purchasing agent, a scheduler (coordinator) and an accountant. The crew will be fully mobilized on site for the duration of construction, after completion of the preliminary works such as access road, construction camp, establishing quarries, etc. A supporting crew of administrative personnel and drivers was also itemized. Other operational costs accounted for include items such as a maintenance crew, vehicles for staff transportation and telephone.

Overall the contractor operating costs were estimated at approximately 7% of the total direct construction cost. In addition, the following indirect costs were also added:

Contractor home office charges	7.0%
Bond	1.5%
Insurance	2.5%
Margin for risk	2.0%
Margin for profit	10.0%

As a result, unit rates calculated on the basis of the costs of labor, equipment and materials have been increased by a margin of 30% to reflect these items.

The resulting unit prices were compared with those obtained through the bidding process on other international water resources projects in Central and South America and appeared to be a reasonable estimate for this type of construction.

The unit prices shown in Table 8-4 were used.

TABLE 8-4 ESTIMATED UNIT PRICES (JAN-2003 LEVEL)

Material	Unit	Cost
Clearing	ha	$2,200
Clearing and Grubbing	m^2	$0.55
Overburden Excavation	m^3	$3.20
Bulk Rock Excavation	m^3	$8.80
Structural Rock Excavation	m^3	$14.80

Material	Unit	Cost
Transfer Tunnel Excavation	m^3	\$91-\$97
Shotcrete	m^2	\$46.00
Rock-bolts	l.m.	\$59.50 -\$67.50
Steel Ribs	kg	\$6.00
Rockfill	m^3	\$11.30
Backfill	m^3	\$7.20
Aggregate, filters, drains	m^3	\$16.10
Mass Concrete	m^3	\$116.00
Structural Concrete	m^3	\$145.00
Tunnel/Shaft Concrete Lining	m^3	\$110-\$180
Formwork	m^2	\$46.50
Reinforcing Steel	kg	\$1.32
Temporary Access Road	km	\$115,200
Permanent Access Road	km	\$147,600

A summary of the construction cost is shown in Table 8-5 below.

TABLE 8-5 SUMMARY COST OF THE RÍO COCLÉ DEL NORTE PROJECT

Item	Estimated Cost
Mitigation and Compensation Costs	**\$140,000,000**
Access Roads and Construction Camp	\$13,500,000
Río Coclé del Norte Storage and Hydro Facilities	\$132,600,000
Water Transfer Tunnel	\$176,400,000
Second Río Indio-Lake Gatun Tunnel	\$85,900,000
Reservoir Clearing	\$22,000,000
Subtotal Direct Cost	**\$430,400,000**
Contingency	\$83,500,000
Direct Cost	**\$513,900,000**
Engineering and Administration	\$77,100,000
Construction Cost (Jan 2003 price level)	**\$591,000,000**
TOTAL COST	**\$731,000,000**

8.9.2 Social, Economic and Environmental Mitigation and Compensation Costs

In the Río Coclé del Norte Reservoir, there is estimated to be about 4,300 persons and about 25,000 ha will be acquired, of which about 8,800 ha is forested. Compensation costs for relocation were estimated by the ACP in the amount of $5,000 per person. Land acquisition was estimated as $5,000/ha of forest, $1,500/ha of shrub land, and $1,000/ha of pasture. Mitigation for habitat loss was estimated on the basis of the current land use and averaged about $1,200/ha over all of the soil uses. Finally, a cost for the replacement of the infrastructure was included, which covered clinics, cemeteries, water supply, commercial agriculture enterprises, parks, generating facilities, transmission lines, and public buildings.

The total mitigation and compensation costs, which are assumed to include contingencies, are estimated to be $140 million.

8.9.3 General Costs

The general cost category includes mobilization, temporary access, and maintenance. The allocation for land acquisition has been included in the compensation and mitigation costs. The lengths and location of the required construction access is presented in Section 8.3.

8.9.4 Reservoir Clearing Costs

The full cost of clearing has been included in the estimate. However, it is likely that this cost will be significantly reduced or eliminated if the clearing is contracted out to a commercial logging company.

8.9.5 Contingencies

A contingency allowance is included in the cost estimate for unforeseen site conditions, approximations, and the potential for future design changes. For these estimates, an allowance of 25% was used for the dam and tunnel excavation to reflect the uncertainties associated with foundation unknowns and the conditions that could be encountered in the long tunnel, 15% was used for all civil items and 10% for all equipment. Overall, the contingency is approximately 13% of the project construction cost or about 18% of the subtotal of the direct costs.

8.9.6 Engineering and Administration

Indirect costs for final design, engineering services during construction, and for administration costs of the APC chargeable to the project are based on previous experience for similar projects. It has been estimated that about 15 percent of the total direct costs will be adequate for engineering and administration.

8.9.7 Capital Cost

An estimate of the capital cost is not provided. The problems associated with an assumption of a long-term inflation rate and escalation and interest rates for a period 20-odd years in the future, precludes any kind of a useful result. For discussion purposes, it is estimated that the capital costs will be between $3 billion and $4 billion.

8.9.8 Disbursement Schedule

A disbursement schedule has been estimated beginning at a point in time when funding is secured according to the implementation schedule. The disbursement schedule has been estimated on the basis of the cost estimate, the implementation schedule, and the detailed construction schedule. The disbursement schedule, presented in Table 8-6 shows an annual distribution for the total project cost.

TABLE 8-6 DISBURSEMENT SCHEDULE

Year	Disbursement of Construction Costs
1 (2025)	$54,000,000
2 (2026)	$72,000,000
3 (2027)	$108,000,000
4 (2028)	$111,000,000
5 (2029)	$133,000,000
6 (2030)	$149,000,000
7 (2031)	$87,000,000
8 (2032)	$17,000,000
Total	**$731,000,000**

8.10 Annual Operating Cost

The annual operating costs include the costs of operation and maintenance (O&M), for the various features, the cost of replacing short-life equipment, administration by the Owner, and insurance.

The O&M for the dam, the hydro plant, and the water transfer facilities will be performed by three O&M groups that will be a part of the ACP's much larger Canal Operation Group. As the personnel are part of a larger group, the management duties will required only part time input from existing staff. A summary estimate of the personnel and equipment requirements and the cost are shown below.

	Number	Annual Unit Cost	Total Annual O&M Cost
Personnel			
Manager	0.4	$100,000	$40,000
Assistant Manager	1.5	$60,000	$90,000
Operation Personnel	10	$35,000	$350,000
Maintenance Personnel	15	$30,000	$450,000
Electrical Foreman	0.5	$50,000	$25,000
Electrician	3	$40,000	$120,000
Mechanical Foreman	0.2	$50,000	$20,000
Hydroelectric Mechanical	3	$40,000	$120,000
Heavy Duty mechanical	3	$35,000	$105,000
Laborers	30	$15,000	$450,000
Subtotal			*$1,750,000*
Equipment			
Vehicles	10	$40,000	$400,000
Spare Parts	LS	$150,000	$150,000
Maintenance Equipment	LS	$150,000	$150,000
Total O&M Cost			**$2,450,000**

The cost of replacing short-life equipment is included in the annual cost as a sinking fund. The cost is computed as the amount to replace all equipment in 25 years at an interest rate of 10% and an inflation rate of 3% per year. The sinking fund amount is estimated to be $110,000 per year.

Administration and general expenses of the owner is for salaries, outside services, injuries and damages, welfare, pensions and miscellaneous expenses. These costs were assumed to equal 40% of the labor cost of the O&M personnel.

The annual cost of insurance was estimated as 0.1% of the construction cost.

In addition, an annual cost associated with watershed management, implementation of the environmental mitigation plan and the relocation activities is included.

The annual operation and maintenance costs are summarized in Table 11-7.

TABLE 8-7 ANNUAL OPERATION AND MAINTENANCE COST

Item	Annual Cost
O&M	$2,450,000
Replacement	$110,000
Admin and General Expenses	$700,000
Insurance	$589,000
Resettlement Administration	$150,000
Watershed Management	$150,000
Mitigation Plan Implementation	$100,000
Total (rounded)	**$4,250,000**

9. ECONOMIC COST OF WATER

The original scope of services for the economic evaluation of the Río Coclé del Norte Project consisted of a series of economic studies that were to include:

- Optimization of the dam height and spillway width,
- Assessment of the economic viability of the combined navigation/M&I project, and
- Evaluation of the addition of hydropower.

During the study, it was determined that no supplemental water supply project would be implemented unless it was a part of a much bigger project to construct a third and even a fourth set of locks. Under these conditions, the existing demand and toll revenues are not valid and any economic justification using these values would be irrelevant. This determination prevented the optimization of the dam height and any assessment of economic feasibility. The evaluation of hydropower was possible and is discussed in Section 6.

Although no economic analysis is possible at this time, it is possible to analyze a series of demand conditions and compare them to the cost of the project to estimate the economic cost of water. The project cost for this analysis excludes the project and annual costs for the power facilities.

If conditions existed where the full amount of the system yield attributable to the implementation of the Norte/Indio Project could be beneficially used immediately upon the completion of construction, the economic cost of water would be about $0.03/m^3. This estimate is derived by dividing the present worth of the total project cost (construction, compensation and mitigation cost) and annual costs by the present worth of the supply, which is 45.4 L/d. In all estimates, a discount rate of 12% was used. This condition is highly unlikely and only serves to indicate a minimum cost of water.

A more likely condition assumes that only a portion of the yield can be used when the project comes on line and that the usable yield increase at some reasonable rate. For example, if the year 2000 demand were assumed to be 38 L/d, the demand increased at 0.75 L/d/yr, the existing system, which is presumed to include the Río Indio Reservoir, could yield 60.3 L/d, and the project came on line in the first year that there was a system deficit (year 2030), the economic cost of water would be about $0.19/m^3. Under these conditions, the full yield of the project is not used within the 50-year period of operation. If the project were delayed for ten years, which would result in the potential for severe shortages during those ten years, the economic cost of water would be reduced to $0.10/m^3.

Under the same assumptions and a rate of increase of 0.6 L/d/yr, the cost of water would be about $0.22/m^3 and $0.11/m^3 for the same two conditions.

For comparison purposes, the following table presents historic demands with a range of growth rates assuming that the current demand for navigation and M&I water is about 38 L/d.

TABLE 9-1 COMPARISON OF DEMANDS AND COST OF WATER

Year	On-Line Year	Recon Report Navigation Demand + MWH M&I Demand	Base Demand Increased by 0.75 L/d/yr	Base Demand Increased by 0.6 L/d/yr
2000		38.0 L/d	38.0 L/d	38.0 L/d
2020		52.5 L/d	53.0 L/d	50.0 L/d
2040		70.8 L/d	68.0 L/d	62.0 L/d
2060		85.1 L/d	83.0 L/d	74.0 L/d
Cost of Water	**First year of deficit**	**$0.15/m^3**	**$0.19/m^3**	**$0.22/m^3**
Cost of Water	**10 yrs after first year of deficit**	**$0.07/m^3**	**$0.10/m^3**	**$0.11/m^3**

The economic cost of water for the Project is high when compared to most of the other projects in the Western Watersheds. The primary reason is that the yield is so large that there is a very long period before the yield is completely used by the Panama Canal. A comparison of the five of the projects in the Western Watersheds studied to date is shown below.

TABLE 9-2 COMPARISON OF PROJECTS AND COST OF WATER

Project	Yield	Base Demand Increased by 0.75 L/d/yr	Base Demand Increased by 0.6 L/d/yr
Coclé del Norte, FSL @ El. 71, with Río Indio	45.4 L/d	$0.19/m^3$	$0.22/m^3$
Coclé del Norte, FSL @ El. 100, with Sucio and Indio	47 L/d	$0.23/m^3$	$0.27/m^3$
Upper Chagres	5.3 L/d	$0.12/m^3$	$0.12/m^3$
Río Indio	15.8 L/d	$0.07/m^3$	$0.10/m^3$
Caño Sucio	2.5 L/d	$0.09/m^3$	$0.12/m^3$

Including hydropower costs and benefits would reduce the cost of water for the Project by about 15 percent.

10. CONCLUSIONS AND RECOMMENDATIONS

Without the information required to perform and economic and financial evaluations (for reasons given in Section 1.3.2), it is not possible to make a recommendation concerning the implementation of the project. The economic cost of water is higher than what might normally be expected for a commercial supply and approaches what might be expected for an M&I supply. However, the current benefits accruing to water supply from the Panama Canal operation also are high and may continue at this level. Therefore, development of the project cannot be ruled out, but the recommendations, at this time, can relate only to the relative attractiveness of the possible alternative developments in the basin.

10.1 Conclusions

As a result of the studies described in this report and its appendices, it is concluded that:

- The Project is technically feasible.
- The dam sites selected in the Reconnaissance Report are suitable sites for the development of the water resources of the Río Coclé del Norte Basin.
- A concrete-faced rockfill dam at the Río Coclé del Norte site is the most appropriate types of dam for the site based on the available information, estimates of cost, and preferences of the ACP.
- It is our considered opinion that there are no geologic or geotechnical problems associated with the site that cannot be accommodated using conventional solutions although the lack of subsurface investigations has increased the potential for inaccuracies in the estimate of cost.
- The yield of the Panama Canal system will increase by about 3,480 MCM/yr (about 45.4 L/d) with the addition of the Project.
- The addition of a 60 MW hydropower plant at Río Coclé del Norte dam is economically attractive.
- The inclusion of a commercial agricultural endeavor is technically feasible, but is not economically viable at this time and development should not be initiated at this time.
- Construction of the project is estimated to cost about $591 million in 2003 dollars. An addition $140 million have been allowed for compensation and mitigation for a total cost of $731 million.
- The economic cost of the water is less than for the project with a full supply level at El. 100 and acting in full regulation with the Río Caño Sucio and Río Indio Reservoirs.

10.2 Recommendations

As a result of these conclusions, it is recommended that the project be favored over the Norte/Sucio/Indio Project (see Volume 2) if development in the Río Coclé del Norte basin is considered further.

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Tables

TABLES

Table 1

LONG-TERM MONTHLY STREAMFLOW AT THE RÍO COCLÉ DEL NORTE DAM SITE

Drainage Area 1594 km^2

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1948	67.5	37.1	30.1	25.0	40.2	50.3	120.0	133.4	128.8	122.3	198.1	82.5	**86.3**
1949	46.6	33.9	25.9	24.5	49.0	152.0	119.4	139.4	176.5	169.9	250.9	212.4	**116.7**
1950	64.7	44.5	32.3	26.4	92.2	139.6	143.6	186.5	140.4	173.9	208.8	209.3	**121.9**
1951	95.0	64.1	44.5	34.3	93.8	107.5	102.3	108.2	155.8	138.8	184.4	126.1	**104.6**
1952	72.5	44.9	30.1	27.8	64.7	120.9	101.6	105.7	151.0	193.9	140.2	178.6	**102.7**
1953	145.8	76.8	50.9	40.9	105.0	97.6	95.7	84.5	97.4	200.5	200.6	132.1	**110.7**
1954	83.2	50.9	37.9	33.1	90.2	93.6	168.8	139.0	172.1	153.9	240.1	153.7	**118.1**
1955	161.3	73.6	46.6	40.2	62.6	154.5	122.1	172.5	198.4	179.0	241.6	164.5	**134.7**
1956	165.8	74.9	52.6	49.9	120.2	155.1	148.5	121.5	168.0	223.4	175.2	120.2	**131.3**
1957	65.0	42.4	32.3	26.4	66.1	66.4	65.8	103.0	109.3	193.7	144.4	124.5	**86.6**
1958	90.7	76.3	50.6	40.9	85.5	96.5	80.9	135.8	121.9	123.8	108.0	108.5	**93.3**
1959	64.6	31.2	15.4	39.9	40.2	197.5	211.1	131.9	119.5	151.7	146.1	271.0	**118.3**
1960	128.9	61.6	50.8	77.4	71.7	100.6	83.5	79.8	110.3	152.0	191.5	275.9	**115.3**
1961	80.3	52.3	36.4	37.0	70.4	92.3	103.1	172.3	115.7	164.6	191.0	199.3	**109.5**
1962	76.2	42.2	26.9	42.6	67.8	92.2	85.2	115.6	105.6	137.3	183.3	131.2	**92.2**
1963	64.0	52.3	37.0	156.2	124.9	114.5	112.9	120.5	100.3	115.6	194.4	97.3	**107.5**
1964	72.8	24.8	20.0	129.5	121.8	157.3	144.6	142.2	141.2	187.3	178.2	67.8	**115.6**
1965	125.4	47.8	23.9	14.1	88.0	55.8	59.8	75.2	73.2	117.0	133.4	160.7	**81.2**
1966	71.7	38.6	29.9	38.5	112.0	137.2	110.6	106.8	86.2	156.6	279.2	223.0	**115.9**
1967	95.5	60.9	29.2	85.4	132.1	181.5	128.1	154.6	159.8	176.6	150.3	113.1	**122.3**
1968	61.9	64.1	64.7	45.2	90.9	129.0	95.9	110.9	125.9	156.0	136.9	143.8	**102.1**
1969	44.6	40.7	18.8	27.7	54.6	84.8	59.6	106.5	115.0	163.7	176.0	164.2	**88.0**
1970	313.0	114.8	55.9	149.3	249.7	86.2	116.4	171.8	191.6	189.4	268.0	353.8	**188.3**
1971	138.2	68.6	96.8	56.7	106.8	139.9	133.9	144.9	168.6	177.1	114.2	59.1	**117.1**
1972	105.3	54.7	39.1	90.0	92.2	70.2	75.6	66.8	123.1	113.5	108.0	71.1	**84.1**
1973	62.4	40.6	19.9	20.7	84.9	125.2	123.6	130.8	176.4	201.9	245.5	200.3	**119.4**
1974	91.6	73.9	46.7	55.8	94.7	90.3	106.5	114.9	104.6	214.5	155.7	103.4	**104.4**
1975	62.6	40.7	23.2	16.4	68.9	72.4	97.3	174.0	215.5	235.9	325.0	283.1	**134.6**
1976	101.5	60.8	37.9	26.2	44.8	44.3	46.0	77.4	137.4	127.5	117.6	49.3	**72.5**
1977	40.1	29.2	17.5	23.5	42.9	80.9	85.1	172.2	130.4	164.6	123.9	72.8	**81.9**
1978	47.0	41.8	28.0	179.2	224.6	106.3	66.7	75.0	137.8	149.5	159.5	93.0	**109.0**
1979	31.3	28.3	21.9	97.5	89.8	143.5	110.3	177.5	144.0	106.2	108.1	157.9	**101.4**
1980	144.8	49.4	24.5	38.8	56.5	86.4	84.2	146.9	109.8	146.8	155.9	161.7	**100.5**
1981	127.0	87.8	68.8	185.8	178.7	149.6	140.8	146.6	95.3	132.2	244.5	341.1	**158.2**
1982	77.8	45.5	31.1	32.8	59.7	85.2	111.5	89.9	100.4	145.2	121.3	61.2	**80.2**
1983	51.3	23.3	16.1	18.2	131.6	81.5	51.9	69.8	154.9	116.3	106.0	131.0	**79.3**
1984	90.2	94.7	68.3	24.5	68.3	112.0	145.2	206.9	164.7	163.8	164.5	79.2	**115.2**
1985	79.6	42.2	38.7	24.1	36.4	141.6	84.6	103.2	99.1	128.5	147.5	169.3	**91.2**
1986	102.6	55.1	37.1	107.0	113.3	114.1	117.3	123.2	134.1	236.2	226.3	83.0	**120.8**
1987	48.1	35.4	24.5	59.4	68.3	65.4	85.9	101.6	115.3	229.6	143.3	96.4	**89.4**
1988	51.3	46.1	23.6	19.9	90.9	89.9	127.5	136.8	137.3	189.1	175.5	96.2	**98.7**
1989	71.1	44.1	34.6	26.6	83.4	106.4	137.2	147.7	137.2	146.1	192.2	126.6	**104.4**
1990	76.8	45.1	30.2	25.1	64.2	66.5	106.2	109.1	160.0	207.1	156.6	205.1	**104.3**
1991	56.6	36.6	79.6	29.0	76.1	96.6	78.7	91.0	152.2	198.5	139.5	132.8	**97.3**
1992	48.6	30.8	21.0	71.1	118.4	125.3	102.6	122.6	176.9	140.6	118.2	85.1	**96.8**
1993	78.3	42.0	47.1	48.6	63.5	128.8	108.5	83.6	204.8	151.5	242.8	165.5	**113.8**
1994	59.2	40.7	35.1	46.9	96.6	150.4	94.4	133.1	162.3	164.6	149.7	75.3	**100.7**
1995	49.8	37.2	30.0	43.3	113.8	108.1	132.2	138.3	163.3	106.6	133.0	180.2	**103.0**
1996	297.4	118.0	74.9	50.0	170.1	167.2	185.4	210.7	232.9	181.3	216.2	319.4	**185.3**
1997	77.0	57.5	36.1	30.6	75.5	63.5	70.9	87.0	81.3	125.8	103.4	53.5	**71.8**
1998	38.2	35.1	27.5	67.4	74.8	71.3	104.0	90.8	113.4	154.3	107.2	140.4	**85.4**
1999	89.5	55.2	38.1	53.4	92.3	110.4	108.8	127.8	141.2	162.8	172.9	149.2	**108.5**
Mean	**89.5**	**52.1**	**37.7**	**53.5**	**91.8**	**108.8**	**107.7**	**125.3**	**139.2**	**162.7**	**173.0**	**149.2**	**107.5**
Maximum	**313.0**	**118.0**	**96.8**	**185.8**	**249.7**	**197.5**	**211.1**	**210.7**	**232.9**	**236.2**	**325.0**	**353.8**	**188.3**
Minimum	**31.3**	**23.3**	**15.4**	**14.1**	**36.4**	**44.3**	**46.0**	**66.8**	**73.2**	**106.2**	**103.4**	**49.3**	**71.8**

Table 2

RIO COCLE DEL NORTE RESERVOIR ACTING IN FULL REGULATION WITH RIO INDIO RESERVOIR

SUMMARY COST ESTIMATE

	US$ million
ACCESS ROADS AND CONSTRUCTION CAMPS	$ 13.5
RIO COCLE DEL NORTE STORAGE PROJECT	$ 132.6
WATER TRANSFER TUNNEL	$ 176.4
SECOND RIO INDIO TO LAKE GATUN TRANSFER TUNNEL	$ 85.9
RESERVOIR CLEARING	$ 22.0
SUBTOTAL DIRECT COSTS	$ 430.4
Contingency	$ 83.5
DIRECT COST	$ 513.9
Engineering and Administration	$ 77.1
CONSTRUCTION COST (Jan 2003 price level)	$ 591.0
Compensation and Mitigation Cost	$ 140.0
TOTAL COST	$ 731.0

RIO COCLE DEL NORTE RESERVOIR ACTING IN FULL REGULATION WITH RIO INDIO RESERVOIR

CONSTRUCTION COST ESTIMATE SUMMARY

ACCESS ROADS AND CONSTRUCTION CAMPS			
1 General		$	360,000
2 Permanent Access Roads		$	10,630,000
3 Bridges		$	950,000
4 Construction Camps		$	1,580,000
	Subtotal	***$***	***13,520,000***
RIO COCLE DEL NORTE STORAGE PROJECT			
1 General		$	3,670,000
2 Diversion		$	11,500,000
3 Dam		$	48,280,000
4 Spillway		$	5,910,000
5 Low Level Outlet Structure		$	7,990,000
6 60-Mw Hydroelectric Power Plant		$	32,340,000
7 Transmission System		$	21,730,000
8 Operation Facilities		$	1,150,000
	Subtotal	***$***	***132,570,000***
WATER TRANSFER TUNNEL			
1 General		$	4,080,000
2 Intake/Outlet And Equipment		$	17,990,000
3 Tunnel		$	139,200,000
4 Lake Tap		$	15,160,000
	Subtotal	***$***	***176,430,000***
SECOND RIO INDIO TO LAKE GATUN TRANSFER TUNNEL			
1 General		$	2,120,000
2 Cofferdam		$	6,570,000
3 Access Adit Rehabilitation (2)		$	750,000
4 Tunnel Intake Portal & Channel		$	3,150,000
5 Tunnel		$	62,370,000
6 Intake Structure		$	430,000
7 Intake Gate Shaft		$	2,320,000
8 Outlet Structure		$	1,340,000
9 Tunnel Outlet Portal & Channel		$	2,600,000
10 Hydromechanical Equipment		$	4,220,000
	Subtotal	***$***	***85,870,000***
RESERVOIR CLEARING		**$**	**22,000,000**
SUBTOTAL DIRECT COSTS		**$**	**430,390,000**
Contingency		$	83,490,000
DIRECT COST		**$**	**513,880,000**
Engineering and Administration		$	77,120,000
CONSTRUCTION COST (Jan 2003 price level)		**$**	**591,000,000**

RIO COCLE DEL NORTE RESERVOIR ACTING IN FULL REGULATION WITH RIO INDIO RESERVOIR

ACCESS ROADS AND CONSTRUCTION CAMPS

Description	Unit	Unit Cost	Quantity	Amount
1 GENERAL				
1.1 Mobilization and Demobilization	LS	$250,000	1	$250,000
1.2 Temporary Facilities Maintenance	mth	$1,000	32	$32,000
1.3 Access Roads Maintenance	mth	$2,500	32	$80,000
Subtotal 1				***$362,000***
2 PERMANENT ACCESS ROADS				
2.1 Main Access Road	km	$147,600	63	$9,298,800
2.2 Other Permanent Access	km	$147,600	9	$1,328,400
Subtotal 2				***$10,627,200***
3 BRIDGES				
3.1 Bridge over the Rio Cocle del Norte	LS			$750,000
3.2 Bridge over the Outlet Channel	LS			$200,000
Subtotal 3				***$950,000***
4 CONSTRUCTION CAMPS				
4.1 Cocle del Norte Construction Camp	LS			$1,580,000
4.2 Transfer Tunnel Construction Camp	Included in appropriate contract costs			
Subtotal 4				***$1,580,000***
Subtotal Direct Cost (rounded)				**$13,520,000**
Contingency				**$2,030,000**
Direct Cost				**$15,550,000**

RIO COCLE DEL NORTE RESERVOIR ACTING IN FULL REGULATION WITH RIO INDIO RESERVOIR

RIO COCLE DEL NORTE STORAGE PROJECT

Description	Unit	Unit Cost	Quantity	Amount
1 GENERAL				
1.1 Mobilization and Demobilization	LS	$2,500,000	1	$2,500,000
1.2 Temporary Facilities Maintenance	mth	$5,000	48	$240,000
1.3 Temporary Access Roads	km	$115,200	7	$806,400
1.4 Access Roads Maintenance	mth	$2,500	48	$120,000
Subtotal 1				***$3,666,400***
2 DIVERSION				
2.1 Site Preparation	m^2	$0.55	80,000	$44,000
2.2 Approach/Discharge Channels				
2.2.1 Overburden Excavation	m^3	$3.20	included in 2.3.1	
2.2.2 Rock Excavation	m^3	$8.80	included in 2.3.2	
2.3 Diversion Tunnel Intake and Outlet Portals				
2.3.1 Overburden Excavation	m^3	$3.20	48,500	$155,200
2.3.2 Rock Excavation	m^3	$8.80	47,200	$415,360
2.3.3 Shotcrete	m^2	$46.00	2,670	$122,820
2.3.4 Rockbolts	l.m.	$59.50	1,330	$79,135
2.3.5 Concrete	m^3	$145.00	1,415	$205,175
2.3.6 Formwork	m^2	$46.50	1,300	$60,450
2.3.7 Reinforcement	kg	$1.32	44,500	$58,740
2.4 Diversion Tunnel				
2.4.1 Tunnel Excavation	m^3	$125.00	38,320	$4,790,000
2.4.2 Shotcrete	m^2	$46.00	7,910	$363,860
2.4.3 Rockbolts	l.m.	$67.50	4,080	$275,400
2.4.4 Steel Ribs	kg	$6.00	57,000	$342,000
2.4.5 Closure Bulkhead	Each	$95,000	2	$190,000
2.5 Cofferdams				
2.5.1 Overburden Excavation	m^3	$3.20	96,200	$307,840
2.5.2 Fill	m^3	$7.30	502,500	$3,668,250
2.5.3 Filter/Drain	m^3	$16.10	26,400	$425,040
Subtotal 2				***$11,503,270***
3 DAM				
3.1 Site Preparation	m^2	$0.55	130,000	$71,500
3.2 Excavation				
3.2.1 Overburden Excavation	m^3	$3.20	307,000	$982,400
3.2.2 Rock Excavation	m^3	$8.80	153,500	$1,350,800
3.3 Grouting				
3.3.1 Cut-off	m^2	$46.00	21,600	$993,600
3.3.2 Consolidation	m	$69.20	1,700	$117,640
3.4 Rockfill				
3.4.1 Mass	m^3	$11.30	2,728,900	$30,836,570
3.4.2 Filter	m^3	$16.10	171,100	$2,754,710
3.4.3 Drain	m^3	$16.10	21,000	$338,100
3.4.4 Backfill	m^3	$7.20	171,200	$1,232,640
3.5 Concrete				
3.5.1 Dental Concrete	m^3	$116.00	6,250	$725,000
3.5.2 Plinth	m^3	$172.00	6,250	$1,075,000
3.5.3 Facing	m^2	$80.00	57,000	$4,560,000
3.5.4 Parapet -US	m^3	$252.00	3,020	$761,040
3.5.5 Parapet -DS	m^3	$252.00	570	$143,640
3.5.6 Crest Road	m^2	$9.60	4,030	$38,688
3.6 Miscellaneous Site Work	LS	5%	1	$2,299,066
Subtotal 3				***$48,280,394***

RIO COCLE DEL NORTE RESERVOIR ACTING IN FULL REGULATION WITH RIO INDIO RESERVOIR

RIO COCLE DEL NORTE STORAGE PROJECT

Description	Unit	Unit Cost	Quantity	Amount
4 SPILLWAY				
4.1 Site Preparation	m^2	$0.55	40,000	$22,000
4.2 Excavation				
4.2.1 Overburden Excavation	m^3	$3.20	79,000	$252,800
4.2.2 Rock Excavation	m^3	$8.80	288,500	$2,538,800
4.2.3 Backfill	m^3	$7.30	4,400	$32,120
4.3 Headworks				
4.3.1 Concrete	m^3	$145.00	2,970	$430,650
4.3.2 Formwork	m^2	$46.50	1,870	$86,955
4.3.3 Reinforcement	kg	$1.32	60,200	$79,464
4.4 Chute and Flip Bucket				
4.4.1 Concrete	m^3	$145.00	7,650	$1,109,250
4.4.2 Formwork	m^2	$46.50	13,300	$618,450
4.4.3 Reinforcement	kg	$1.32	335,100	$442,332
4.4.4 Drains	l.m.	$9.00	1,790	$16,110
4.4.5 Anchors	l.m.	$37.00	2,750	$101,750
4.5 Bridge				
4.5.1 Concrete	m^3	$145.00	440	$63,800
4.5.2 Formwork	m^2	$46.50	550	$25,575
4.5.3 Reinforcement	kg	$1.32	68,992	$91,069
Subtotal 4				***$5,911,125***
5 LOW LEVEL OUTLET STRUCTURE				
5.1 Shaft				
5.1.1 Shaft Excavation	m^3	$295.00	5,240	$1,545,800
5.1.2 Shotcrete	m^2	$46.00	1,900	$87,400
5.1.3 Rockbolts	l.m.	$59.50	1,870	$111,265
5.1.4 Concrete	m^3	$180.00	3,020	$543,600
5.1.5 Formwork	m^2	$46.50	4,840	$225,060
5.1.6 Reinforcement	kg	$1.32	118,540	$156,473
5.2 Intake Structure				
5.2.1 Concrete, High Strength	m^3	$160.00	6,890	$1,102,400
5.2.2 Formwork	m^2	$46.50	5,220	$242,730
5.2.3 Reinforcement	kg	$1.32	311,400	$411,048
5.2.4 Concrete Plug	m^3	$116.00	480	$55,680
5.3 Tunnel Lining				
5.3.1 Concrete, High Strength	m^3	$125.00	7,980	$997,500
5.3.2 Formwork	m^2	$46.00	10,810	$497,260
5.3.3 Reinforcement	kg	$1.32	312,800	$412,896
5.3.4 Anchors	l.m.	$37.00	4,730	$175,010
5.3.5 Steel Lining	LS	$50,000	1	$50,000
5.4 Hydromechanical Equipment				
5.4.1 Control Gate (3.6m x 6m)	Each	$295,000	2	$590,000
5.4.2 Bulkhead (3.6m x 6m)	Each	$195,000	2	$390,000
5.4.3 Operator	Each	$100,000	2	$200,000
5.4.3 Surface Structure	LS	$100,000	1	$100,000
5.4.3 Power and Controls	LS	$100,000	1	$100,000
Subtotal 5				***$7,994,122***

RIO COCLE DEL NORTE RESERVOIR ACTING IN FULL REGULATION WITH RIO INDIO RESERVOIR

RIO COCLE DEL NORTE STORAGE PROJECT

Description	Unit	Unit Cost	Quantity	Amount
6 60-MW HYDROELECTRIC POWER PLANT				
6.1 Power Intake				
6.1.1 Civil Work				
Site Preparation	m^2	$0.55	2,000	$1,100
Overburden Excavation	m^3	$3.20	5,400	$17,280
Rock Excavation	m^3	$8.80	2,800	$24,640
Portal Excavation	m^3	$14.80	1,400	$20,720
Structural Concrete	m^3	$145.00	6,550	$949,750
Formwork	m^2	$46.50	13,750	$639,375
Steel Reinforcement	Ton	$1,320	295.0	$389,400
Steel Liner	Ton	$3,200	14.4	$46,080
Miscellaneous Metal Works	%	5%		$104,417
6.1.2 Equipment				
Wheeled Intake Gate (3.6 x 3.4) and Hoist	Each	$375,000	3	$1,125,000
Stoplogs	Each	$125,000	3	$375,000
Trash Screen Bays	Each	$312,500	3	$937,500
Trash Rake	Each	$106,250	2	$212,500
Emergency Diesel Generator (50 kW)	Each	$62,500	1	$62,500
Power and Control Equipment	LS	$50,000	1	$50,000
Cabling, MV & LV Power, Cont/Comm	LS	$37,500	1	$37,500
6.2 Shaft Tunnel and Manifold				
Portal Excavation	m^3	$14.80	1,940	$28,712
Shaft Excavation	m^3	$310.00	1,150	$356,500
Tunnel Excavation	m^3	$115.00	9,070	$1,043,050
Shotcrete	m^2	$46.00	3,740	$172,040
Rockbolts	l.m.	$67.00	1,420	$95,140
Steel Ribs	kg	$6.00	51,300	$307,800
Tunnel Concrete Lining	m^3	$165.00	3,300	$544,500
Shaft Concrete Lining	m^3	$180.00	350	$63,000
Formwork (shaft)	m^2	$46.50	730	$33,945
Steel Reinforcement (shaft)	Ton	$1,320	17.5	$23,100
Structural Concrete (manifold)	m^3	$145.00	730	$105,850
Formwork (manifold)	m^2	$46.50	1,095	$50,918
Steel Reinforcement (manifold)	Ton	$1,320	32.9	$43,428
Steel Liner and Manifold	Ton	$3,200	664.0	$2,124,800
Miscellaneous	%	5%		$249,639
6.3 Tailrace				
Overburden Excavation	m^3	$3.20	10,500	$33,600
Rock Excavation	m^3	$8.80	3,500	$30,800
6.4 Powerhouse				
6.4.1 Civil Work				
Overburden Excavation	m^3	$3.20	35,000	$112,000
Rock Excavation	m^3	$8.80	5,200	$45,760
Mass Concrete	m^3	$116.00	6,520	$756,320
Structural Concrete	m^3	$145.00	2,950	$427,750
Formwork	m^2	$46.50	18,200	$846,300
Steel Reinforcement	Ton	$1,320	315.0	$415,800
Roof, siding, windows, doors, etc	m^2	$310	1,040	$322,400
Miscellaneous	%	5%		$146,317

RIO COCLE DEL NORTE RESERVOIR ACTING IN FULL REGULATION WITH RIO INDIO RESERVOIR

RIO COCLE DEL NORTE STORAGE PROJECT

Description	Unit	Unit Cost	Quantity	Amount
6.4.2 Equipment				
Power Generating				
Main Inlet Valve (2.5 m dia)	Each	$437,500	3	$1,312,500
Turbine/Generator Unit (25 MW)	Each	$3,750,000	3	$11,250,000
25-MW Unit Auxiliaries	Each	$375,000	3	$1,125,000
Draft Tube Gates	Each	$70,000	6	$420,000
Tunnel Release				
Main Inlet Valves (1.5 m dia)	Each	$218,500	1	$218,500
Pressure Reducing Control Valves (1.5 r	Each	$437,500	1	$437,500
Draft Tube Gates	Each	$60,000	1	$60,000
Miscellaneous Mechanical				
Dewatering System	LS	$112,500	1	$112,500
Semi-Gantry Crane	LS	$470,000	1	$470,000
Miscellaneous Electrical				
Main Power Transformer -30 MVA	Each	$437,500	3	$1,312,500
Switchgear - 13.8 kV	LS	$125,000	1	$125,000
Station Service Transformer	Each	$50,000	1	$50,000
Stand-by Diesel Generator	Each	$250,000	1	$250,000
Station Auxiliaries (light, HVAC, etc.)	LS	$450,000	1	$450,000
Control and Communication Equip	LS	$375,000	1	$375,000
Cabling, MV & LV Power, Cont/Comm	LS	$1,000,000	1	$1,000,000
Subtotal 6				***$32,340,730***
7 TRANSMISSION SYSTEM				
7.1 Switchyard				
7.1.1 230-kV Equipment Bays	Each	$312,500	3	$937,500
7.1.2 Service Power Transformer - 5MV	Each	$112,500	1	$112,500
7.1.3 Protection, Control and Comm. Equip	LS	$562,500	1	$562,500
7.1.4 Cabling, MV & LV Power, Cont/Comm	LS	$875,000	1	$875,000
7.1.5 Control Building Auxiliaries	LS	$43,750	1	$43,750
7.1.6 Steel structures	LS	$600,000	1	$600,000
7.1.7 Civil Work	LS	$350,000	1	$350,000
7.2 La Chorrera Substation				
7.2.1 230-kV Equipment Bays	Each	$312,500	1	$312,500
7.2.2 Protection, Control and Comm. Equip	LS	$125,000	1	$125,000
7.2.3 Cabling, MV & LV Power, Cont/Comm	LS	$100,000	1	$100,000
7.3 230-kV Transmission Line				
7.3.1 Civil Works (survey, Found., Struc.)	km	$62,500	109	$6,812,500
7.3.2 Conductors and Shield Wire	km	$62,500	109	$6,812,500
7.3.3 Insulators and Accessories	km	$31,250	109	$3,406,250
7.3.4 Grounding and Miscellaneous	%	4.00%		$681,250
Subtotal 7				***$21,731,250***
8 OPERATION FACILITIES				
8.1 Diesel Generators	Each	$35,000	2	$70,000
8.2 SCADA	LS	$200,000	1	$200,000
8.3 Communication	LS	$100,000	1	$100,000
8.4 Security and Lighting	LS	$126,000	1	$126,000
8.5 Landscaping and Drainage	LS	$150,000	1	$150,000
8.6 Instrumentation	LS	$500,000	1	$500,000
Subtotal 8				***$1,146,000***
Subtotal Direct Cost (rounded)				**$132,570,000**
Contingency				**$21,200,000**
Direct Cost				**$153,770,000**

RIO COCLE DEL NORTE RESERVOIR ACTING IN FULL REGULATION WITH RIO INDIO RESERVOIR

WATER TRANSFER TUNNEL

Description	Unit	Unit Cost	Quantity	Amount
1 GENERAL				
1.1 Mobilization and Demobilization	LS	$1,500,000	1	$1,500,000
1.2 Temporary Access Roads	km	$115,200	5	$576,000
1.3 Construction Camps	Each	$850,000	2	$1,700,000
1.4 Temporary Facilities Maintenance	mth	$5,000	60	$300,000
Subtotal 1				***$4,076,000***
2 INTAKE/OUTLET AND EQUIPMENT				
2.1 Site Preparation	m^2	$0.55	200,000	$110,000
2.2 Intake Portal				
2.2.1 Overburden	m^3	$3.20	244,200	$781,440
2.2.2 Rock	m^3	$8.80	123,600	$1,087,680
2.2.3 Shotcrete	m^2	$46.00	3,080	$141,680
2.2.4 Rockbolts	l.m.	$59.50	1,540	$91,630
2.2.5 Concrete	m^3	$116.00	1,460	$169,360
2.2.6 Formwork	m^2	$46.50	760	$35,340
2.2.7 Reinforcement	kg	$1.32	66,100	$87,252
2.3 Intake Tunnel (D&B)				
2.3.1 Rock Excavation	m^3	$125.00	17,000	$2,125,000
2.3.2 Shotcrete	m^2	$46.00	3,150	$144,900
2.3.3 Rockbolts	l.m.	$67.50	1,500	$101,250
2.3.4 Steel Ribs	kg	$6.00	22,600	$135,600
2.3.5 Concrete	m^3	$113.00	4,050	$457,650
2.3.6 Formwork	m^2	$46.50	4,400	$204,600
2.3.7 Reinforcement	kg	$1.32	158,000	$208,560
2.4 Intake Shaft				
2.4.1 Shaft Excavation	m^3	$295.00	2,380	$702,100
2.4.2 Shotcrete	m^2	$46.00	860	$39,560
2.4.3 Rockbolts	l.m.	$59.50	850	$50,575
2.4.4 Concrete	m^3	$180.00	1,020	$183,600
2.4.5 Formwork	m^2	$46.50	1,090	$50,685
2.4.6 Reinforcement	kg	$1.32	51,400	$67,848
2.5 Outlet Shaft				
2.5.1 Overburden	m^3	$3.20	13,000	$41,600
2.5.2 Rock	m^3	$8.80	26,000	$228,800
2.5.3 Shaft Excavation	m^3	$295.00	6,720	$1,982,400
2.5.4 Shotcrete	m^2	$46.00	3,560	$163,760
2.5.5 Rockbolts	l.m.	$59.50	2,750	$163,625
2.5.6 Concrete	m^3	$180.00	3,000	$540,000
2.5.7 Formwork	m^2	$46.50	2,750	$127,875
2.5.8 Reinforcement	kg	$1.32	166,300	$219,516

RIO COCLE DEL NORTE RESERVOIR ACTING IN FULL REGULATION WITH RIO INDIO RESERVOIR

WATER TRANSFER TUNNEL

2.6 Hydromechanical Equipment				
2.6.1 Trashracks and Embeds	kg	$4.40	32,000	$140,800
2.6.2 U/S Gate (4.0 x 8.0 m)	Each	$450,000	2	$900,000
2.6.3 U/S Operator	Each	$125,000	2	$250,000
2.6.4 U/S Surface Structure	LS	$100,000	1	$100,000
2.6.5 U/S Power and Controls	LS	$100,000	1	$100,000
2.6.6 US Trashrake	LS	$100,000	1	$100,000
2.6.7 D/S Control Gates (4.0 x 7.0 m)	Each	$1,100,000	4	$4,400,000
2.6.8 D/S Operator	Each	$250,000	4	$1,000,000
2.6.9 D/S Surface Structure	LS	$100,000	1	$100,000
2.6.10 D/S Power and Controls	LS	$100,000	1	$100,000
2.6.11 Miscellaneous	LS	5%		$360,000
Subtotal 2				***$17,994,686***
3 TUNNEL				
3.1 Site Preparation	m^2	$0.55	20,000	$11,000
3.2 TBM Set-up	LS	$150,000	1	$150,000
3.3 TBM Adit Portal				
3.3.1 Overburden Excavation	m^3	$3.20	18,200	$58,240
3.3.2 Rock Excavation	m^3	$8.80	36,400	$320,320
3.3.3 Shotcrete	m^2	$46.00	1960	$90,160
3.3.4 Rockbolts	l.m.	$59.50	980	$58,310
3.3.5 Concrete	m^3	$116.00	400	$46,400
3.3.6 Formwork	m^2	$46.50	200	$9,300
3.3.7 Reinforcement	kg	$1.32	15,700	$20,724
3.4 Main Tunnel				
3.4.1 TBM Operation	l.m.	$6,300	15,830	$99,729,000
3.4.2 Lining	l.m.	$2,180	15,830	$34,509,400
3.4.3 Disposal	m^3	$2.10	1,911,000	$4,013,100
3.5 TBM Tunnel Adit Plug				
3.5.1 Concrete	m^3	$116.00	1,215	$140,940
3.5.2 Formwork	m^2	$46.50	162	$7,533
3.5.3 Reinforcement	kg	$1.32	23,814	$31,434
Subtotal 3				***$139,195,861***
4 LAKE TAP				
4.1 Tunnel				
4.1.1 Rock Excavation	m^3	$125.00	66,100	$8,262,500
4.1.2 Shotcrete	m^2	$46.00	12,260	$563,960
4.1.3 Rockbolts	l.m.	$67.50	5,730	$386,775
4.1.4 Steel Ribs	kg	$6.00	88,200	$529,200
4.1.5 Concrete	m^3	$112.00	15,760	$1,765,120
4.1.6 Formwork	m^2	$46.00	17,100	$786,600
4.1.7 Reinforcement	kg	$1.32	615,000	$811,800
4.2 Lake Tap				
4.2.1 Underground Excavation	LS	$1,655,000	1	$1,655,000
4.2.2 Dredging	LS	$400,000	1	$400,000
Subtotal 4				***$15,160,955***
Subtotal Direct Cost (rounded)				**$176,430,000**
Contingency				**$37,530,000**
Direct Cost				**$213,960,000**

RIO COCLE DEL NORTE RESERVOIR ACTING IN FULL REGULATION WITH RIO INDIO RESERVOIR

SECOND RIO INDIO TO LAKE GATUN TRANSFER TUNNEL

Description	Unit	Unit Cost	Quantity	Amount
1 GENERAL				
1.1 Mobilization and Demobilization	LS	$1,500,000	1	$1,500,000
1.2 Temporary Access Roads	km	$115,200	3	$345,600
1.3 Temporary Facilities Maintenance	mth	$5,000	36	$180,000
1.4 Access Roads Maintenance	mth	$2,500	36	$90,000
Subtotal 1				***$2,115,600***
2 COFFERDAM				
2.1 Sheetpiles	kg	$2.50	2,275,000	$5,687,500
2.2 Fill material	m^3	$7.30	46,000	$335,800
2.3 Clearing	LS	$50,000	1	$50,000
2.4 Care of water	LS	$500,000	1	$500,000
Subtotal 2				***$6,573,300***
3 ACCESS ADIT REHABILITATION (2)				
3.1 Clearing	m^3	$3.20	24,500	$78,400
3.2 Tunnel Excavation	m^3	$91.00	1,850	$168,350
3.3 Shotcrete	m^2	$46.00	7,200	$331,200
3.4 Rockbolts	l.m.	$67.50	1,500	$101,250
3.5 Miscellaneous	LS	10%	1	$67,920
Subtotal 3				***$747,120***
4 TUNNEL INTAKE PORTAL & CHANNEL				
4.1 Overburden Excavation	m^3	$3.20	27,560	$88,192
4.2 Rock Excavation	m^3	$8.80	305,189	$2,685,663
4.3 Shotcrete	m^2	$46.00	3,833	$176,318
4.4 Rockbolts	l.m.	$59.50	1,917	$114,062
4.5 Concrete	m^3	$116.00	426	$49,416
4.6 Formwork	m^2	$46.50	282	$13,113
4.7 Reinforcement	kg	$1.32	16,560	$21,859
Subtotal 4				***$3,148,623***
5 TUNNEL				
5.1 Rock Excavation	m^3	$95.00	384,300	$36,508,500
5.2 Shotcrete	m^2	$46.00	90,770	$4,175,420
5.3 Rockbolts	l.m.	$67.50	42,070	$2,839,725
5.4 Steel Ribs	kg	$6.00	357,900	$2,147,400
5.5 Concrete	m^3	$110.00	95,975	$10,557,250
5.6 Formwork	m^2	$10.00	142,872	$1,428,720
5.7 Reinforcement	kg	$1.32	3,574,109	$4,717,824
Subtotal 5				***$62,374,839***
6 INTAKE STRUCTURE				
6.1 Concrete	m^3	$116.00	1,598	$185,368
6.2 Formwork	m^2	$46.50	1,837	$85,421
6.3 Reinforcement	kg	$1.32	123,291	$162,744
Subtotal 6				***$433,533***
7 INTAKE GATE SHAFT				
7.1 Shaft Excavation	m^3	$295.00	4,181	$1,233,395
7.2 Shotcrete	m^2	$46.00	1,521	$69,966
7.3 Rockbolts	l.m.	$67.50	1,496	$100,980
7.4 Concrete	m^3	$145.00	3,052	$442,540
7.5 Formwork	m^2	$46.50	2,772	$128,898
7.6 Reinforcement	kg	$1.32	259,752	$342,873
Subtotal 7				***$2,318,652***

RIO COCLE DEL NORTE RESERVOIR ACTING IN FULL REGULATION WITH RIO INDIO RESERVOIR

SECOND RIO INDIO TO LAKE GATUN TRANSFER TUNNEL

Description	Unit	Unit Cost	Quantity	Amount
8 OUTLET STRUCTURE				
8.1 Concrete	m^3	$145.00	4,481	$649,745
8.2 Formwork	m^2	$46.50	2,734	$127,131
8.3 Reinforcement	kg	$1.32	331,458	$437,525
8.4 Steel Lining	LS	$64,000	1	$64,000
8.5 Anchors	l.m.	$59.50	1,020	$60,690
Subtotal 8				***$1,339,091***
9 TUNNEL OUTLET PORTAL & CHANNEL				
9.1 Overburden Excavation	m^3	$3.20	39,427	$126,166
9.2 Rock Excavation	m^3	$8.80	198,360	$1,745,568
9.3 Shotcrete	m^2	$46.00	8,488	$390,448
9.4 Rockbolts	l.m.	$59.50	4,244	$252,518
9.5 Concrete	m^3	$116.00	426	$49,416
9.6 Formwork	m^2	$46.50	282	$13,113
9.7 Reinforcement	kg	$1.32	16,560	$21,859
Subtotal 9				***$2,599,089***
10 HYDROMECHANICAL EQUIPMENT				
10.1 Trashracks and Embeds	kg	$4.50	40,000	$180,000
10.2 U/S Bulkhead	Each	$145,000	2	$290,000
10.3 U/S Operator	Each	$50,000	2	$100,000
10.4 U/S Surface Stucture	LS	$50,000	1	$50,000
10.5 U/S Power and Controls	LS	$50,000	1	$50,000
10.6 D/S Control Gates (3.5 x 5.4 m, bonneted)	Each	$700,000	4	$2,800,000
10.7 D/S Operator	Each	$150,000	4	$600,000
10.8 D/S Surface Stucture	LS	$50,000	1	$50,000
10.9 D/S Power and Controls	LS	$100,000	1	$100,000
Subtotal 10				***$4,220,000***
Subtotal Direct Cost (rounded)				**$85,870,000**
Contingency				**$19,430,000**
Direct Cost				**$105,300,000**

RIO COCLE DEL NORTE RESERVOIR ACTING IN FULL REGULATION WITH RIO INDIO RESERVOIR

RESERVOIR CLEARING

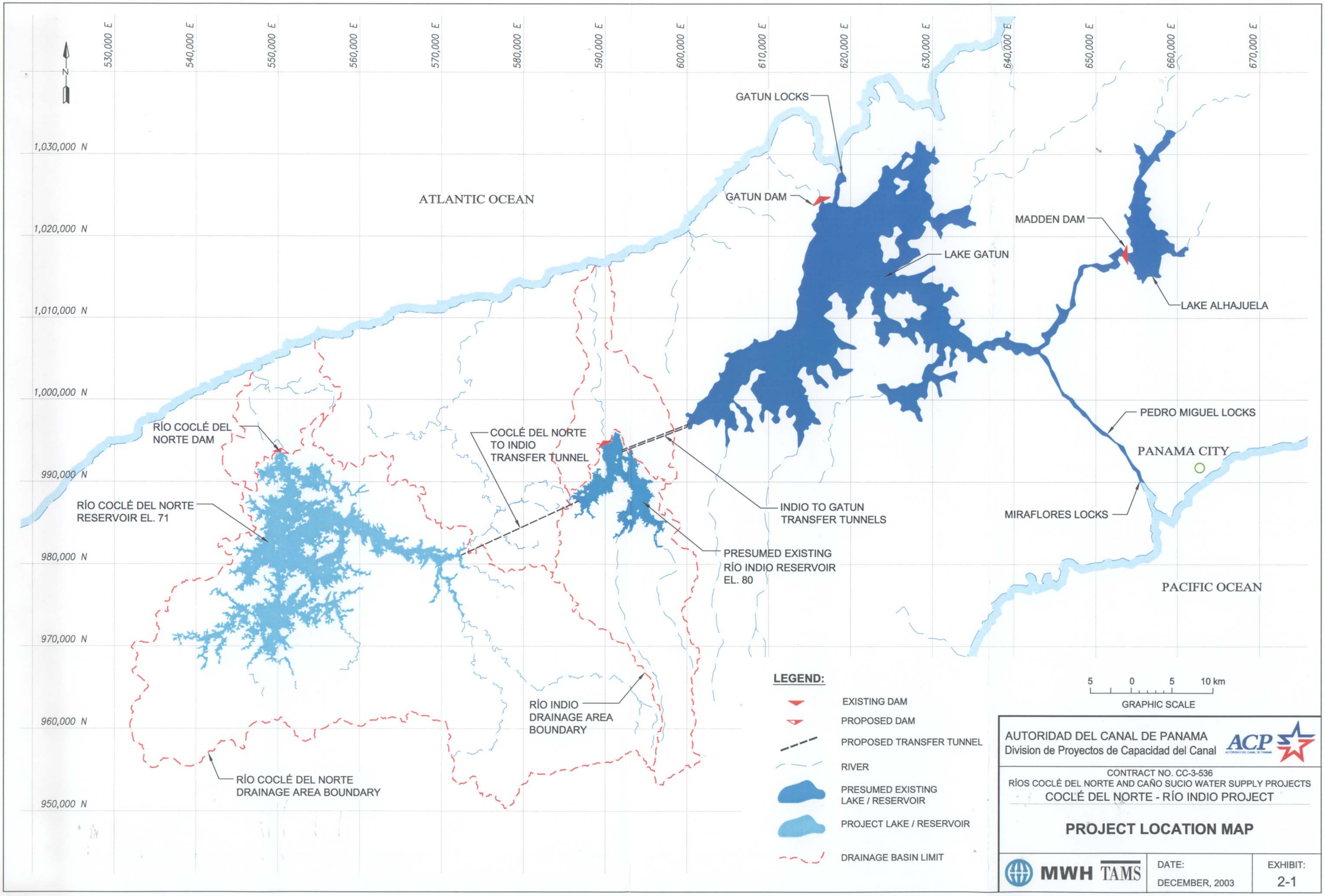
Description	Unit	Unit Cost	Quantity	Amount
1 RESERVOIR CLEARING				
1.1 Cocle del Norte Reservoir	ha	$2,200	10,000	$22,000,000
Subtotal Direct Cost (rounded)				**$22,000,000**
Contingency				**$3,300,000**
Direct Cost				**$25,300,000**

Exhibits

EXHIBITS

No.	Title
2-1	Project Location Map
2-2	Regional Isohyetal Map
2-3	Río Coclé del Norte Basin Drainage Configuration
2-4	Regional Geologic Map
2-5	Map of Faults and Folds in Panama
2-6	Plate Boundaries
3-1	General Plan of the Project
3-2	Río Coclé del Norte Project, Site Plan
3-3	Río Coclé del Norte to Río Indio Water Transfer Tunnel Alignment
3-4	Second Río Indio Reservoir to Lake Gatun Tunnel Alignment
4-1	Río Coclé del Norte, PMF Inflow and Outflow Hydrographs
4-2	Seismicity of Panama
4-3	Río Coclé del Norte, Construction Material Sources
4-4	Río Coclé del Norte Reservoir, Area and Volume Vs. Elevation
5-1	Río Coclé del Norte Dam, Typical Cross Section and Details
5-2	Río Coclé del Norte Spillway – Plan, Profile, and Details
5-3	Río Coclé del Norte Spillway – Sections and Elevation
5-4	Río Coclé del Norte River Diversion Facilities, Plan Profile and Sections
5-5	Río Coclé del Norte Emergency Drawdown Facilities, Details
5-6	Río Coclé del Norte to Río Indio Water Transfer Tunnel - Plan and Details
5-7	Río Coclé del Norte to Río Indio Water Transfer Tunnel - Profile
5-8	Río Coclé del Norte to Río Indio Water Transfer Tunnel - Intake Structure and Access Shaft
5-9	Río Coclé del Norte to Río Indio Water Transfer Tunnel - Downstream Access Shaft and Outlet Works
5-10	Second Río Indio Reservoir to Lake Gatun Tunnel Alignment
5-11	Second Río Indio to Lake Gatun Tunnel – Plan and Profile (three sheets)
5-12	Second Río Indio to Lake Gatun Tunnel – Intake Structure and Access Shaft
5-13	Second Río Indio to Lake Gatun Tunnel – Outlet Structure Profile and Section

EXHIBITS, cont.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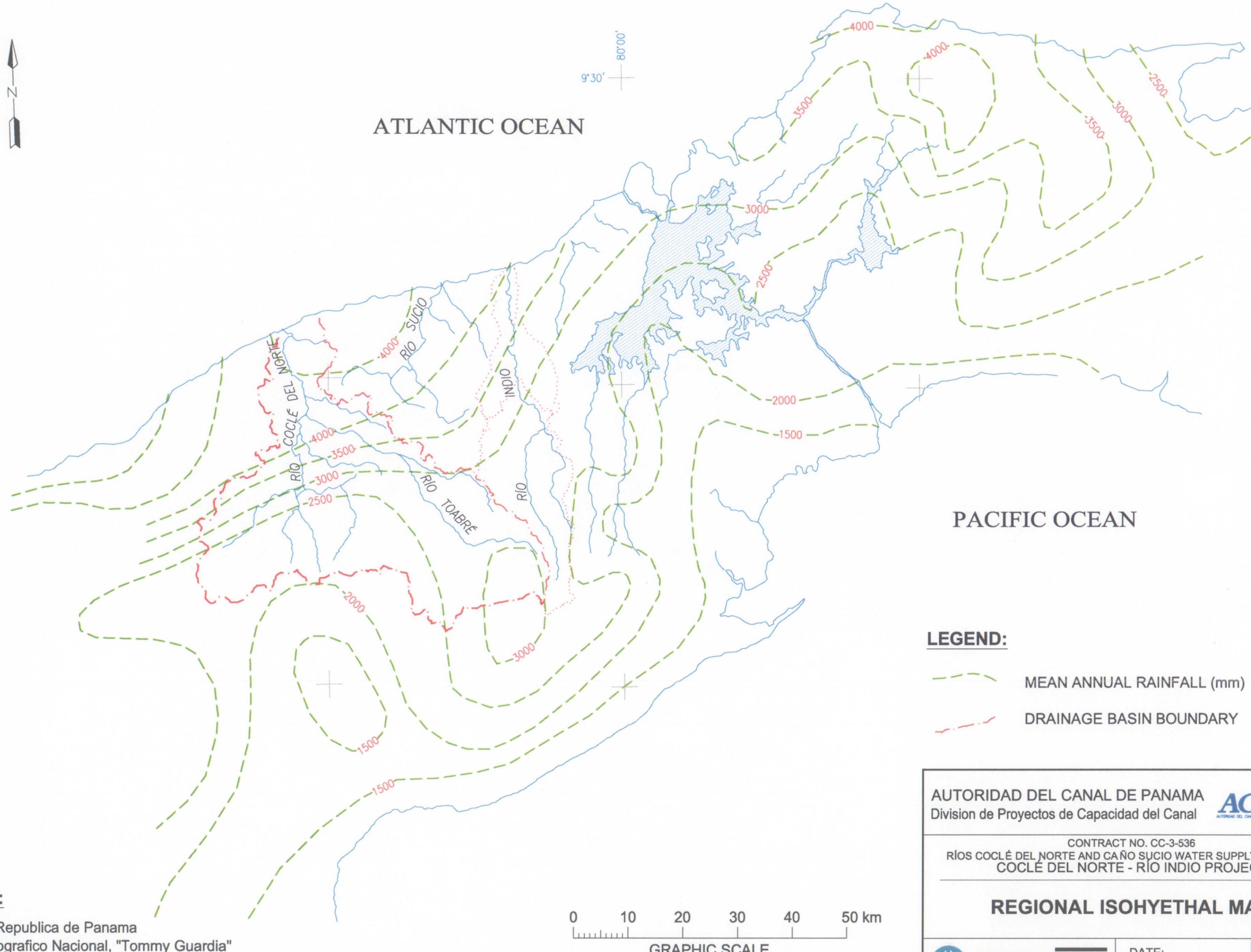
PACIFIC OCEAN
PANAMA CITY
GATUN LOCKS
GATUN DAM
MADDEN DAM
LAKE GATUN
LAKE ALHAJUELA
PEDRO MIGUEL LOCKS
MIRAFLORES LOCKS
RÍO COCLÉ DEL NORTE DAM
COCLÉ DEL NORTE TO INDIO TRANSFER TUNNEL
INDIO TO GATUN TRANSFER TUNNELS
RÍO COCLÉ DEL NORTE RESERVOIR EL. 71
PRESUMED EXISTING RÍO INDIO RESERVOIR EL. 80
RÍO INDIO DRAINAGE AREA BOUNDARY
RÍO COCLÉ DEL NORTE DRAINAGE AREA BOUNDARY
LEGEND:
EXISTING DAM
PROPOSED DAM
PROPOSED TRANSFER TUNNEL
RIVER
PRESUMED EXISTING LAKE / RESERVOIR
PROJECT LAKE / RESERVOIR
DRAINAGE BASIN LIMIT
5 0 5 10 km
GRAPHIC SCALE
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal
ACP
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT
PROJECT LOCATION MAP
MWH TAMS
DATE:
DECEMBER, 2003
EXHIBIT:
2-1



SOURCE:

Atlas de la Republica de Panama
Instituto Geografico Nacional, "Tommy Guardia"

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

REGIONAL ISOHYETHAL MAP

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 2-2

LEGEND:

- PRESUMED EXISTING DAM SITE
- PROPOSED DAM SITE

0 5 10 15 20 25 km

GRAPHIC SCALE

SOURCE:

IRHE, Departamento De Hidrometeorologia

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

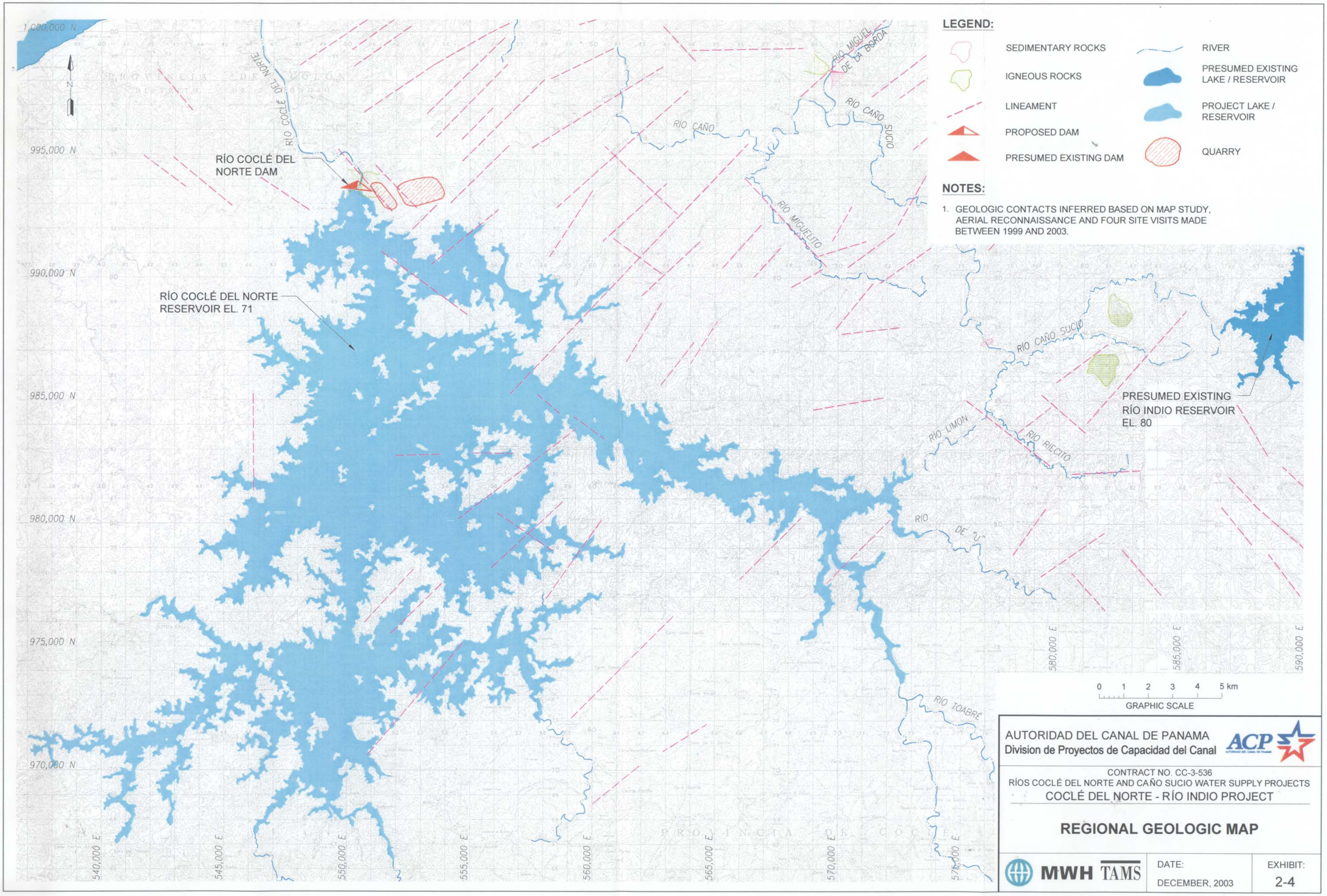
ACP

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

RÍO COCLÉ DEL NORTE
BASIN DRAINAGE CONFIGURATION

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	2-3


LEGEND:
SEDIMENTARY ROCKS
IGNEOUS ROCKS
LINEAMENT
PROPOSED DAM
PRESUMED EXISTING DAM
RIVER
PRESUMED EXISTING LAKE / RESERVOIR
PROJECT LAKE / RESERVOIR
QUARRY
NOTES:
1. GEOLOGIC CONTACTS INFERRED BASED ON MAP STUDY, AERIAL RECONNAISSANCE AND FOUR SITE VISITS MADE BETWEEN 1999 AND 2003.
RÍO COCLÉ DEL NORTE DAM
RÍO COCLÉ DEL NORTE RESERVOIR EL. 71
PRESUMED EXISTING RÍO INDIO RESERVOIR EL. 80
RIO COCLE DEL NORTE
RIO MIGUEL DE LA BORDA
RIO CAÑO SUCIO
RIO CAÑO
RIO MIGUELITO
RIO CAÑO SUCIO
RIO LIMON
RIO RIECITO
RIO DE "U"
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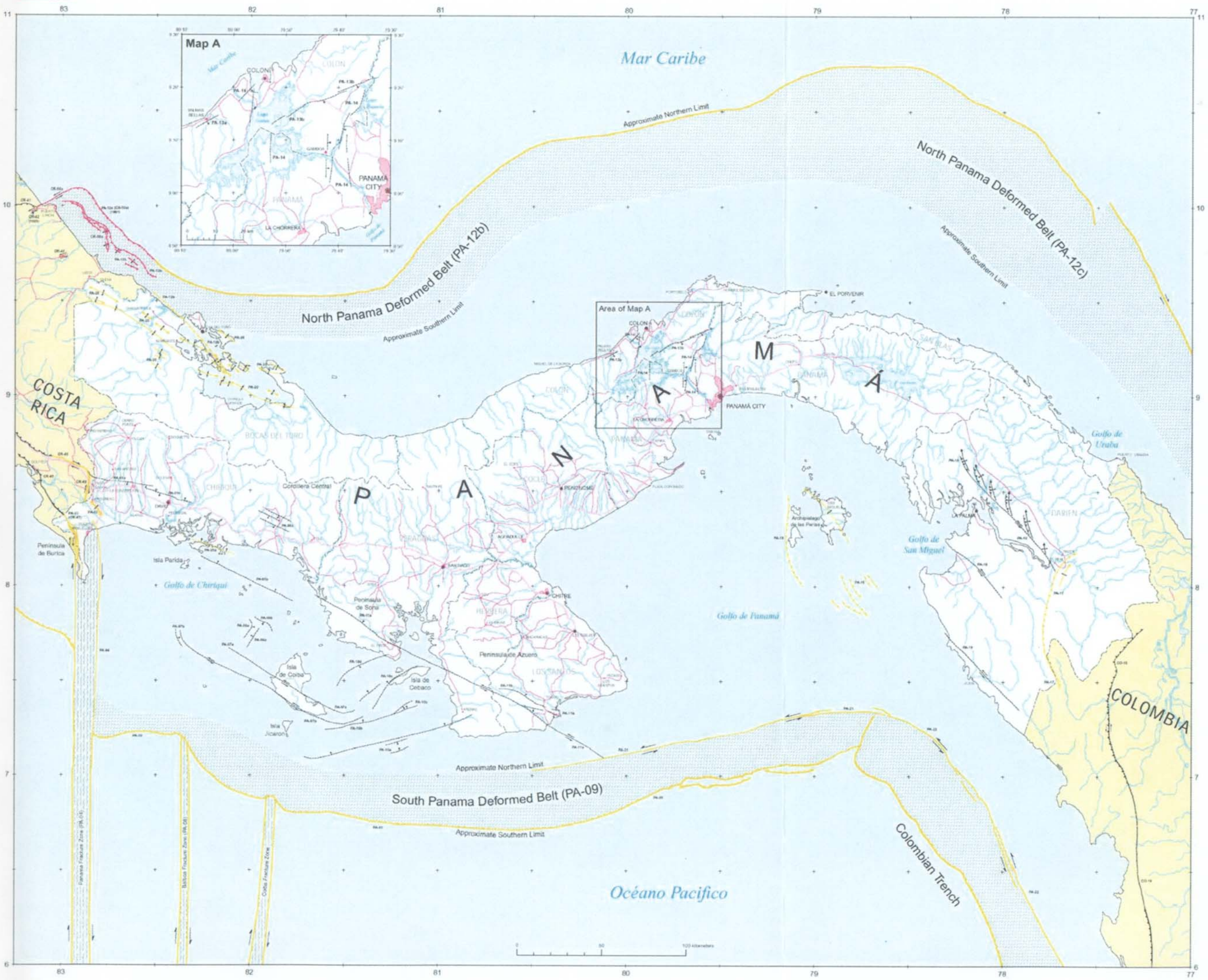
GRAPHIC SCALE
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal
ACP
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT
REGIONAL GEOLOGIC MAP
MWH TAMS
DATE:
DECEMBER, 2003
EXHIBIT:
2-4

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY



Map of Quaternary Faults and Folds of Panama and Its Offshore Regions

Scale 1:750,000 Mercator Projection
(longitude of central meridian, 80 W; latitude of true scale 0; Clarke 1886 spheroid)

A project of International Lithosphere Program Task Group II-2, Major Active Faults of the World

A cooperative project between the U.S. Geological Survey, the Institute of Geosciences of the University of Panama, the Swedish Agency for Research Cooperation with Developing Countries (SAREC), and NORSAR, Norway
1998

QUATERNARY FAULTS AND FOLDS OF PANAMA AND ITS OFFSHORE REGIONS

Number	Name of Structure	* Primary topographic map sheet (number, see map below)	Time of most recent faulting	Slip rate (mm/yr)
PA-01	Longitudinal fault zone			
PA-01A	Unnamed section	David (2)	Probably < 1.6 m.y.	Probably < 1
PA-01B	Unnamed section	David (2)	Probably < 1.6 m.y.	Probably < 1
PA-02	Madre Vieja Anticline	David (2)	Probably historic (1934) < 15 k.y.	Probably > 1 (uplift rate)
PA-03	Medial fault zone	David (2)	Probably < 15 k.y.	Probably > 10
PA-04	Panama fracture zone	Isla de Coiba (3) and offshore	Historic (1934) < 15 k.y. for zone	Probably > 50
PA-05	Unnamed series of faults			
PA-05A	Unnamed section	David (2)	Probably < 15 k.y.	Unknown
PA-05B	Unnamed section	David (2)	Probably < 1.6 m.y.	Unknown
PA-05C	Unnamed section	David (2)	Probably < 1.6 m.y.	Unknown
PA-06	Unnamed faults			
PA-06A	Unnamed section	Isla de Coiba (3)	< 1.6 m.y.	Unknown
PA-06B	Unnamed section	Isla de Coiba (3)	< 1.6 m.y.	Unknown
PA-06C	Unnamed section	Isla de Coiba (3)	< 1.6 m.y.	Unknown
PA-07	Central and South Coiba fault zones			
PA-07A	Central Coiba fault zone	Isla de Coiba (3)	Probably < 1.6 m.y.	Unknown
PA-07B	South Coiba fault zone	Isla de Coiba (3)	Probably < 1.6 m.y.	Unknown
PA-08	Balboa fracture zone	Isla de Coiba (3) and offshore	< 15 k.y. for entire zone	Probably > 5
PA-09	South Panama deformed belt	Isla de Coiba (3) and offshore	Probably < 15 k.y. for entire belt	Probably 1-5
PA-10	Unnamed fault system			
PA-10A	Rio Flores fault zone	Chitre (6)	< 1.6 m.y.	Unknown
PA-10B	Unnamed fault	Chitre (6)	< 1.6 m.y.	Unknown
PA-10C	Unnamed fault	Chitre (6)	< 1.6 m.y.	Unknown
PA-10D	Unnamed fault	Chitre (6)	< 1.6 m.y.	Unknown
PA-11	Azuero-Sona fault zone			
PA-11A	Azuero-Sona fault	Chitre (6)	Probably < 1.6 m.y.	Unknown
PA-11B	Unnamed fault	Chitre (6)	< 1.6 m.y.	Unknown
PA-12	North Panama deformed belt			
PA-12A	Limon fault	Bocas del Toro (1)	Historic (1991)	Unknown
PA-12B	Western section	Bocas del Toro (1) Donoso (4) and offshore	< 15 k.y.	Unknown
PA-12C	Eastern section	Ustupo (10) and offshore	Historic (1882) < 15 k.y. for section	Probably 1-5
PA-13	Unnamed fault system			
PA-13A	Unnamed fault S. of Palmas Bellas	Donoso (4)	Probably < 1.6 m.y.	Unknown
PA-13B	Rio Gatun fault	Panama Norte (7)	Probably < 1.6 m.y.	Probably < 1
PA-14	Unnamed fault system	Panama Norte (7)	Probably < 1.6 m.y.	Unknown
PA-15	Unnamed faults of the East Panama deformed belt	Panama Sur (8) and offshore	Probably < 15 k.y. for entire belt	Unknown
PA-16	Sanson Hills fault zone	La Palma (11)	Probably < 1.6 m.y.	Unknown
PA-17	Pirre Hills fault zone	Jaque (12)	Possibly historic (1974) < 15 k.y. for zone	Unknown
PA-18	Sambu fault zone	La Palma (11)	Probably < 1.6 m.y.	Unknown
PA-19	Jaque River fault zone	Jaque (12)	Probably < 1.6 m.y.	Unknown
PA-20	Unnamed series of folds	Bocas del Toro (1)	Historic (1991) < 15 k.y. for series	Unknown
PA-21	Southern Panama fault zone	Offshore	Probably historic < 15 k.y. for zone	Probably > 5
PA-22	Colombian accretionary complex (deformation zone)	Offshore	Probably historic < 15 k.y. for zone	>5

* From special series of 12 topographic maps at 1:250,000 scale, entitled "Mapa General de la Republica de Panama" (edition 10) by the Instituto Geografico Nacional "Tommy Guardia" (IGNTG), Ministerio de Obras Publicas, Panama

MAP EXPLANATION

TIME OF MOST RECENT SURFACE RUPTURE

Historic
Holocene (<10,000 yrs) or post glacial (<15,000 yrs)
Quaternary, undifferentiated (< 1,600,000 yrs)

SLIP RATE

> 5 mm/yr
1-5 mm/yr
< 1 mm/yr

QUALITY

Continuous at map scale
Poor or discontinuous at map scale
Inferred or concealed

STRUCTURE TYPE

Trust or reverse fault (teeth on upper block)
Right-lateral (dextral) strike-slip fault
Right-lateral (sinistral) strike-slip fault
Normal fault
Anticline
Syncline
Plunge direction

PATTERNS

Broad deformed belts
Broad fracture zones

REFERENCE: USGS OFR 98-0779

AUTORIDAD DEL CANAL DE PANAMA
División de Proyectos de Capacidad del Canal

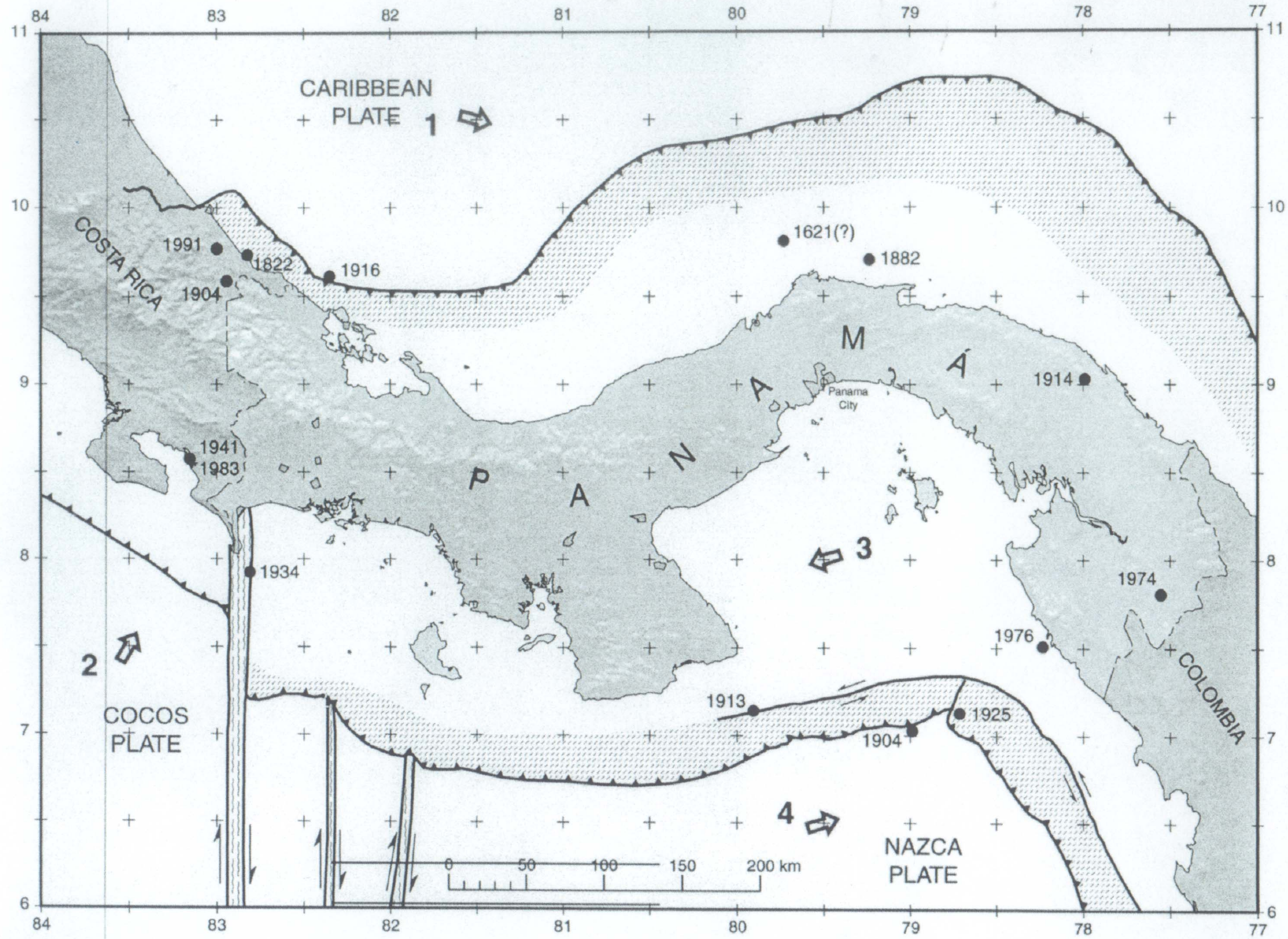
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

MAP OF FAULTS AND FOLDS IN PANAMA

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 2-5



RELATIVE PLATE MOTION

No.	Location	Fixed	Moving	Velocity	Direction
1	81.5 W/10.5 N	South America	Caribbean	1.40 cm	105.64
2	83.5 W/7.5 N	Caribbean	Cocos	9.40 cm	29.94
3	79.5 W/8.0 N	Nazca	Panama	5.09 cm	252.60
4	79.0 W/6.5 N	Panama	Nazca	5.19 cm	72.64

Source: Kensaku Tamaki, Ocean Research Institute, University of Tokyo
1-15-1 Minamidai, Nakano-ku, Tokyo, 164, Japan (tamaki@ori.u-tokyo.ac.jp)

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

ACP

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

PLATE BOUNDARIES

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 2-6

LEGEND:

- 230 kV TRANSMISSION LINE
- PRESUMED EXISTING TRANSFER TUNNEL
- PROPOSED TRANSFER TUNNEL
- PROPOSED DAM
- PRESUMED EXISTING DAM
- PRESUMED EXISTING LAKE/ RESERVOIR
- PROPOSED RESERVOIR

5 0 5 10 km
GRAPHIC SCALE

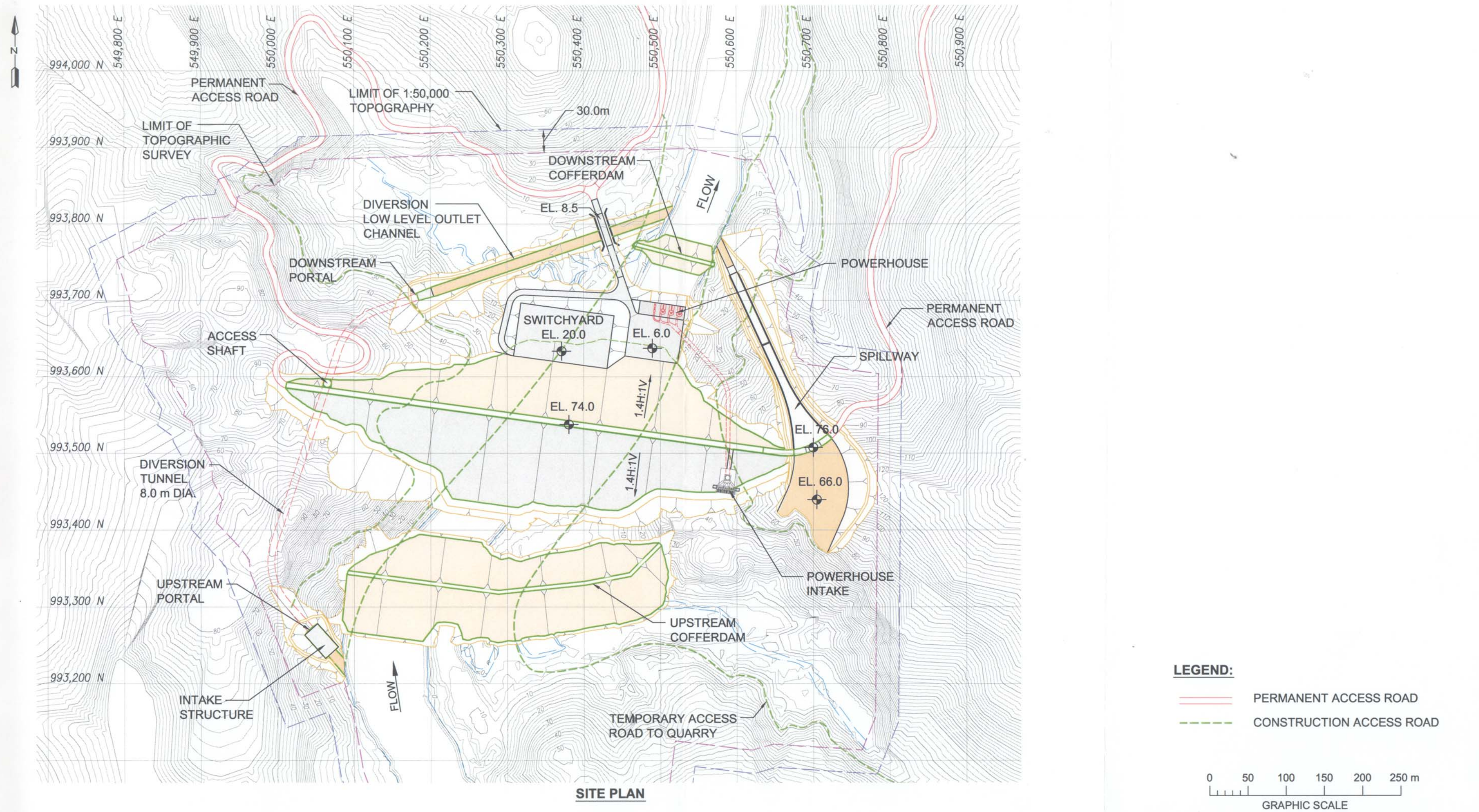
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

GENERAL PLAN OF THE PROJECT

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	3-1



SITE PLAN

UPSTREAM DAM ELEVATION

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

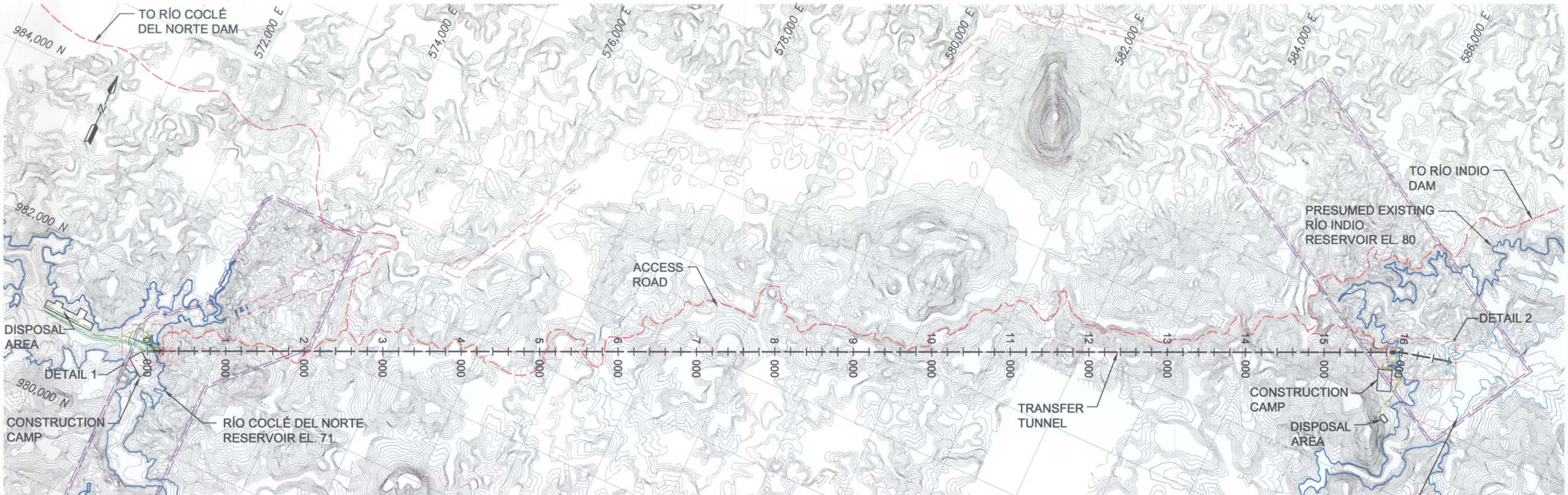
ACP

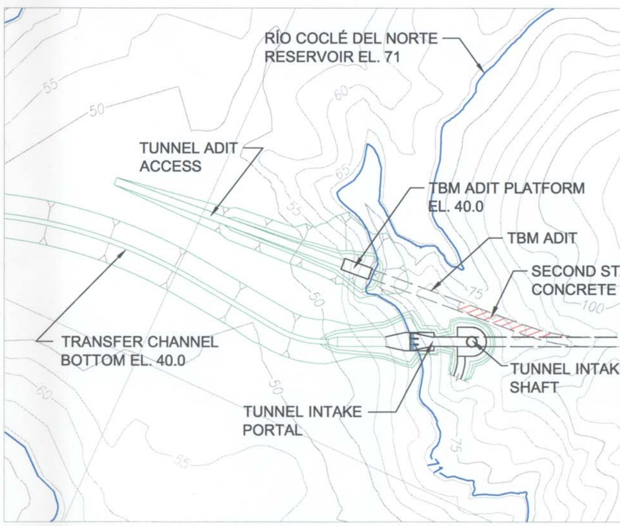
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

RÍO COCLÉ DEL NORTE PROJECT
SITE PLAN

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	3-2





DETAIL 1
TRANSFER TUNNEL INTAKE AND TBM ADIT

0 50 100 m
GRAPHIC SCALE

PRESUMED EXISTING RÍO INDIO RESERVOIR EL. 80

DETAIL 2
TRANSFER TUNNEL OUTLET

0 50 100 m
GRAPHIC SCALE

NOTE:

TOPOGRAPHY COMPILED FROM THE FOLLOWING SOURCES:

1. GROUND SURVEY (IASA, 2003)
2. AERIAL PHOTOGRAPHY (GEOCART - GRAFOS, 2002)
3. PUBLISHED 1:50,000 TOPOGRAPHIC MAPS (TOMMY GUARDIA)

0 0.5 1.0 1.5 2.0 2.5 km
GRAPHIC SCALE

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

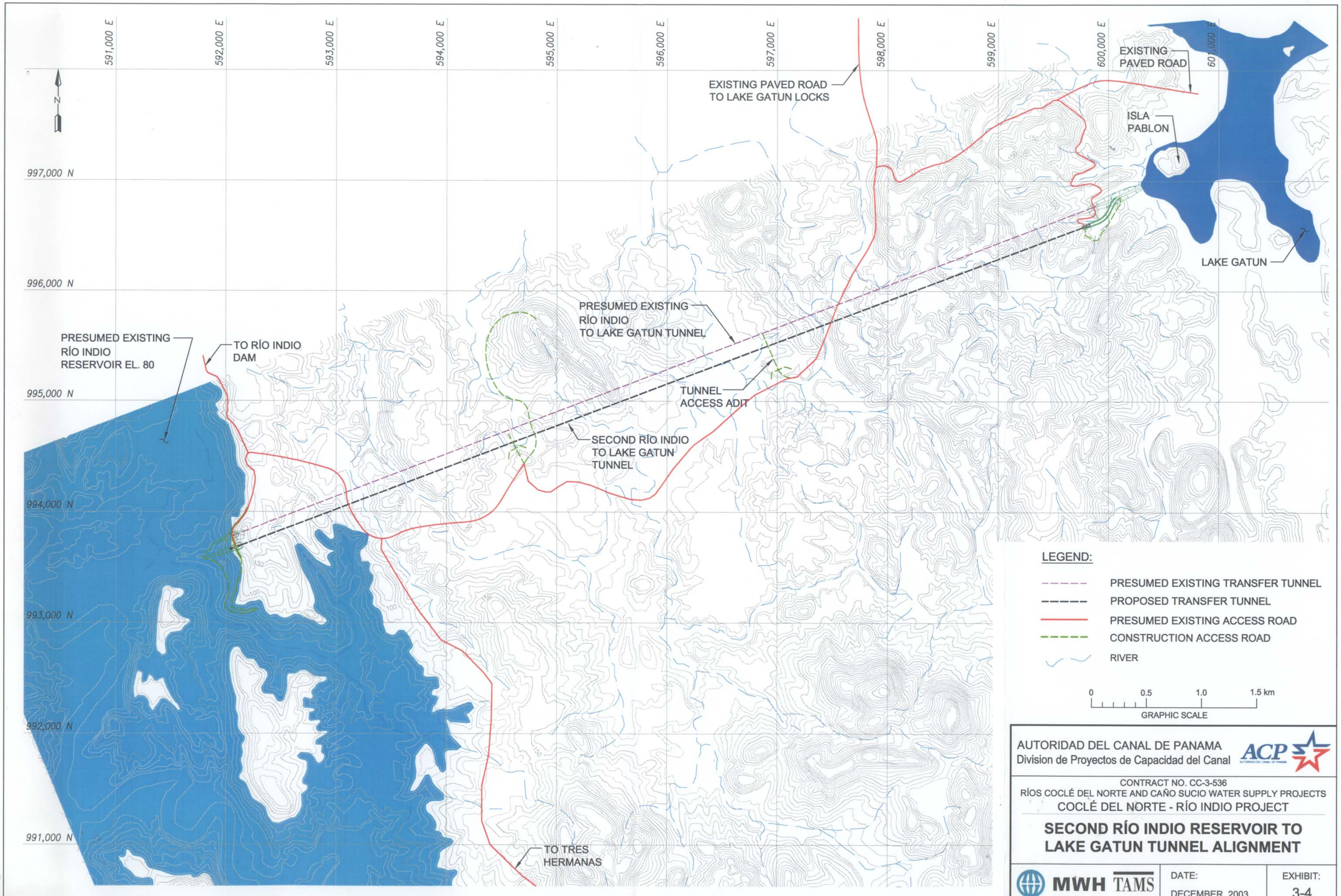
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

RÍO COCLÉ DEL NORTE TO RÍO INDIO WATER TRANSFER TUNNEL PLAN AND DETAILS

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 3-3



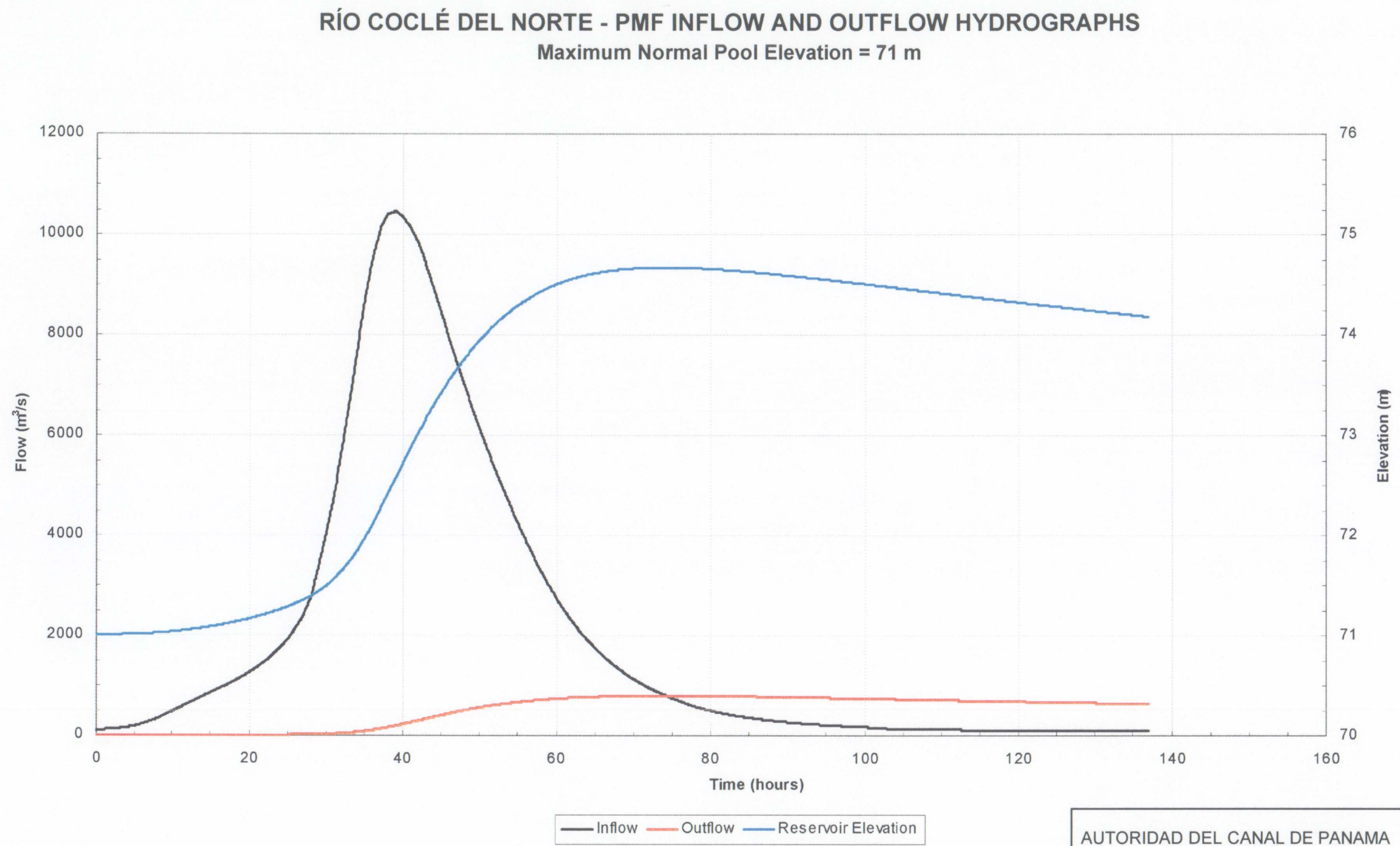
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

SECOND RÍO INDIO RESERVOIR TO LAKE GATUN TUNNEL ALIGNMENT

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	3-4



AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

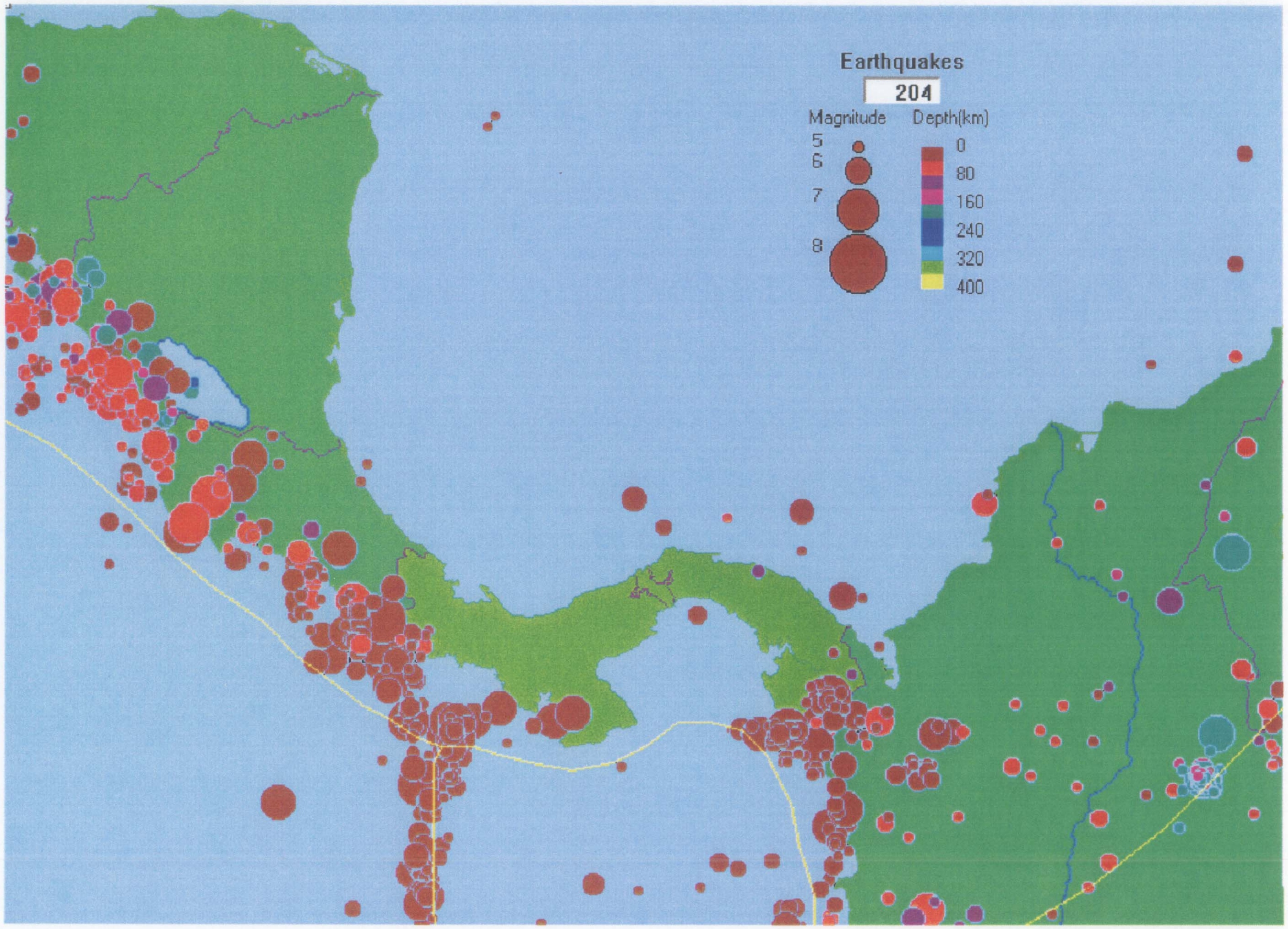
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

RÍO COCLÉ DEL NORTE - PMF INFLOW AND OUTFLOW HYDROGRAPHS

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 4-1



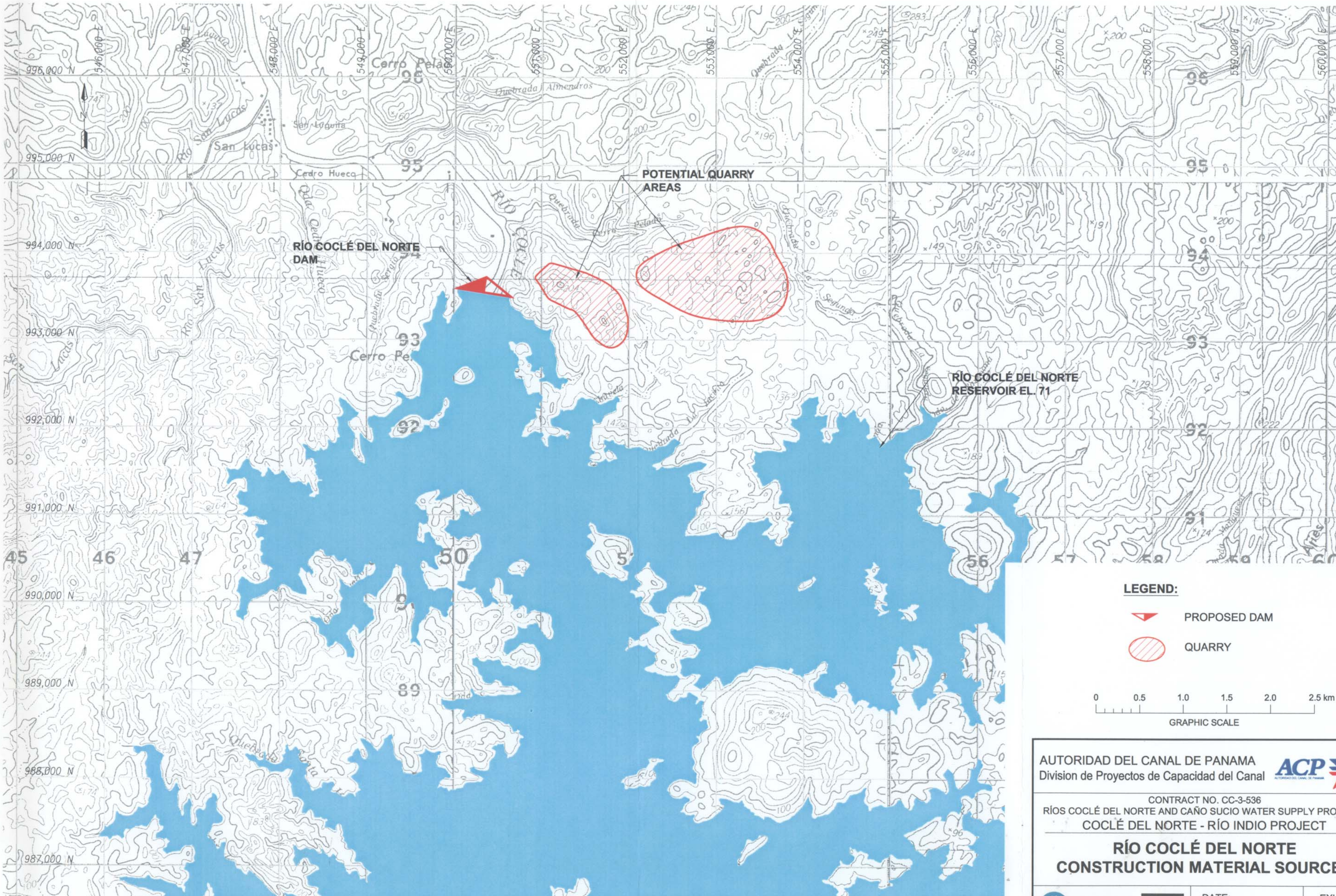
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

SEISMICITY OF PANAMA

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	4-2



LEGEND:

PROPOSED DAM

QUARRY

0 0.5 1.0 1.5 2.0 2.5 km

GRAPHIC SCALE

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

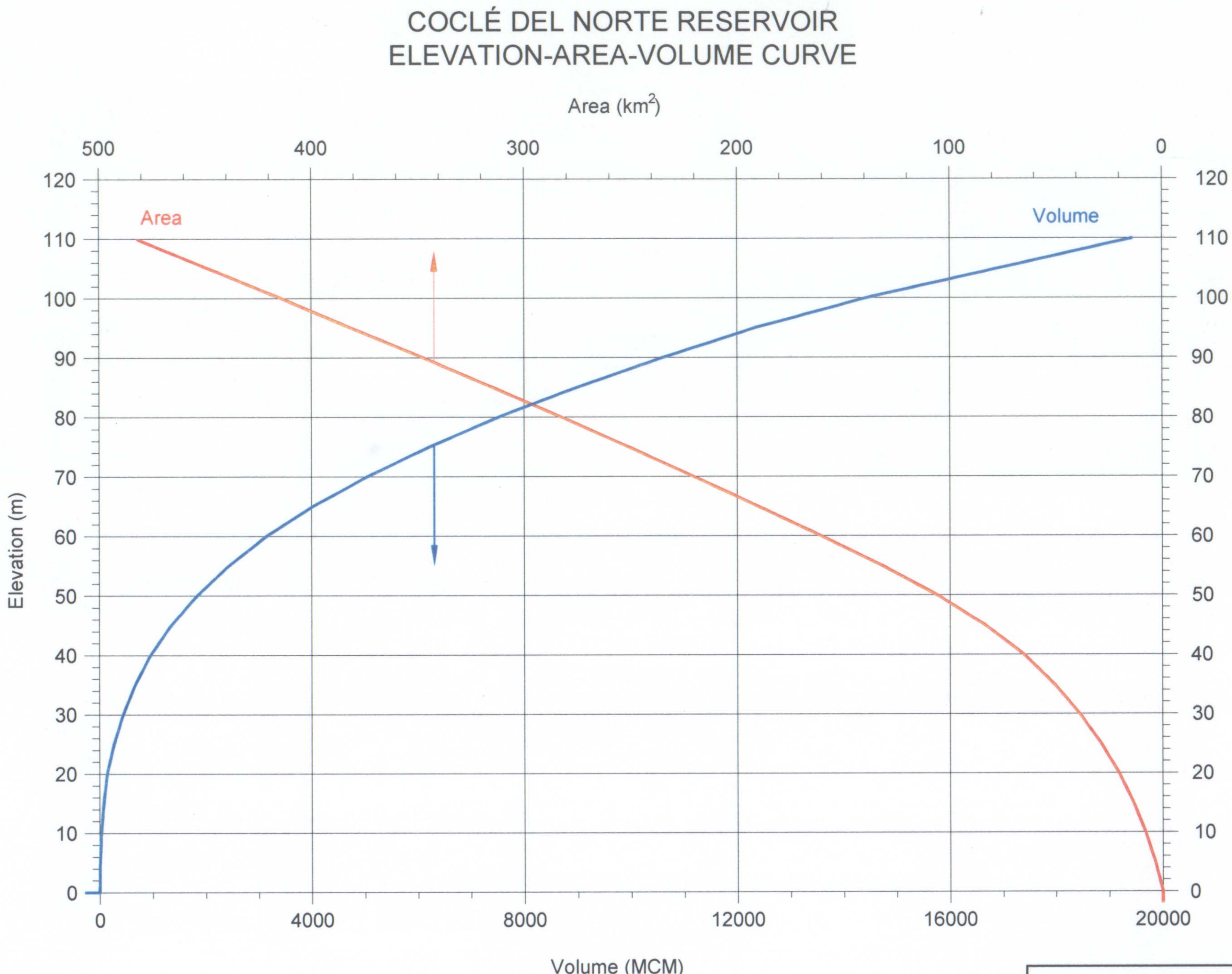
ACP

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

RÍO COCLÉ DEL NORTE
CONSTRUCTION MATERIAL SOURCES

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	4-3



AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

ACP

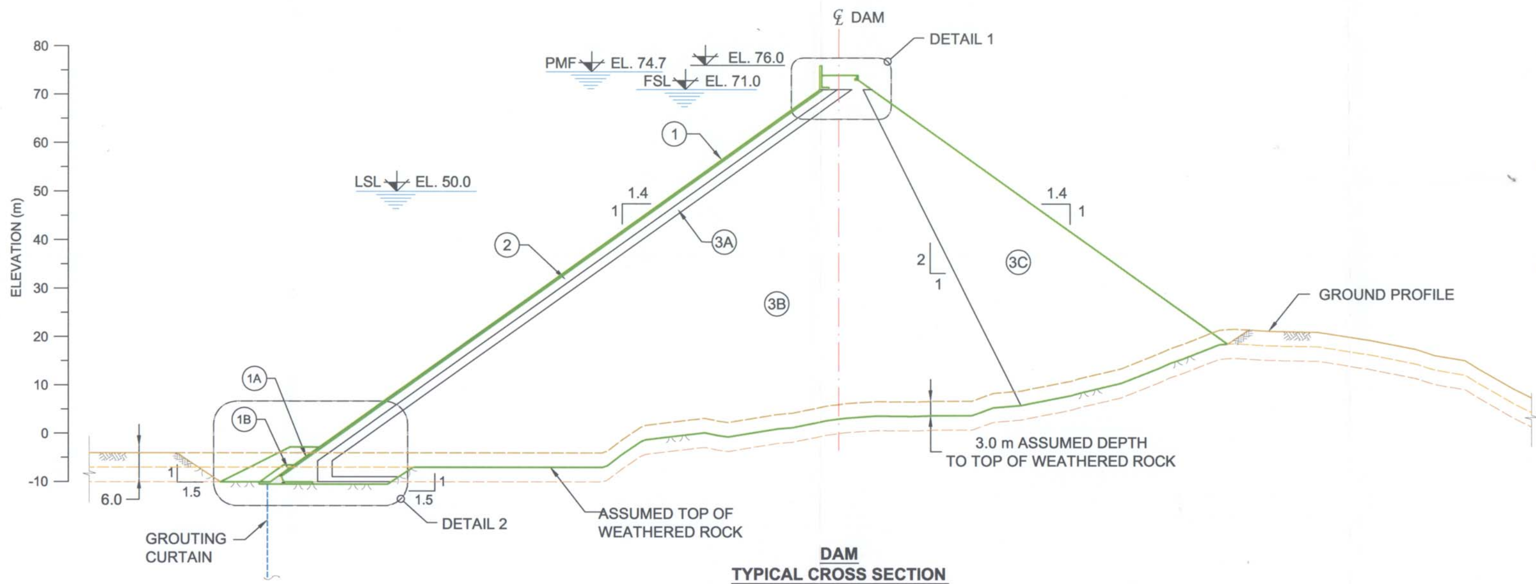
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

COCLÉ DEL NORTE RESERVOIR AREA AND VOLUME VS. ELEVATION

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 4-4

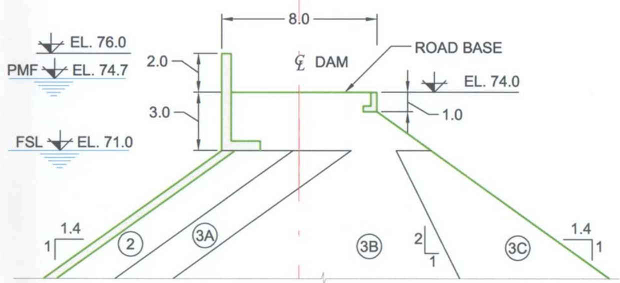


DAM TYPICAL CROSS SECTION

0 10 20 m
GRAPHIC SCALE

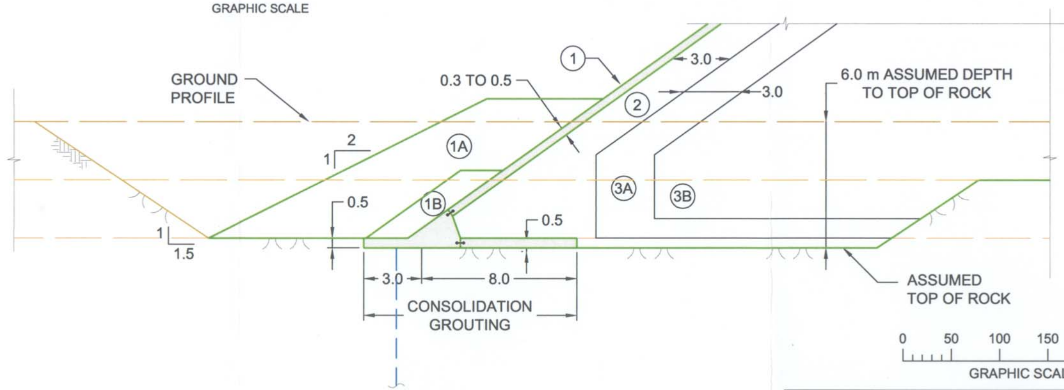
LEGEND:

- (1) CONCRETE FACE SLAB
- (1A) MISCELLANEOUS FILL
- (1B) SILTY SAND
- (2) FILTER
- (3A) FINE ROCKFILL
- (3B) ROCKFILL
- (3C) COARSE ROCKFILL



DETAIL 1

0 2 4 m
GRAPHIC SCALE



0 50 100 150 200 250 m
GRAPHIC SCALE

DETAIL 2

0 2 4 m
GRAPHIC SCALE

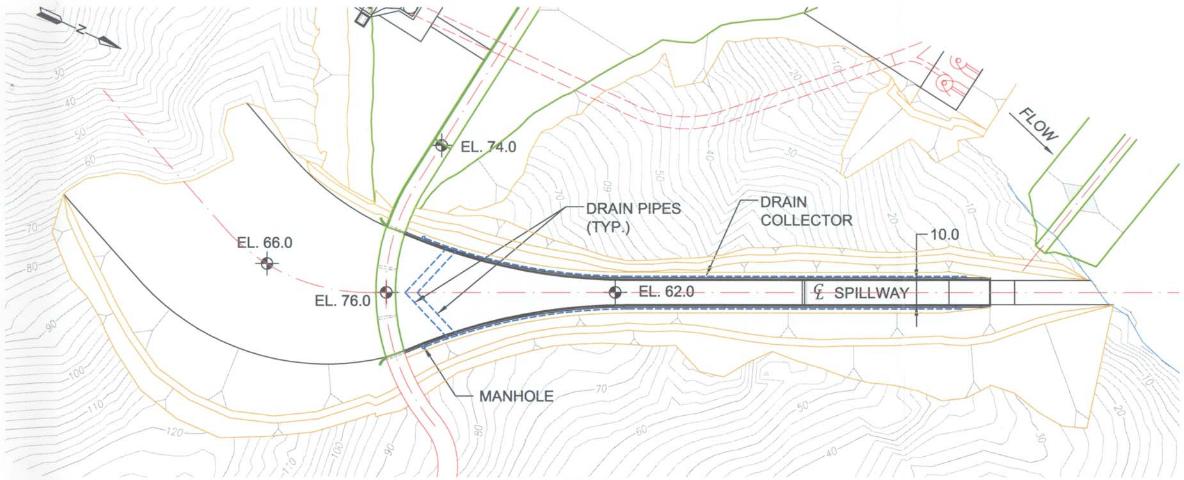
AUTORIDAD DEL CANAL DE PANAMA
División de Proyectos de Capacidad del Canal
ACP

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

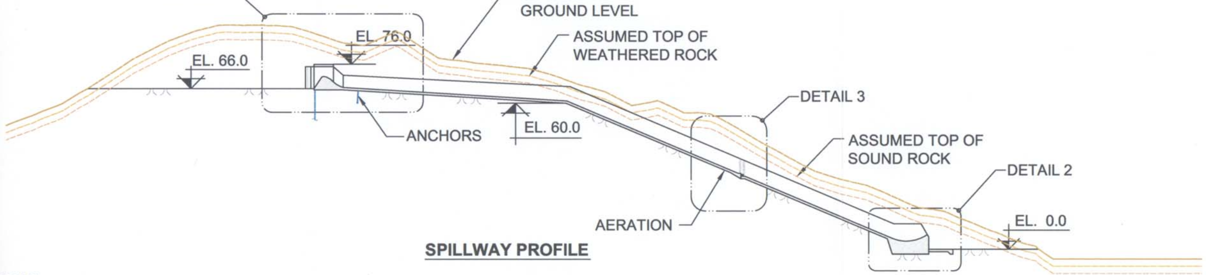
RÍO COCLÉ DEL NORTE DAM
TYPICAL CROSS SECTION AND DETAILS

MWH TAMS

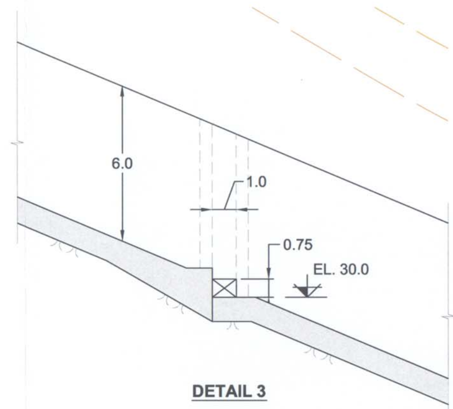
DATE:	EXHIBIT:
DECEMBER, 2003	5-1



SPILLWAY PLAN

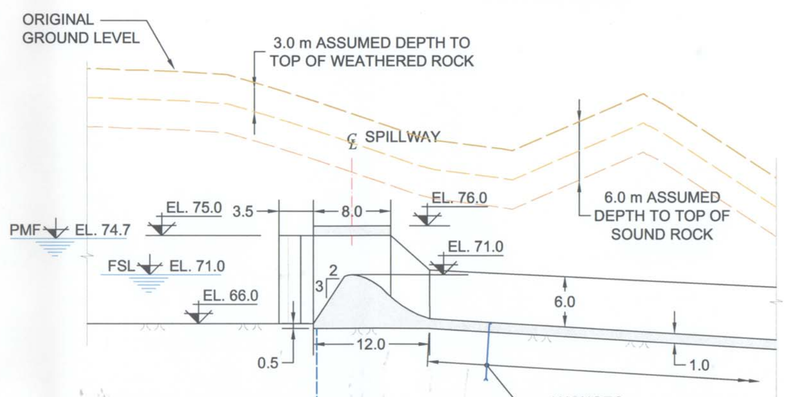


SPILLWAY PROFILE



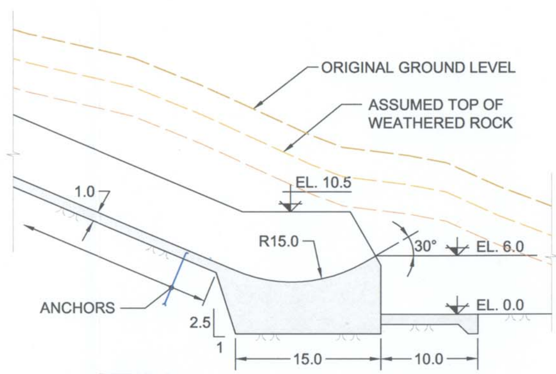
DETAIL 3

0 2 4 m
GRAPHIC SCALE



DETAIL 1

0 5 10 m
GRAPHIC SCALE



DETAIL 2

0 5 10 m
GRAPHIC SCALE

0 20 40 60 80 100 m
GRAPHIC SCALE

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

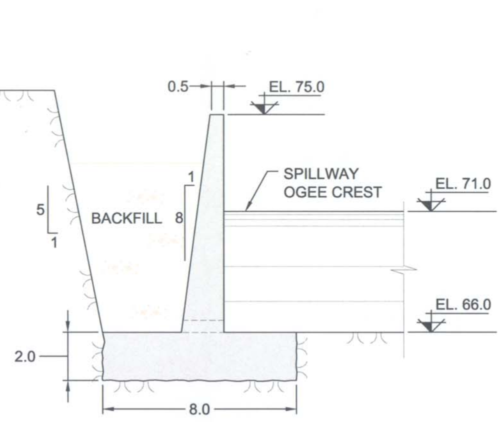
ACP

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

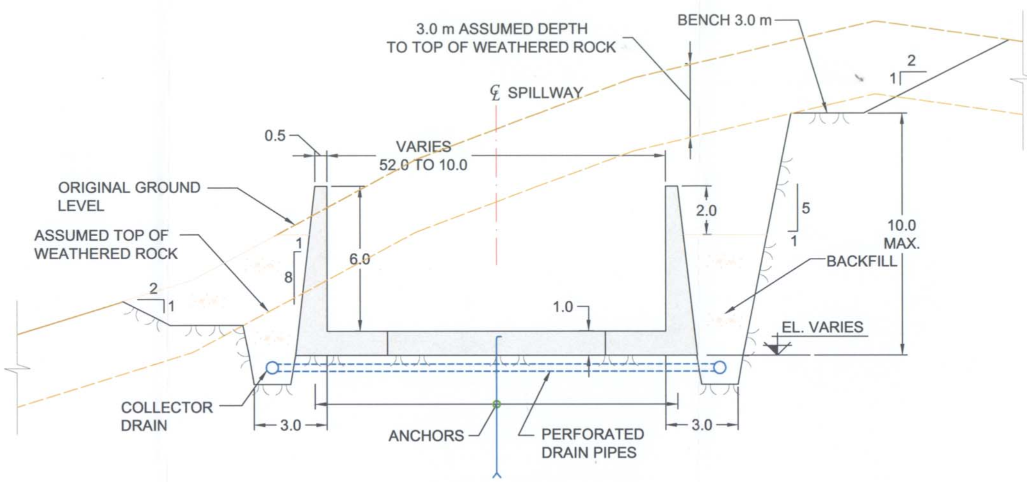
RÍO COCLÉ DEL NORTE SPILLWAY PLAN, PROFILE AND DETAILS

MWH TAMS

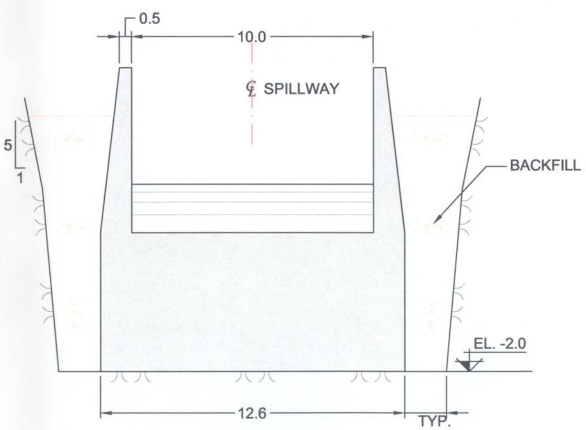
DATE:	EXHIBIT:
DECEMBER, 2003	5-2



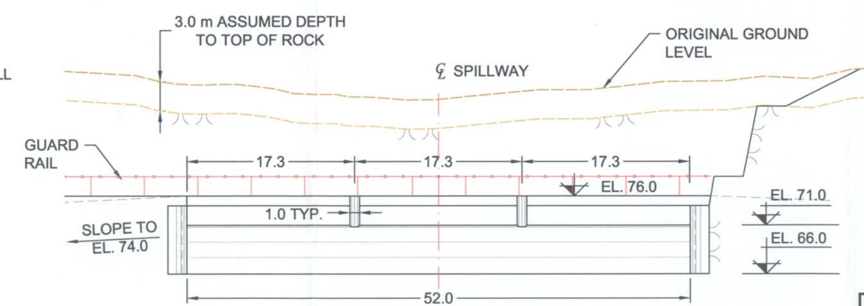
SPILLWAY APPROACH WALL SECTION



SPILLWAY CHUTE TYPICAL CROSS-SECTION



FLIP BUCKET TYPICAL CROSS-SECTION



SPILLWAY CONTROL STRUCTURE UPSTREAM ELEVATION

0 5 10 m
GRAPHIC SCALE

0 10 20 30 40 50 m
GRAPHIC SCALE

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

ACP

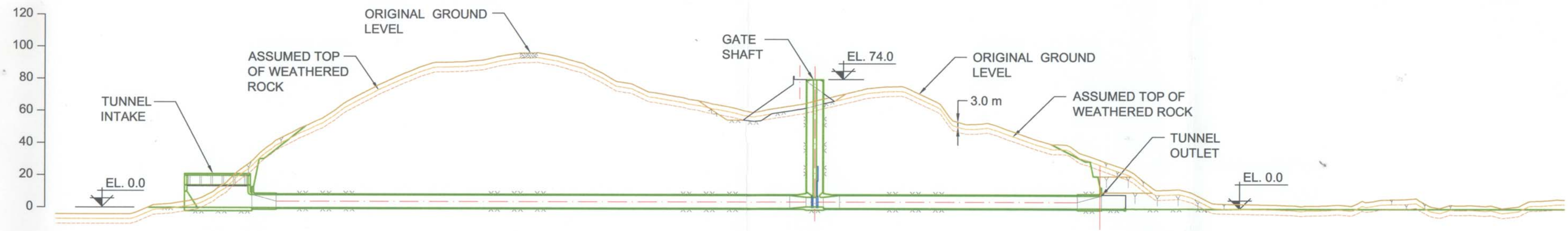
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

RÍO COCLÉ DEL NORTE SPILLWAY SECTIONS AND ELEVATION

MWH TAMS

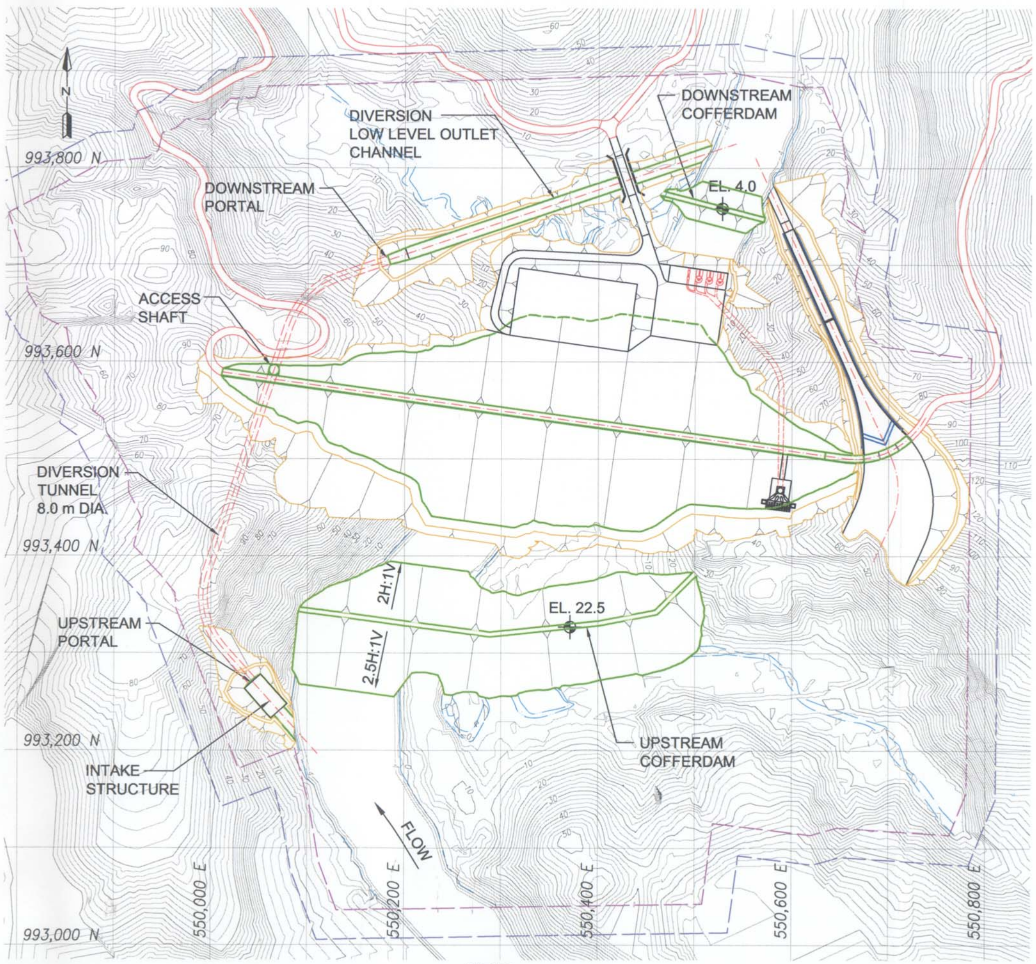
DATE: DECEMBER, 2003

EXHIBIT: 5-3

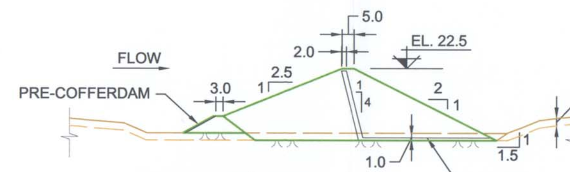


PROFILE
DIVERSION TUNNEL AND LOW LEVEL OUTLET

0 25 50 m
GRAPHIC SCALE

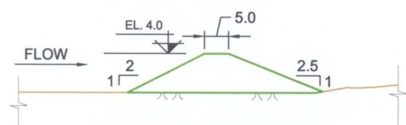


PLAN



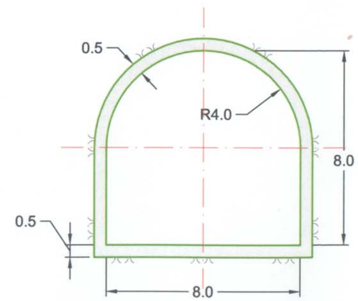
UPSTREAM COFFERDAM
TYPICAL CROSS SECTION

0 20 40 m
GRAPHIC SCALE



DOWNSTREAM COFFERDAM
TYPICAL CROSS SECTION

0 10 20 m
GRAPHIC SCALE



TYPICAL DIVERSION TUNNEL CROSS SECTION

0 2 4 m
GRAPHIC SCALE

0 50 100 150 200 250 m
GRAPHIC SCALE

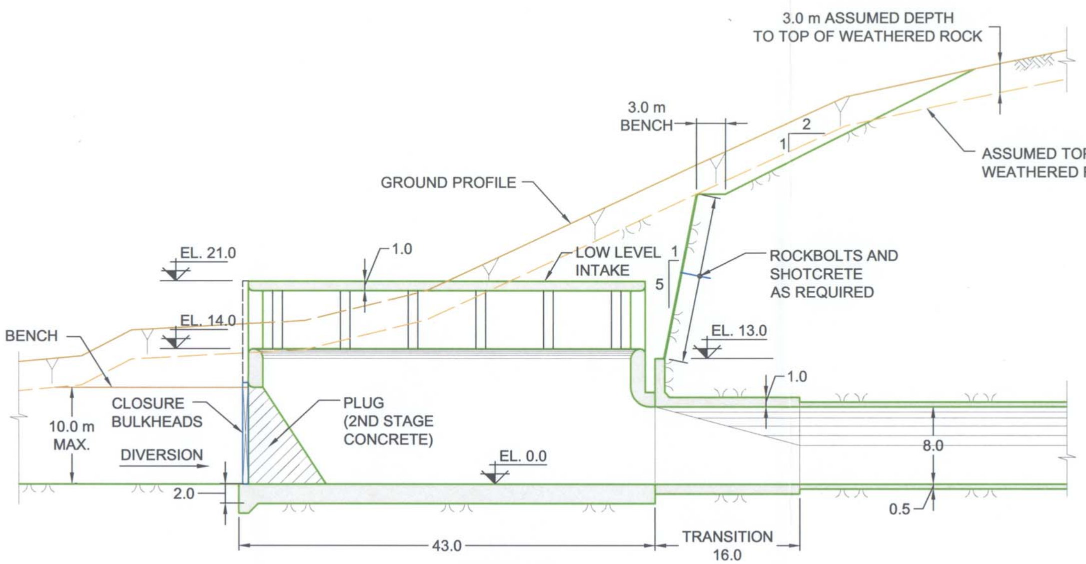
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal
ACP

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

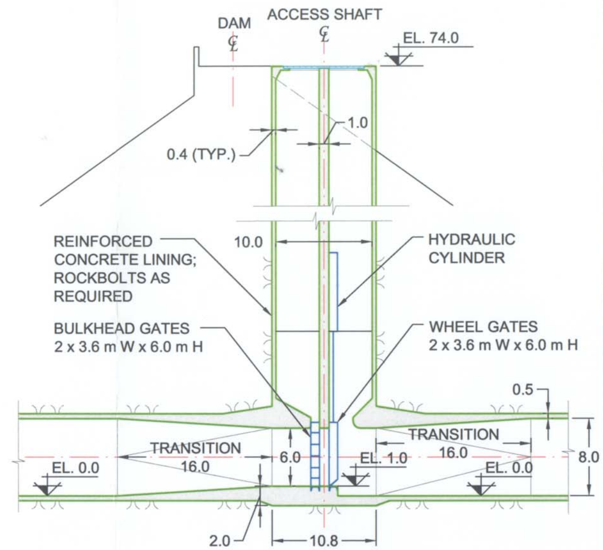
RÍO COCLÉ DEL NORTE
RIVER DIVERSION FACILITIES
PLAN, PROFILE AND SECTIONS

MWH TAMS

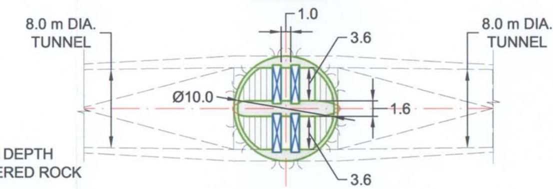
DATE:	EXHIBIT:
DECEMBER, 2003	5-4



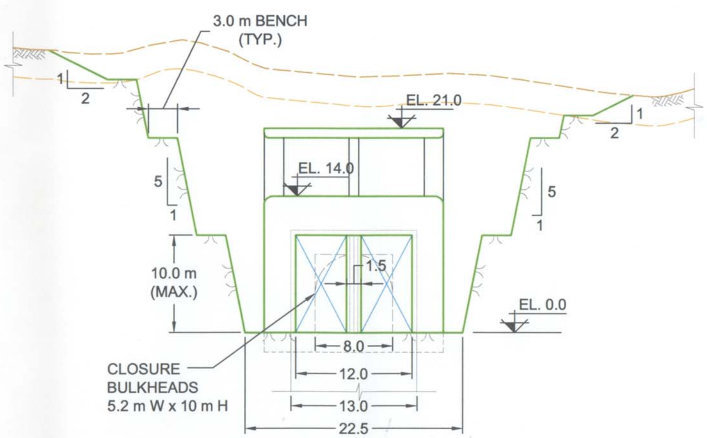
TUNNEL INLET PROFILE



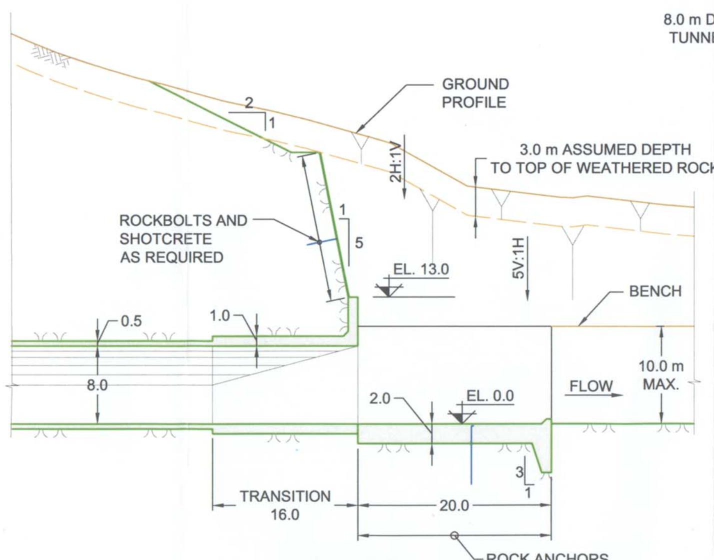
ACCESS SHAFT PROFILE



ACCESS SHAFT TYPICAL CROSS SECTION



TUNNEL INLET UPSTREAM VIEW



TUNNEL OUTLET PROFILE

0 5 10 15 20 25 m

GRAPHIC SCALE

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

ACP

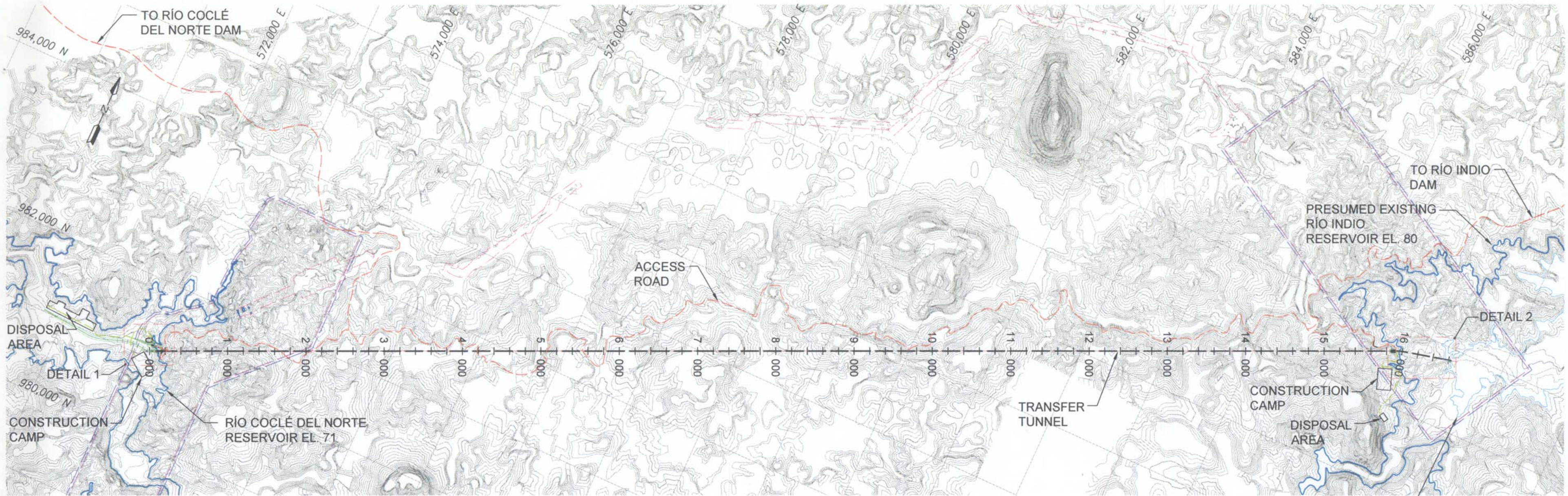
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

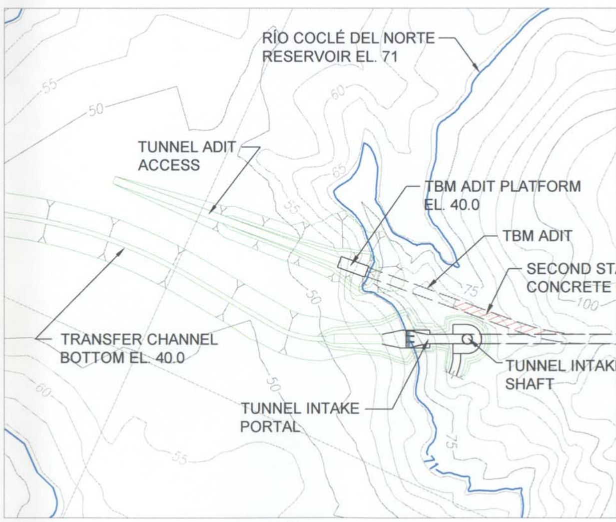
RÍO COCLÉ DEL NORTE EMERGENCY DRAWDOWN FACILITIES DETAILS

MWH TAMS

DATE: DECEMBER, 2003

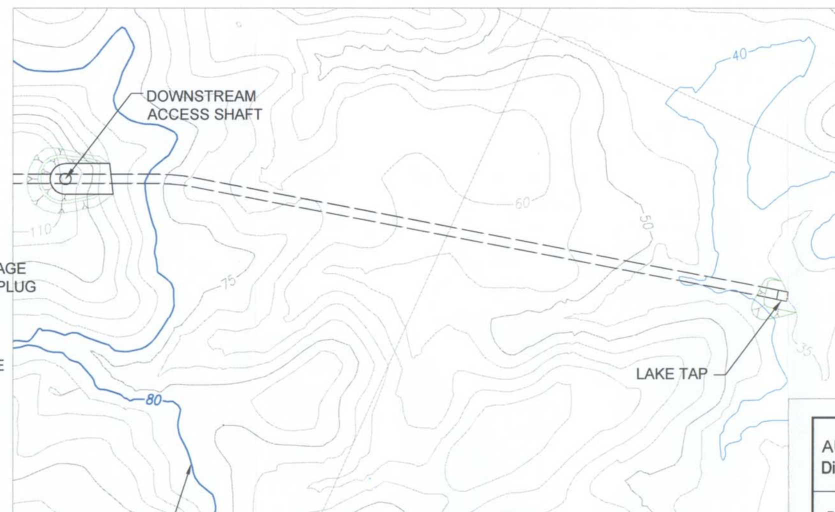
EXHIBIT: 5-5





DETAIL 1
TRANSFER TUNNEL INTAKE AND TBM ADIT

0 50 100 m
GRAPHIC SCALE



PRESUMED EXISTING RÍO INDIO RESERVOIR EL. 80

DETAIL 2
TRANSFER TUNNEL OUTLET

0 50 100 m
GRAPHIC SCALE

NOTE:

TOPOGRAPHY COMPILED FROM THE FOLLOWING SOURCES:

1. GROUND SURVEY (IASA, 2003)
2. AERIAL PHOTOGRAPHY (GEOCART - GRAFOS, 2002)
3. PUBLISHED 1:50,000 TOPOGRAPHIC MAPS (TOMMY GUARDIA)

0 0.5 1.0 1.5 2.0 2.5 km
GRAPHIC SCALE

AUTORIDAD DEL CANAL DE PANAMA
División de Proyectos de Capacidad del Canal

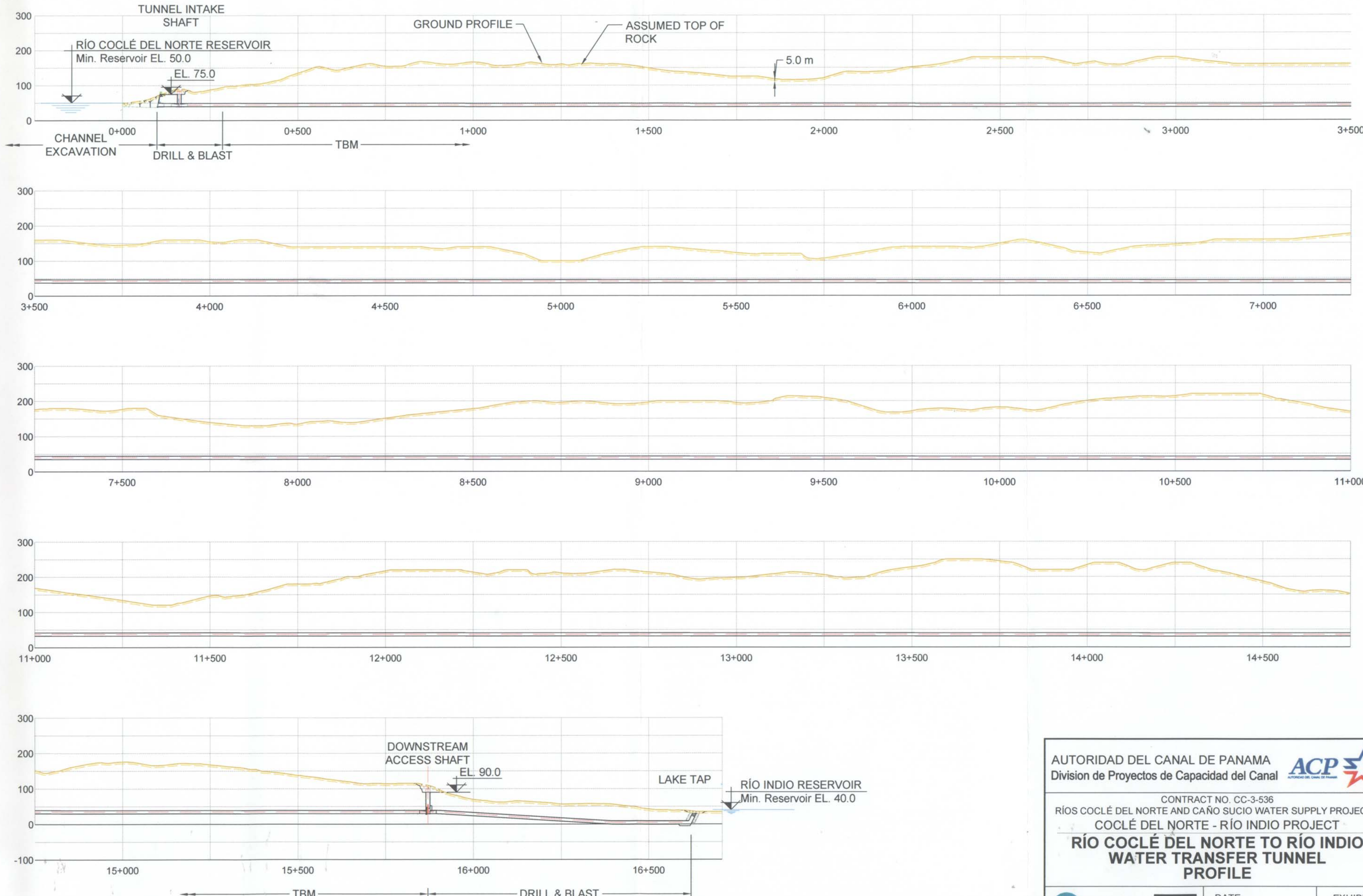
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

RÍO COCLÉ DEL NORTE TO RÍO INDIO WATER TRANSFER TUNNEL PLAN AND DETAILS

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 5-6



AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

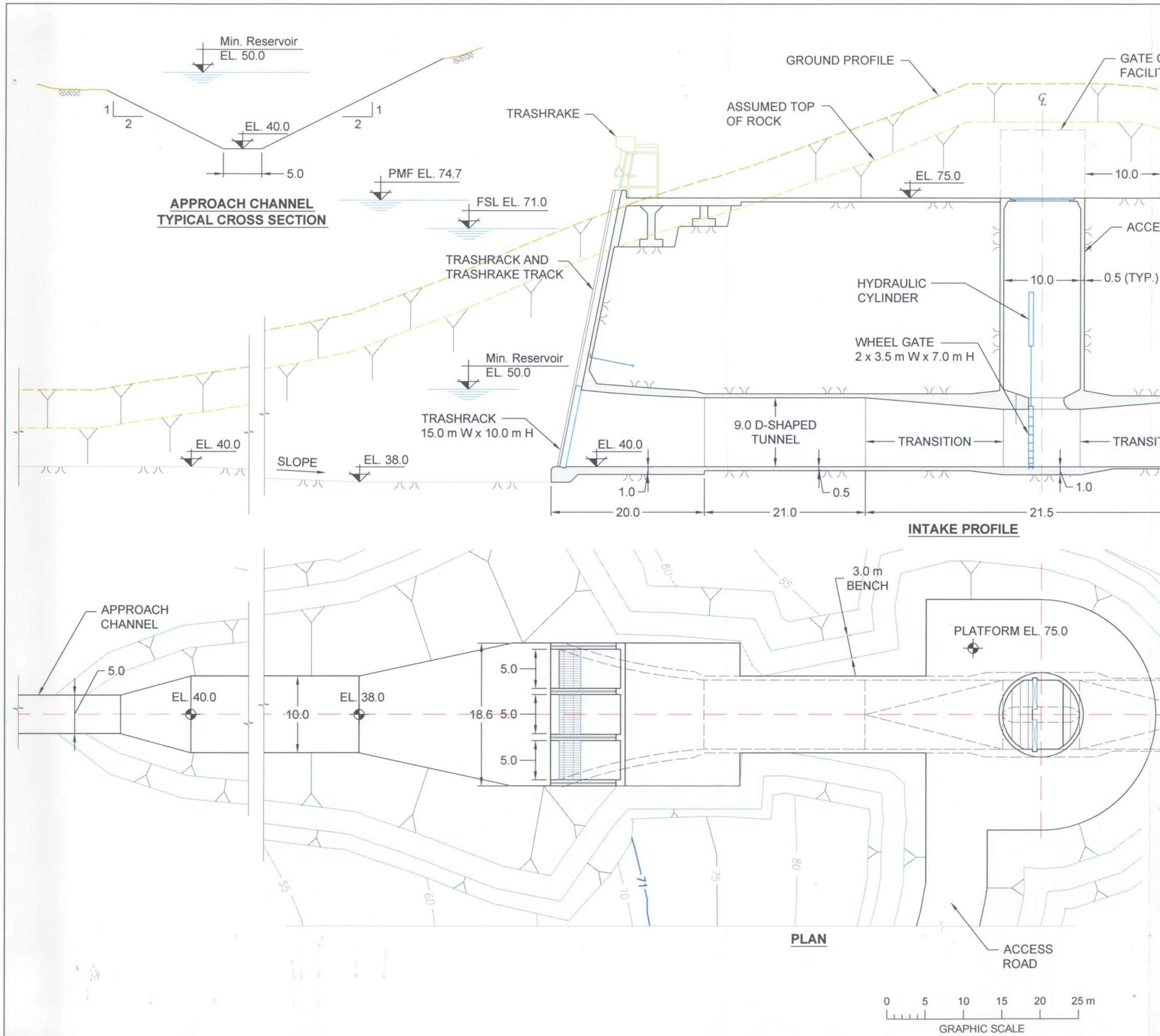
ACP

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

RÍO COCLÉ DEL NORTE TO RÍO INDIO WATER TRANSFER TUNNEL PROFILE

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	5-7



AUTORIDAD DEL CANAL DE PANAMA
División de Proyectos de Capacidad del Canal

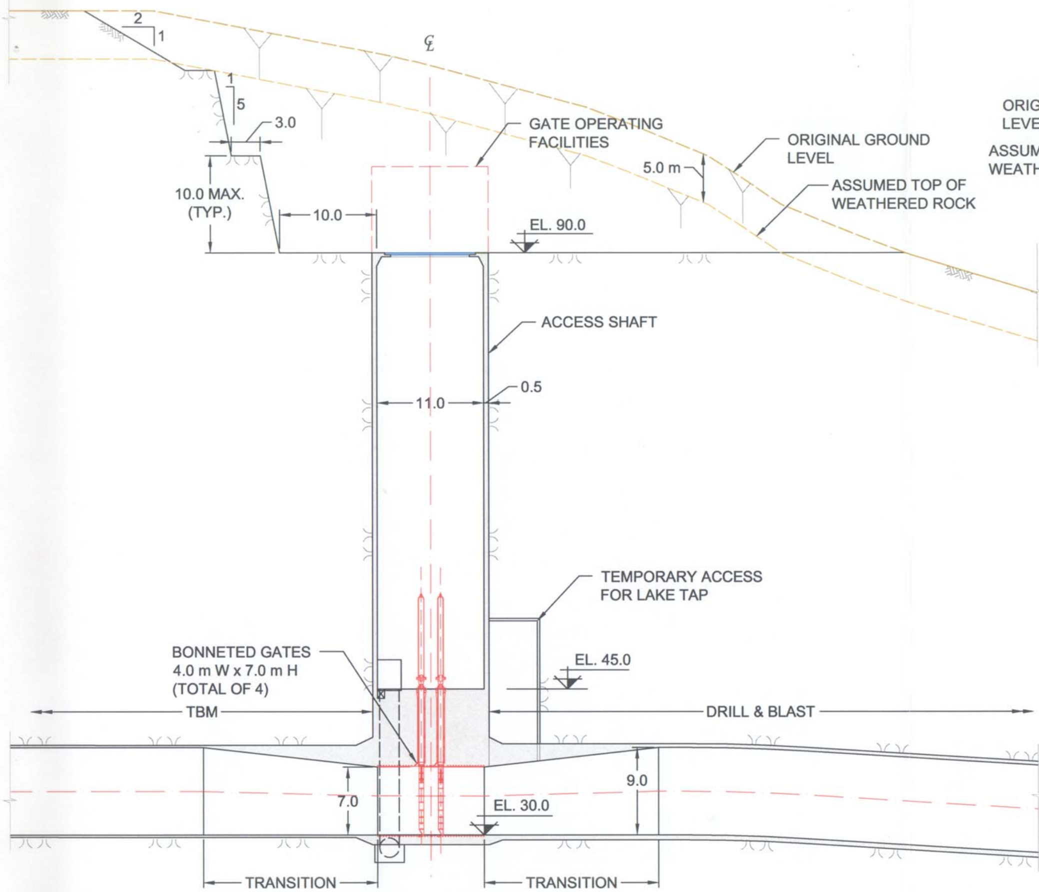
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

RÍO COCLÉ DEL NORTE TO RÍO INDIO WATER TRANSFER TUNNEL INTAKE STRUCTURE AND ACCESS SHAFT

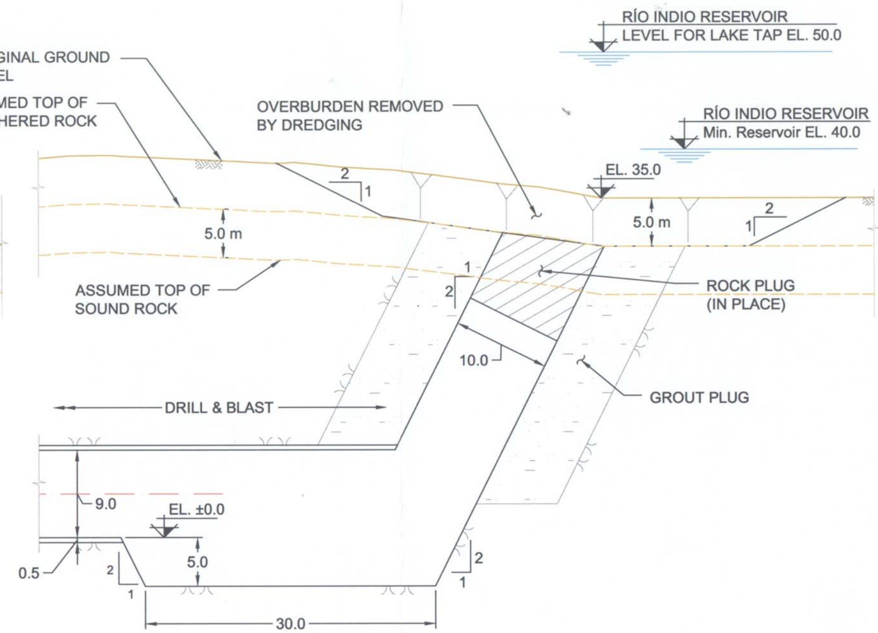
MWH TAMS

DATE: DECEMBER, 2003

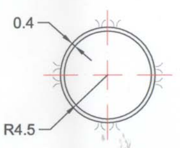
EXHIBIT: 5-8



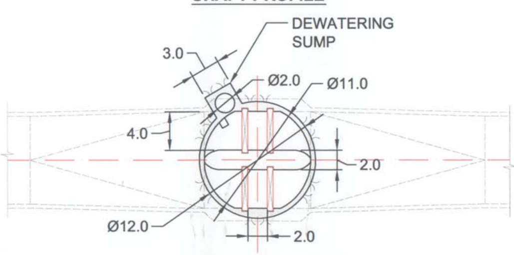
SHAFT PROFILE



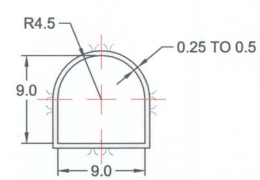
LAKE TAP



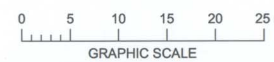
TBM
TYPICAL SECTION



SECTION @ EL. 45.0



TUNNEL DRILL & BLAST
TYPICAL SECTION



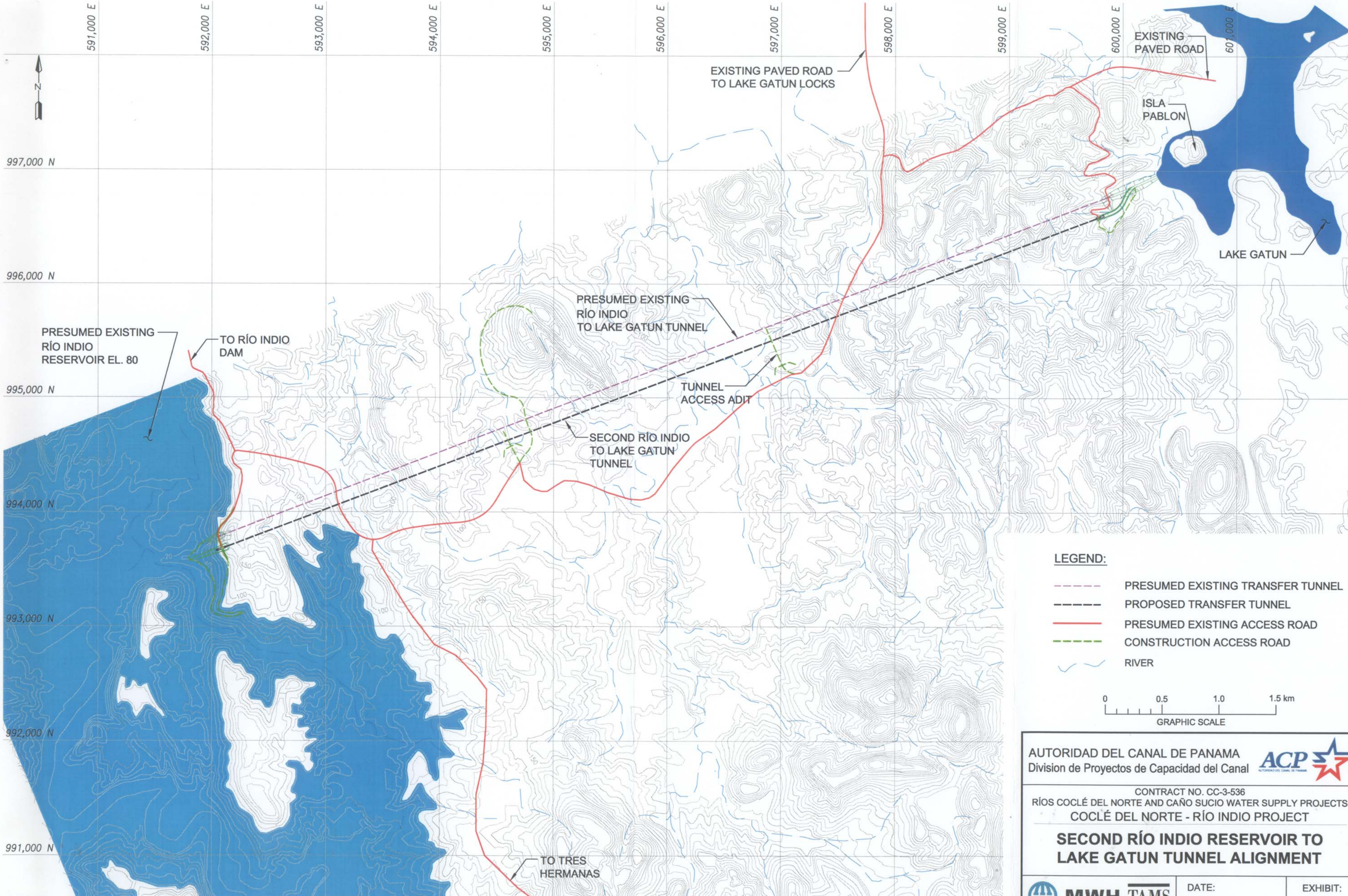
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal
ACP

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

RÍO COCLÉ DEL NORTE TO RÍO INDIO WATER TRANSFER TUNNEL D/S ACCESS SHAFT AND OUTLET WORKS

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	5-9



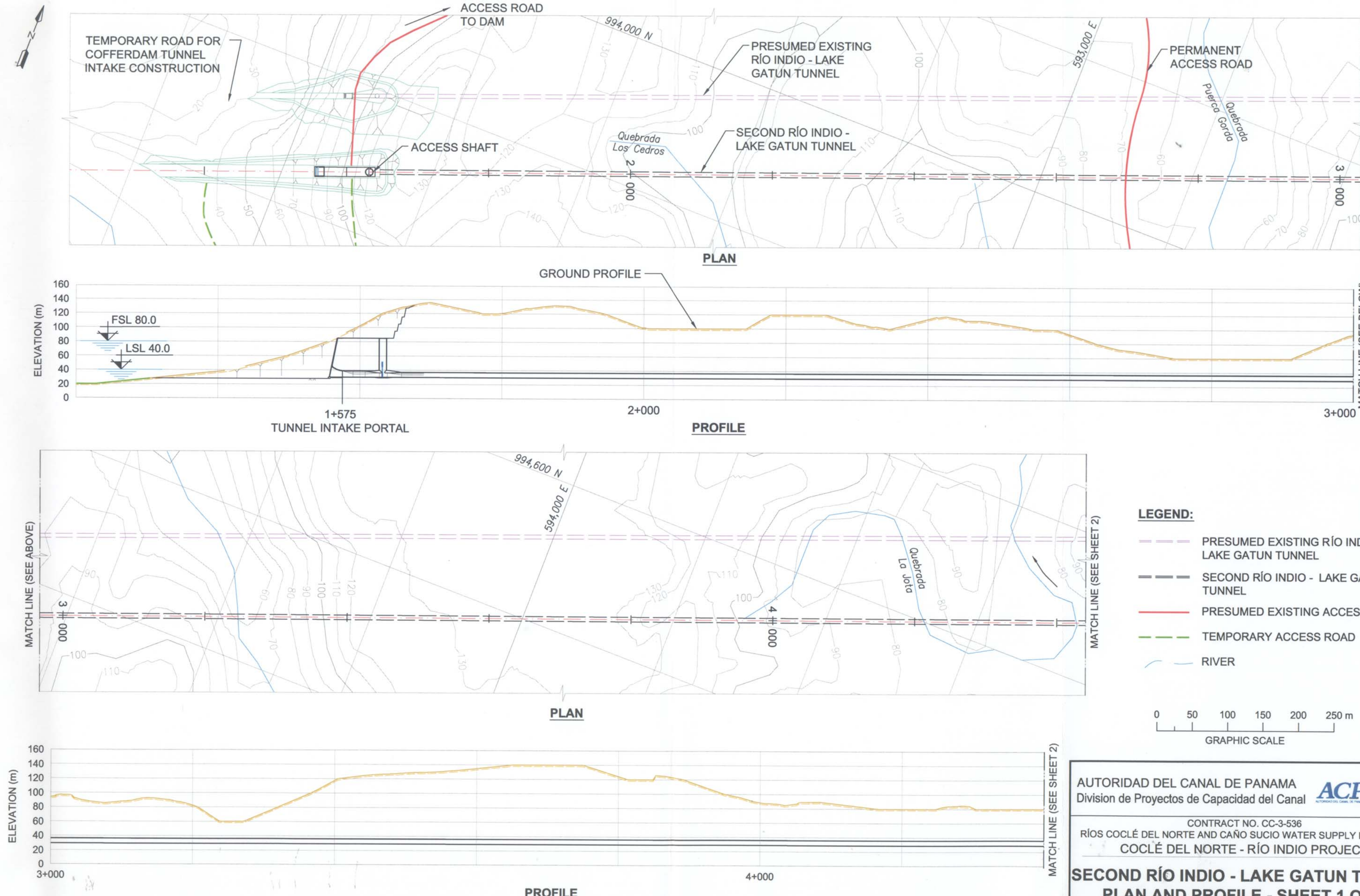
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

SECOND RÍO INDIO RESERVOIR TO LAKE GATUN TUNNEL ALIGNMENT

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	5-10



AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

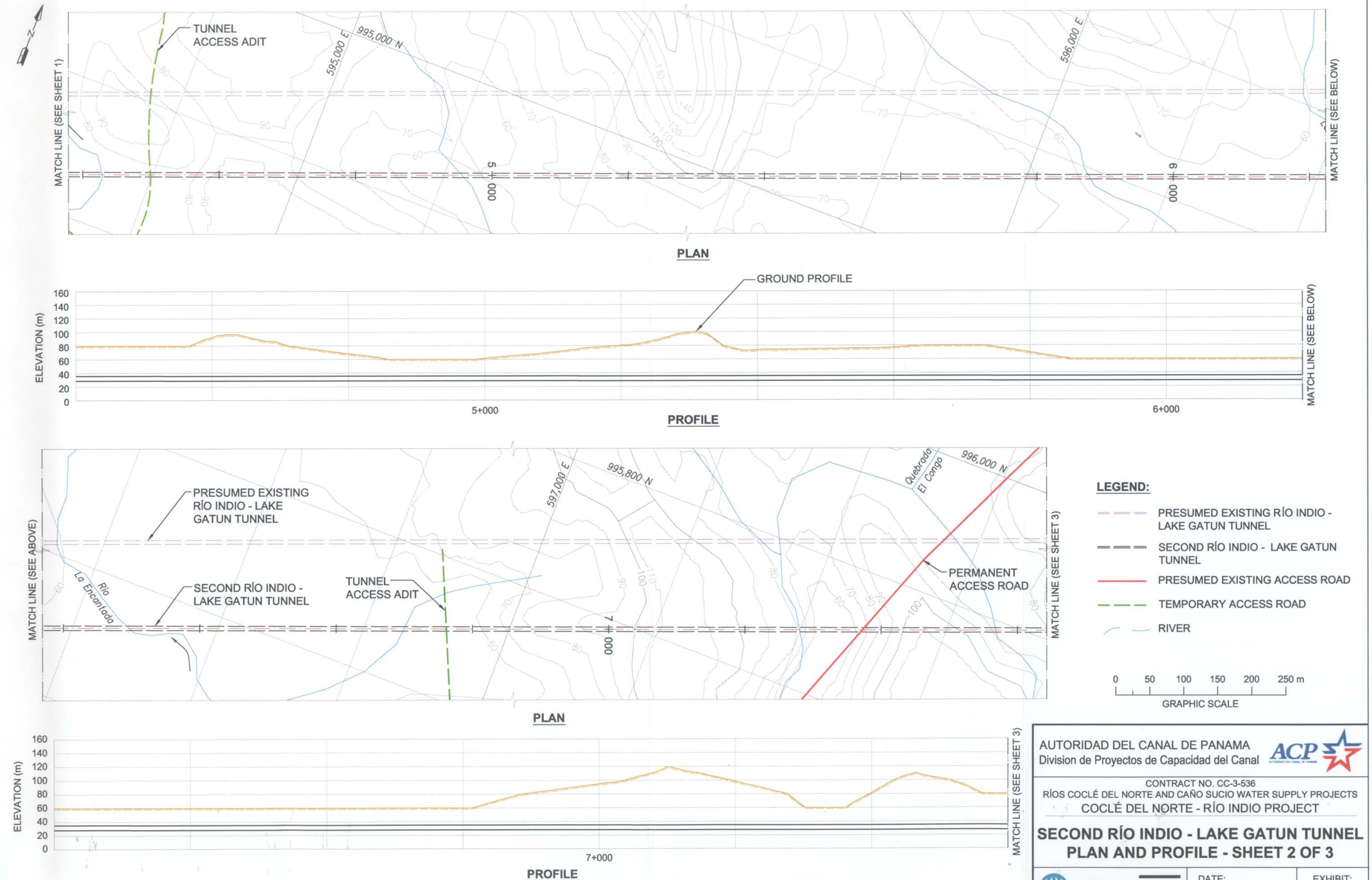
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

SECOND RÍO INDIO - LAKE GATUN TUNNEL
PLAN AND PROFILE - SHEET 1 OF 3

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 5-11



AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

ACP

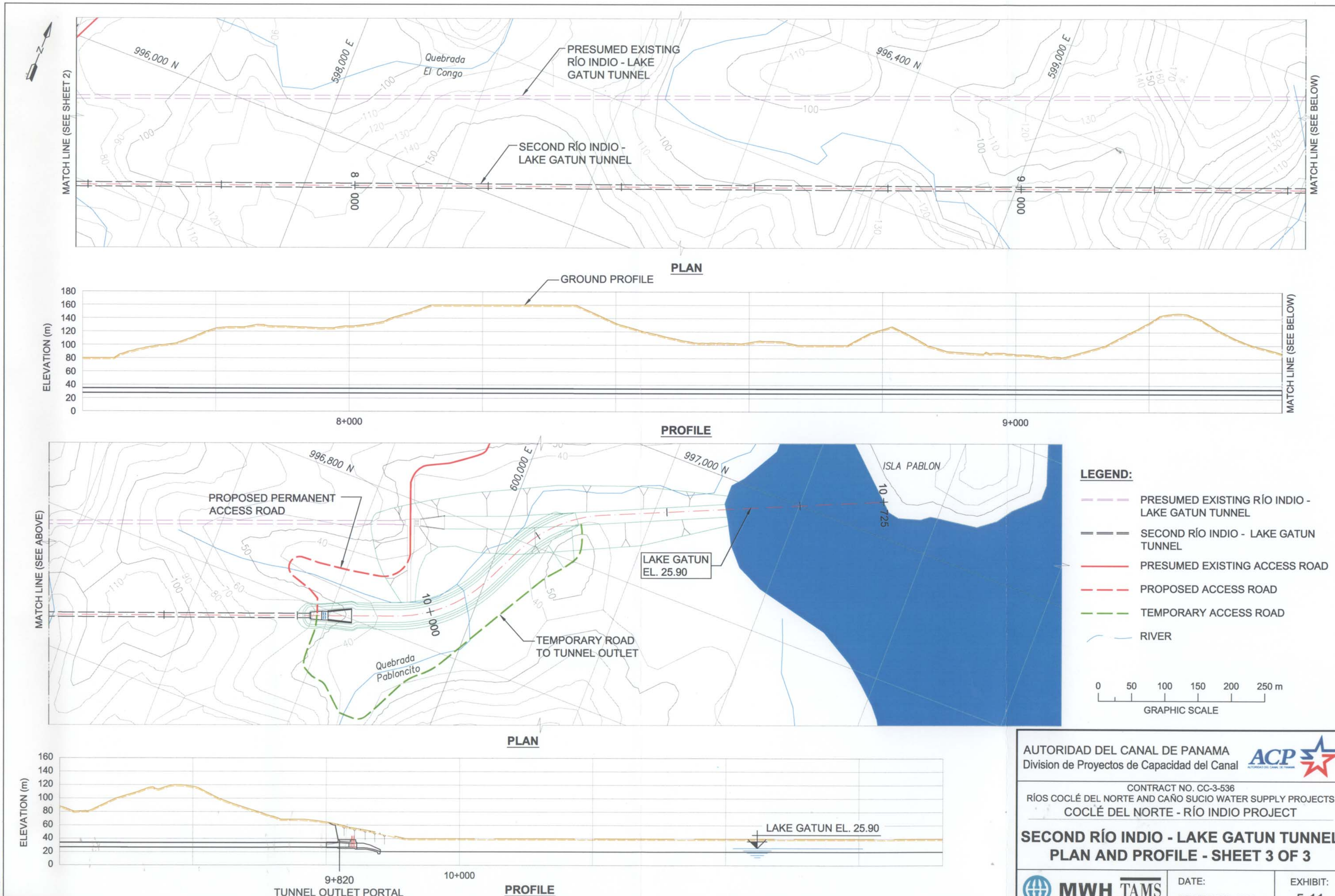
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

SECOND RÍO INDIO - LAKE GATUN TUNNEL
PLAN AND PROFILE - SHEET 2 OF 3

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 5-11



AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

ACP

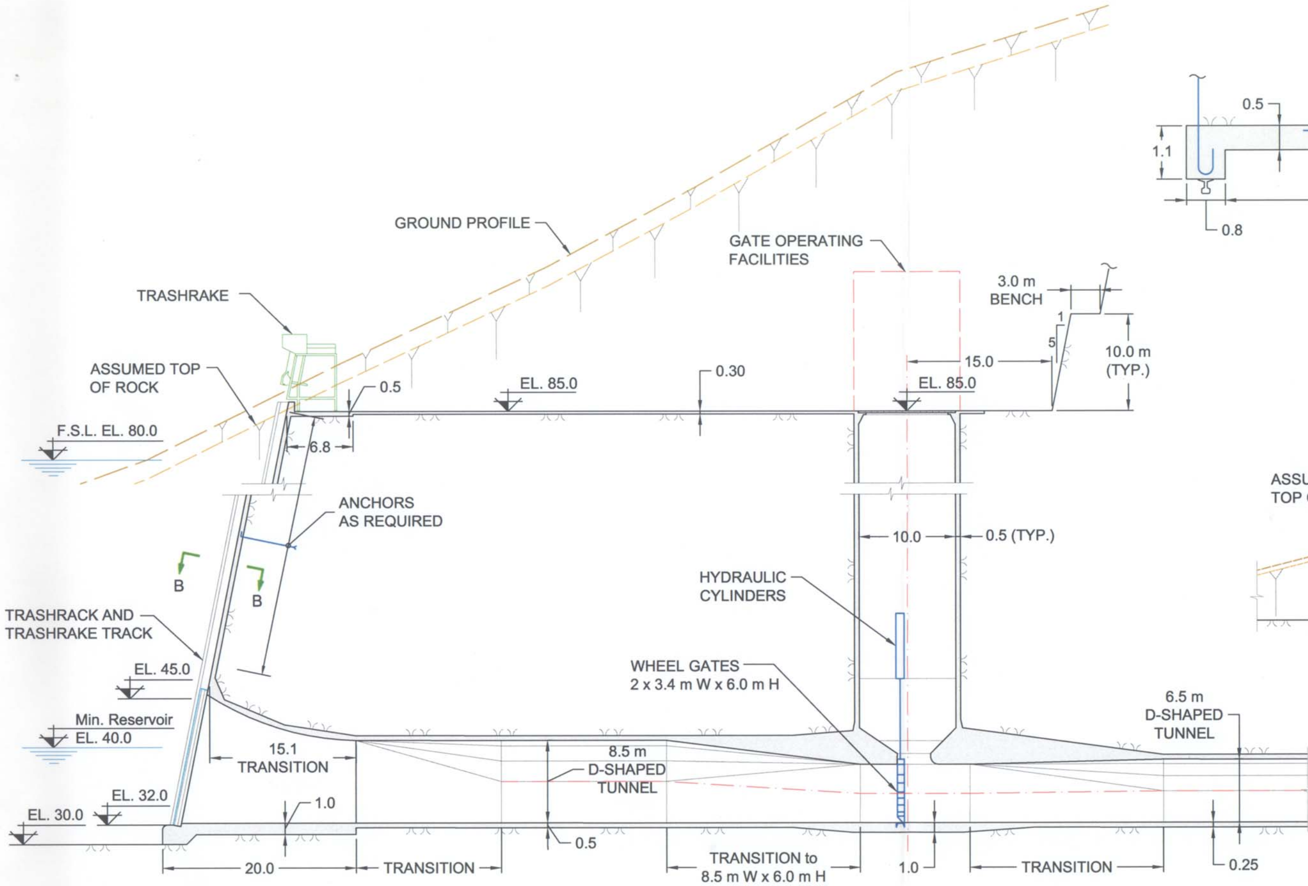
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

SECOND RÍO INDIO - LAKE GATUN TUNNEL
PLAN AND PROFILE - SHEET 3 OF 3

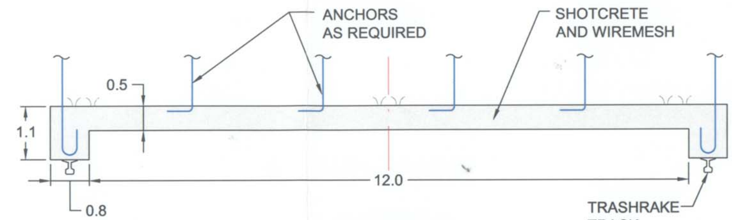
MWH TAMS

DATE: DECEMBER, 2003

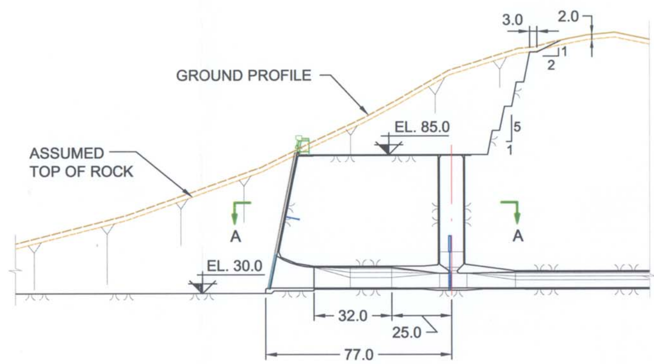
EXHIBIT: 5-11



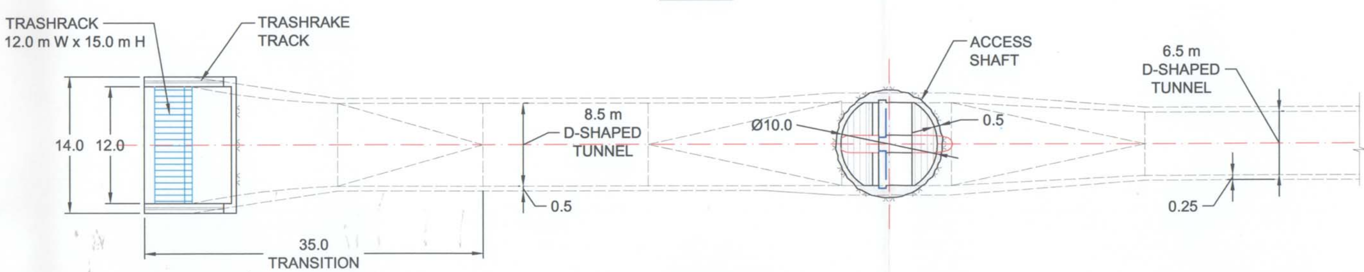
PROFILE



SECTION B - B



KEY PROFILE



SECTION A - A

0 5 10 15 20 25 m

GRAPHIC SCALE

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

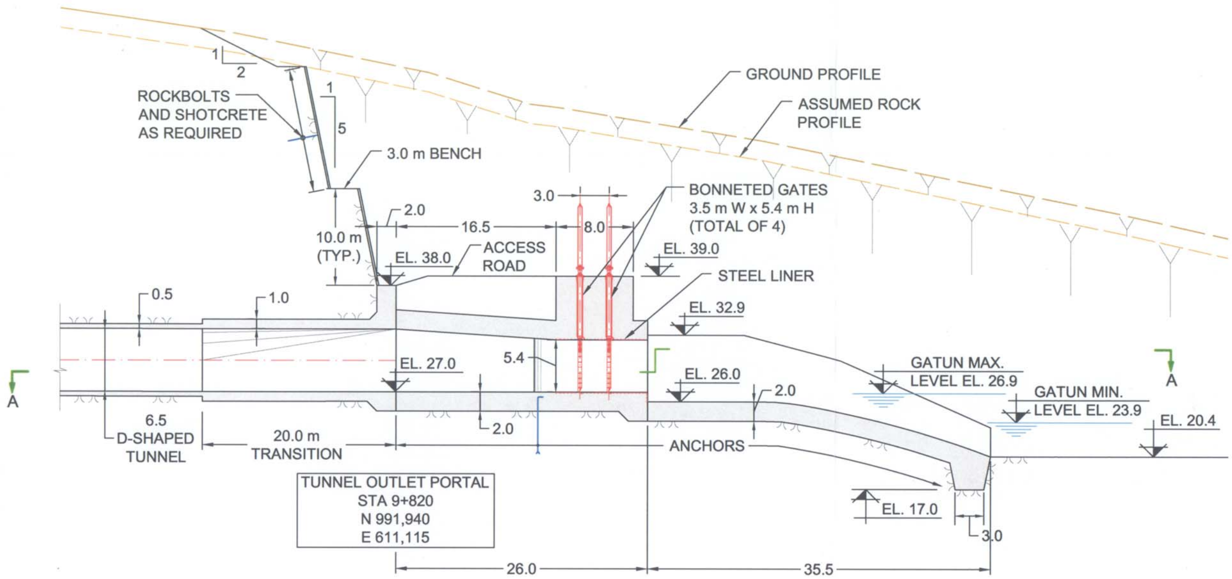
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

SECOND RÍO INDIO - LAKE GATUN TUNNEL INTAKE STRUCTURE AND ACCESS SHAFT

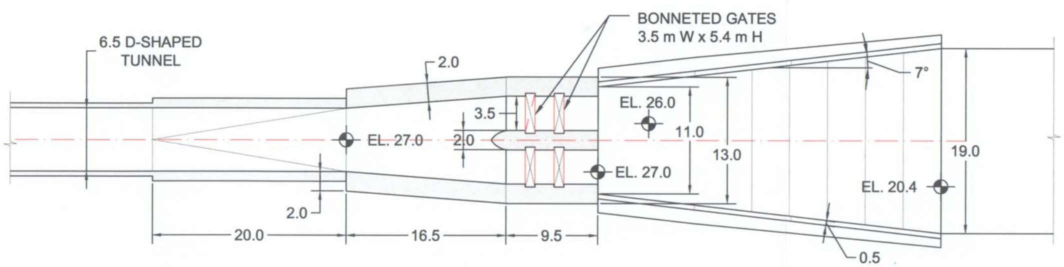
MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 5-12



PROFILE



SECTION A - A

0 5 10 15 20 25 m

GRAPHIC SCALE

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

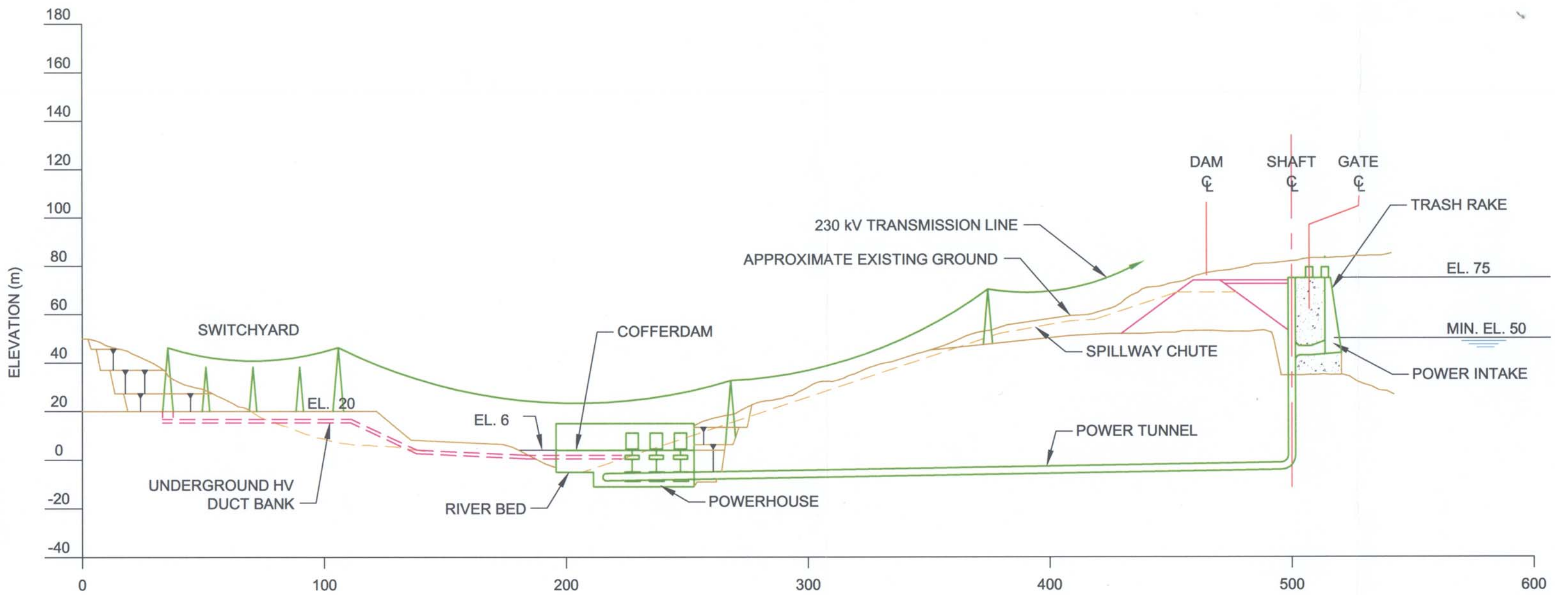
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

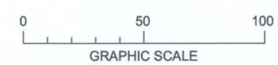
SECOND RÍO INDIO - LAKE GATUN TUNNEL OUTLET STRUCTURE - PROFILE AND SECTION

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 5-13





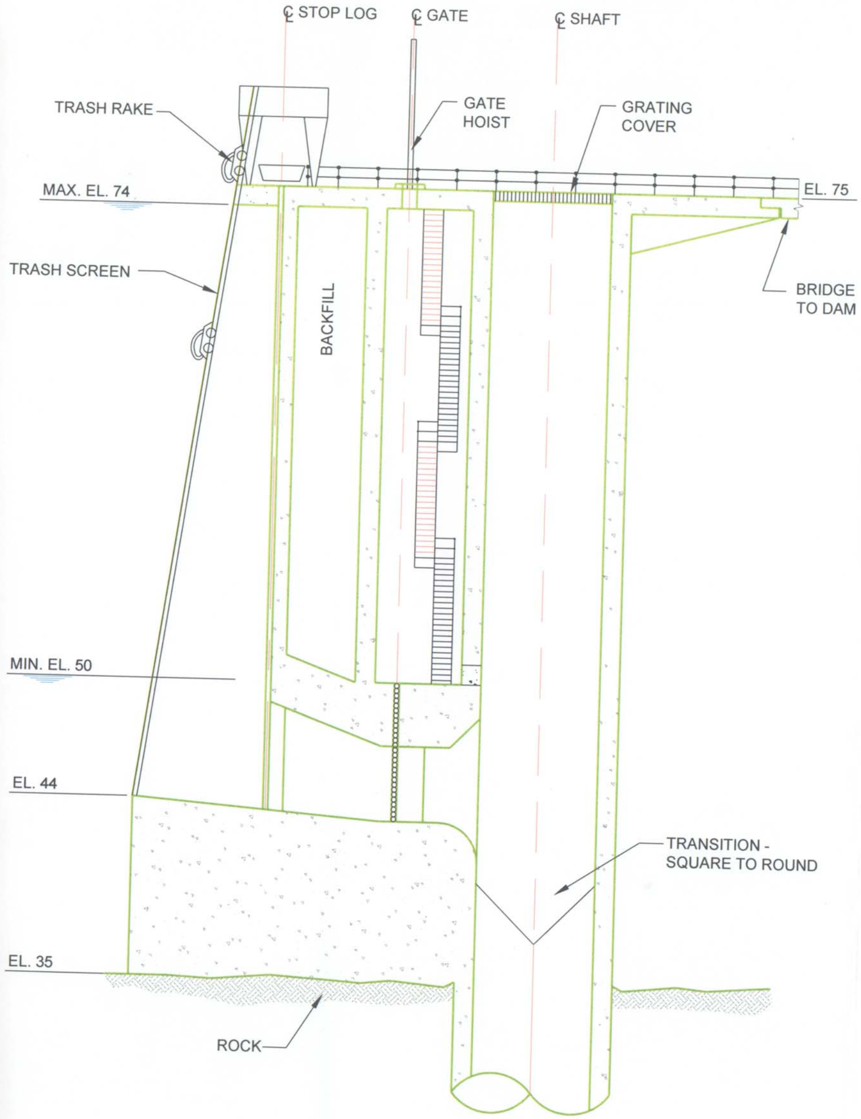
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

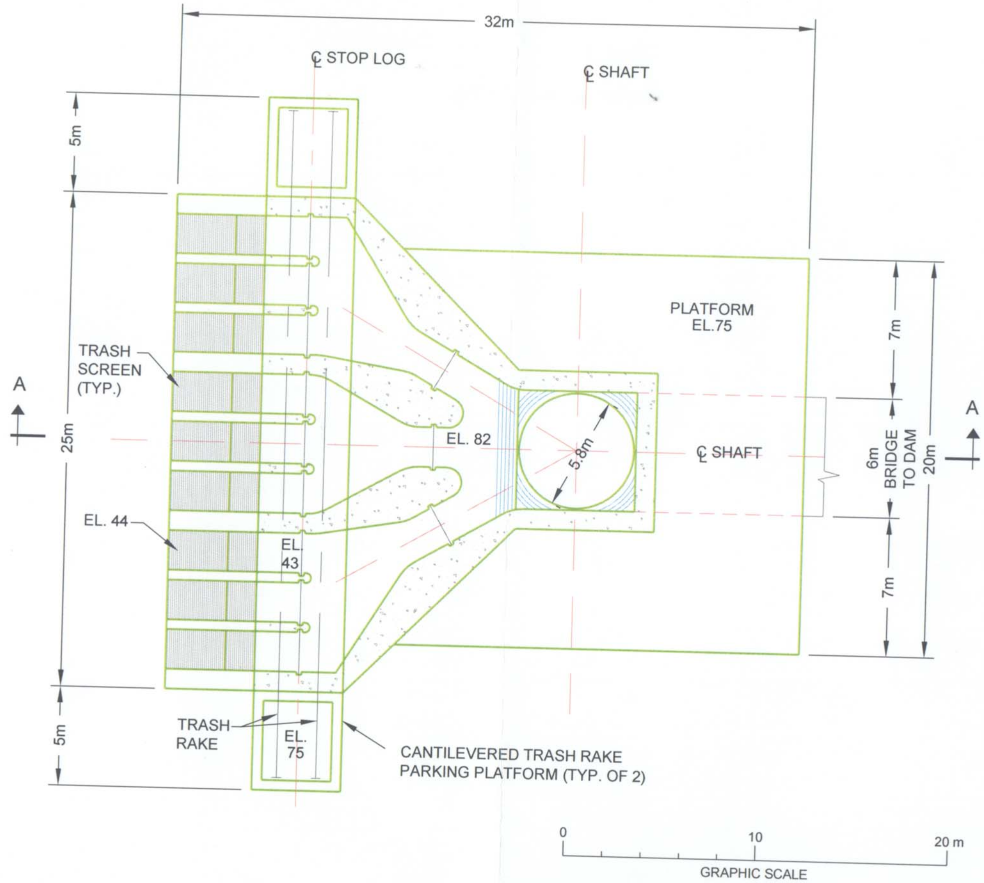
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

RÍO COCLÉ DEL NORTE (FSL 71)
HYDROELECTRIC POWER SCHEME
PROFILE

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	6-1





AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

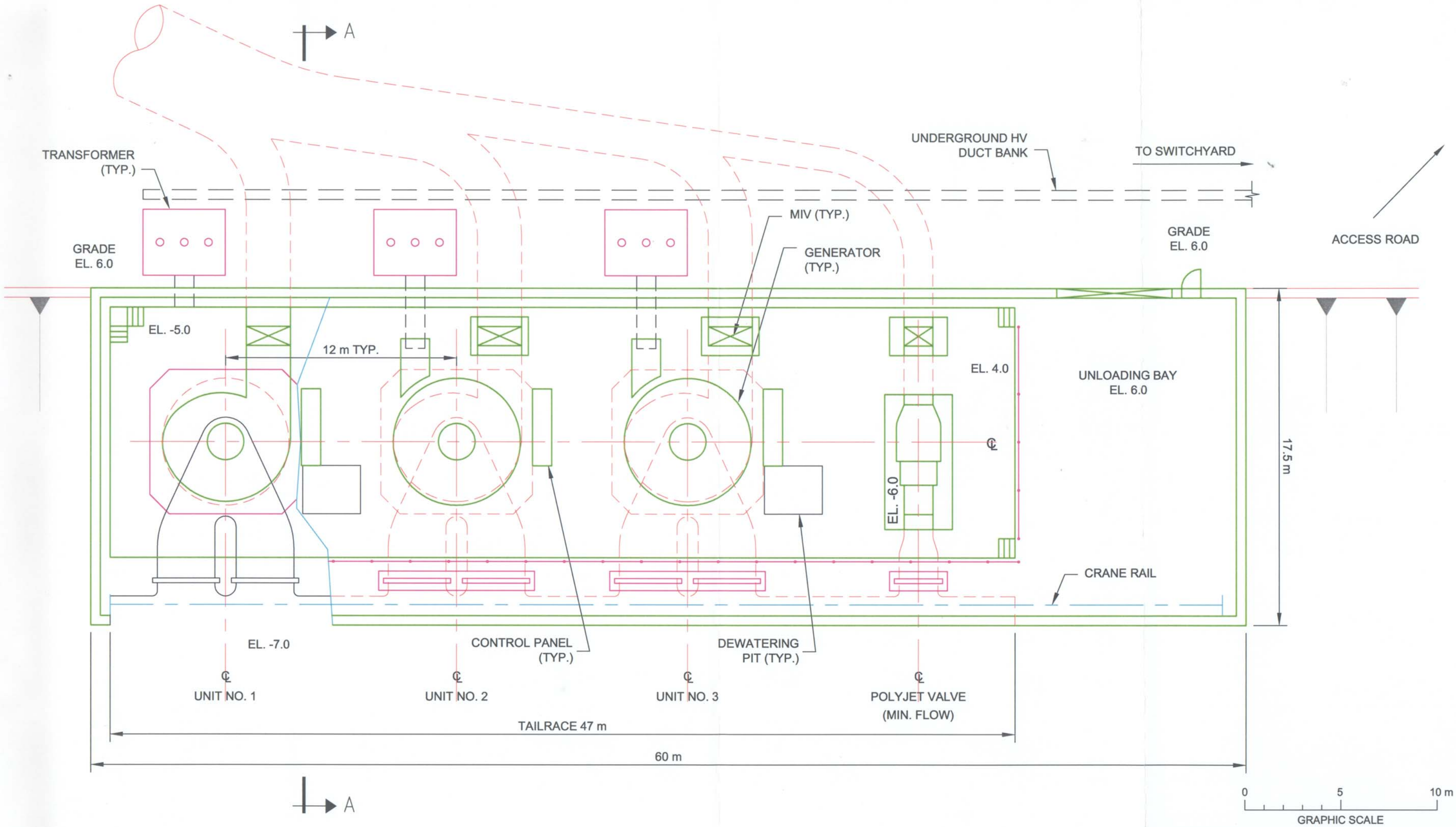
ACP

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

RÍO COCLÉ DEL NORTE (FSL 71)
POWER INTAKE - PLAN AND SECTIONS

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	6-2



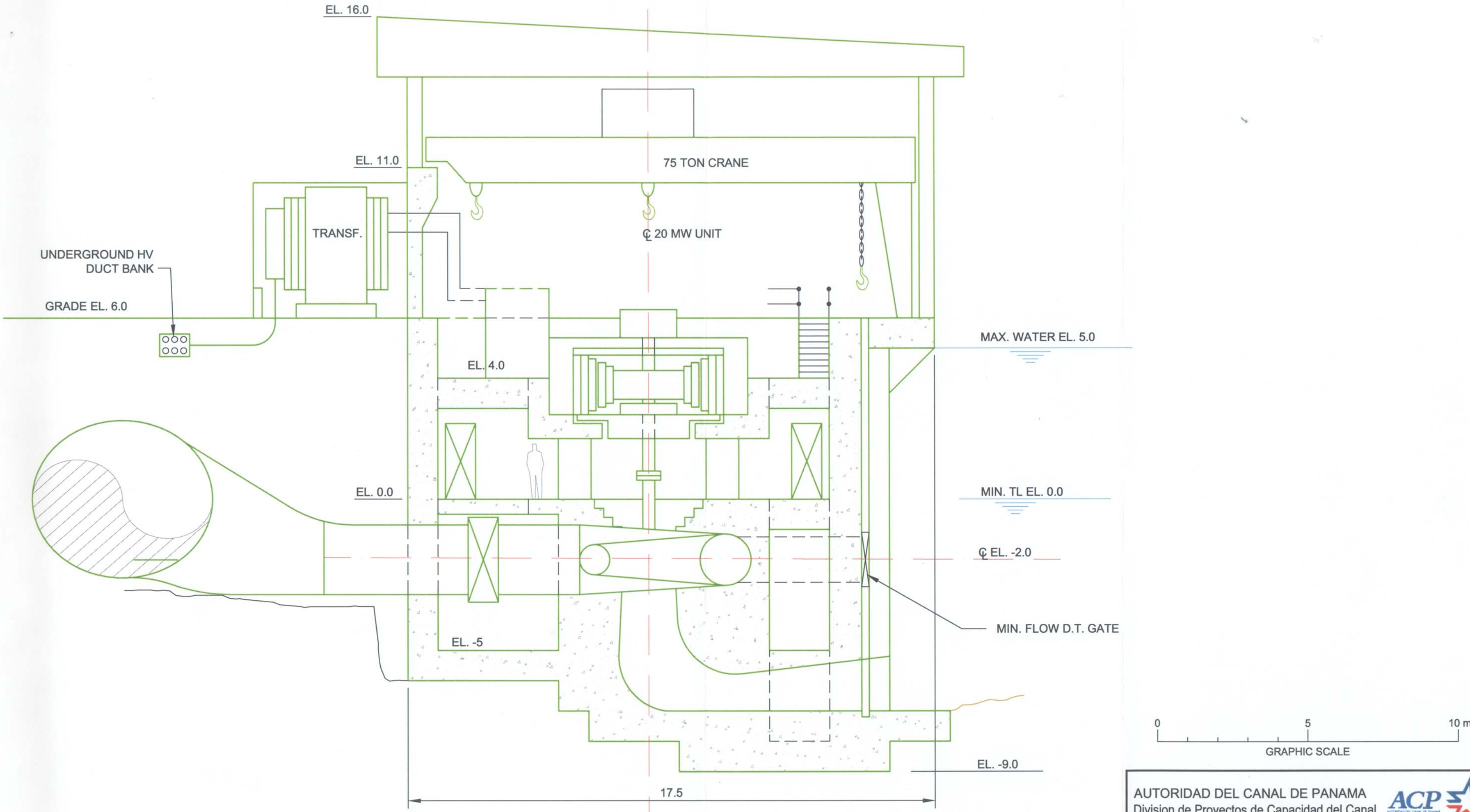
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

RÍO COCLÉ DEL NORTE POWERHOUSE - PLAN

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	6-3



SECTION A-A

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

RÍO COCLÉ DEL NORTE (FSL 71)
POWERHOUSE - SECTION

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	6-4

230 kV YARD AT RIO COCLÉ DEL NORTE
PLAN VIEW

NOT TO SCALE

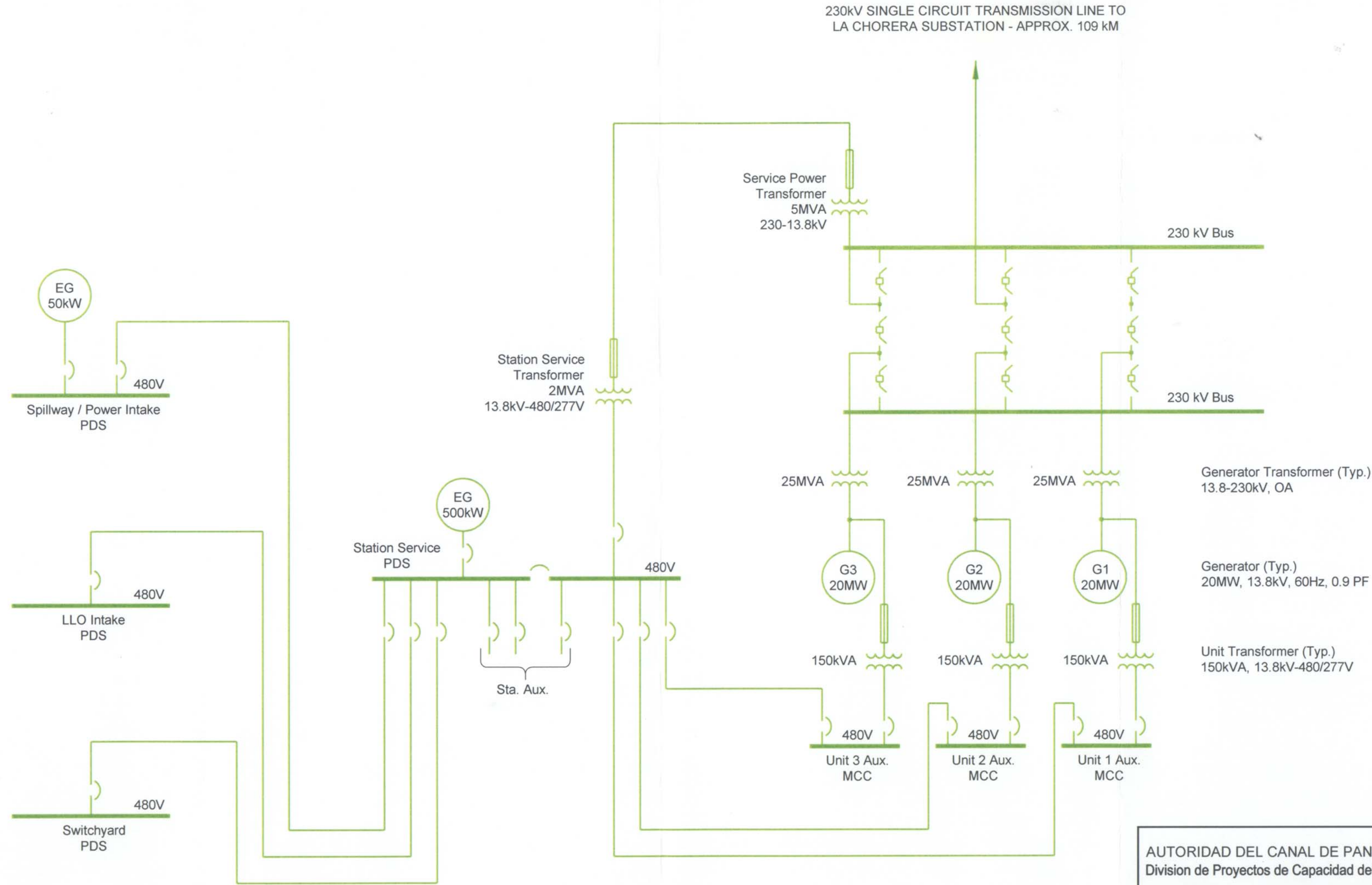
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

RÍO COCLÉ DEL NORTE (FSL 71)
230 kV SWITCHYARD - PLAN

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	6-5



AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

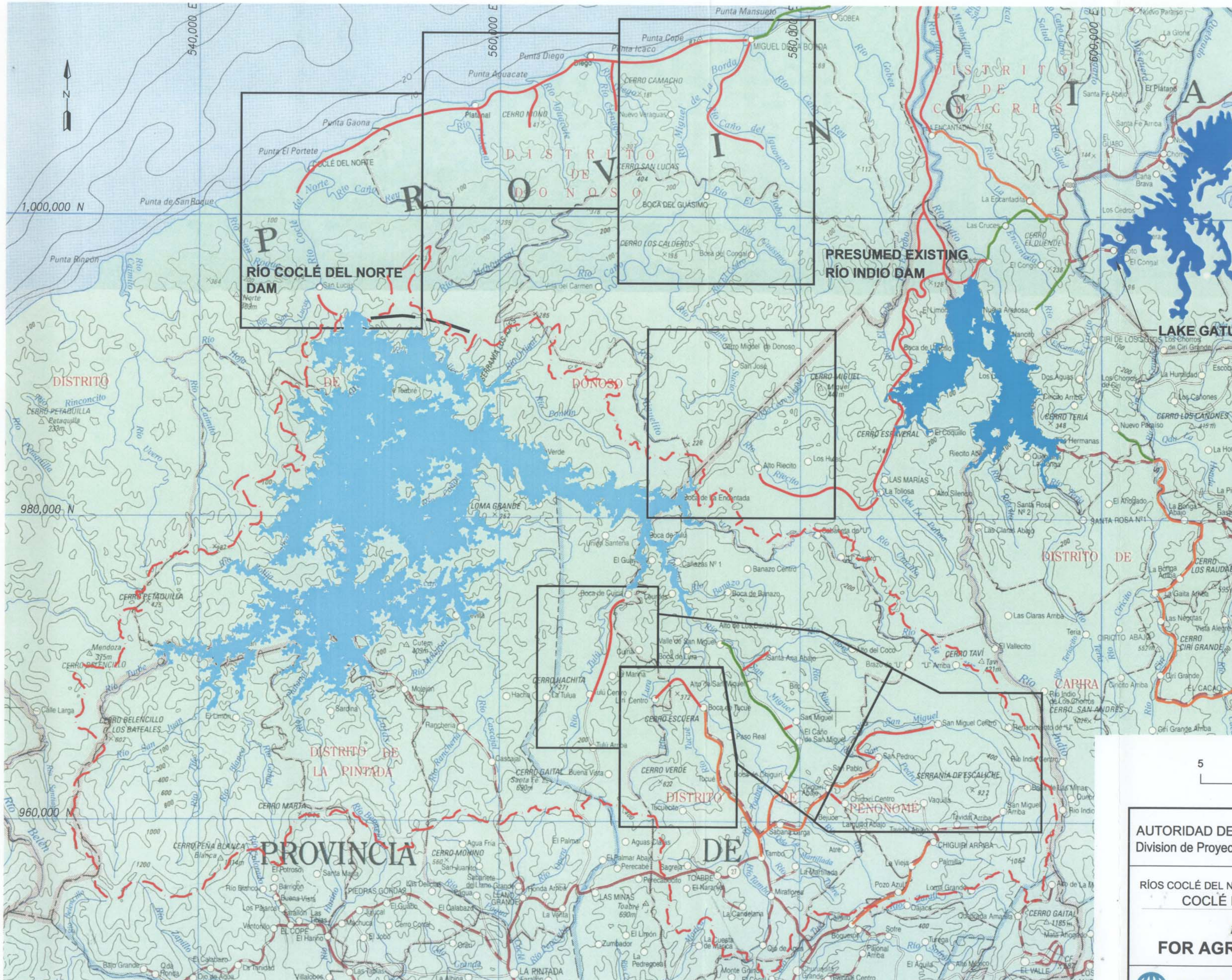
ACP

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

RÍO COCLÉ DEL NORTE (FSL 71)
ONE-LINE DIAGRAM

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	6-6



LEGEND:

- EXISTING PAVED ROAD
- EXISTING EARTH ROAD (DRY WEATHER) NEEDS UPGRADE
- EXISTING GRAVEL ROAD NEEDS REHABILITATION
- PROPOSED UPGRADE TO EXISTING EARTH ROAD (GRAVEL SURFACING, BASE, DRAINAGE, STRUCTURES
- PROPOSED REHABILITATION OF EXISTING GRAVEL ROAD
- PROPOSED NEW ROAD CONSTRUCTION.
- DRAINAGE BOUNDARY
- AREA CONSIDERED FOR AGRICULTURAL DEVELOPMENT

NOTES:

1. THE PROPOSED PROJECT ACCESS ROADS SHOWN ON THIS MAP INCLUDE ACCESS TO THE RIO INDIO PROJECT AS IT WILL HAVE BEEN DEVELOPED PRIOR TO THE IMPLEMENTATION OF THE RIO COCLE DEL NORTE PROJECT.

5 0 5 10 km

GRAPHIC SCALE

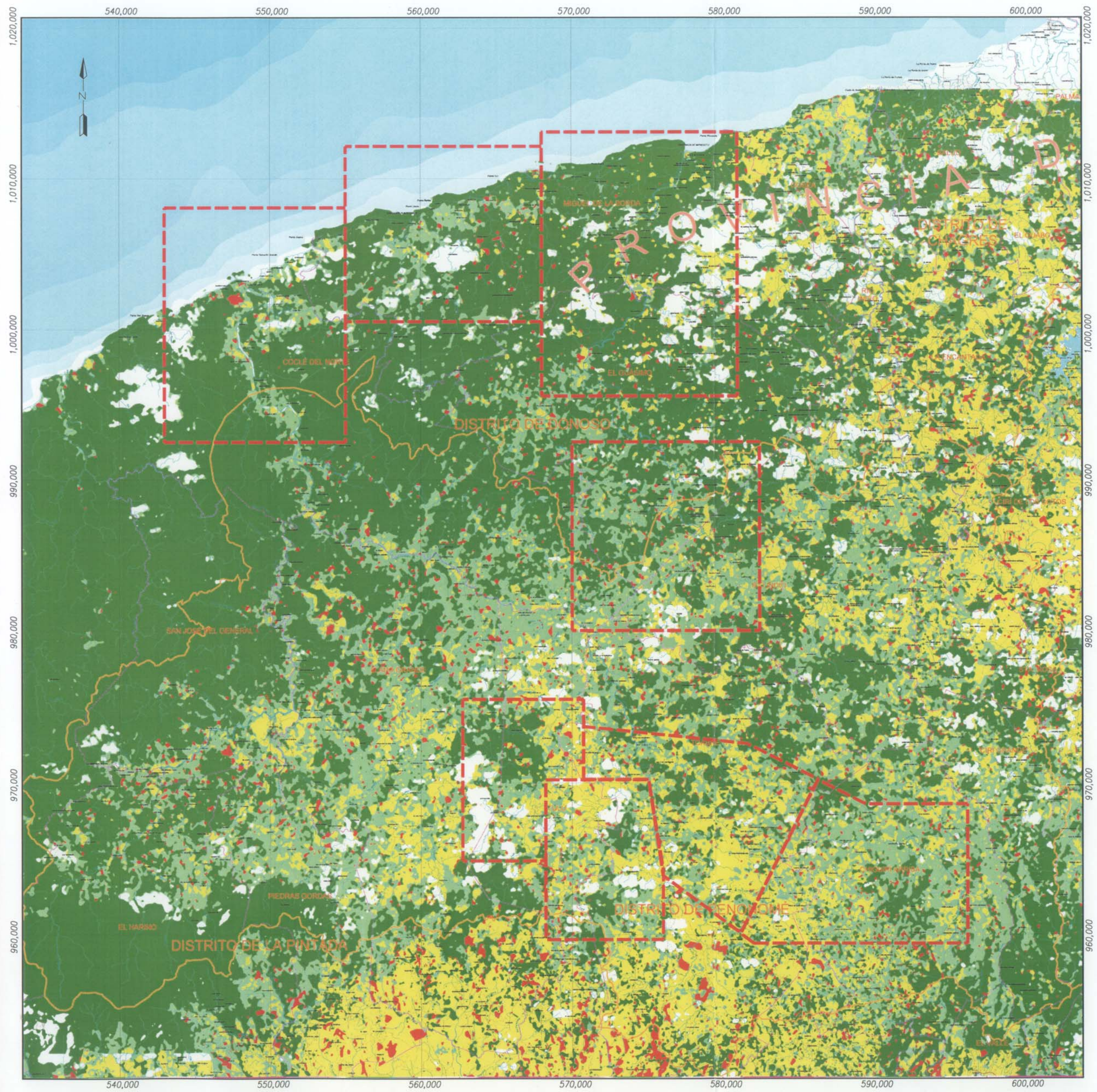
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

AREA CONSIDERED FOR AGRICULTURAL DEVELOPMENT

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	7-1



LEGEND:

- FOREST COVER
- SLASH AND BURN AREAS
- BUSH / THICKET
- PASTURE
- WATER BODIES
- MISCELLANEOUS (INCLUDES AREAS SMALL CULTIVATED AREA, STUBBLE) *Lacking Information,*
- AREAS CONSIDERED FOR AGRICULTURAL DEVELOPMENT SEE APPENDIX F FOR ADDITIONAL INFORMATION

NOTE:

THE LAND USE MAP HAS BEEN PREPARED BY THE ACP DIVISION DE ADMINISTRACION DEL MEDIO AMBIENTAL.

5 0 5 10 km

GRAPHIC SCALE

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

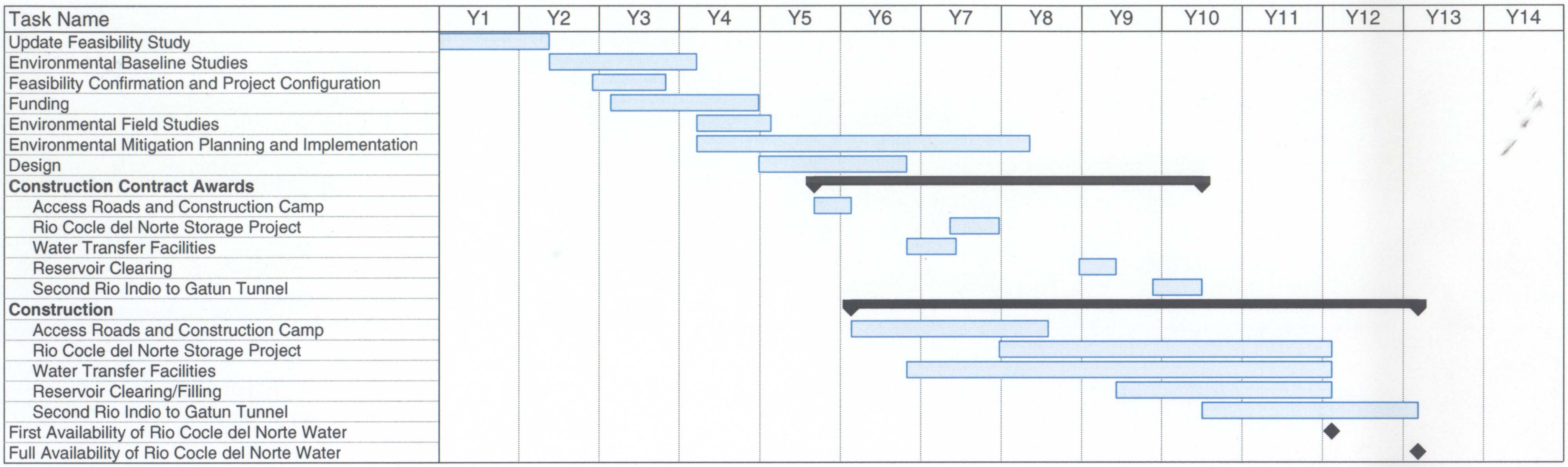
LAND USE MAP

MWH TAMS

DATE:	EXHIBIT:
DECEMBER, 2003	7-2

Cocle del Norte - Rio Indio Project

Implementation Schedule



AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

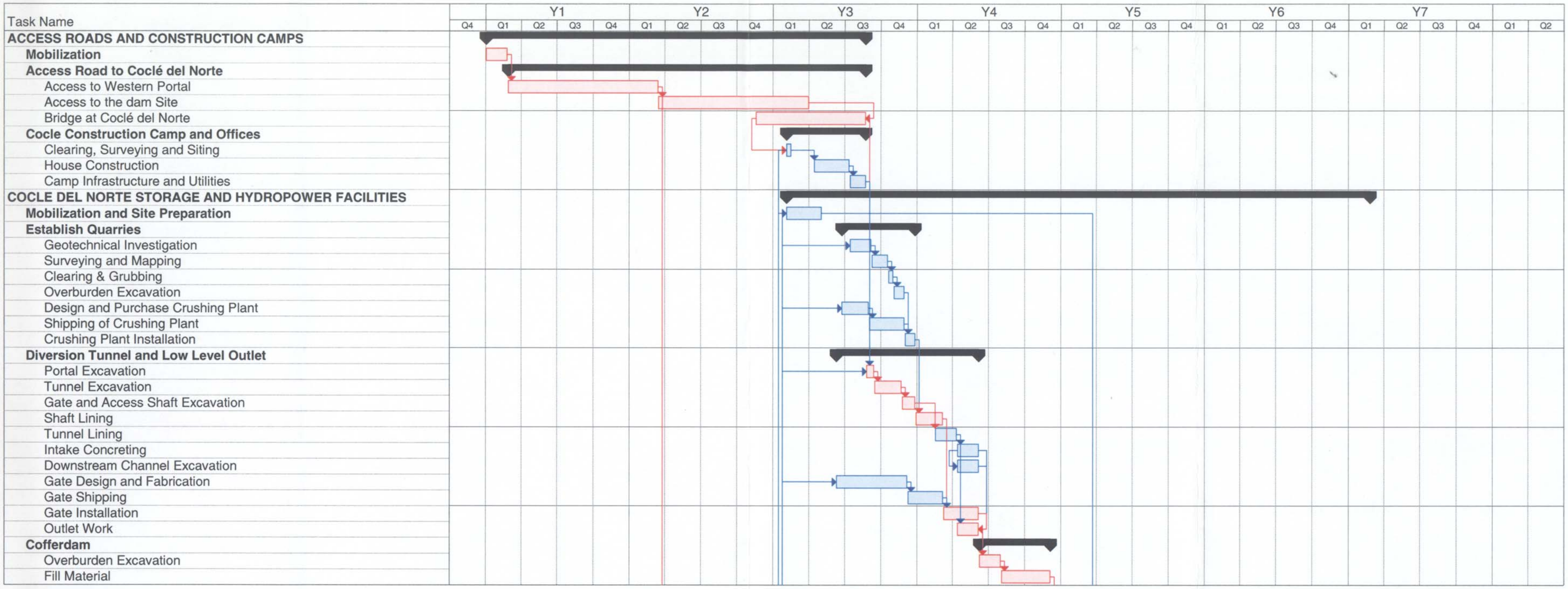
IMPLEMENTATION SCHEDULE

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 8-1

Rio Coclé del Norte Operating Range El. 71 - El. 50
Construction Schedule



AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

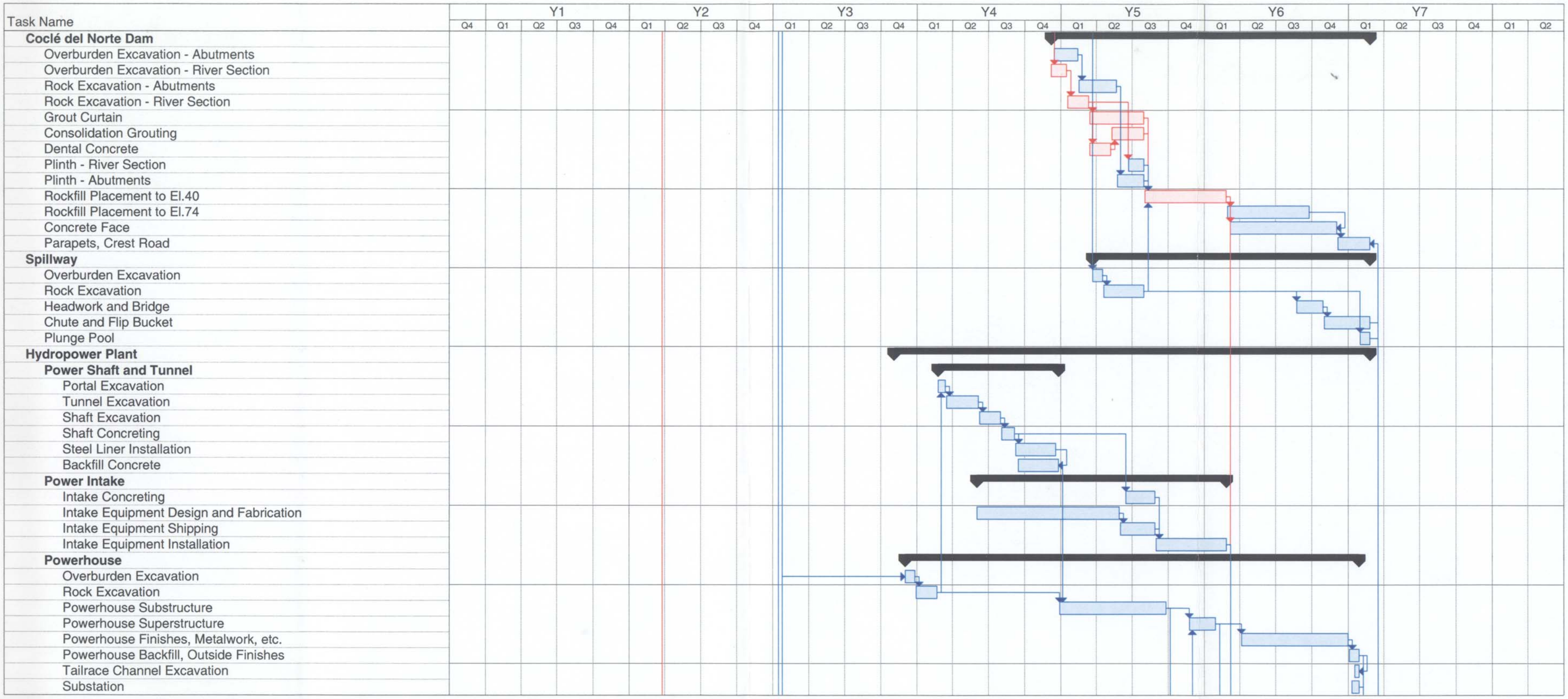
CONSTRUCTION SCHEDULE
SHEET 1 OF 4

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 8-2

Rio Coclé del Norte Operating Range El. 71 - El. 50
Construction Schedule



AUTORIDAD DEL CANAL DE PANAMA
División de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

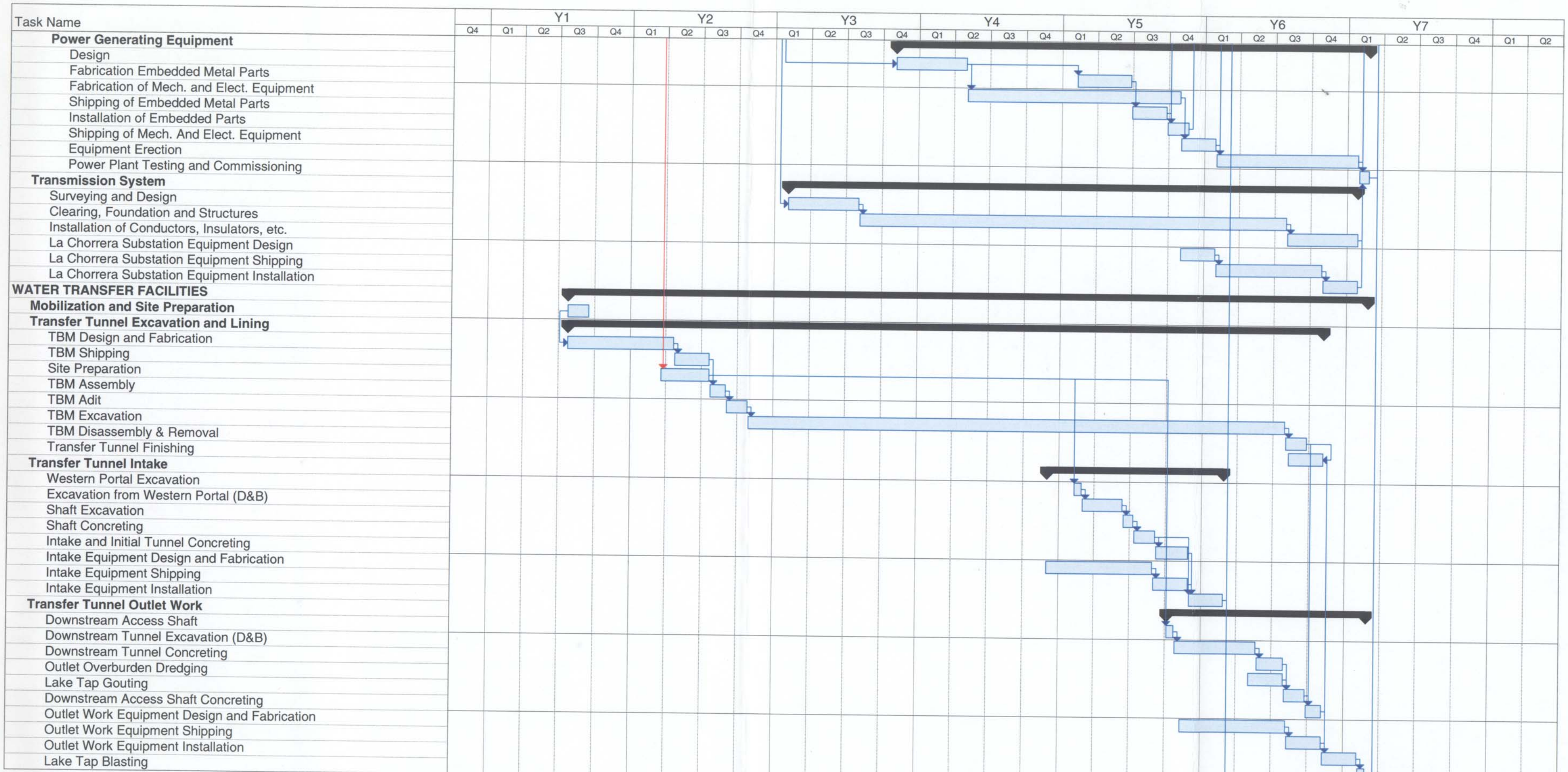
CONSTRUCTION SCHEDULE
SHEET 2 OF 4

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 8-2

Rio Coclé del Norte Operating Range El. 71 - El. 50
Construction Schedule



AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

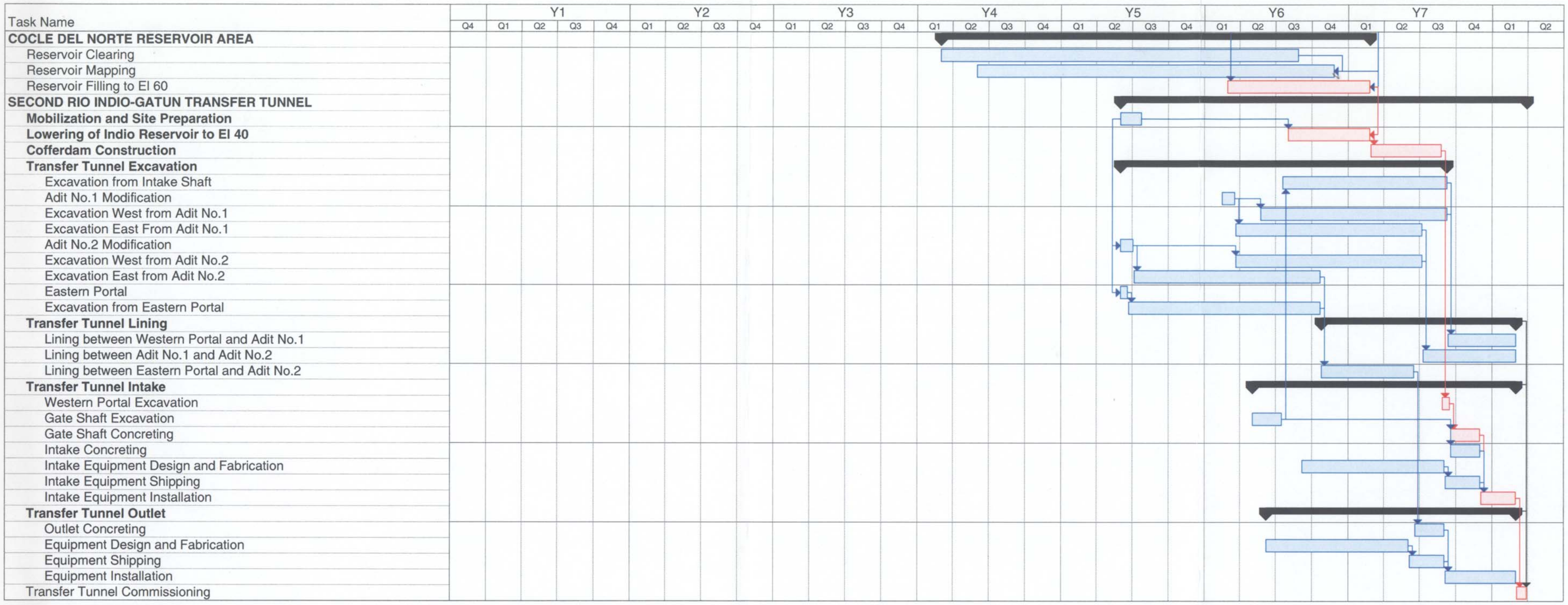
CONSTRUCTION SCHEDULE
SHEET 3 OF 4

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 8-2

Rio Coclé del Norte Operating Range El. 71 - El. 50
Construction Schedule



AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

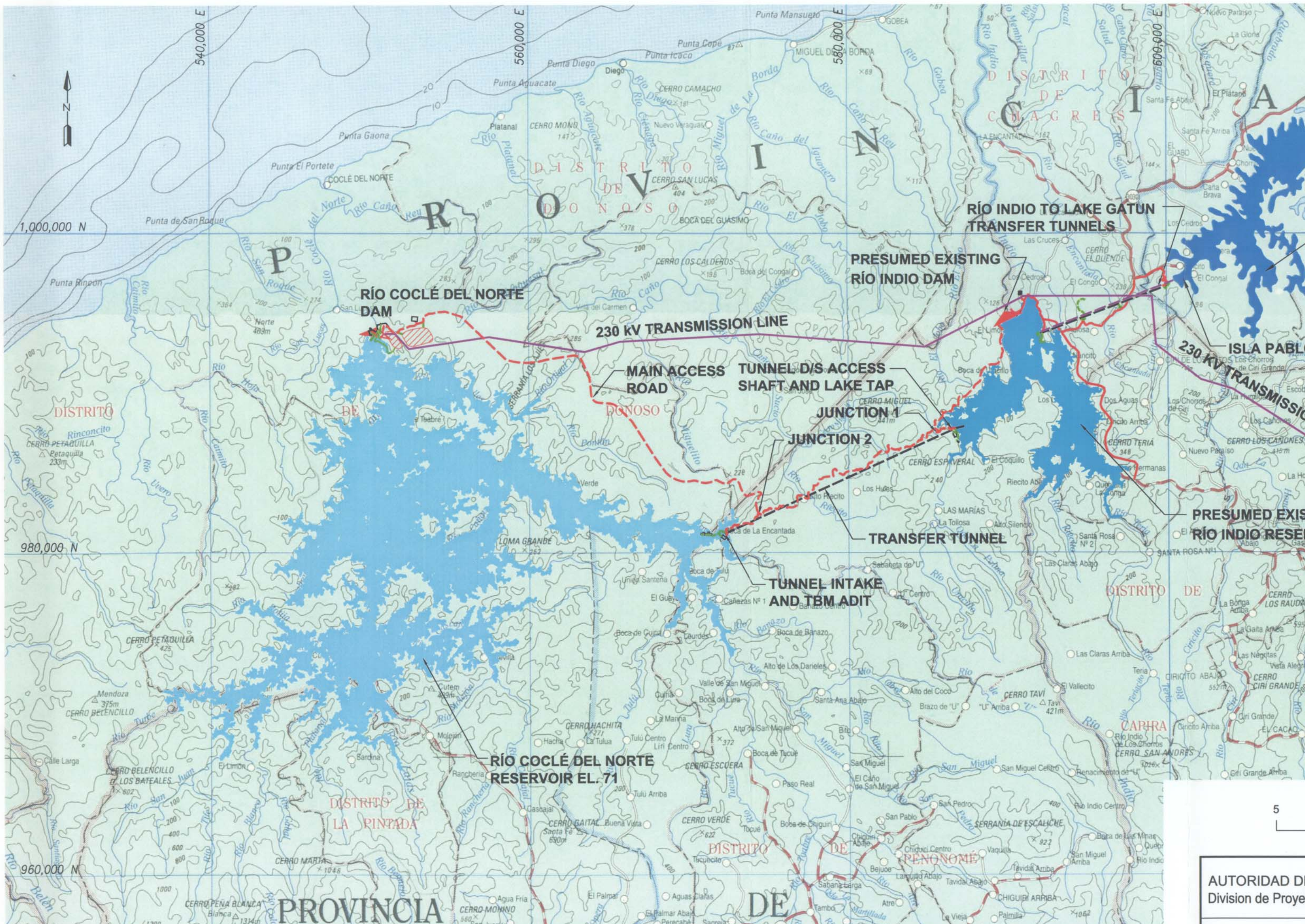
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

CONSTRUCTION SCHEDULE
SHEET 4 OF 4

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 8-2



LEGEND:

230 kV TRANSMISSION LINE	PROPOSED PERMANENT ACCESS ROAD	PROPOSED DAM
PRESUMED EXISTING TRANSFER TUNNEL	PRESUMED EXISTING PAVED ROAD	PRESUMED EXISTING DAM
PROPOSED TRANSFER TUNNEL	CONSTRUCTION ACCESS	PRESUMED EXISTING LAKE/ RESERVOIR
CONSTRUCTION CAMP	QUARRY	PROPOSED RESERVOIR

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

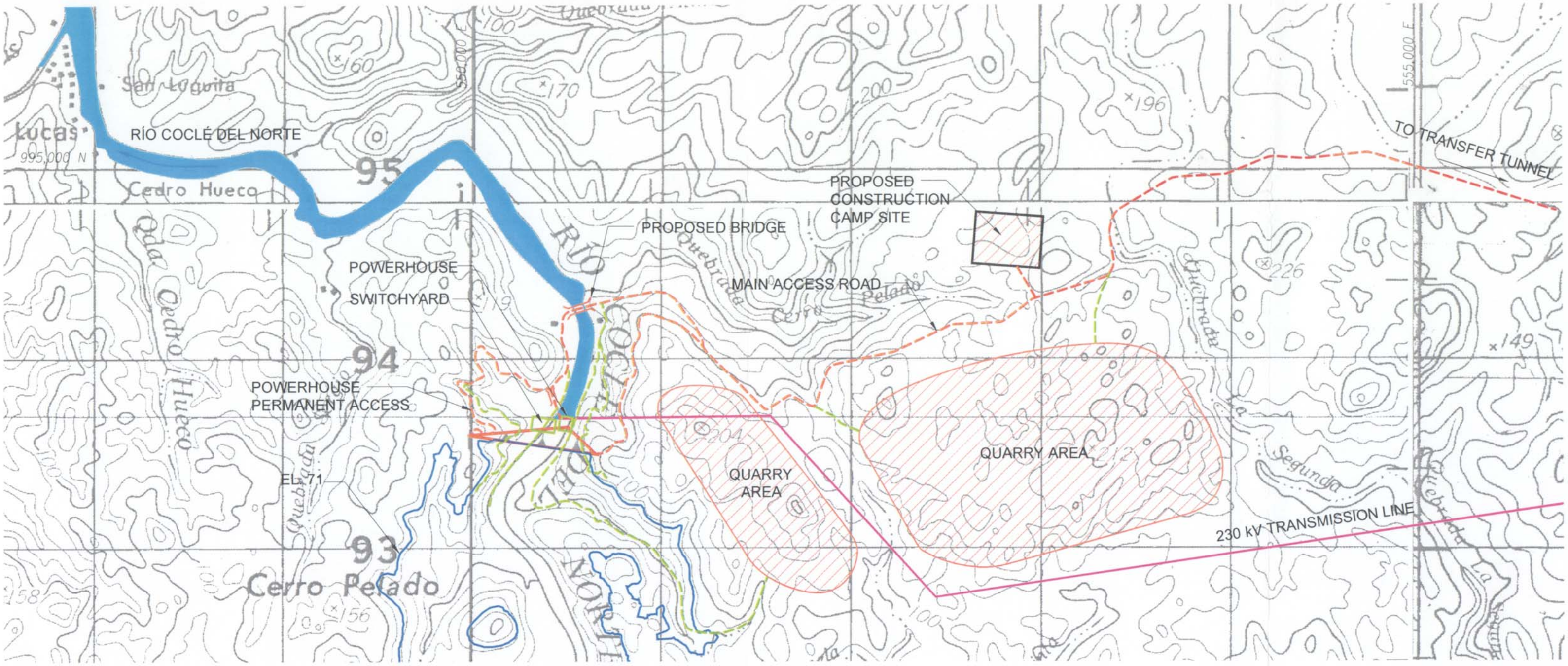
CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

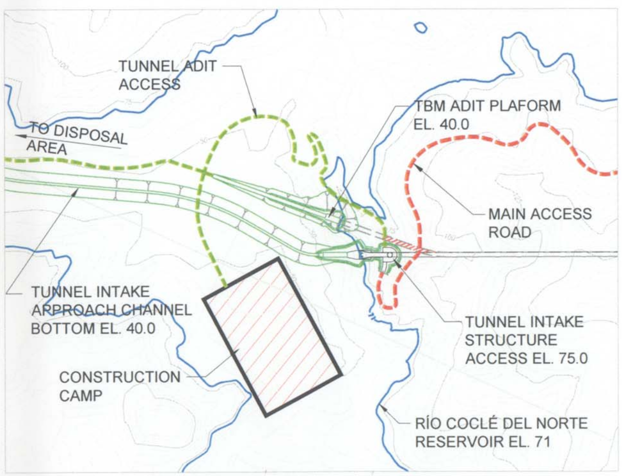
ACCESS ROADS
SHEET 1 OF 2

MWH TAMS

DATE: DECEMBER, 2003

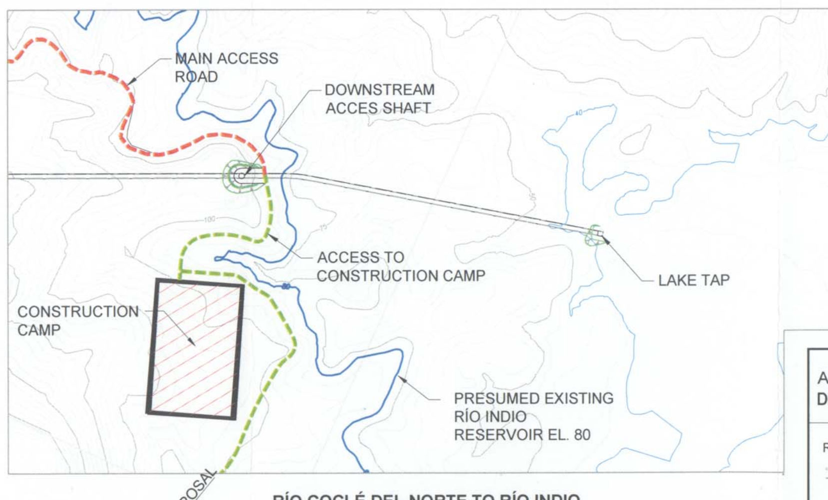
EXHIBIT: 8-3





RÍO COCLÉ DEL NORTE TO RÍO INDIO WATER TRANSFER TUNNEL INTAKE

0 100 200 m
GRAPHIC SCALE



RÍO COCLÉ DEL NORTE TO RÍO INDIO WATER TRANSFER TUNNEL OUTLET

0 100 200 m
GRAPHIC SCALE

LEGEND:

- PERMANENT ACCESS
- CONSTRUCTION ACCESS

500 0 500 1000 m
GRAPHIC SCALE

AUTORIDAD DEL CANAL DE PANAMA
División de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
RÍOS COCLÉ DEL NORTE AND CAÑO SUCIO WATER SUPPLY PROJECTS
COCLÉ DEL NORTE - RÍO INDIO PROJECT

ACCESS ROADS
SHEET 2 OF 2

MWH TAMS

DATE: DECEMBER, 2003

EXHIBIT: 8-3