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ACP

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

Work Order No.3 Feasibility Design For The Río Indio Water Supply Project

Contract Number CC-3-536

Panama Canal

VOLUME 1: MAIN REPORT

MWH

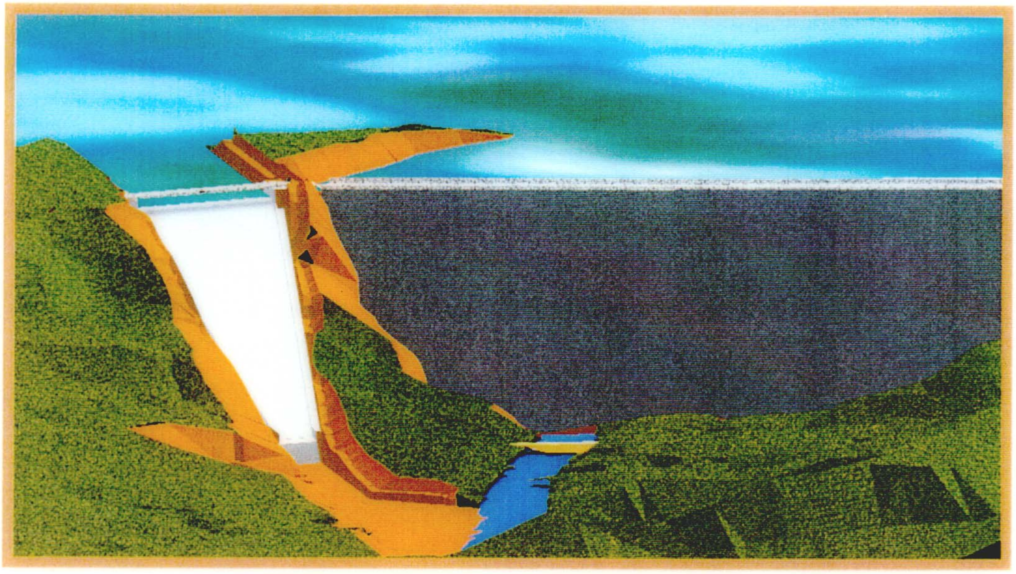
In association with

TAMS

AN EARTH TECH COMPANY

April 2003

The Río Indio Water Supply Project



MWH in association with TAMS
AN EARTH TECH COMPANY

ACP

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

THE PANAMA CANAL

ENGINEERING SERVICES

Work Order No. 3
Río Indio Water Supply Project

Feasibility Study

Volume 1 MAIN REPORT

APRIL 2003

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

Contract No. 20075 [CC-5-536]
Work Order No. 3
RÍO INDIO WATER SUPPLY PROJECT

Prepared for

AUTORIDAD DEL CANAL DE PANAMA

Division de Proyectos de Capacidad del Canal

By

MWH

In association with

TAMS Consultants, Inc.

Ingenieria Avanzada, S.A.

Tecnilab, S.A.

April 2003

EXECUTIVE SUMMARY

INTRODUCTION

The US Army Corps of Engineers (USACE) performed a reconnaissance study to identify and evaluate potential water supply projects to augment the supply of water to the Panama Canal. Three projects were identified as having significant potential. One of the three, the Río Indio Water Supply Project, is the subject of this study. A location map is shown on Exhibit 1. A table of significant data is presented at the end of this summary.

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 Indio Water Supply Project (Project) under Contract CC-3-536, Work Order 0003, dated September 1, 1999.

OBJECTIVE OF THE STUDY

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

During the course of the study, it was not possible to implement the subsurface investigation program or the refraction surveys. Also, during the course of the study, it was decided by the ACP to implement the Río Indio Project 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 Indio Project could not be assessed at this time. Therefore, a determination of technical and economic feasibility was not possible. The objective of the study was changed to an assessment of technical feasibility.

HYDROLOGY AND RIVER HYDRAULICS

Studies were performed to confirm the long-term streamflow sequence adopted for the reconnaissance study, and to estimate the spillway design flood and anticipated reservoir sedimentation.

The ACP developed the long-term streamflow sequence. MWH reviewed the approach and concluded that it was logical and that the results are acceptable. The mean annual flow at the damsite is estimated to be 25.8 m^3/s. The monthly distribution of flow is shown below in m^3/s.

Seismicity

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 Río Indio project is classified as a significant project. The project was analyzed for a return period near 2,000 years. The recommended seismic design parameters for the Río Indio Project are as follows:

- Maximum Design Earthquake (MDE) = 0.21 g
- Operating Basis Earthquake (OBE) = 0.14 g

The Río Indio dam was analyzed for deformation of the rockfill due to the MDE.

Engineering Geology

In general, the foundation bedrock at the site is not expected to present any significant constraints on project development that cannot be taken care of with appropriate conventional design details and construction practices.

It is probable that tunnel construction for the inter-basin transfer will be 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) and agglomerates. For estimating costs, it was assumed that tunnel construction would utilize drill-and-blast techniques from six headings.

Experience indicates that groundwater inflow should be expected. The potential for encountering hazardous gases and stress-related problems is considered remote.

Construction Materials

The types of required construction materials and the anticipated source of these materials is as follows:

The diversion cofferdams will be constructed from locally available random fill obtained from the immediate area of the dam site. The most significant source is the right abutment excavation for the spillway. Another source is located two to three kilometers upstream from the dam in the terraces along the banks of the river.

the upstream and downstream faces will be conservatively set at 1.4H:1.0V. The main body of the dam will be comprised of rockfill and the downstream shell will be coarse rockfill. The rockfill shells of the dam have an in-place volume of about 2.7 million cubic meters. A reinforced concrete facing will act as the impermeable membrane. The average thickness of the concrete face will be 0.4 m.

With reservoir full supply level at El. 80, two saddle dams will be required, one on the north side of the right abutment and the second about 4 km south-east of the main dam. The saddle dams will contain a volume of about 860,000 m^3 of material.

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 950 m^3/s using a surcharge of 4.0 m above the full supply level.

The spillway will consist of an approach channel, an ogee control section, a tapered chute, a flip bucket, and an excavated channel to direct the water back to the natural river channel.

The facilities for the diversion of the Río Indio during construction consist of cofferdams upstream and downstream from the damsite and a tunnel in the right abutment. The tunnel will serve to:

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

The diversion tunnel will be a 4.0-m diameter, modified horseshoe with vertical sides and a horizontal invert, 635 m long. Under the 50-year flood event, the tunnel will discharge about 113 m^3/s with the upstream water surface at El. 21.6 and the downstream water surface at El. 7.8. The upstream and downstream cofferdams will be at E. 22.5 m and El. 8.5 respectively. The total volume of both cofferdams will be about 107,500 m^3.

A low-level intake structure will be constructed at the intake portal and a gate shaft will be constructed at about the mid-point of the tunnel to facilitate its use as a low level outlet for reservoir evacuation.

A minimum release facility, sized to pass 2.6 m^3/s, will be located in the right abutment. The intake structure will be located on the face of the CFRD just below El. 40.0, the minimum operating level of the reservoir. The intake will connect through the face of the dam to a steel penstock, nominally sized at 1.0 m. A 1.6 MW turbine/generator will be included in the minimum release facility to provide power to the resettlement area and for project operation.

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

The existing PNIS has an installed capacity of 1,079 MW (year 2002). On the basis of the peak load and energy requirements, the existing, committed, and scheduled retirement, the power balance in year 2010 should be about as follows:

	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

Therefore, it can be concluded that there is a substantial market for additional power in the near future and that the Indio hydro will be easily absorbed into the PNIS.

Potential for Adding Hydropower to the Río Indio Project

Studies were performed to determine if the addition of hydropower to the water supply project was viable. The studies consisted of estimating the potential energy production under a variety of conditions, evaluating the alternative locations for generating electricity, and determining the viability of the most attractive alternatives.

Three alternatives to generate power as a part of the Río Indio Project were evaluated:

1. Maximize production at the tunnel powerplant
2. Maximize the power production at the Gatun Powerplant.
3. Maximize the power production at Río Indio Dam.

The land use was initially identified by reviewing available aerial photographs and verified by a field reconnaissance. 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. As a result of the land resources investigations, eight potential development areas were identified having a gross area of approximately 5,500 ha and a net area for farming of about 3,500 ha.

Crops included in a suggested pattern are dry-seeded and transplanted rice, maize, plantain, cassava, vegetables, yams, pasture, and nursery crops. These crops were selected to match the current farmer preferences while allowing for the production of a marketable surplus as well as farm-family requirements.

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.

Costs were estimated to average about $16,000/ha over the eight areas. Based on cropping pattern options for each area, average net benefits were estimated by hectare and for each potential area using data from the Ministry of Agriculture Extension Service.

The economic returns of the agricultural development ranged from 7% to 12%. Therefore, it is concluded that the potential for irrigated agriculture exists, however, implementation of the development is not warranted at this time.

COST OF THE PROJECT

The cost estimate for the construction of the Río Indio Water Supply Project has been developed on the basis of the present feasibility design and construction schedule. The estimates represent the prevailing rates during the middle of 2001. The estimates are based on the assumption that an international contractor will construct the storage facilities and the water transfer tunnel without restriction on sources of supplies and equipment. The unit prices have been estimated at feasibility level. The quantities have been estimated with the constraint of no subsurface investigations. A summary of the construction cost is shown in the following table.

CONCLUSIONS AND RECOMMENDATIONS

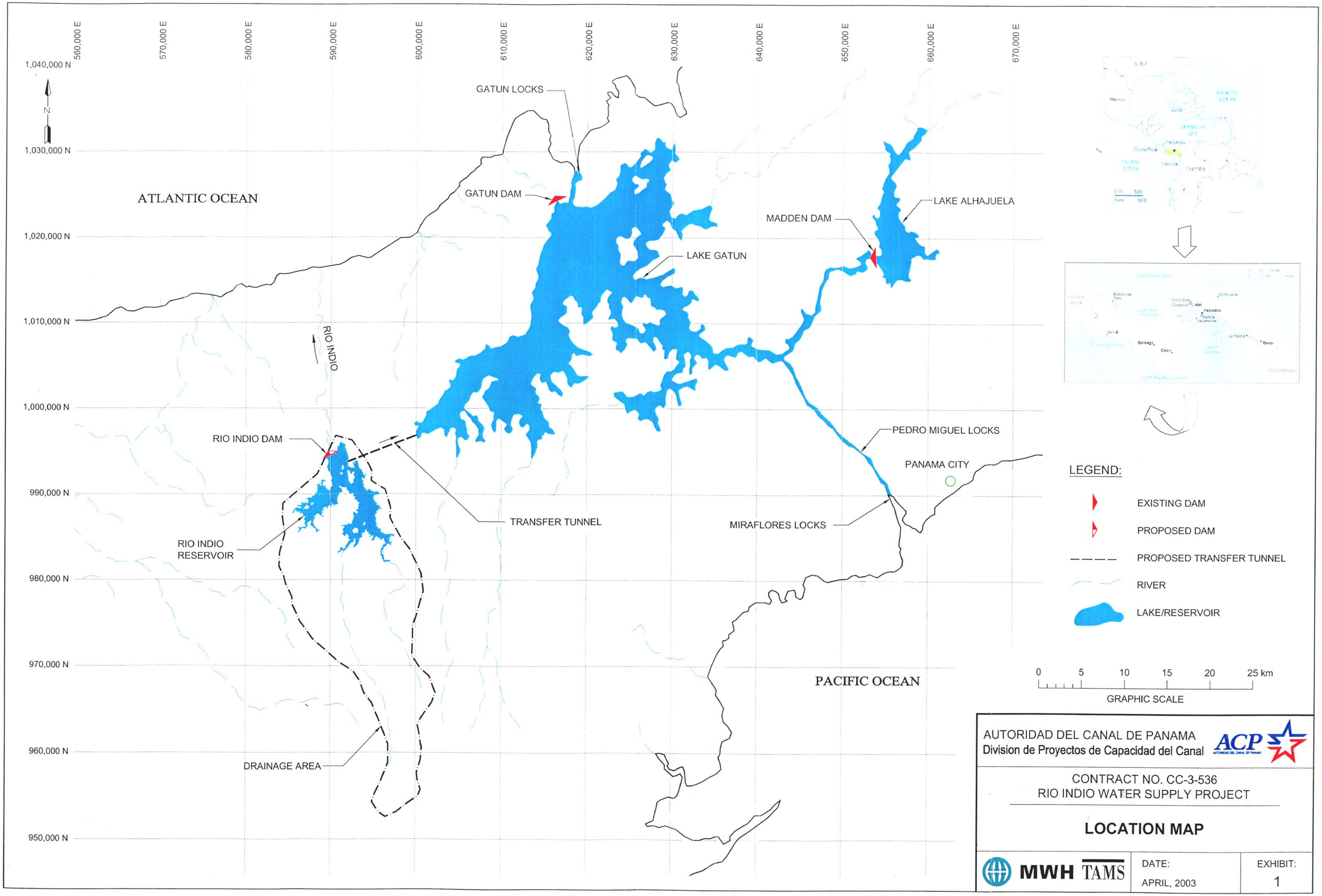
As a result of the studies described in this report and its appendices, it is concluded that:

- The Río Indio Water Supply Project is technically feasible;
- The dam site selected in the Reconnaissance Report is the most suitable site for the development of the water resources of the Río Indio Basin;
- Either a concrete-face rockfill dam or a roller compacted concrete dam is suitable for the site and cost effective. A concrete-faced rockfill dam was selected based on a preliminary analysis and discussions with the ACP;
- The lack of subsurface investigations has increased the potential for inaccuracies in the estimate of cost. However, it is our considered opinion that there are no geologic or geotechnical problems associated with the site that cannot be accommodated using conventional solutions;
- The yield of the Panama Canal system will increase by about 1,200 MCM/yr (about 15.8 L/d) with the addition of the Río Indio Project;
- The addition of hydropower to the Project is not warranted at this time. However, a 1.6 MW plant has been included to generate electricity from the minimum release for project operation and to serve the needs of the resettled population. Any plans to implement any other project to the west of the Río Indio Project will improve the economics of the hydropower addition and should cause the issue to be revisited;
- The inclusion of a commercial agricultural endeavor is technically feasible, but is not warranted at this time due to a lack of government services, infrastructure, and an adequate labor pool;
- The project is estimated to cost about $230 million in 2001 dollars. Allowing for inflation at 3% per year, escalation during construction at 3% per year, and interest during construction at 10% per year, the capital cost of the project in current dollars would be about $303 million.
- A project that delivers about 1,200 MCM/yr for a cost on the order of $300 million is a very attractive proposition.

As a result of these conclusions, it is recommended that:

1. The Río Indio Project is considered as a suitable source of water for any canal expansion.
2. Concurrent with the evaluation of new-lock schemes and alternative sources of water, subsurface investigations and environmental studies of the Río Indio Project should continue without hiatus.

Diversion During Construction		
Section Shape	modified horseshoe; vertical sides; horizontal invert	
Diameter	4.0	m
Length	635	m
Diversion Flood	820	m^3/s
Discharge Capacity	113	m^3/s
Upstream Cofferdam Height (hydraulic)	18	m
Downstream Cofferdam Height (hydraulic)	3	m
Cofferdam fill Volume	107,500	m^3
Minimum Release Facility		
Type	Concrete encased steel pipeline under dam	
Capacity	2.6	m^3/s
Water Transfer Tunnel		
Intake		
Type of structure	Reinforced concrete	
Invert Elevation	El. 32	msl
Tunnel		
Shape	Modified horseshoe	
Length	8,350	m
Diameter	4.5	m
Capacity at Maximum Pool	94	m^3/s
Capacity at Minimum Pool	43	m^3/s
Outlet		
Type of Structure	Reinforced concrete	
Invert Elevation	El. 27	msl
Estimated Project Cost		
Construction Cost	$230,430,000	
Annual Cost	$1,940,000	
Estimated Project Yield		
Volumetric Reliability	99.6	%
Yield L/d	15.8	L/d
Yield MCM/year	1,200	MCM/yr



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

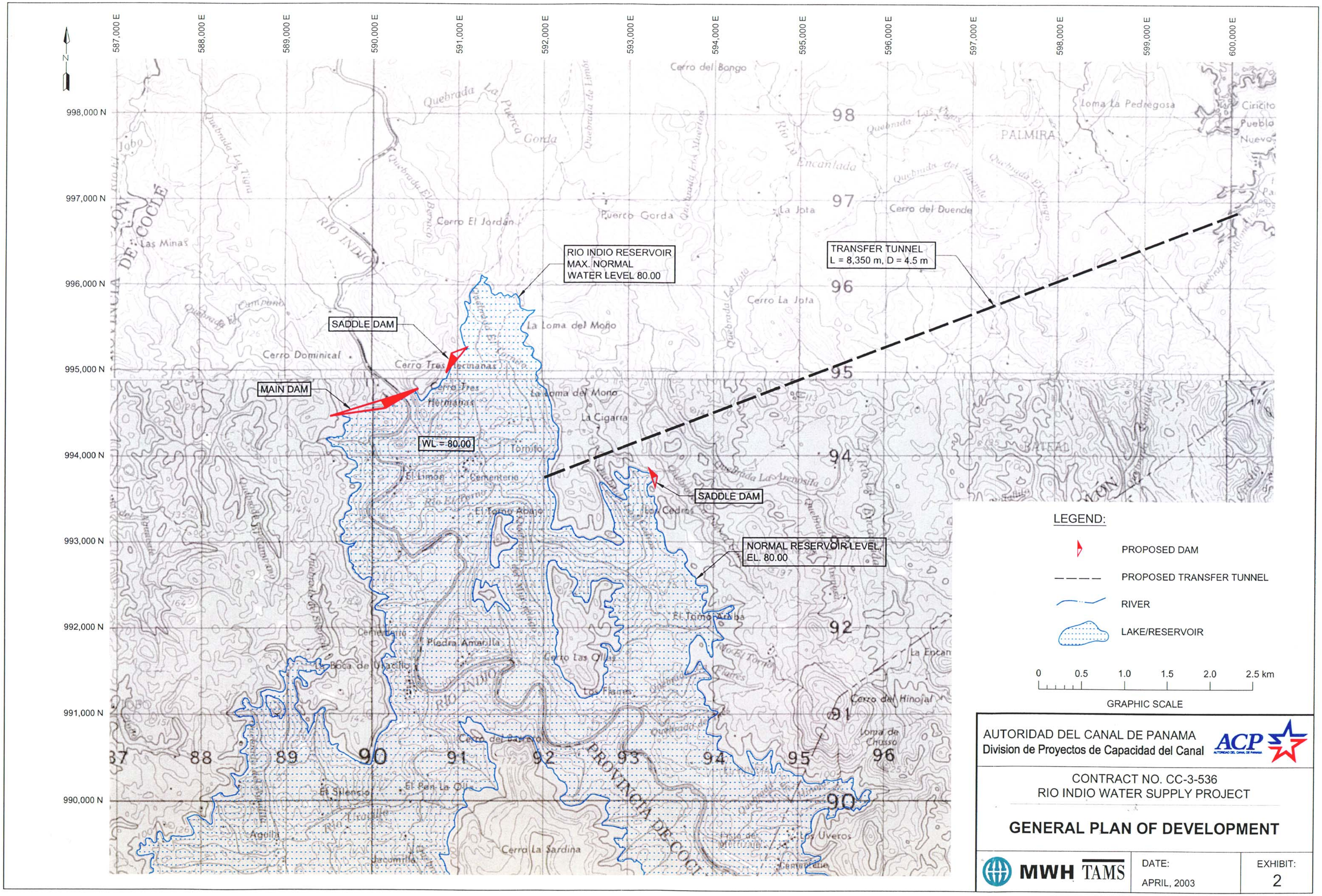
CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

LOCATION MAP

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 1



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

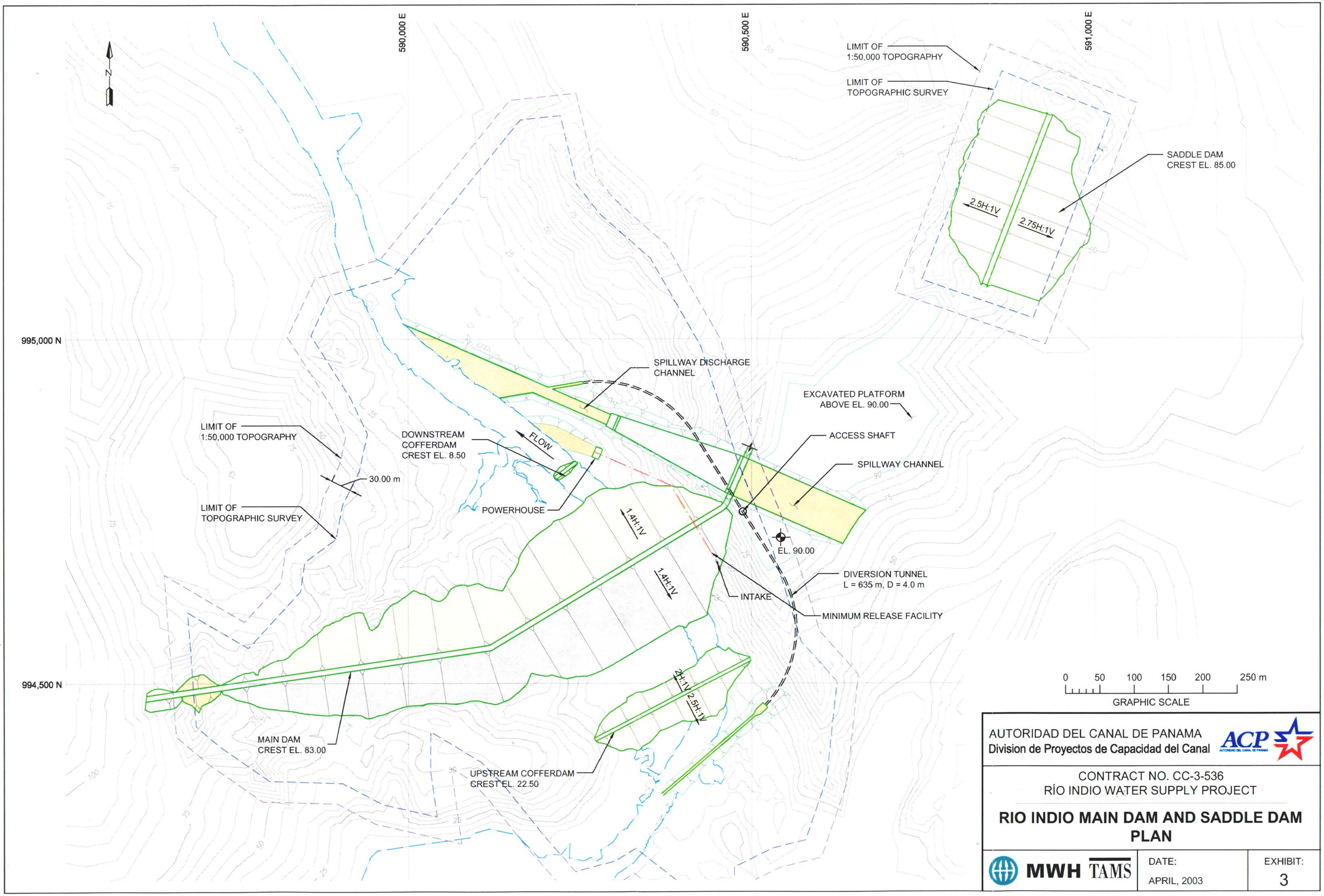
CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

GENERAL PLAN OF DEVELOPMENT

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 2



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

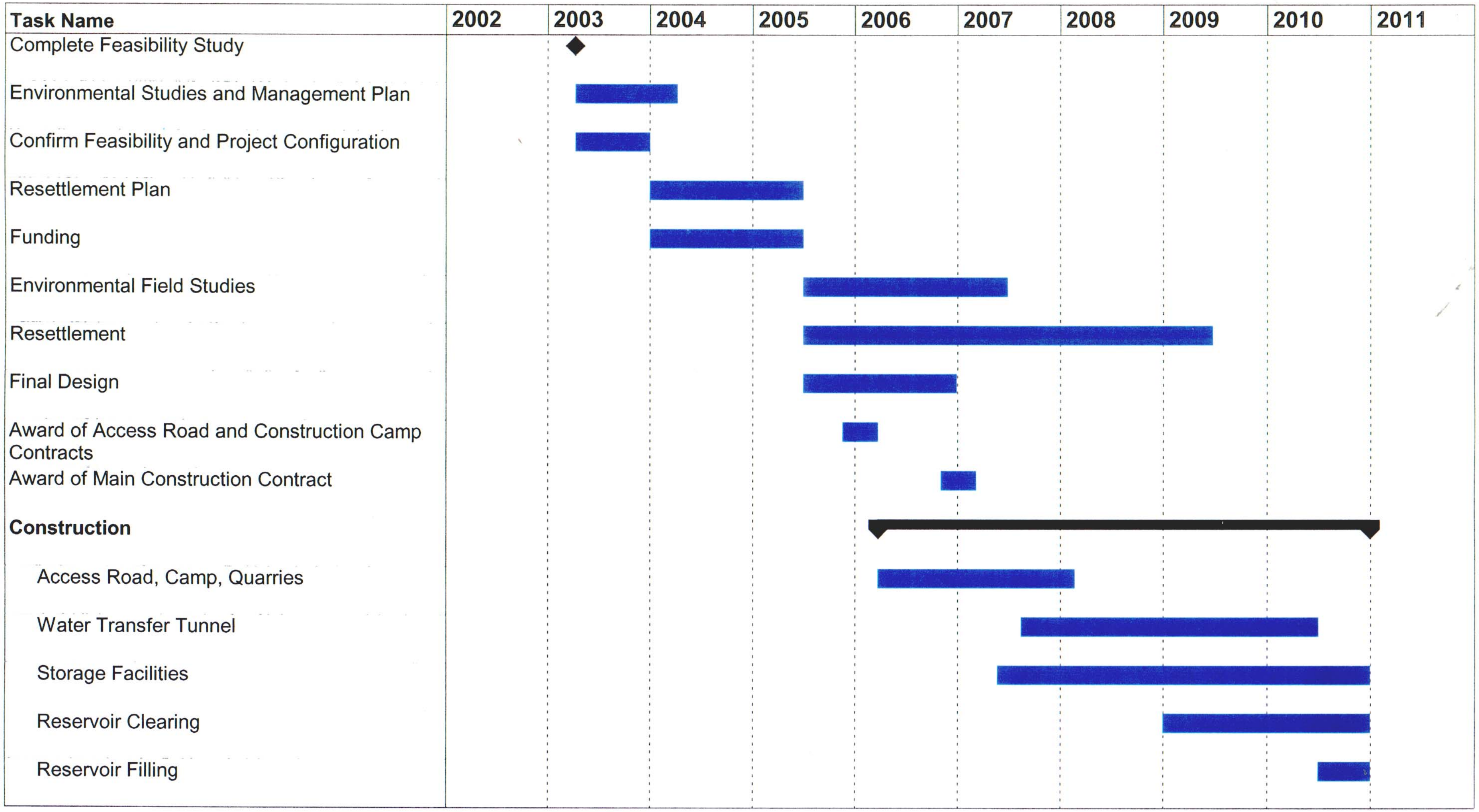
ACP

CONTRACT NO. CC-3-536
RÍO INDIO WATER SUPPLY PROJECT

RIO INDIO MAIN DAM AND SADDLE DAM PLAN

MWH TAMS

DATE:	EXHIBIT:
APRIL, 2003	3



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

ACP

CONTRACT NO. CC-3-536
RÍO INDIO WATER SUPPLY PROJECT

IMPLEMENTATION SCHEDULE

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 4

Main Report

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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 Indio Water Supply Project (Project) under Contract CC-3-536, Work Order 0003, dated September 1, 1999.

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.

Recent climatological phenomena have shown that the existing water supplies for the Canal would not be sufficient to meet the anticipated future demand. A recent long-term traffic demand forecast indicates that, over the next 50 years, the number of transits per year will almost double and the tonnage passed will increase at a greater rate (1)[1]. In addition, the municipal and industrial water demand in Panama is expected to increase substantially over the near term and, as this demand must be met first, the availability of water for Canal operations will be further constrained. As a result, a major component of the study of the operating systems is the formulation and development of additional water supplies.

The US Army Corps of Engineers (USACE) performed a reconnaissance study to identify and evaluate potential water supply projects (1). Three projects were identified as having significant potential to augment the existing water supply to the Canal. One of the three, the Río Indio Water Supply Project, is the subject of this study.

1.3 Objectives

1.3.1 Original Objective

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

[1] All references are located at the end of the text.

- Estimate evaporation and reservoir sediment deposition

Task 4 River Hydraulics. Assess the impact of construction on the water quality downstream from the dam and the stability of the river channel as a result of the project's development. 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.

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 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 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 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.

1.7 Acknowledgements

MWH gratefully acknowledges the assistance that has been provided during the course of the studies. In particular, the following persons and organizations have provided invaluable assistance.

- Augustin A. Arias, Division Director, Canal Capacity Projects Division, Autoridad del Canal de Panama;
- Jorge de la Guardia, Manager, Canal Capacity Projects Division, Autoridad del Canal de Panama;
- Jose Pascal, Water Projects Team Leader, Canal Capacity Projects Division, Autoridad del Canal de Panama;
- 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 Indio 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:

Ingenieria Avanzada, S.A., Panama, and
Tecnilab, S.A., Panama.

2. PROJECT SETTING

The Río Indio Water Supply Project is located essentially in the middle of the Republic of Panama, immediately to the west of the Panama Canal Watershed and about 75 km northwest of Panama City. A location map is presented on Exhibit 2-1. 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 (ITZ). When the ITZ 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. Based on extended records for the *Boca de Uracillo* station, the single rainfall station in the Río Indio basin, the mean annual rainfall is 3,078 mm and the mean monthly rainfall varies from a low of 75 mm in February to a high of 409 mm in October. Mean monthly rainfall values are shown in Table 2-1.

TABLE 2-1 MEAN MONTHLY RAINFALL, BOCA DE URACILLO

Month	Dry Season Rainfall (mm)	Month	Wet Season Rainfall (mm)
January	135	May	361
February	75	June	318
March	84	July	287
April	181	August	306
		September	307
		October	409
		November	368
		December	247
Mean Annual Rainfall 3,078 mm			

There are two major tributary systems to the Río Indio, both flow parallel to the river in the wide middle part of the basin. On the east (right) bank, the Río Teria system, which drains an area of about 96 km^2 flows into the Río Indio at kilometer 48 or about 19 kilometers upstream from the damsite. On the west (left) bank, the Río Uracillo system, which drains an area of about 103 km^2 flows into the Río Indio at kilometer 38. The two major river systems cover slightly more than one-half of the drainage area above the dam. In addition, there are two other sizable tributaries, Río El Torno and Río Riacito plus about 20 smaller creeks that flow into the Río Indio.

There are no significant features in the basin. The topography is characterized by strongly dissected and moderately steep terrain with irregularly spaced conical-shaped hills and a dendritic drainage pattern. The landforms appear to be the result of high rainfall-caused runoff and well-developed stream erosion. Although a majority of the basin is forested, significant amounts of clearing and subsistence farming have occurred, especially in the proposed reservoir area.

Access to the basin is very limited. From the south, several asphalt roads approach the basin but access is only by gravel-surfaced roads and even this access is only to limited areas. The favored access route is by paved road from Santa Rita to La Trinidad and then by a dry-weather road to the middle of the basin. When the drilling program is implemented, dry-season, access to the site will be possible due to the planned improvements for the existing road system. From the Atlantic Ocean side, there is an all-weather road from Colon to the mouth of the river and then motor-driven canoes can be used to reach the site. As a part of the Project, permanent access to the site has been planned.

According to the Reconnaissance Report (1), the reservoir area is devoted to subsistence farming and ranching. There are 6 towns and villages in the reservoir area that will need to be relocated; *El Limon, Los Uveros, La Boca de Uracillo, Los Cedros, El Coquillo, and Tres Hermanas*, and approximately 30 other small settlements.

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 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 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.

The ACP also is currently deepening the navigation channel through Lake Gatun by three feet (0.91 m).

2.3.2 Canal Traffic

The Canal 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 (2). Actual use of the canal by PANAMAX ships already is 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 (3):

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 the regulation of 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 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 area; *El Limon, Los Uveros, Uveros, La Boca de Uracillo, Los Cedros, El Coquillo, and Tres Hermanas*, with a combined total population of about 900. It is estimated that about 600 persons reside in 14 communities in the area downstream of the dam site with about 150 in *La Boca del Río Indio.* Residential developments consist of scattered groupings of houses with few amenities.

An extensive compilation of the socio-economic data for the basin is presented in the March 2002 report *Recopilacion y Presentacion de Datos Socioeconomicos de la Region Occidental de la Cuenca del Canal de Panama.*

Slash and burn farming is the major economic activity and it is only at the subsistence level. The farmer draws a major portion of his subsistence from his own crops or livestock and the family is the main source of labor. There is no access to farm machinery and little access to work animals. There are no major industries or beef or poultry processing plants in the area.

In general, the level of education in the basin is relatively low. *El Limon* in the basin, and *El Silencio, San Cristobal,* and *Piedra Amarilla* have elementary schools

There are few public services. Several towns have cemeteries, churches, and medical centers. 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

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 line, 134 km of 115 kV line, and ten 230-kV substations with a total capacity of 885 MVA (16). 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 MWh to about 452,000 consumers. Aggregate distribution by consumer category is shown in Table 2-3.

Small farms are predominant; the prevailing size of the holdings is about 0.5 ha. The small size appears to be the result of difficulties in obtaining labor. The farmer draws a major portion of his subsistence from his own crops or livestock and the family is the main source of labor. There is no access to farm machinery and little access to work animals.

2.7 Geologic Setting

The proposed Río Indio Project is located in an area underlain by Oligocene-aged sedimentary rocks of the three-membered Caimito Formation of Oligocene age (Woodring, 1982 a, 1982 b). A general stratigraphic column is presented as Table 2-5 and a regional geologic map is presented as Exhibit 2-4. The general pattern and distribution of major faulting in the region is depicted on Exhibit 2-5.

2.7.1 Regional Geology

Regional geologic mapping for this part of the country consists only of the 1:1,000,000 scale national map, which provides negligible detail for the project area. The following descriptions are derived from interpretations made during the course of the geologic studies, from published reports, and this map.

The lower member of the Caimito Formation is composed of conglomerate, greywacke, and tuffaceous sandstone while the middle member consists of tuffaceous sandstone, greywacke, and lenticular foraminiferal limestone. The upper principal member consists of tuff, agglomeratic tuff, tuffaceous siltstone, and discontinuous sandy tuffaceous foraminiferal limestone. The deposits are primarily marine, but lithologically heterogeneous and the rocks of all members are hard, thinly to thickly bedded, and closely to moderately jointed.

The sedimentary units at the Río Indio and Caño Sucio sites comprise tuffaceous siltstones and sandstones, conglomerates and agglomerates. These are interbedded with lavas and in some parts of the reservoir area, the sedimentary rocks are stratigraphically overlain or are intruded by andesite and basalt flows, sills, and dikes. The volcanic units form many of the steep hills and high plateaus that are readily apparent on topographic maps and aerial photographs. Some of the volcanic formations might represent older units cropping out as erosional inliers. More recent volcanic sequences are found south of the project area.

2.7.2 Regional Tectonics

The tectonics in the Central American region is 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, 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 (Bodare, 2001).

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 (Camacho et al., 1994):

- 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 (Cowan 1995). 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 (Acres, 1981).

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 Southern Panama Deformed Belt, while the eastern portion of the Nazca plate is being subducted under South America (Cowan 1995). 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

2.8.4 Air Quality

Air quality in the project area is generally good, except during the periods of slash and burn activities. At the end of the dry season in March or early April, sizable areas of established forests and secondary growth are burned and cleared to prepare the land for agricultural use. Based on observations in the Río Indio project area, approximately 10 percent (or 400 ha) of forested land is burned annually.

2.8.5 Cultural and Historic Resources

No parks or other government-protected lands are known to be located in the Río Indio impoundment area. In the pre-Columbian period, the Río Indio constituted a language frontier; that is, the inhabitants on each side of the river spoke a different native language. During the Spanish colonial period, the river served as a political boundary; therefore, the project area has a high potential to be rich in archaeological and historical remains. A potentially significant archaeological site has been identified in Boca de Uracillo, about nine kilometers above the damsite. It should also be noted that most of the Atlantic region of Panama is within the interest and objectives of the Mesoamerican Biological Corridor, an international project to conserve biodiversity.

3. PROJECT DEFINITION STUDIES

The project definition studies are the basic studies that preceded the selection of the final project arrangement. For many of the studies, an appendix is attached.

3.1 Topography

Ingenieria Avanzada, S.A. prepared topographic mapping of the proposed dam site area under subcontract to MWH. The services were completed and submitted to the ACP under Contract CC-3-536, Task Order 2, Altimetric and Planimetric Surveys of 13 sites located on the Western Side of Lake Gatun. The extent of the topographic coverage is shown on the plan views of the proposed project. 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).

3.2 Hydrology Studies

Hydrologic analyses were performed to confirm the long-term streamflow sequence adopted for the Reconnaissance Study (1), to estimate reservoir evaporation, 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.

3.2.1 Long-Term Streamflow

The long-term flow sequence was developed by the APC and reviewed by Harza. Four gages, identified in Table 3-1, were considered in the development of the long-term streamflow record.

TABLE 3-1 STREAM GAGES USED IN ANALYSIS OF LONG TERM FLOW RECORD

Station	Location	Period of Record	Drainage Area	Type of Gage	Missing Data
Rio Indio at Limon	Slightly upstream from the dam site	1958 - 1980	376 km^2	Non-recording	
Rio Indio at Boca de Uracillo	5 km upstream from the damsite	1979 - date	365 km^2	Recording	28 months

3.2.2 Net Reservoir Evaporation

Net reservoir evaporation is estimated to total 1,134 mm 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 this study. The estimate is presented in Table 3-3.

TABLE 3-3 MEAN MONTHLY NET RESERVOIR EVAPORATION, RÍO INDIO RESERVOIR
(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

3.2.3 Construction Period Floods

Construction period floods were estimated using both available regional flood frequency data and annual maximum instantaneous flood peaks at the Boca de Uracillo gage. The maximum instantaneous peak of 16 annual peaks available for the Boca de Uracillo gage was 772 m^3/s. On this basis, the estimate for the 10-year flood of 1,390 m^3/s from the regional data was considered to be too high and not probable for the Indio basin.

Both Log-Pearson Type III (LPIII) and the Generalized Extreme Value (GEV) distributions were fitted to the annual peaks. The flood peaks estimated using the GEV distribution ranged up to about 8% higher than the flood peaks estimated using the LPIII distribution. However, both distributions indicated a good fit with the data. The values resulting from the GEV distribution were adopted as a conservative (high) estimate. To account for the possibility that flood protection works could also be designed for protection during the dry season, a flood frequency analysis was performed for monthly flood peaks occurring during the period January through March. The construction period flood information is presented in Table 3-4.

arranged sequentially using the "alternating block method (10), adjusted for losses, and applied to a unit hydrograph developed using the Clark Method (11). The total excess rainfall amounted to 583 mm and the maximum one-hour increment was 104 mm. For a base flow of 50 m^3/s, estimated from an analysis of five major floods at the Boca de Uracillo gage, the probable maximum flood hydrograph has a peak of 4,345 m^3/s and a 5-day volume of 243 MCM. The PMF and excess rainfall are shown on Exhibit 3-3.

3.2.5 Tailwater Rating

A tailwater rating curve was developed for the Río Indio at the damsite. The analysis was based on 20 river sections spaced over 16 km 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 are shown in Table 3-5.

TABLE 3-5 TAILWATER RATING INFORMATION

Flow Rate (m^3/s)	Tailwater Elevation (m)
0	5.3
200	8.7
400	10.5
600	11.6
800	12.4
1,000	13.2

3.2.6 Reservoir Sedimentation

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

Suspended sediment data are not available for the Río Indio. However, significant amounts of data are available. ETESA has collected 46 samples on the Río Coclé del Norte at Canoas and 56 samples from the Río Toabre at Batatilla. 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. The suspended sediment rating curves for Norte and Toabre fitted by ETESA were revised to reflect a limiting concentration of 10,000 mg/l rather than the maximum observed concentration. This increase was based

3.2.7.1 Flood Regime Downstream from the Dam

Pre-project floods were based on the flood frequency data presented in Table 3-4, 1 and 2 day volumes for the selected return periods, and a hydrograph shape based on the Dec 4-6, 1991 storm. The post-project floods were estimated by routing the pre-project floods through the reservoir. The flood peaks are shown in Table 3-7.

TABLE 3-7 FLOOD FREQUENCY DATA IN RÍO INDIO CHANNEL DOWNSTREAM FROM THE DAM

Return Period (years)	Pre-Project Flood Peak (m^3/s)	Post-Project Flood Peak (m^3/s)
2	562	57
5	657	71
10	713	79
25	780	89
50	820	100
100	859	108

3.2.7.2 Hydraulic and Bed Material Characteristics

The hydraulic characteristics of the channel downstream from the dam were based on a survey of 6 cross sections and the HEC-2 computer model. 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 the six cross sections. These characteristics are presented in Table 3-8.

TABLE 3-8 CHARACTERISTICS OF THE RÍO INDIO BED MATERIAL

Size Designation	Particle Size (mm)
D35	1.6
D50	6.0
D65	14.0
D90	50.0
Median D	**16.5**

- 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.

Particular attention was paid to possible faults identified as photolinears in photogeologic studies and on regional geologic maps (shown on Exhibit 2-5).

Reconnaissance geologic mapping was performed along the Río Indio from the upstream end of the reservoir area to immediately downstream of the dam site (Cerro Tres Hermanas). Geologic mapping was also carried out at selected locations to help identify conditions along prospective water transfer tunnel alignments, tunnel portals and intake locations, and possible powerhouse sites. A general reconnaissance of the proposed reservoir area 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 Río Indio 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;

to the Caimito Formation or its age equivalent (see Table 2-5: Regional Stratigraphic Column).

It is suspected these units are interbedded with lavas in the vicinity of the larger (eastern) saddle dam. In some parts of the reservoir area, and in the area of the village of Limon, the sedimentary rocks are stratigraphically overlain by andesite and basalt flows. The volcanic units form many of the steep hills and high plateaus that are readily apparent on topographic maps and aerial photographs. Some of the volcanic formations might represent older units cropping out as erosional inliers. More recent volcanic sequences are found south of the project area.

Tuffaceous sandstones and siltstones form the uppermost bedrock unit at the dam site and are widespread throughout the project area. Most of the bedrock is covered by overburden, however in some areas shallow landslides/slumps have removed the overburden to expose underlying *in situ* bedrock. Residual soils developed from the weathering of the sandstones and siltstones at the dam site tend to be clay-silts, as described in previous paragraphs. Andesite and basalt rock units form many of the steep hills and high plateaus in the project area.

3.3.2.3 Structural Geology

The principal geologic structures at the Río Indio 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 Panama Canal Watershed, it is likely that several small faults and shear zones could exist at the dam site. Such structures can locally influence the pattern and degree of weathering in the rock mass, and probably have exerted a minor control over the morphological development of the site, and either singly or in combination significantly affect the strength and deformation modulus of the rock in local areas.

From regional geologic mapping and photogeologic studies, the presence of major faults is not expected at the dam site. Some photogeologic linears have been interpreted parallel to the river valley at the site and trending northwest but these are not thought to be caused by significant faulting in this direction, rather are more likely related to fold structures in the sedimentary rock cover.

Based on limited observations at rock outcrops in the dam site area, bedding in the tuffaceous sandstone is found to more or less horizontal to slightly inclined. The strata are intersected by a well-developed pattern of systematic, near-vertical joints. At this time, few details have been gathered on the characteristics and properties of such jointing but two distinct sets are thought to present, one trending northwest and the other northeast. Currently, there are insufficient data to develop typical stereographic plots. Joints of 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 Indio Project are as follows:

- Maximum Design Earthquake (MDE) = 0.21 g
- Operating Basis Earthquake (OBE) = 0.14 g

The Río Indio dam was analyzed for deformation of the rockfill due to the MDE.

3.3.4 Engineering Geology

In general, the foundation bedrock at the site is not expected to present any significant constraints on project development that cannot be taken care of with appropriate conventional design details and construction practices. In regard to other geological aspects, there do not appear to be any strongly adverse conditions or fatal flaws at the site that would seriously hinder or prevent development or make it too costly to construct Río Indio Dam.

3.3.4.1 Geotechnical Design Parameters

Geotechnical design parameters and criteria used for developing project layouts and cost estimates for dam type selection are presented in Table 3-9.

Foundation drainage will be provided for the spillway to control seepage to reduce pore pressures in the rock mass, and hence uplift. For estimating purposes, a drain hole spacing of 3 m was assumed with depths extending to about half the depth of the grout curtain. Holes would be appropriately inclined in order to maximize the number of joint/fracture interceptions.

3.3.4.3 Diversion and Cofferdams

River diversion during construction will be accomplished by a 4.0-m diameter, 635-m long diversion tunnel in the right abutment. The tunnel will be horse-shoe (or modified horseshoe) in shape and will be concrete-lined.

The diversion tunnel will be excavated entirely in tuffaceous sandstone. This bedrock should be of moderate strength and unweathered over most of the tunnel length except at the tunnel portals. Sandstone should provide favorable tunneling conditions using conventional drill and blast methods.

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 3-5 m to top of rock).

3.3.4.4 Water Transfer Tunnel

The tunnel outlet at Lake Gatun will be founded on sound igneous bedrock, however, design details, such as the extent of tailrace channel excavation and the extent of tunnel steel lining will depend on final arrangements with respect to local topography. At the intake end, reconnaissance revealed that the topography in the portal area is favorable and provides a range of options for detailed design, i.e. flexibility in vertical and horizontal location. The bedrock geology consists of thick-bedded sandstone units, such as found at the dam site, which crop out or are mantled with a thin layer of cobbly/bouldery colluvium.

It is probable that tunnel construction for the inter-basin transfer will be encounter a wide range of rock types and tunneling conditions. The range and relative persistence of various conditions will depend on alignment selection. Rock types could include sandstone and softer epiclastics of the Caimito Formation as well as hard, strong lavas (andesites, dacites, and basalts) and agglomerates. There is potential for transition over short distances from very hard strong rock (such as andesite or basalt) to soft, weak almost clay-like materials. Differing ground conditions can be expected for any of the tunnel alignments considered in this study. 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.

It is assumed that the tunnel will be fully lined throughout mostly to prevent erosion and deterioration of the rock in areas of soft or highly fractured rock, to control water loss in low cover zones and areas of severely fractured rock and, to a lesser intent, for hydraulic reasons. With additional subsurface investigations, a better understanding of the rock structure may enable a reduction in the length on lined tunnel. A cast-in-place concrete lining has been assumed in all rock conditions with a minimum lining thickness of 25 cm except in reaches of low cover where it will be 50 cm.

The anticipated geologic and tunneling conditions strongly influenced the estimate of excavation advance rate and of course construction cost. The daily advance rate assumed for estimating costs was 4 m/day, which is considered realistic. Limiting factors on the production rates will probably not be geologic but rather other aspects such as resource availability and intermediate access.

3.3.4.5 Water Transfer Tunnel Outlet Area

Geologic investigation at the end of the water transfer tunnel, where any power development would occur (i.e. Lake Gatun end) was limited to reconnaissance visits only. Based on observations made during this reconnaissance, the powerhouse will be entirely located on bedrock consisting of relatively strong, sound igneous rock units that are probably andesitic in composition.

The backslope for the powerhouse will be benched and cut to a suitable slope to maintain stability. The exposed surface of the excavation will be rock-bolted and covered with chain-link to control loosening and falling of small blocks. Shotcrete and drain-relief holes will be included in areas on permanent slopes that are more weathered or closely fractured. A complete subsurface and surface drainage system will be installed to intercept and control surface runoff and prevent erosion damage.

3.3.5 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.

3.3.5.1 Diversion Cofferdams

The diversion cofferdams will be constructed from locally available random fill obtained from the immediate area of the dam site. The most significant source is the right

3.4.1.1 Identification of Sites

Six alternative dam sites were identified during a map study using the best available mapping, which consisted of 1:50,000 scale topographic maps. The sites were located over a reach of river from about 17 km downstream of the Reconnaissance site to 10 km upstream of the site. The sites and a legend giving the distance upstream form the mouth in river miles and the coordinates of the axes are presented on Exhibit 3-6. The most downstream site was selected as the farthest downstream site that could impound a significant reservoir. The most upstream site is immediately upstream from the confluence of the Río Indio and the Río Uracillo. Moving farther upstream would significantly lessen the project yield.

In a meeting with the ACP, the six alternatives were reduced to four as follows:

Site	Distance above mouth (river miles)	Comment
Alt. 1	12.5	Accepted. Most downstream site
Alt. 2	15.2	Rejected in favor of Alt. 3. Alt 2 would be more costly with no additional benefits to offset the cost.
Alt. 3	16.0	Accepted.
Alt. 4	28.1	Rejected. Can be considered in final design as an alternative axis to the Reconnaissance site
Recon Site	29.8	USACE site
Alt.5	33.5	Accepted. Site is upstream from Limon
Alt. 6	40.1	Accepted. Site is upstream of Uracillo and is the last site that can fully develop the full basin yield.

3.4.1.2 Site Inspection

In preparation for the site inspection, a dam footprint and alignments for the diversion and spillway were developed. With this information, MWH and ACP staff performed a reconnaissance of the reach of the Río Indio river valley within which the sites were located. The field reconnaissance consisted of two parts, a helicopter flyover and a traverse of the river from Boca del Río Indio to Alternative 6, which is just upstream from Boca de Uracillo. As a result of this site inspection, it was concluded that:

- The reconnaissance site is the only location where the morphology is clearly favorable for the placement of a dam.
- Dams of different heights and widths could be constructed at all of the sites.

Relative cost, yield and social information are presented for each alternative in Table 3-12. Additional social information developed by the ACP is presented in Appendix D.

TABLE 3-12 DAM SITE EVALUATION CRITERIA

Criterion	Alt 1	Alt 3	Recon	Alt 5	Alt 6
Comparison at live storage equivalent to near-optimum development at the Recon Site (1,294 MCM)					
Crest Elevation (m)	60	60	85	90	101
Relative Cost to Recon Site	1.2	1.2	1.0	2.1	3.4
Yield (L/d)	15.7	13.7	15.8	16.2	13.7
Economic Cost	$.027	$.031	$.022	$.046	$.089
Area Inundated (km^2)	101	92	47	44	40
No of persons directly impacted	3,900	3,500	2,000	1,600	1,500
Comparison at "Best supply level"					
Crest Elevation (m)	68	62	85	(1)	129
Relative Cost to Recon Site	1.6	1.3	1.0		5.9
Yield (l/d)	22.7	15.7	15.8		25.7
Economic Cost	$.025	$.030	$.022		$.082
Area Inundated (km^2)	117	96	47		57
No of persons directly impacted	4,200	3,600	2,000		2,000
Archaeological impacts	Major	Major	Major	Major	Minor

(1) Indeterminate as yield and cost increase in a straight line over range of values studied and no best supply level could be determined.

3.4.1.4 Conclusions

On the basis of these criteria, it is concluded that the site identified in the reconnaissance report is the most suitable site for the development of the Río Indio basin for the following reasons:

1. The sites downstream from the reconnaissance site, Alternatives 1 and 3, provide about the same yield for a slightly greater cost; however, the social impact is significantly greater. Both sites 1 and 3 inundate approximately twice the area and impact almost twice the number of people. In addition, neither 1 nor 3 eliminates the major archaeological impact and neither site has more favorable morphology or geology.

2. Alternative 5 would provide the same yield as the reconnaissance site for about twice the cost. The major advantage of Alternative 5 is that is would not inundate

The diversion tunnel was located in the right abutment and consisted of a 5.0-m diameter D-shaped tunnel, 635 m long.

The ungated spillway was located in the right abutment because of the favorable topographic conditions and to take advantage of the right abutment excavation as a source of construction materials. To minimize additional excavation, a side-channel spillway arrangement was selected discharging over an ogee-shaped control structure into a tapering chute and terminating in a flip bucket. As configured, the spillway would have a capacity of 770 m^3/s for a control structure length of 50 m and the chute would taper from 20 m to 10 m over a length of 250 m.

The gated spillway was also located in the right abutment. To develop the assumed flood surcharge, it consisted of a two-bay gated control structure, with 5.0-m wide by 7.0-m high radial gates, a 13-m wide chute and a flip bucket. The capacity of the spillway at full-gate would be 300 m^3/s.

3.4.2.2 Roller Compacted Concrete Dam

The RCC dam was configured for a vertical upstream slope and a downstream slope of 0.75H:1V. The crest would be 8-m wide at El. 83 and a parapet wall would be constructed to El. 85. The estimate was based on a low-paste concrete mix and bedding mixes as required. A drainage system would be installed from a gallery situated in the upstream toe.

The diversion arrangement would include two 2.0-m wide by 3.0-m high culverts located to the left of the river channel. The culverts would be founded on rock and be about 250 m long.

The ungated spillway would have the same hydraulic capacity as for the CFRD. It was located on the RCC dam to discharge directly into the channel by means of a chute and flip bucket.

The gated spillway also will be placed on the RCC dam and will have the same hydraulic capacity as for the CFRD alternative. It also will discharge directly into the Río Indio by means of a chute and flip bucket.

3.4.2.3 Dam Type Selection

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

The RCC alternatives resulted in a cost about 6% lower than the CFRD alternatives and the ungated and gated configurations were equal in cost.

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.

A simulation run of the operation of Lake Madden and Lake Gatun was made for the period of January 1970 to December 1997. For both reservoirs, the validation model results in terms of reservoir elevations were essentially the same as the observed elevations. Therefore, the model configuration was assumed to be consistently accounting for the water in the system.

3.5.1 Reservoir Rule Curves

The ACP has developed rule curves for the tandem operation of Gatun and Madden Lakes. The purpose of the curves is to provide a minimum draft for ships with a maximum level of reliability. Several curves have been in use throughout the more than 85 years of operation of the Canal, the existing set was implemented in the late 1970's. The development of the curves has been based on the experience with the hydrology in the Panama Canal Watershed, with a dry season extending from January through April and the rainy season from May through December. In general the intent of the curves is to use in the dry season the water stored during the rainy season and to fill both lakes by the end of the year.

The Indio Rule curve was developed by trial and error to maximize the yield of the Río Indio basin while maintaining the Lake Gatun elevations according to its rule curve. The operating rules consist of a mandatory release 2.6 m^3/s into the Rio Indio, 43 m^3/s for the four-month period from February through May to Lake Gatun, and operating the reservoir to bring the water level to the rule-curve elevations during the other months. The Río Indio rule curve is presented as Exhibit 3-8.

3.5.2 Results of the Operation Simulations

Operation simulations were made for a demand identified in terms of daily lockage requirements (Lockages per day, L/d) using the live storage in Río Indio reservoir between El. 80 and El. 40. One lockage was assumed to equal 55 million gallons or 208,000 m^3. The yield allocated to the Río Indio Project was estimated as the total system yield, (Gatun after deepening, Madden, and Indio) less the yield of the system without Indio. 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 estimated yield of the Rio Indio under these conditions is shown in Table 3-13.

A flood with a return period of 50 years was selected for the construction diversion flood. This flood would have a peak discharge of 820 m^3/s and a 2-day volume of about 55 MCM.

3.6.2 Reservoir Operating Levels and Live Storage

The reservoir operating level is determined as a part of the project optimization studies. Normally, the reservoir live storage would be increased until the value of the yield from that storage just equals the cost of providing the storage (maximizing net benefits). As mentioned earlier, 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. This decision precluded the determination of an optimum level of development. However, in our analysis of optimum dam height, which was performed before the decision was made, several developmental assumptions were determined. First, based on an analysis of the hydraulics of the transfer tunnel, it was determined that the minimum pool of the reservoir could be lowered to El 40. Second, although not verifiable by an economic analysis, it is apparent that a reasonable level of development can be obtained with the full supply level at El. 80. On the basis of these unused dam-height optimization studies and the results of the Reconnaissance Report, it was decided to complete the Río Indio studies with a live storage between El. 80 and El. 40. This results in a live storage of approximately 1,294 MCM.

3.6.3 Spillway Type

As a part of the dam-type selection studies, a concrete-face rockfill dam was selected. In the selection analysis, a side-channel spillway was assumed. The configuration studies include a review of the type of ungated spillway and optimization of the size of the spillway.

A side-channel spillway configuration is usually considered when the abutment topography results in massive quantities of excavation for a conventional spillway (considered to be when the crest is parallel to the dam axis). Based on the spillway width suggested by the USACE in their Reconnaissance Report and the right-abutment topography, it was decided to use a side-channel spillway for the dam-type study. Further inspection of the abutment material and the selection of a CFRD led to the conclusion that most of the abutment excavation could be used in the dam at a lower cost than the next best material source. Therefore, it was decided to revisit the type of spillway to determine if a conventional spillway might be less expensive. A cost comparison was performed, assigning most of the abutment excavation cost to the dam. The conventional chute spillway was determined to be less expensive and was selected.

For reservoir drawn, the Río Indio is assumed to be a significant hazard, significant risk project as classified by the U.S. Bureau of Reclamation in ACER Technical Memorandum No. 3 dated 1982. The guidelines for reservoir drawdown are as follows:

Drawdown to	Time (days)
75% of full supply volume	30-40
50% of full supply volume	50-60
25% of full supply volume	80-100

As discussed in the following section, the water transfer tunnel diameter for a single-purpose water supply project is 4.5 m (actually computed at 4.35 m but rounded up). In addition, in Section 5, Power Development, it is concluded that the optimum water transfer tunnel diameter for a project that includes power is 5.0 m. Based on a hydraulic analysis and routing studies, for a water transfer tunnel diameter of 4.5 m and 5.0 m, the reservoir drawdown criteria can be met with a diversion tunnel of 4.0 m and 3.5 m respectively.

Therefore, a diameter of 4.0 m is selected for the diversion tunnel. The upstream water surface would rise to El. 21.6 for a 50-year flood and the downstream water surface would rise to El. 7.8.

3.6.5 Water Transfer Tunnel Size and Alignment

The diameter of the Indio to Gatun water transfer tunnel was determined as a part of the HEC-5 runs, which were used to estimate system yield as discussed above. The tunnel was sized to allow a near-maximum development of the Indio basin while minimizing the diameter of the tunnel. After extensive analyses of the system operation, it was determined that a tunnel with a diameter of 4.5 m would provide sufficient capacity to maximize the yield of the Gatun-Madden-Indio system. At this diameter, the tunnel will have a design capacity of 94 m^3/s at a gross head of 53 m and a capacity of about 43 m^3/s at the low supply pool level in the Río Indio Reservoir, El. 40.0 m. If power is added to the project, as discussed in Section 5, the diameter would increase to 5.0 m to improve the transient conditions in the tunnel.

Reservoir and tunnel operating criteria adopted for these studies included the following:

- The maximum reservoir water level will be at El. 80.
- The minimum reservoir water level will be at El. 40.
- The invert of the tunnel intake will be at El. 32.
- The invert of the tunnel at its outlet will be at El. 28.

Each of the alignments was finalized on the basis of profiles to ensure, to the extent possible, that adequate cover is available.

Tunnel profiles were then prepared with tunnel rock types for Alignments 1, 3 and 6. The extent of rock support classes were estimated for the different alignments based on the general knowledge of the geology of the area, geologic mapping, and judgment to account for:

- Potential widths and degree of rock fracturing in faults,
- Depth of cover and potential for development of weathered ground,
- Effects of tectonic shears commonly associated with folding of rocks,
- Other factors such as the presence of water or proximity to a major stream crossing, and
- The extent to which a tunnel alignment could encounter mixed face conditions or rock types of markedly different character alternating over short distances.

Tunnel lining, consisting of cast-in-place concrete from 25 cm to 50 cm, was assumed for the entire length. Heavier lining was included in tunnel reaches with minimum ground cover to provide containment. Approach channels were estimated to the inlet portals to reflect the topographic conditions in the vicinity of the inlet and to allow for adequate submergence and velocity through the trashracks.

The estimated costs for each of the tunnel alignments is presented in Table 3-14.

TABLE 3-14 TUNNEL ALIGNMENT ALTERNATIVE COSTS

Alignment Alternative	Estimated Cost (4.5 m Diameter)
1	$31,700,000
3	$31,000,000
6	$36,700,000

The water transfer tunnel is a significant component of the overall cost of the Río Indio development. Selection of the alignment for the water transfer tunnel is based on a best value approach – one that minimizes the construction cost and also the construction risks.

The effect of minimizing tunnel lengths and poor ground conditions is reflected in the cost of the alternatives. In addition, when the estimated costs of alignments are within the limits of the estimate accuracy, it is also necessary to consider minimizing geologic risk. A rigorous evaluation of risk is not possible due to the limited availability of geologic and topographic information. Assessing incremental risk also is made more

4. DESCRIPTION OF THE RIO INDIO WATER SUPPLY PROJECT

The major elements that comprise the Río Indio Water Supply project include:

- A concrete face rockfill dam and appurtenant works at the Tres Hermanas site with its crest at El. 83.
- A 4.5 m diameter, 8,400-m long water transfer tunnel from the Río Indio Reservoir to Lake Gatun.
- A minimum release facility, which will include a 1.6 MW power plant.

The dam will impound a reservoir with a gross storage capacity of 1,577 MCM at El. 80, the full supply level. Live storage between El. 80 and El. 40 will be 1,294 MCM. The resultant dead storage is far more than needed for the estimated sediment deposition although after 100 years it is estimated that the live storage will be reduced by about two percent. The reservoir area at the full supply level, El. 80, is 45.6 square kilometers.

A general plan of the development, showing the location of the dam, the reservoir boundary, and the water transfer tunnel alignment is shown on Exhibit 4-1. A plan of the dam and appurtenant works is shown on Exhibit 4-2, and profile along the centerline of the dam and several typical sections are shown on Exhibit 4-3.

Upon completion of the dam and transfer tunnel, the yield of the water supply system for the Panama Canal with be increased by about 1,200 million cubic meters per year with a reliability of 99.6%. This is about equivalent to 15.8 additional lockages per day in the canal system. The demand on the water supply system of the Canal will depend on the future configuration of the Canal system, the adopted reliability of supply, and the continued supply of M&I water from the system to the Panama Canal Watershed through IDAAN. The implementation of the Río Indio Project will greatly assist the ACP in meeting whatever needs arise. As an example, using the unconstrained navigation demand schedule presented in the Reconnaissance Report and the most current M&I demand estimate, Río Indio Project will be able to supply the additional requirements at a 99.6% reliability through year 2028.

4.1 Description and Preliminary Design of 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 3 and are presented in detail in Appendixes A and B.

should be nominal and only local. Contingency quantities for backfill concrete have been included to reflect the potential for unforeseen conditions.

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 concrete face and through the spillway concrete (or from a grout slab prior to placing first stage spillway concrete). Grout takes should be low to moderate through most of the curtain. The average grout consumption was assumed for estimating purposes to be about 30 kg/m.

Foundation drainage will be provided for the spillway to control seepage to reduce pore pressures in the rock mass, and hence uplift. For estimating purposes, a drain hole spacing of 5 m was assumed with depths extending to about half the depth of the grout curtain. holes would be appropriately inclined in order to maximize the number of joint/fracture interceptions.

4.1.3 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 950 m^3/s using a surcharge of 4.0 m above the full supply level.

The spillway will consist of an approach channel, an ogee control section, a tapered chute, a flip bucket, and an excavated channel to direct the water back to the natural river channel. A plan and sections of the spillway are shown on Exhibit 4-5 and 4-6.

The approach channel will be 52 m wide and will be excavated to El.75. The channel will be straight and approximately 150 m long.

The uncontrolled ogee section will consist of three bays with a total 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 180 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 12 m at the upstream end of the flip bucket. An aeration ramp will be installed about two-thirds of the way down the chute. The chute is sloped at about 33% to facilitate founding the entire structure on competent rock. At this slope the discharge will be supercritical. The maximum water depth will vary from 4.0 m at the crest to 1.5 m at the upstream end methods will be used for excavation and tunnel support will vary from steel sets at the portals to shotcrete in the better sections.

The upstream and downstream cofferdams will be 18-m high and 3.0-m high respectively. The upstream and downstream slopes of the cofferdams will be 2.5H:1V and 2H:1V respectively (the upstream slope of the downstream cofferdam is on the downstream side). Although not yet designed, it is expected that the upstream section will be relatively finer impervious material and the downstream shell will be courser material. A chimney and blanket filter will be provided. The total volume of both cofferdams will be about 107,500 m^3.

A low-level intake structure will be constructed at the intake portal and a gate shaft will be constructed at about the mid-point of the tunnel to facilitate its use as a low level outlet for reservoir evacuation. The intake structure will be constructed to El. 12 to permit continuous operation over the life of the project without interference from sediment buildup. The gate shaft will house a 4-m wide by 4-m high wheel gate and a similar sized bulkhead gate. The diversion tunnel opening in the low-level intake will be plugged when the gate shaft is completed. Water can then rise to El. 12 and flow through the low-level intake and be controlled at the gate shaft.

4.1.5 Minimum Release Facility

A minimum release facility is required to maintain flow in Río Indio downstream of the project. The minimum release has been assumed to equal 10% of the average flow or about 2.6 m^3/s. Computer modeling studies have been performed of the water quality expected in the Río Indio Reservoir (20). While the studies generally indicate that the quality of water in or released from the Río Indio Reservoir should not present any problems that require mitigation, the model did predict low dissolved oxygen levels under some operation scenarios at lower reservoir elevations. There are no water quality concerns discharging through the transfer tunnel into Lake Gatun. When making minimum releases downstream of the Río Indio dam, aeration would likely raise dissolved oxygen levels above minimum acceptable levels. However, to avoid any potential for discharging reservoir water with low levels of dissolved oxygen, the minimum release facility intake will be located at elevations above the projected low oxygen content water, or above El. 30.0.

An intake structure will be located on the face of the CFRD just below El. 40.0, the minimum operating level of the reservoir. The 1.0 m wide x 2.0 m high intake will be equipped with a trashrack and slide gate housed in an inclined structure located on the concrete facing of the dam. Both will be operated from the crest of the CFRD. The intake will connect through the face of the dam to a steel penstock, nominally sized at 1.0 m to provide more than sufficient capacity for the assumed minimum release. The penstock will transfer the minimum release flow 150 m through the dam then 100 m

Tunnel Length (%)	Approximate Length (m)	Rock Support Class	
25	2,100	Excellent	I
40	3,400	Good to Fair	II
30	2,500	Fair to poor	III
5	400	Poor	IV

It is assumed that the tunnel will be fully lined. The lining is included to prevent erosion and deterioration of the rock in areas of soft or highly fractured rock. The lining will be cast-in-place concrete with a minimum thickness of 0.25 m. Reinforcement, thicker concrete, and steel lining will be included as required. For the cost estimate, it is assumed that the concrete lining will be increased to 0.5 m and nominal reinforcement will be provided where the rock cover is relatively low to provide containment.

A gate shaft and gate will be provided at the upstream end of the tunnel for dewatering. It is located 50 m from the intake structure. The gate will be 3.8 m wide by 4.5 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 2.5 m wide by 4.5 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. Details of the outlet facility are shown on Exhibit 4-13 and 4-14.

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 ends at El. 20, slightly below the minimum level of Lake Gatun. The sill widens from 9 m wide at the outlet structure to 19 m wide at the downstream channel.

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

4.1.7 Operation Facilities

Operation facilities are required for the Río Indio Water Supply Project. Without the addition of hydropower, and with only the Indio to Gatun transfer tunnel gates requiring daily adjustment, the project lends itself to remote operation. Operation facilities will

5. 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 5-1.

TABLE 5-1 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	5	1963(2),'66,'71(2)	93

As a part of the reconnaissance studies performed by the USACE (1), the potential for adding hydropower to the Río Indio Project was considered. The analysis indicated that, at a benefit of $0.07/kWh, the addition of hydropower was marginally 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 Indio Project consisted of a 25 MW installation at the base of the dam, operating at a plant factor of 0.5, and a 5.0 MW installation at the downstream end of the transfer tunnel to Lake Gatun. The facilities also included substations at each powerhouse, and a 115 kV transmission line from the dam to the tunnel powerhouse and on to the La Chorrera substation (estimated in the current studies to be about 47 km long from the transfer tunnel powerhouse).

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

5.1 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

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 the Río Indio Project and that all other demands occurring in the Panama Canal Watershed will be subject to competition.

5.1.2 National Market

Historic energy demand and peak load for the Panama National Integrated System (PNIS) is presented in Table 5-3:

TABLE 5-3 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 10-year period. 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 1999 are shown in Table 5-4:

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 5-5:

TABLE 5-5 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 for all three estimates below:

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 at 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.

may be attractive. The details of the power and energy studies for the Río Indio Water Supply Project are presented in Appendix E.

5.4.1 Alternatives for Power Development

The potential for power development was made within the constraints of the operating criteria for the water supply project. Based on a series of operation simulations using the HEC-5 model, it was determined that the opportunity exists to alter the operation and water transfer schedule from the Río Indio reservoir to Lake Gatun to favor the production of energy while satisfying the navigation and M&I water demands. As mentioned previously, the navigation demands are not well defined and, therefore, for these studies of potential energy demand, the navigation demands presented in the Reconnaissance Report (1) are used to assess the timing of the partial yields.

5.4.1.1 Power Development Alternatives When the Demand is Equal to or Greater than the Indio Yield

Potential energy production was estimated for the following operating conditions:

- For discharge through the water transfer tunnel under maximum yield conditions with the tunnel sized for water supply (4.35 m).
- For discharge through the water transfer tunnel under maximum yield conditions with the tunnel diameter increased to 5.0 m.
- For discharge through the water transfer tunnel under maximum yield conditions with the tunnel diameter increased to 6.0 m.
- For the same three conditions above, but with the operating regime changed to allow a constant monthly water transfer rather than the 4-month transfer that resulted from the operation studies.

Under the reservoir operating criteria described in Section 3.5, three distinct patterns of release occur through the tunnel. Referring to Exhibit 5-1, the patterns are as follows:

- For 56% of the time, the discharge in the tunnel is 43 m^3/s. This discharge occurs with the reservoir level between El. 80 and El. 40 and corresponds to the months of February to May when the discharge is governed by the Río Indio rule curve established in the operation studies.
- For 17% of the time, the discharge varies between 0 and 55 m^3/s while the reservoir is at or near El. 80. These discharges are made to satisfy the demand at Lake Gatun. Under these conditions, the tunnel is not discharging at full capacity.
- The final pattern occurs when the tunnel is operated at maximum capacity.

The existing system complemented with the (on-going) deepening of Lake Gatun by about 1.0 m will yield 44.5 lockages per day (L/d), which will be sufficient to meet the assumed demand until 2010. By 2029, using the demand schedule described above, the full yield of the existing system plus Río Indio operating between El. 80 and El. 40 will be required. Over this 19-year period, the opportunity exists to operate under one of the three alternatives.

Based on an assessment of the total system generation, at Gatun, Madden, Isla Pablon, and the damsite, it was determined that Alternatives 1 and 3a warranted further study. Alternatives 2 and 3b were rejected as having a similar cost to Alternatives 1 and 3 respectively and generating less electricity.

5.4.1.3 Comparison of Selected Alternatives and Definition of Potential for Development

The comparison of alternatives consisted of selecting an optimum or appropriate level of development for each power plant for each alternative and performing an economic evaluation of the two alternatives.

The economic value of the development was based on information provided by the ACP Power Department. It was suggested that the benefits be computed on the basis of the current value of energy and capacity, which are $45/MWh and $60/kW-year respectively. The capacity benefit was based on firm capacity. Firm capacity is computed as the energy provided 95% of the time over an 8-hour period. The energy benefit is based on average annual energy produced at the power plant.

The economic costs were estimated as the cost of the project with power less the cost of the project without power. Annual costs were estimated as 0.5% of the civil cost plus 1.25% of the equipment costs plus 1% of the transmission line cost. The major cost components of the power facilities were as follows:

- The powerhouse and powerhouse intake associated with the Isla Pablon plant;
- The powerhouse and powerhouse intake associated with the Río Indio Dam power plant;
- Adjustments to the water transfer tunnel;
- The transmission system to link the development to the national grid, and;
- Elimination of the water supply transfer tunnel intake and energy dissipation features. and the Río Indio Dam low-level outlet facilities.

As a result of a hydraulic analysis of the water transfer tunnel for power operation, two major requirements were identified to provide acceptable transient conditions. First, it was determined that a surge tank is necessary. Second, in order for the surge tank to

5.4.1.5 Description of the Potential Hydropower Facilities

The facilities associated with Alternative 1 are as follows:

Isla Pablon Power Plant Facilities

- An intake located adjacent to the transfer tunnel gate chamber with facilities for raking and removing trash;
- Increasing the diameter of the 8,400-m long, 4.5 m diameter modified horseshoe shaped tunnel to 5.0 m and installing a steel liner over the last 250 m;
- A surge tank located 250 m upstream from the powerhouse;
- A powerhouse located at the end of the water transfer tunnel;
- Two vertical-shaft Francis turbines each rated at 7.0 MW direct connected to synchronous generators rated at 7,800 kVA with a power factor of 0.9 and a rotational speed of 360 rpm;
- Appropriate gates, valves, and a 30-ton crane;
- Switchyard and switchgear, and;
- A 47-km long, 115 kV, single circuit transmission line to the existing La Chorrera substation.

Rio Indio Power Plant Facilities

- A 250-m long 2.5 m diameter power tunnel in the right abutment of the dam;
- A power intake with trash screening and raking facilities;
- A powerhouse at the downstream end of the tunnel;
- A horizontal-shaft Francis turbine rated at 2.5 MW direct connected to a 2,777 kVA synchronous generator with a 0.9 power factor and an rotational speed of 600 rpm;
- Appropriate gates, valves and a 12-ton crane;
- Switchyard and switchgear, and;
- A 12.6-km long, 13.8 kV, single circuit transmission line to the Isla Pablon site.

5.4.2 Evaluation of the Hydropower Potential

A summary estimate of cost for the hydropower facilities described above is presented in Table 5-8.

6. 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.

6.1 Land Use

The land use was initially identified by reviewing available aerial photographs and verified by a field reconnaissance. The aerial photographs were dated from 1979 through 1993. The land use categories adopted for this study were forest, pasture, and stubble and combinations of these categories. These elements have been subjected to the most drastic changes in terms of use over time and it was assumed that they are indicative of present land use. The field adjustments were based on transects and random observations over the course of two field visits.

In the area, mature forests generally do not exist. The vegetation consists mostly of pasture, secondary forest, and stubble. Farming is nearly exclusively at a subsistence level. Crops are not discretely differentiated from stubble. The farming systems found consist mainly of two cropping cycles:

- First cycle
    - Main crop – rice and maize
    - Ancillary crop – root crops, plantains

- Second cropping cycle
    - Main crop – maize
    - Ancillary crops – beans in association with maize

Coffee is also grown on small, dispersed farm holdings. Most of the cleared holdings are covered with native pasture that has evolved from the process of slash and burn farming. The present land use is shown on Exhibit 6-1 for four primary and five mixed-use categories.

streams supplying the potential areas, after deduction a minimum flow, was estimated to be 6.6 liters per second.

The source and estimated available flows for all of the areas are shown in Table 6-2:

TABLE 6-2 – WATER AVAILABLE FOR IRRIGATION

Area	Source of Water	Catchment Area (km^2)	Available Minimum Flow (l/s)
1	Release from reservoir	-	-
2	Release from reservoir	-	-
3A	Release from reservoir	-	-
3B	Reservoir	-	-
4	Río Jobo at El. 65	7	46
5	Río Teria at El/ 80	70	460
6	Río Uracillo at El. 125	23	152
7	Río Indio at El. 220	40	264
8	Río Indio at El. 120	50	330

6.3 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 identified crops were selected to match the current farmer preferences while allowing for the production of a marketable surplus as well as farm-family requirements. Cropping patterns were developed that match these crops to three general landscape positions as follows:

TABLE 6-3 CROP PATTERN DESIGN

	Landscape Position		
	Fluvial Terraces	Side Slopes and Bench/Terraces	Side Slopes and Mini Plains
Dry seeded and transplanted rice	X		
Transplanted rice		X	X

Based on cropping pattern options for each area, average net benefits were estimated by hectare and for each potential area. 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 6-4.

TABLE 6-4 ECONOMIC ANALYSIS OF AGRICULTURAL DEVELOPMENT IN POTENTIAL AREAS

Potential Area	Construction Cost ($1,000)	Annual Cost ($1,000)	Benefits ($1,000)	Rate of Return
1 Mouth of Río Indio	3,171	45	380	10
2 Río Indio Valley	17,895	156	2,608	12
3A La Encantada	4,442	44	509	10
3B La Encantada	16,107	155	2,035	10
4 El Papayo	4,065	55	356	7
5 Nuevo Paraiso	6,451	97	822	10
6 Las Marias	1,847	22	183	8
7 Río Indio Abajo	814	6	91	10
8 Tierra Buena	2,135	30	274	10

The construction costs in Table 6-4 exclude the cost of land, power supply, and marketing infrastructure such as access roads, farm support and marketing facilities. With these exclusions, the economic results suggest that each of the areas is marginally suitable for agricultural development.

To assess the viability of a commercial development, all of the areas were considered as one development and the cost of power and access was included. The total cost associated with power supply for irrigation development is estimated to be $1,200,000. An allocation of the cost of such supply for each of the proposed area is presented in Appendix F. The road development program for the Rio Indio Study Area, which is presented in Appendix F, has been estimated at approximately $12,800,000. The cost specifically associated to the agriculture and irrigation development is estimated to be $6,600,000. If all potential areas are considered as one development and the cost of power and access is added, the rate of return will be about nine percent.

Therefore, it is concluded that the potential for irrigated agriculture exists; however, implementation of the development is not warranted at this time.

7. 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 only water supply facilities are warranted at this time. Therefore, an implementation schedule, a detailed construction schedule and cost estimate have been prepared for the project as described in Section 4 Additional details of the construction plan and cost estimate are presented in Appendix G.

7.1 Implementation

The major steps required for implementation following this engineering study are as follows:

- Completion of the Environmental Studies
- Confirmation of Feasibility and Project Configuration
- Funding
- Resettlement Plan
- Environmental Field Studies
- Resettlement
- Final Design
- Award of Construction Contracts
- Construction

An implementation schedule is presented on Exhibit 7-1.

The environmental base line studies are underway. Prior to securing funding for the project, it will be necessary to confirm feasibility and probably to develop an acceptable resettlement plan. The confirmation studies will include a feasibility-level drilling program and an economic analysis, and finally, the confirmation of the project arrangement.

Once the decision to obtain funding has been taken, a resettlement program will be required. This can be prepared while funding is being secured. With funding in place, the design-level investigation program and final designs can commence along with the implementation of the resettlement program and any environmental field studies.

Construction of the project has been scheduled for two separate general contracts: 1) Access Roads and the Construction Camp, and; 2) The storage facilities and the transfer tunnel. It is anticipated that the access road contract will be let to a local contractor and an international contractor will handle the dam and tunnel contract.

7.2.1 Preliminary Works

The preliminary works include mobilization, access road construction, construction camp, power supply and other services, establishing quarries, crushing and concrete plants, etc.

7.2.1.1 Mobilization

Upon receiving Notice to Proceed, the contractor will initiate mobilization of staff and equipment. The effort is anticipated to extend over nearly one year as the contractor's effort will built-up during the execution to the preliminary works including access road, establishing construction camp and power supply, establishing quarries and installing crushing plant and concrete plant. Most of the heavier pieces of equipment will be mobilized towards the end of the first year when the main access road has been completed and when the construction of the main features of the project starts.

The mobilization of personnel and equipment for road construction is expected to be rapid as it is entirely available locally.

7.2.1.2 Access Roads

Construction of the project requires both temporary and permanent access improvements. No attempt has been made to locate the regional access that will be necessary as a part of the resettlement program. However, to the extent possible, the permanent access described herein will be used. The temporary and permanent access is presented on Exhibit 7-3.

The Río Indio dam site is located at approximately 66 km by road from the Cristobal Harbor (Colon) and approximately 88 km from the Balboa Harbor (Panama City).

From Cristobal Harbor, a paved road (No. 3030) reaches the western end of Lake Gatun near the upper reaches of the Río Salud and Quebrada La Encantadita. A dry weather road approximately 12 km long joins Route No. 3030 to El Limòn in the vicinity of the dam site.

From Balboa Harbor, a paved road passes through La Chorrera and reaches El Cigual approximately 18 km West of La Chorrera. The following 27 km from El Cigual to Tres Hermanas in the Río Teria valley consists of a gravel road; another 13 km of dry-weather road joins Tres Hermanas to El Limòn.

Although access from Colon is shorter, the crossing of the Gatun Locks through the existing moveable bridge may represent a major disruption to the flow of supply for the of the project. Eight months of construction will be sufficient to provide housing for the initial crews working at the dam site and at the transfer tunnel.

7.2.1.4 Power Supply

Construction needs for electrical power 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. It is anticipated that the contractor will generate the required power by providing small size diesel generators (300-kW to 500-kW) at appropriate locations.

7.2.1.5 Rock and Aggregate Quarries

Two quarries have been identified for use in this project: one located on Cerro La Jota, East of the dam site at 6.5 km by road from El Limòn, and the second located on Cerro Las Ollas approximately 3.0 km by road South of the dam site. The Cerro La Jota quarry is anticipated to be mainly used for the manufacturing of concrete aggregates (290,000 m^3) and an estimated 270,000 m^3 of rockfill for the dam. Approximately 920,000 m^3 of rockfill will be extracted from Cerro Las Ollas.

A crushing plant and an aggregate stockpile area will also be established near Cerro La Jota. The establishment of the quarries is anticipated to take approximately 6 months including geotechnical investigations and it is not on the critical path as investigations can be initiated at any time during the first year of activities well before aggregates are needed.

7.2.2 Transfer Tunnel

The drill-and-blast method was selected for the purpose of scheduling, as tunnel boring machine (TBM) are most appropriate for uniform rock formation. Further geologic investigations will be required to finalize the selection of the tunneling method. The advance rate of excavation greatly depends on the rock quality: it can vary from approximately one meter per day in Type IV ground to five meters per day in the best ground. An advance rate of three to four meters per day has been adopted as a realistic estimate for the Río Indio transfer tunnel.

In order to complete the project in a reasonable construction period it is anticipated that additional adits are required. It is recommended to build the tunnel with two adits.

Overall the tunnel construction, including the intake and outlet works, is expected to take about 32 months. The last activity to be completed prior to the initial filling of the reservoir is the installation and testing of the intake gate at the upstream end of the tunnel.

7.2.4 Reservoir Clearing and Filling

Approximately 47 km^2 (4,700 hectares) of land needs to be cleared to reach El.85. The reservoir area will also need to be surveyed to determine the initial reservoir volume and also to be used as the base survey to monitor sedimentation. The vegetation clearing is expected to take a minimum of two years and will be started from the lower level working towards the higher elevations.

The project will only be operational when it is capable of delivering water into the Lake Gatun. Also it is important to be capable to be able to test the hydraulic turbine at the dam and all mechanical and electrical equipment. For these reasons, 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. At that time the power intake and the transfer tunnel intake will be completed with all equipment, power supply and controls.

For the purpose of determining the required time to fill the reservoir, the monthly flow sequence of 52 years from 1948 to 1999 was used. It was also assumed that a minimum release of 2.6 m^3/sec would be continuously released during the filling period. The results of this analysis are presented in Table 7-1:

TABLE 7-1 RESERVOIR FILLING

Filling Period	Duration	Reached Levels		
		At 90% probability	At 50% Probability	At 10% Probability
Jul – Dec	6 months	El.43	El.51	El.59
Jan – Dec	12 months	El.49	El.57	El.66
Jan – Jun	18 months	El.54	El.62	El.70
Jul – Dec	18 months	El.67	El.72	El.80 (15%)
Jan – Dec	24 months	El.70	El.77	El.80 (35%)

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.57. This level is sufficient to transfer water to the Lake Gatun and to test the Río Indio unit near its design condition. 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.

It is anticipated that materials including explosives, cement, and reinforcement steel will be imported for the most part. International unit prices were used: Table 7-3 below shows estimated unit costs of materials delivered at the site:

TABLE 7-3 MATERIAL UNIT COST

Material	Unit	Cost
Cement	Kg	$0.12
Explosive	Kg	$1.50
Reinforcement Steel	Kg	$0.76

The Contractor operational costs 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 42 months 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 to these costs, the following additional costs were assumed:

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 appear to be reasonable estimate for this type of construction.

The unit prices shown in Table 7-4 were used:

TABLE 7-5 SUMMARY COST OF THE RÍO INDIO PROJECT

Item	Estimated Cost
Land Acquisition and Resettlement	$26,100,000
General Costs including Construction and Permanent Access	$23,839,000
Diversion	$3,603,000
Main Dam	$52,704,000
Spillway	$6,043,000
Low-Level Outlet	$3,049,000
Saddle Dams	$7,427,000
Interbasin Water Transfer Tunnel	$46,765,000
Minimum Release Facility	$837,000
Operation Facilities	$1,139,000
Subtotal Direct Cost	**$171,506,000**
Contingency	$28,868,000
Direct Cost	**$200,374,000**
Engineering and Administration	$30,056,000
Construction Cost (mid-2001 price level)	**$230,430,000**

7.3.3 General Costs

The General Costs include mobilization, land acquisition and resettlement, temporary facilities, access roads, a bridge across the Rio Indio, watershed management, mitigation plan implementation, and reservoir clearing. Certain of these costs are discussed in more detail below.

7.3.3.1 Land Acquisition and Resettlement Costs

The allocation for land acquisition will include all land in and around the reservoir up to El. 90, plus land for structures, borrow areas, construction roads, construction camp, other temporary structures, and disposal areas. These areas comprise a total area estimated to be about 55 sq. km. The value of these lands has been estimated to average $1,000/ha based on information supplied by the ACP.

Implementation of the Río Indio Project will require resettling the people living in the reservoir area and the natural increase in this population. In many instances, it is expected that the resettlement will be involuntary. It is the intention of the ACP to follow the guidelines of multilateral and bilateral donors, which can be summarized as

7.3.4 Contingencies

A contingency allowance is included in the cost estimate for unforeseen site conditions, approximations, and the chance of future design changes. For these estimates, an allowance of 25% was used for dam and tunnel excavation to reflect the uncertainties associated with foundation unknowns and the conditions that could be encountered in the long water-transfer tunnel, 10% for all equipment, and 15% for all other categories. Overall, the contingency is approximately 12.5% of the project construction cost or about 17% of the subtotal of the direct costs.

7.3.5 Engineering and Administration

Indirect costs for 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 15 percent of the total direct costs will be adequate for engineering and administration.

7.3.6 Capital Cost

An estimate of the capital cost is provided to indicate the anticipated financial cost of the project if it is implemented according to the schedules shown on Exhibits 7.1 and 7.2. The capital cost provides for inflation from the price level date to the beginning of construction, escalation for each of the features according to the construction schedule, and interest during construction.

For estimating purposes, it was assumed that inflation and escalation would occur at a rate of 3% per year and that interest would accrue at a rate of 10% per year.

It was further assumed that construction of the storage facilities and water transfer tunnel will require about five years and that the earliest required on-line date for the water supply will be January 2011. Therefore the construction cost, priced at the mid 2001 level, was inflated at 3% per year for 4.5 years and then escalated at 3% according to an expenditure schedule derived form the construction schedule. For the interest computation, it was assumed that the year's disbursement would be borrowed in January and July and that the interest would accrue.

The estimated capital cost is shown below:

input from existing staff. An estimate of the personnel and equipment requirements and the cost are shown below:

	Number	Annual Unit Cost	Total Annual O&M Cost
Personnel			
Manager	.25	$80,000	$20,000
Assistant Managers	1	$50,000	$50,000
Operation Personnel	5	$30,000	$150,000
Maintenance Personnel	8	$25,000	$200,000
Laborers	15	$10,000	$150,000
Equipment			
Vehicles	5	$40,000	$200,000
Spare Parts	LS	$100,000	$100,000
Maintenance Equipment	LS	$150,000	$150,000
Total O&M Cost			**$1,020,000**

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 for an interest rate of 10% and an inflation rate of 3%per year. The sinking fund amount is estimated to be $114,000 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 7-7:

8. ECONOMIC COST OF WATER

The original scope of services for the economic evaluation of the Río Indio 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 the Río Indio Project would probably not 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 5.

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.

If conditions existed where the full amount of the system yield attributable to the implementation of the Río Indio Project could be beneficially used, the economic cost of water would be about $0.03/m^3. This estimate is derived by dividing the present worth of the construction and annual costs by the present worth of the supply, which is 15.8 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 without Indio could yield 44.5 L/d, and the project came on line in year 2011, the economic cost of water would be about $0.07/m^3. Under these conditions, it would take about 20 years for the full yield of the project to be utilized. In other words, if the benefit of water was $0.07/m^3, which would be about $5.3 million/year for one lockage, the benefit cost ratio under the condition described above would be 1.0 for an interest rate of 12%.

Under the same assumptions and a rate of increase of 0.6 L/d/yr, the cost of water would be about $0.10.

9. CONCLUSIONS AND RECOMMENDATIONS

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

- The Río Indio Water Supply Project is technically feasible.
- The dam site selected in the Reconnaissance Report is the most suitable site for the development of the water resources of the Río Indio Basin.
- Either a concrete-face rockfill dam or a roller compacted concrete dam is suitable for the site and cost effective. A concrete-faced rockfill dam was selected based on a preliminary analysis and discussions with the ACP.
- The lack of subsurface investigations has increased the potential for inaccuracies in the estimate of cost. However, it is our considered opinion that there are no geologic or geotechnical problems associated with the site that cannot be accommodated using conventional solutions.
- The yield of the Panama Canal system will increase by about 1,200 MCM/yr (about 15.8 L/d) with the addition of the Río Indio Project.
- The addition of hydropower to the Project is not warranted at this time. However, a 1.6 MW plant has been included to generate electricity from the minimum release for project operation and to serve the needs of the resettled population. Any plans to implement any other project to the west of the Río Indio Project will improve the economics of the hydropower addition and should cause the issue to be revisited.
- The inclusion of a commercial agricultural endeavor is technically feasible, but is not warranted at this time due to a lack of government services, infrastructure, and an adequate labor pool.
- The project is estimated to cost about $230 million in 2001 dollars. Allowing for inflation at 3% per year, escalation during construction at 3% per year, and interest during construction at 10% per year, the capital cost of the project in current dollars would be about $303 million.
- A project that delivers 1,200 MCM/yr for a capital cost on the order of $300 million is a very attractive proposition.

As a result of these conclusions, it is recommended that:

1. The Río Indio Project is considered as a suitable source of water for any canal expansion.

2. Concurrent with the evaluation of new-lock schemes and alternative sources of water, subsurface investigations and environmental studies of the Río Indio Project should continue without hiatus.

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TABLES

Table 1

LONG TERM MONTHLY STREAMFLOW AT THE DAM SITE
(cubic meters per second)

Drainage Area: 381.1 km^2

YEAR	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AVE
1948	12.16	4.82	3.46	2.56	5.46	7.75	28.59	33.33	31.70	29.41	58.60	16.44	19.52
1949	6.88	4.18	2.72	2.48	7.43	40.23	28.37	35.54	49.78	47.16	81.57	64.64	30.92
1950	11.40	6.41	3.86	2.80	19.39	35.61	37.08	53.84	35.91	48.76	63.14	63.35	31.80
1951	20.30	11.24	6.41	4.26	19.92	24.35	22.63	24.57	41.70	35.32	52.97	30.74	24.53
1952	13.55	6.49	3.46	3.05	11.40	28.89	22.40	23.75	39.87	56.87	35.83	50.65	24.68
1953	37.89	14.77	7.90	5.62	23.52	21.13	20.52	17.05	21.05	59.61	59.68	32.88	26.80
1954	16.67	7.90	4.98	4.02	18.79	19.85	46.73	35.39	48.04	40.97	76.73	40.89	30.08
1955	43.81	13.85	6.88	5.46	10.85	41.18	29.33	48.18	58.75	50.80	77.37	45.05	35.96
1956	45.56	14.23	8.29	7.67	28.67	41.40	38.92	29.11	46.44	69.37	49.27	28.67	33.97
1967	11.47	5.93	3.86	2.80	11.78	11.86	11.70	22.85	24.94	56.80	37.37	30.15	19.29
1958	18.94	14.62	7.82	5.62	17.35	20.75	28.52	38.33	37.15	48.55	39.43	20.97	24.84
1959	9.43	5.78	4.10	3.62	5.46	83.66	93.45	14.19	16.64	50.15	34.71	43.94	30.43
1960	21.07	8.77	9.10	11.27	26.62	28.18	27.87	28.70	25.27	40.25	55.90	93.01	31.34
1961	15.79	8.23	4.68	4.80	8.34	20.87	18.44	20.45	32.66	50.46	44.46	35.96	22.10
1962	13.22	7.13	4.23	3.90	5.80	8.78	12.04	29.96	25.80	34.62	35.96	27.37	17.40
1963	11.06	7.46	4.12	8.34	18.02	21.61	26.01	33.69	34.10	48.43	54.21	18.13	23.77
1964	9.11	4.91	3.21	3.67	13.33	43.03	42.42	43.24	51.88	55.83	65.49	20.35	29.70
1965	15.68	7.79	4.46	2.64	4.12	8.12	7.24	16.43	13.11	26.95	33.38	35.44	14.61
1966	12.57	6.25	4.23	4.46	25.59	35.03	28.30	25.22	18.41	53.00	70.70	54.31	28.17
1967	17.60	8.67	4.57	7.13	21.40	50.06	37.81	41.50	55.22	63.68	42.62	20.14	30.87
1968	9.54	6.91	4.46	4.01	10.85	30.38	22.87	32.14	33.69	56.53	54.61	26.53	24.38
1969	11.39	6.69	3.44	5.24	10.63	21.61	55.55	88.14	51.62	44.05	48.02	29.24	31.30
1970	24.02	10.74	9.11	9.65	28.51	19.19	21.51	46.40	39.35	58.65	46.30	95.73	34.10
1971	41.70	14.93	8.45	6.36	24.97	36.99	31.52	45.87	50.46	55.93	66.19	19.40	33.56
1972	13.22	8.79	5.43	14.51	12.36	22.35	9.93	14.29	32.66	32.97	34.57	14.19	17.94
1973	8.17	5.11	2.49	2.72	9.71	39.04	40.37	32.45	57.54	63.98	75.79	37.40	31.23
1974	16.96	10.46	7.63	4.58	8.84	18.97	23.08	26.64	31.31	87.42	50.16	26.53	26.05
1975	11.82	6.99	4.74	3.00	7.91	15.57	22.87	43.54	60.47	66.79	101.74	54.31	33.31
1976	21.30	11.39	6.79	5.96	13.86	12.79	6.68	8.18	23.92	55.73	38.73	15.47	18.40
1977	9.48	5.98	3.75	2.97	8.11	12.04	11.50	25.70	29.55	54.92	40.99	22.66	18.97
1978	11.16	7.36	4.92	26.95	23.50	32.86	31.73	42.79	44.83	51.16	43.60	25.62	28.87
1979	14.31	11.09	10.08	11.40	18.19	29.26	28.96	36.44	38.94	36.65	27.04	26.00	24.03
1980	24.22	8.72	4.10	2.78	14.10	19.11	20.99	49.28	24.74	37.59	33.83	29.03	22.37
1981	20.99	13.57	12.32	30.17	30.90	34.56	41.55	39.26	29.97	50.12	61.18	78.93	36.96
1982	19.42	6.02	3.98	5.46	9.52	22.13	28.19	18.06	29.03	52.83	27.25	9.24	19.26
1983	6.08	3.16	1.89	1.59	16.29	24.33	17.23	19.32	47.09	36.75	31.22	40.09	20.42
1984	16.39	10.39	6.73	3.71	17.64	28.61	32.16	50.64	41.55	46.57	39.36	13.36	25.59
1985	8.95	5.58	4.31	2.77	8.76	31.53	18.06	40.72	39.26	36.54	42.29	27.67	22.20
1986	9.82	5.13	3.13	16.71	19.84	31.01	23.18	19.63	28.71	58.57	64.00	15.66	24.62
1987	7.72	5.20	3.02	5.22	14.93	23.91	26.83	32.47	41.76	75.28	33.41	18.48	24.02
1988	7.83	5.30	3.00	2.71	12.32	24.64	26.31	34.56	34.77	54.92	42.70	23.07	22.68
1989	13.16	7.29	5.01	2.93	13.78	19.32	29.03	37.27	36.13	38.00	56.17	31.32	24.12
1990	15.87	7.09	4.85	3.30	25.78	18.70	23.92	24.89	43.30	62.38	41.99	64.74	28.07
1991	10.74	6.02	7.32	3.26	14.59	20.80	15.33	19.02	40.32	50.98	34.79	46.08	22.44
1992	9.54	3.54	3.85	5.74	27.89	29.08	27.98	48.16	44.98	39.19	32.94	20.22	24.43
1993	12.25	6.96	5.68	9.07	11.62	31.20	22.78	17.64	36.91	51.43	65.62	34.56	25.48
1994	12.61	7.33	5.97	6.48	14.00	21.95	16.29	12.63	26.58	37.60	38.55	13.93	17.83
1995	8.57	4.56	3.02	4.20	24.00	37.51	32.90	30.10	38.21	32.13	43.66	30.84	24.14
1996	59.90	27.89	14.23	7.68	21.88	43.51	47.96	59.03	42.80	74.41	58.04	53.80	42.59
1997	11.80	7.37	4.85	3.55	5.88	7.16	8.36	6.86	16.64	21.69	26.24	11.53	10.99
1998	5.34	4.42	3.00	4.10	14.20	13.22	23.18	18.98	26.31	41.11	24.23	35.91	17.83
1999	18.55	10.14	7.67	8.75	24.55	33.81	23.79	53.26	66.15	35.06	50.38	67.28	33.28
AVE	16.48	8.30	5.42	6.22	15.83	26.91	27.33	32.49	37.27	49.33	48.94	35.23	25.81

(Monthly flows for Indio at Damsite were obtained from flows of Indio at Uracillo adjusted with the ratio of the drainage areas of Indio at Damsite = 381.1 Km^2 and Indio at Uracillo = 365 Km)
Indio Damsite = Indio at Uracillo * (381.1/365)

TABLE 2
RIO INDIO WATER SUPPLY PROJECT
CONSTRUCTION COST ESTIMATE SUMMARY
(mid-2001 price level)

DESCRIPTION	AMOUNT
1 GENERAL	$49,939,000
2 DIVERSION	$3,603,000
3 DAM	$52,704,000
4 SPILLWAY	$6,043,000
5 LOW LEVEL OUTLET STRUCTURE	$3,049,000
6 SADDLE DAMS	$7,427,000
7 INTERBASIN TRANSFER TUNNEL	$46,765,000
8 MINIMUM RELEASE FACILITY	$837,000
9 OPERATION FACILITIES	$1,139,000
SUBTOTAL	$171,506,000
CONTINGENCIES	$28,868,000
ENGINEERING AND ADMINISTRATION (15%)	$30,056,000
TOTAL PROJECT COST	**$230,430,000**

TABLE 2
RIO INDIO WATER SUPPLY PROJECT
CONSTRUCTION COST ESTIMATE
(mid-2001 price level)

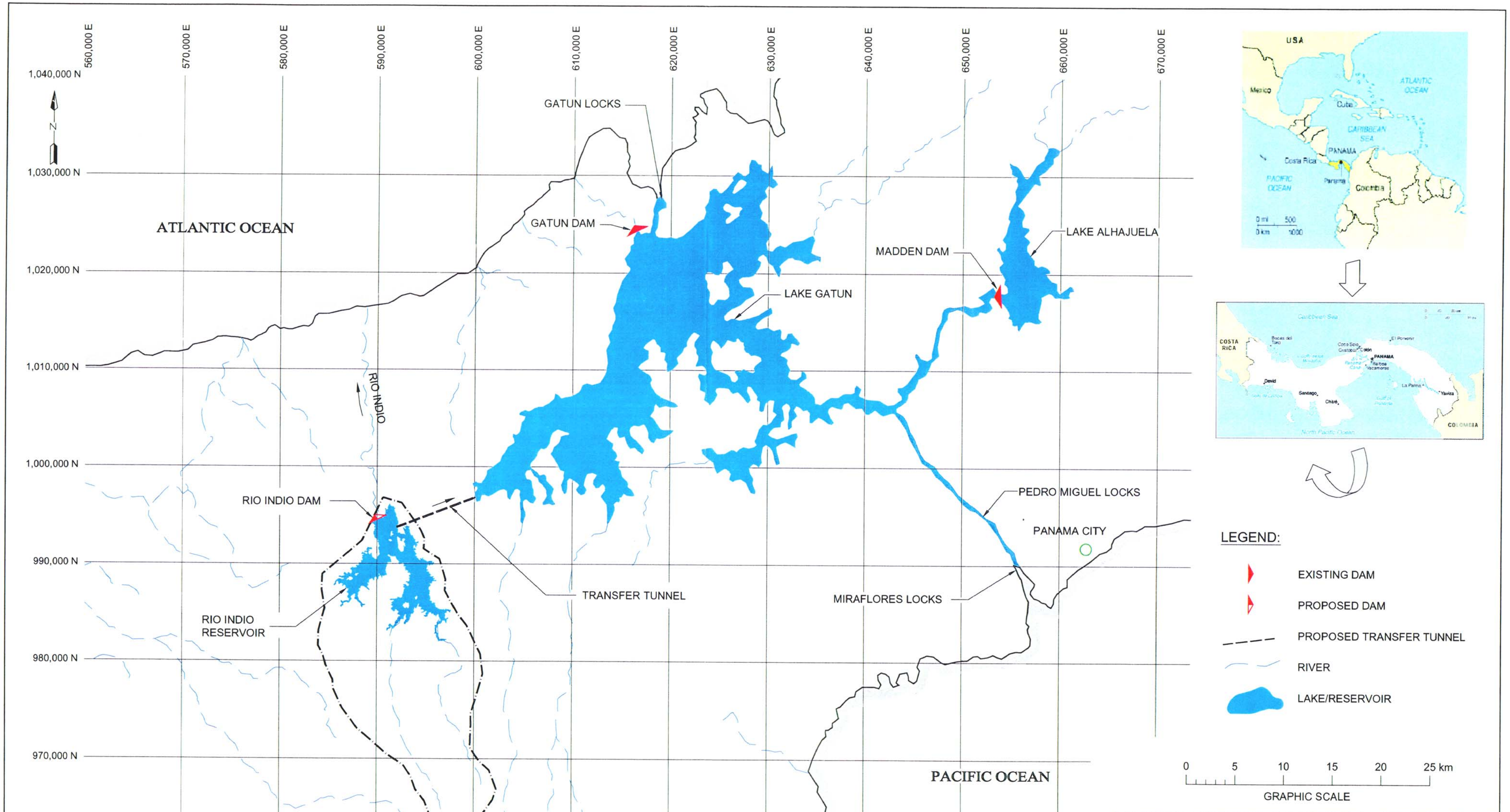
Description	Unit	Unit Cost	Quantity	Amount
1 GENERAL				
1.1 Mobilization and Demobilization	LS		1	$3,000,000
1.2 Land Acquisition and Resettlement				
1.2.1 Land Acquisition	ha	1000	5,500	$5,500,000
1.2.2 Home and Facilities	fam	17000	500	$8,500,000
1.2.3 Ag Development Facilities	ha	500	10,800	$5,400,000
1.2.4 Local Roads	LS			$800,000
1.2.5 Power Supply and Transmission	LS			$1,780,000
1.2.6 Other Infrastructure	LS			$4,120,000
1.3 Temporary Facilities	LS		1	$3,055,000
1.4 Access Roads				
1.4.1 Road Improvements (Permanent/Temporary)	Km	$66,000	38.5	$2,541,000
1.4.2 Permanent Roads	Km	$146,000	16.0	$2,336,000
1.4.3 Temporary Roads	Km	$114,000	5.5	$627,000
1.5 Rio Indio Bridge	LS	$495,800	1	$495,800
1.6 Watershed Management	LS			$2,000,000
1.7 Mitigation Plan Implementation/Archaeological	LS			$2,000,000
1.7 Reservoir Clearing	ha	$2,200	3,538	$7,784,000
Subtotal 1				**$49,938,800**
2 DIVERSION				
2.1 Site Preparation	m^2	$0.55	40,000	$22,000
2.2 Approach/Discharge Channels				
2.2.1 Overburden Excavation	m^3	$3.20	9,400	$30,080
2.2.2 Rock Excavation	m^3	$8.75	7,700	$67,375
2.3 Diversion Tunnel Intake and Outlet Portals				
2.3.1 Overburden Excavation	m^3	$3.20	4,700	$15,040
2.3.2 Rock Excavation	m^3	$8.75	15,500	$135,625
2.3.3 Shotcrete	m^2	$45.90	3,330	$152,847
2.3.4 Rockbolts	l.m.	$60.50	1,670	$101,035
2.3.5 Concrete	m^3	$115.00	220	$25,300
2.3.6 Formwork	m^2	$46.20	220	$10,164
2.3.7 Reinforcement	kg	$1.36	8,300	$11,288
2.4 Diversion Tunnel				
2.4.1 Tunnel Excavation	m^3	$103.20	13,950	$1,439,640
2.4.2 Shotcrete	m^2	$45.90	5,700	$261,630
2.4.3 Rockbolts	l.m.	$60.50	3,200	$193,600
2.4.4 Steel Ribs	kg	$2.90	59,200	$171,680
2.5 Cofferdams				
2.5.1 Overburden Excavation	m^3	$3.20	30,700	$98,240
2.5.2 Fill	m^3	$7.20	96,750	$696,600
2.5.3 Filter/Drain	m^3	$15.90	10,750	$170,925
Subtotal 2				**$3,603,069**
3 DAM				
3.1 Site Preparation	m^2	$0.55	300,000	$165,000
3.2 Excavation				
3.2.1 Overburden Excavation	m^3	$3.20	454,600	$1,454,720
3.2.2 Rock Excavation	m^3	$8.75	271,500	$2,375,625
3.2.3 Overburden Excavation (Right Abutment)	m^3	$3.20	309,000	$988,800
3.2.4 Rock Excavation (Right Abutment)	m^3	$8.75	933,600	$8,169,000
3.3 Grouting				
3.3.1 Cut-off	m^2	$46.00	27,300	$1,255,800
3.3.2 Consolidation	m	$69.20	2,250	$155,700
3.4 Rockfill				
3.4.1 Mass from Site Excavation	m^3	$3.75	1,509,500	$5,660,625
3.4.2 Mass from Quarry 1	m^3	$13.70	269,600	$3,693,520
3.4.3 Mass from Quarry 2	m^3	$13.70	916,500	$12,556,050
3.4.4 Filter	m^3	$15.90	216,000	$3,434,400
3.4.5 Drain	m^3	$15.90	19,600	$311,640
3.4.6 Backfill	m^3	$7.20	145,800	$1,049,760
3.5 Concrete				
3.5.1 Dental Concrete	m^3	$115.00	8,400	$966,000
3.5.2 Plinth	m^3	$172.00	8,400	$1,444,800
3.5.3 Facing	m^2	$80.00	66,100	$5,288,000
3.5.4 Parapet -US	m^3	$252.00	3,850	$970,200
3.5.5 Parapet -DS	m^3	$252.00	750	$189,000
3.5.6 Crest Road	m^2	$9.60	6,800	$65,280
3.6 Miscellaneous Site Work	LS	5%	1	$2,509,696
Subtotal 3				**$52,703,616**

TABLE 2
RIO INDIO WATER SUPPLY PROJECT
CONSTRUCTION COST ESTIMATE
(mid-2001 price level)

Description	Unit	Unit Cost	Quantity	Amount
7 INTERBASIN TRANSFER TUNNEL				
7.1 Site Preparation	m^2	$0.55	180,000	$99,000
7.2 Construction Access Adits (2)				
7.2.1 Overburden Excavation	m^3	$3.20	24,500	$78,400
7.2.2 Bulk Rock Excavation	m^3	$8.75	6,400	$56,000
7.2.3 Portal Excavation	m^3	$14.70	850	$12,495
7.2.4 Tunnel Excavation	m^3	$105.00	12,900	$1,354,500
7.2.5 Shotcrete	m^2	$45.90	5,600	$257,040
7.2.6 Rockbolts	lm	$60.50	3,400	$205,700
7.2.7 Steel Ribs	kg	$2.90	55,000	$159,500
7.2.8 Portal Concrete	m^3	$140.00	1,250	$175,000
7.2.9 Formwork	m^2	$46.20	650	$30,030
7.2.10 Invert Concrete	m^3	$115.00	600	$69,000
7.2.11 Miscellaneous	L.S.	5%	1	$119,883
7.3 Tunnel Portals				
7.3.1 Excavation	m^3	$8.75	76,600	$670,250
7.3.2 Shotcrete	m^2	$45.90	5,800	$266,220
7.3.3 Rockbolts	l.m.	$60.50	2,900	$175,450
7.3.4 Concrete	m^3	$115.00	710	$81,650
7.3.5 Formwork	m^2	$46.20	470	$21,714
7.3.6 Reinforcement	kg	$1.36	27,600	$37,536
7.4 Tunnel				
7.4.1 Rock Excavation	m^3	$72.30	225,200	$16,281,960
7.4.2 Shotcrete	m^2	$45.90	72,700	$3,336,930
7.4.3 Rockbolts	l.m.	$60.50	43,400	$2,625,700
7.4.4 Steel Ribs	kg	$2.90	437,300	$1,268,170
7.4.5 Concrete	m^3	$118.00	73,400	$8,661,200
7.4.6 Formwork	m^2	$10.00	97,200	$972,000
7.4.7 Reinforcement	kg	$1.36	2,934,300	$3,990,648
7.5 Intake Structure				
7.5.1 Concrete	m^3	$115.00	780	$89,700
7.5.2 Formwork	m^2	$46.30	920	$42,596
7.5.3 Reinforcement	kg	$1.36	51,200	$69,632
7.6 Intake Gate/Access Shaft				
7.6.1 Shaft Excavation	m^3	$295.00	1,620	$477,900
7.6.2 Shotcrete	m^2	$45.90	1,000	$45,900
7.6.3 Rockbolts	l.m.	$60.50	740	$44,770
7.6.4 Concrete	m^3	$140.00	1,140	$159,600
7.6.5 Formwork	m^2	$46.20	1,200	$55,440
7.6.6 Reinforcement	kg	$1.36	51,200	$69,632
7.7 Outlet Structure				
7.7.1 Concrete	m^3	$140.00	3,420	$478,800
7.7.2 Formwork	m^2	$46.20	4,320	$199,584
7.7.3 Reinforcement	kg	$1.36	178,200	$242,352
7.7.4 Steel Lining	kg	$3.20	25,000	$80,000
7.7.5 Anchors	l.m.	$60.50	900	$54,450
7.8 Discharge Channel				
7.8.1 Excavation	m^3	$3.20	326,600	$1,045,120
7.9 Hydromechanical Equipment				
7.9.1 Trashracks and Embeds (8 x 10)	kg	$4.50	27,000	$121,500
7.9.2 U/S Gates (3.8 x 4.5 m)	kg	$10.00	13,100	$131,000
7.9.3 Embedded Metals	kg	$4.50	7,500	$33,750
7.9.4 U/S Operator	L.S.	$50,000	1	$50,000
7.9.5 U/S Surface Structure	L.S.	$50,000	1	$50,000
7.9.6 U/S Power and Controls	L.S.	$50,000	1	$50,000
7.9.7 D/S Gates 4 - 2.5 x 3.6	kg	$10.00	148,800	$1,488,000
7.9.8 D/S Operators	L.S.	$125,000	4	$500,000
7.9.9 D/S Surface Structure	L.S.	$50,000	1	$50,000
7.9.10 D/S Power and Controls	L.S.	$100,000	1	$100,000
7.9.11 Miscellaneous	L.S.	5%	1	$128,713
Subtotal 7				**$46,765,415**

Exhibits

EXHIBITS



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

ACP

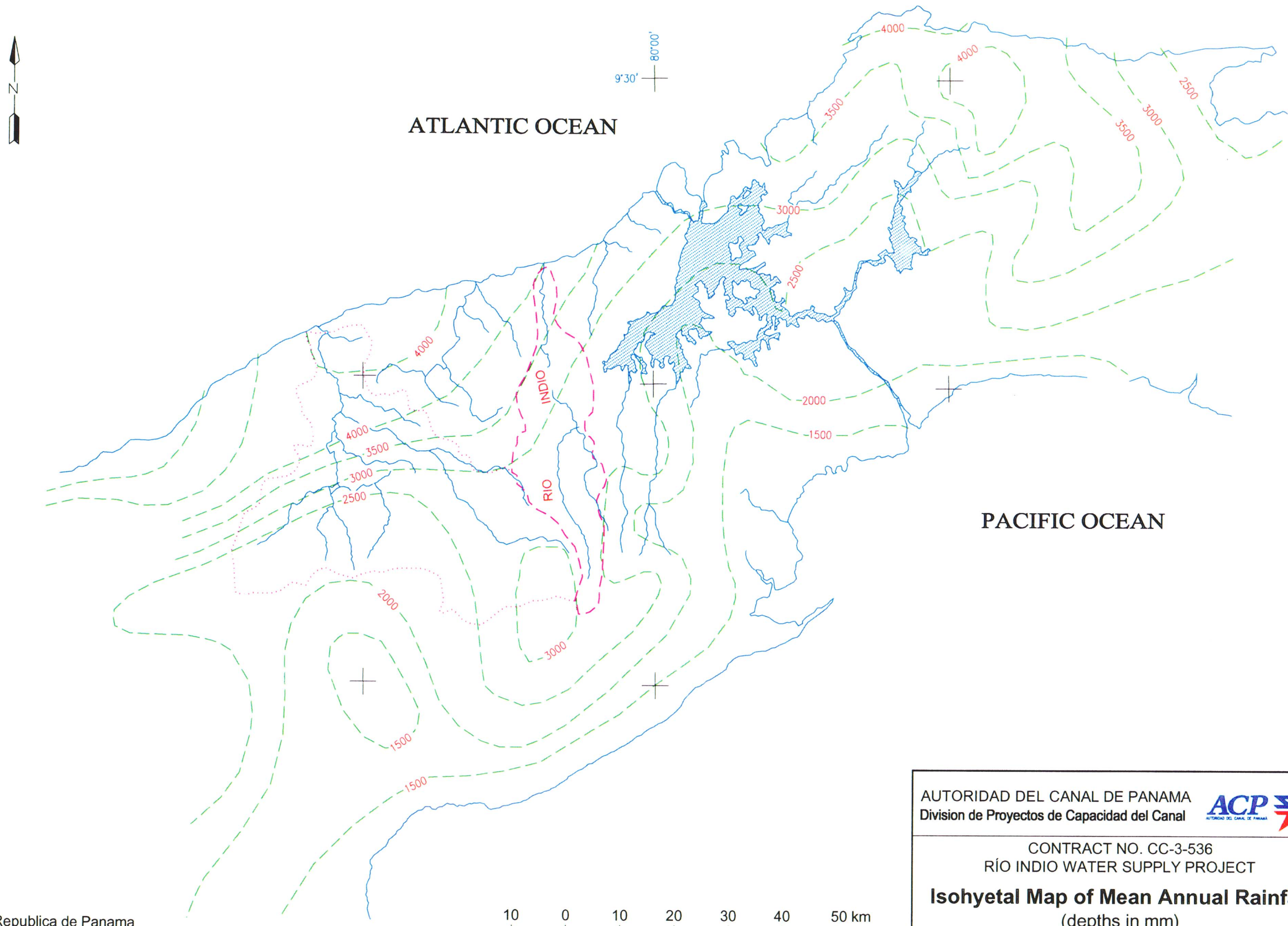
CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

LOCATION MAP

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 2-1



10 0 10 20 30 40 50 km

GRAPHIC SCALE

Source:

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

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

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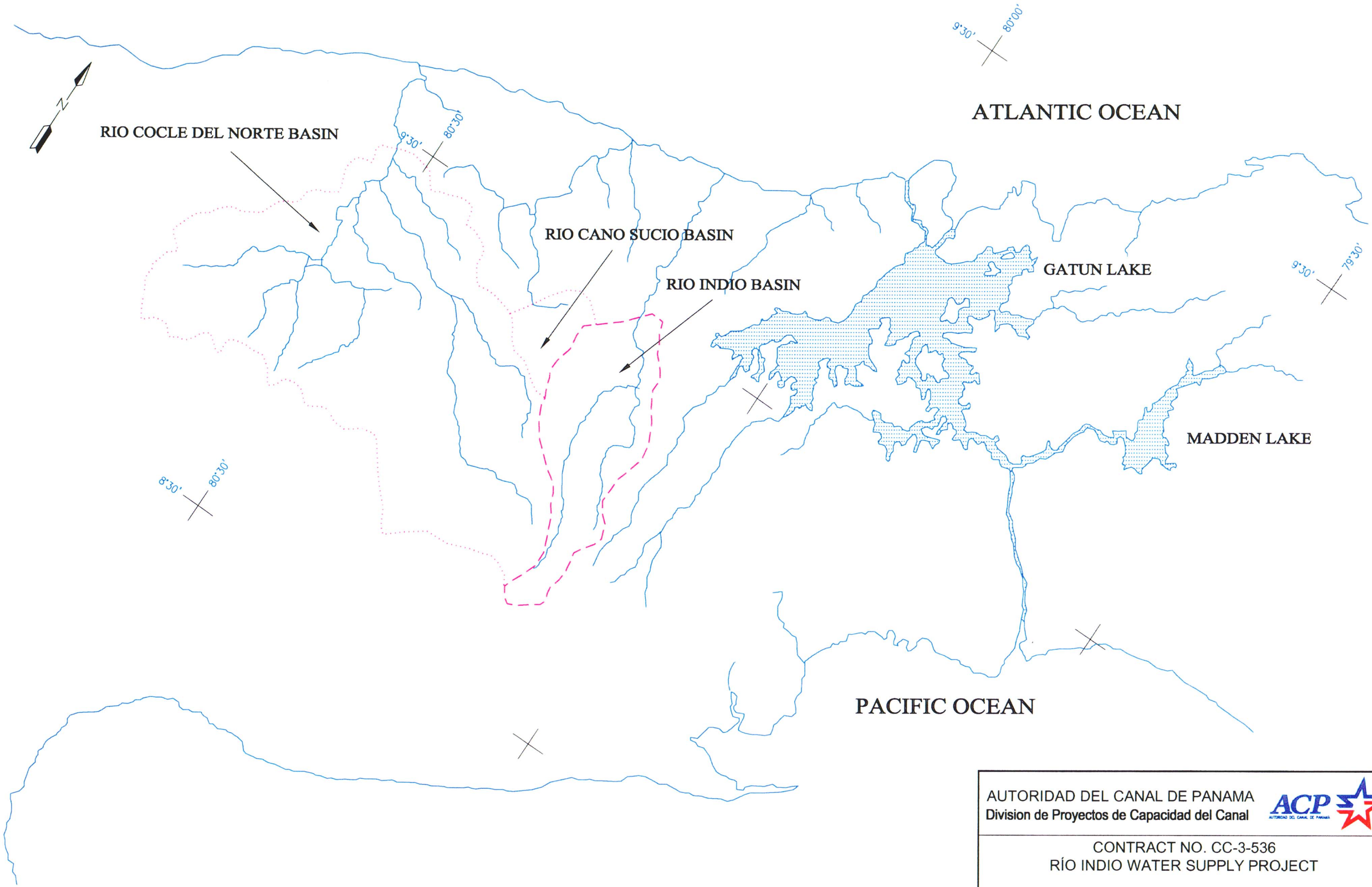
CONTRACT NO. CC-3-536
RÍO INDIO WATER SUPPLY PROJECT

Isohyetal Map of Mean Annual Rainfall
(depths in mm)

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 2-2



Source:
US NWS, February 1978 Report

10 0 10 20 30 40 50 km
GRAPHIC SCALE

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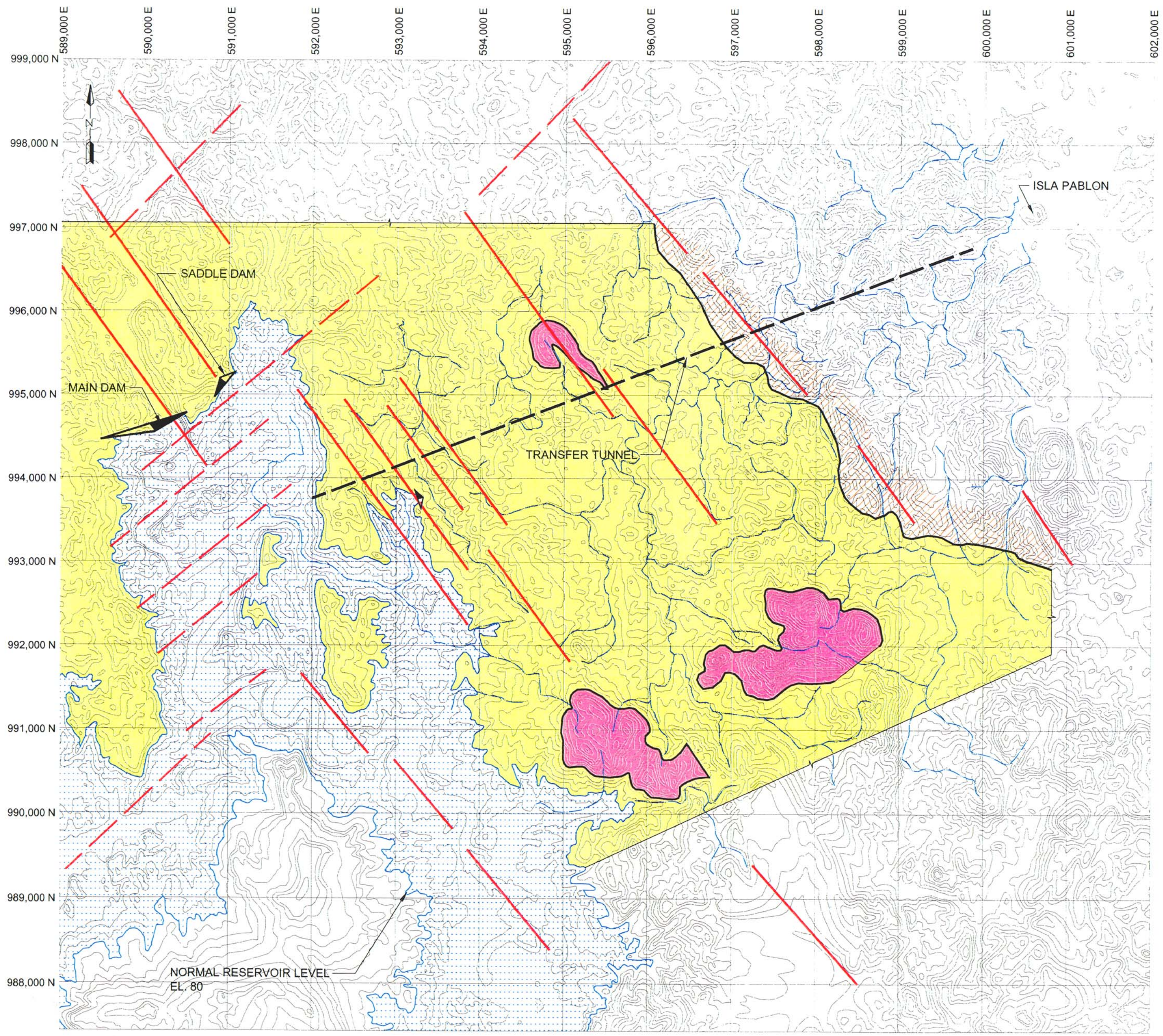
CONTRACT NO. CC-3-536
RÍO INDIO WATER SUPPLY PROJECT

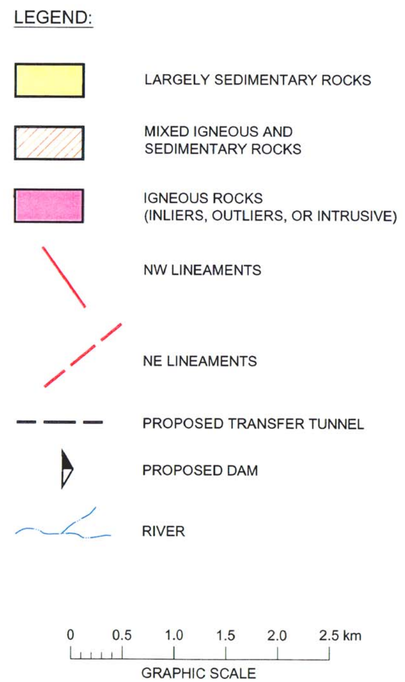
Rio Indio Basin Location

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 2-3





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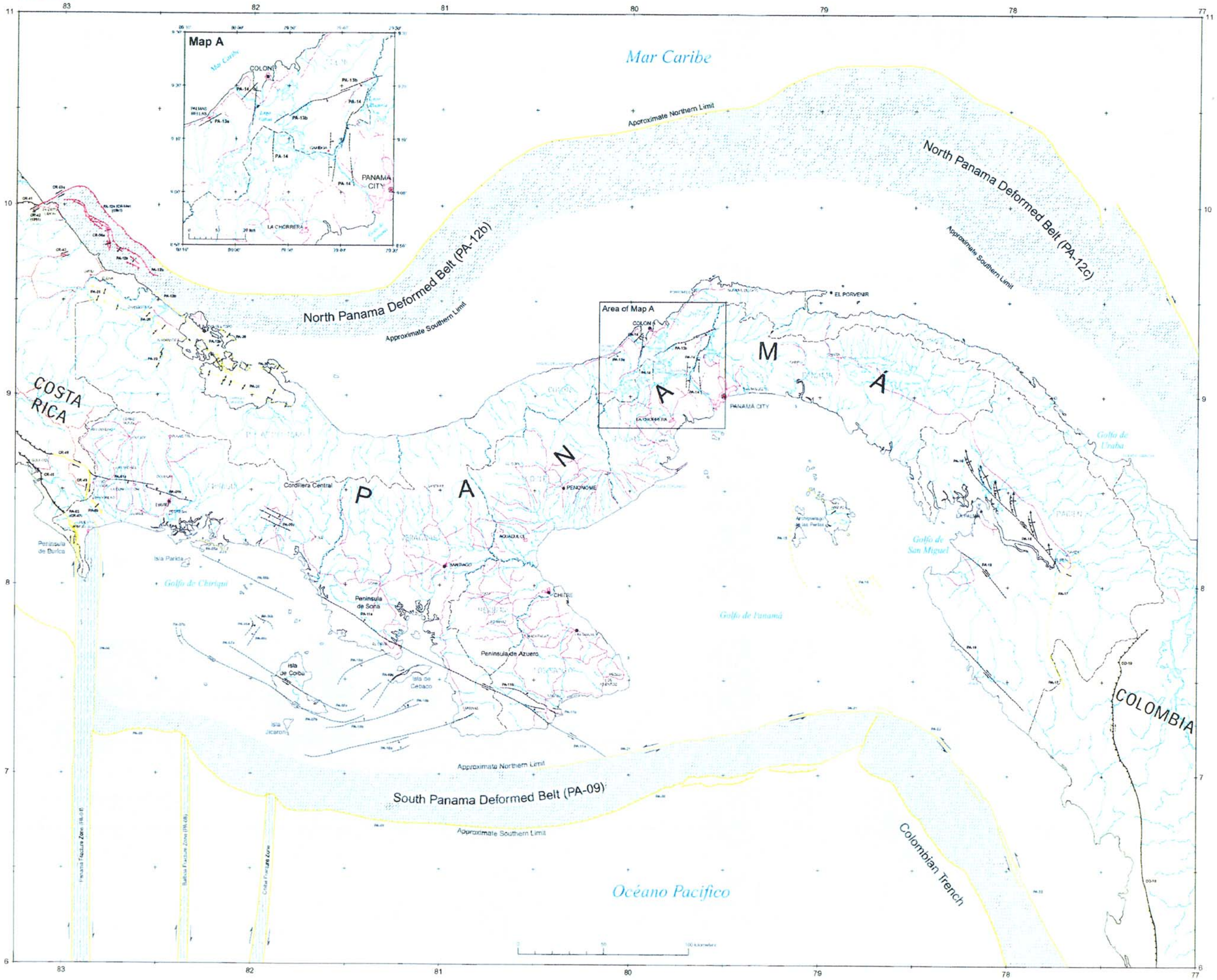
CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

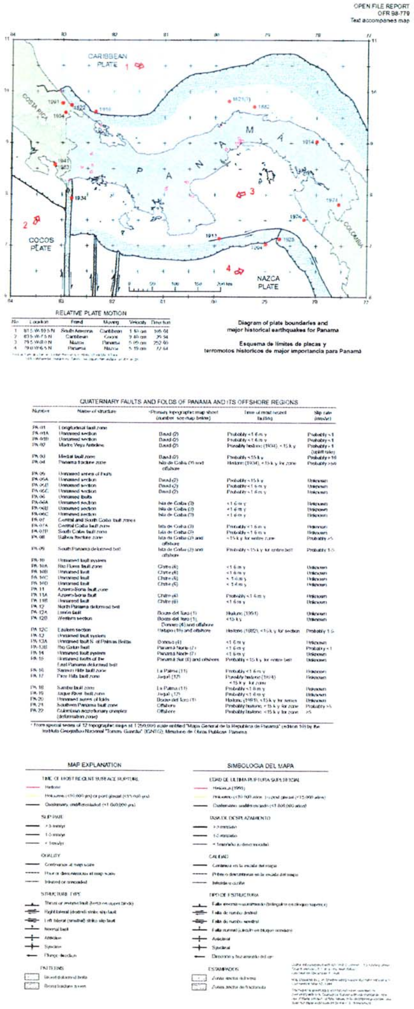
REGIONAL GEOLOGY

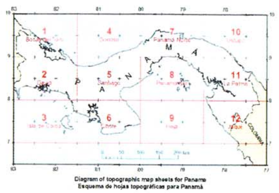
MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 2-4







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

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

Data compiled by Hugh Cowan, digital representation by Richard L. Dart, and project coordinated by Michael N. Machette (Co-chairman, ILP Task Group II-2)

1998

Scale 1:750,000 Mercator Projection
(longitude of central meridian, 80 W, latitude of true scale 0, Clarke 1866 spheroid)

Mapa de Fallas y Pliegues Cuaternarios de Panamá y Regiones Oceanicas Adyacentes

Proyecto Internacional de la Litosfera, Grupo de Trabajo II-2,
Principales Fallas Activas del Mundo

Un proyecto de cooperación entre el U.S. Geological Survey, el Instituto de Geociencias de la Universidad de Panamá la Agencia Sueca para Investigaciones Cooperativas con Naciones en Desarrollo (SAREC), y NORSAR, Norway

Datos compilados por Hugh Cowan, representacion digital por Richard L. Dart, y proyecto coordinado por Michael N. Machette (Co-chairman, ILP Grupo de Trabajo II-2)

1998

Escala 1:750,000 Proyección de Mercator
(longitud de meridiano central 80 W, latitud de escala verdadera 0, con base en el esferoide de Clarke 1866)

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

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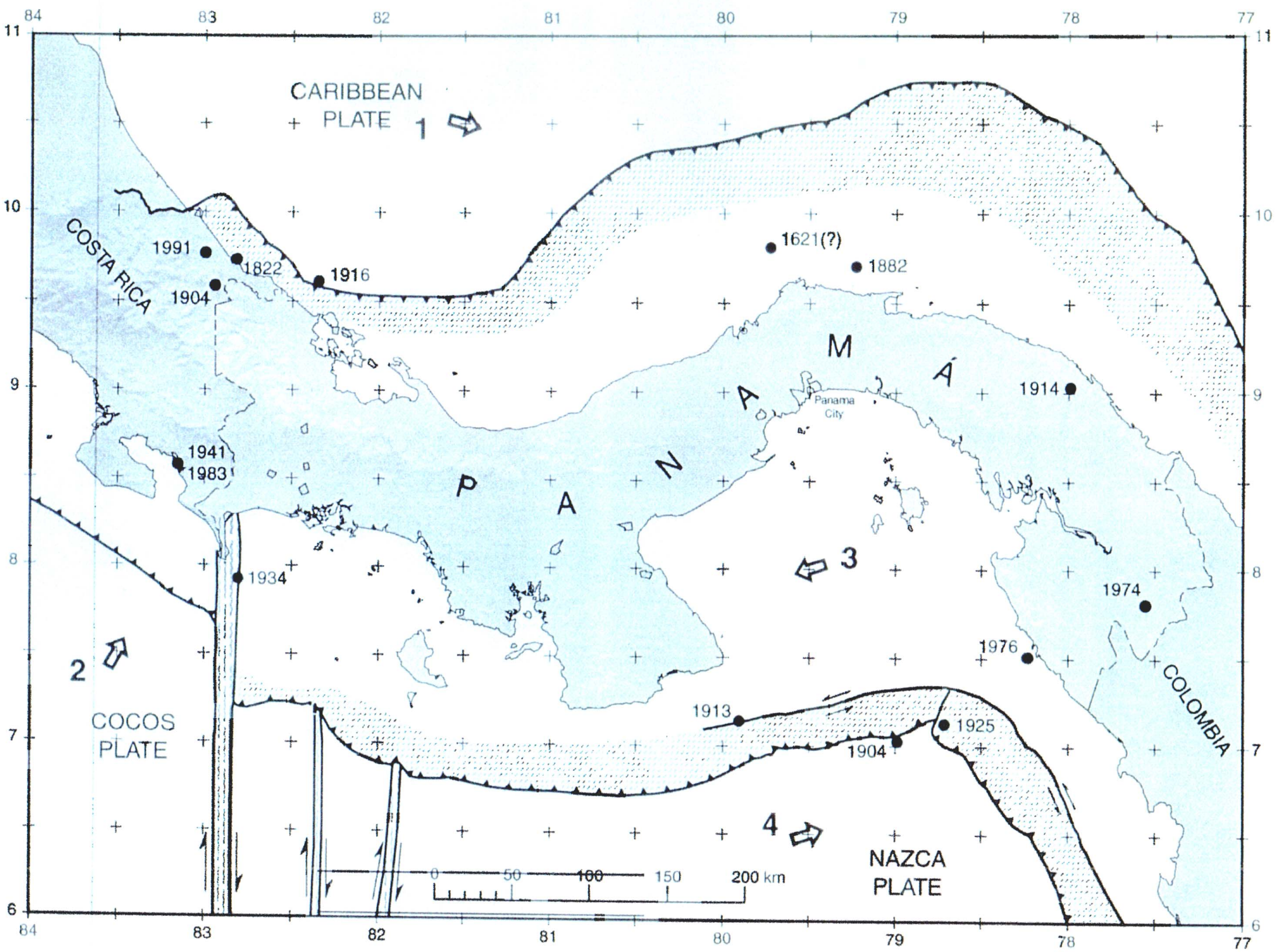
CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

MAP OF FAULTS AND FOLDS IN PANAMA

MWH TAMS

DATE:	EXHIBIT:
APRIL, 2003	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
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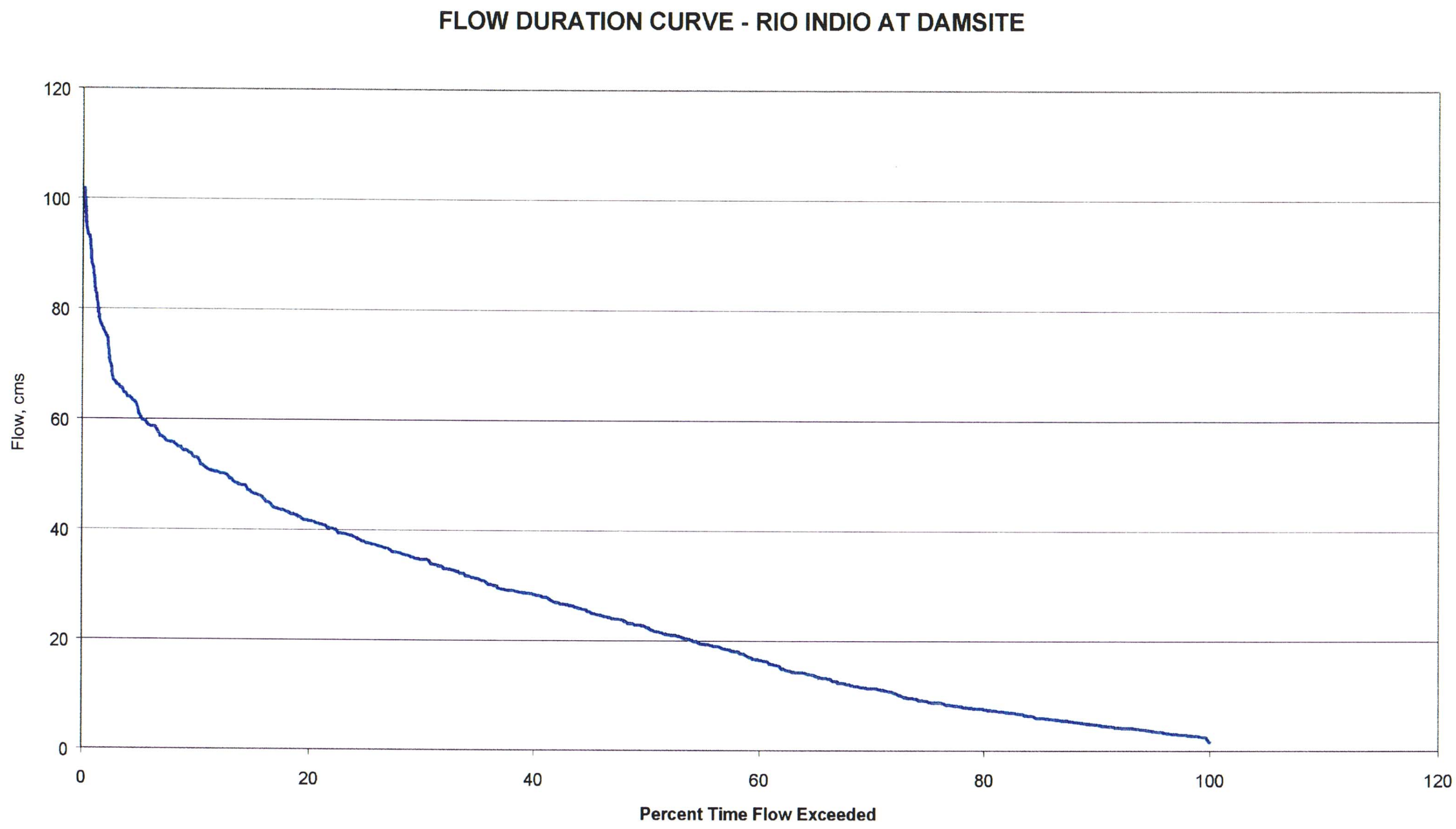
CONTRACT NO. CC-3-536
RÍO INDIO WATER SUPPLY PROJECT

Tectonic Plate Boundaries

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 2-6



AUTORIDAD DEL CANAL DE PANAMA
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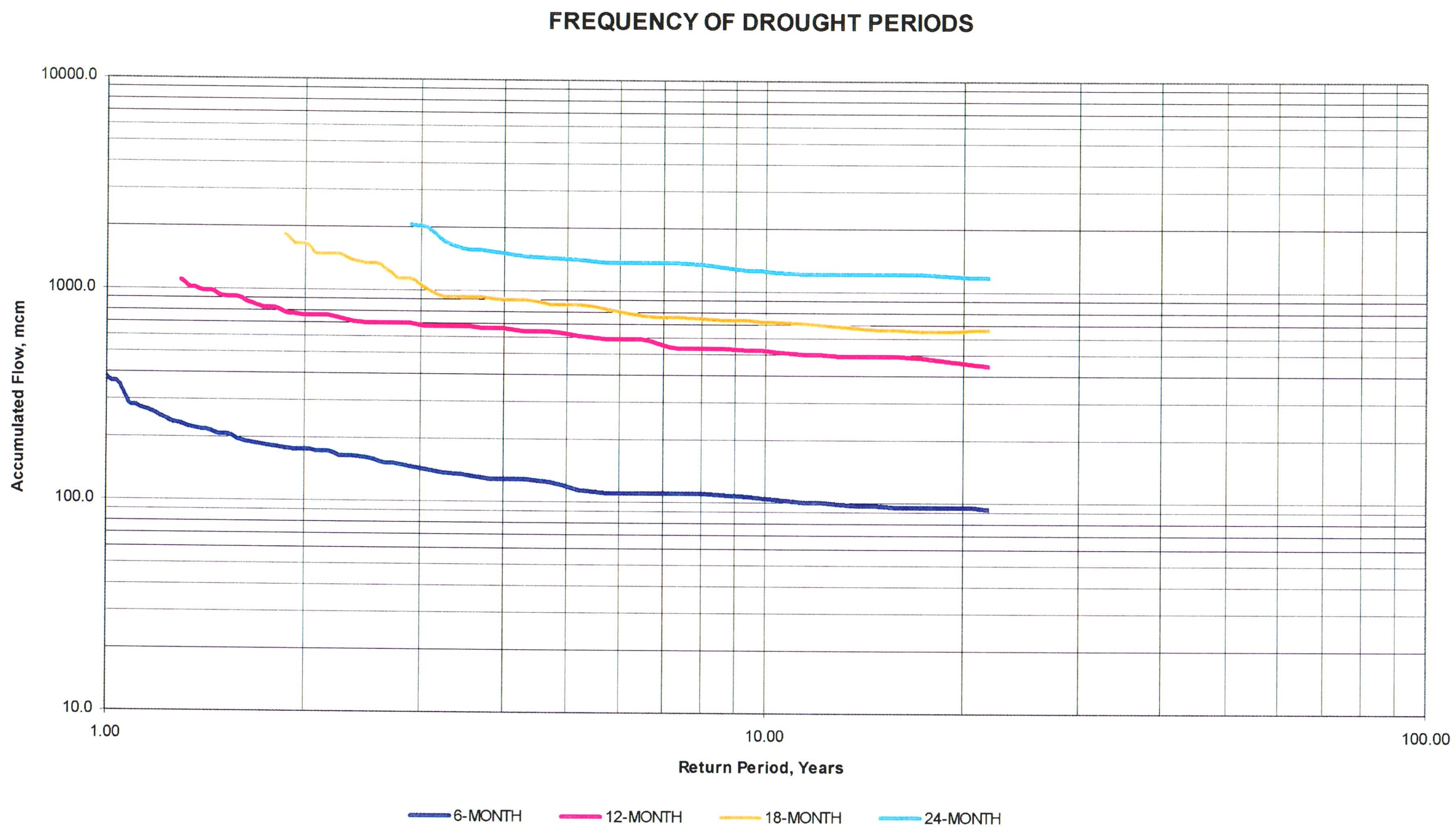
CONTRACT NO. CC-3-536
RÍO INDIO WATER SUPPLY PROJECT

Flow Duration at the Rio Indio Dam Site

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 3-1



AUTORIDAD DEL CANAL DE PANAMA
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CONTRACT NO. CC-3-536
RÍO INDIO WATER SUPPLY PROJECT

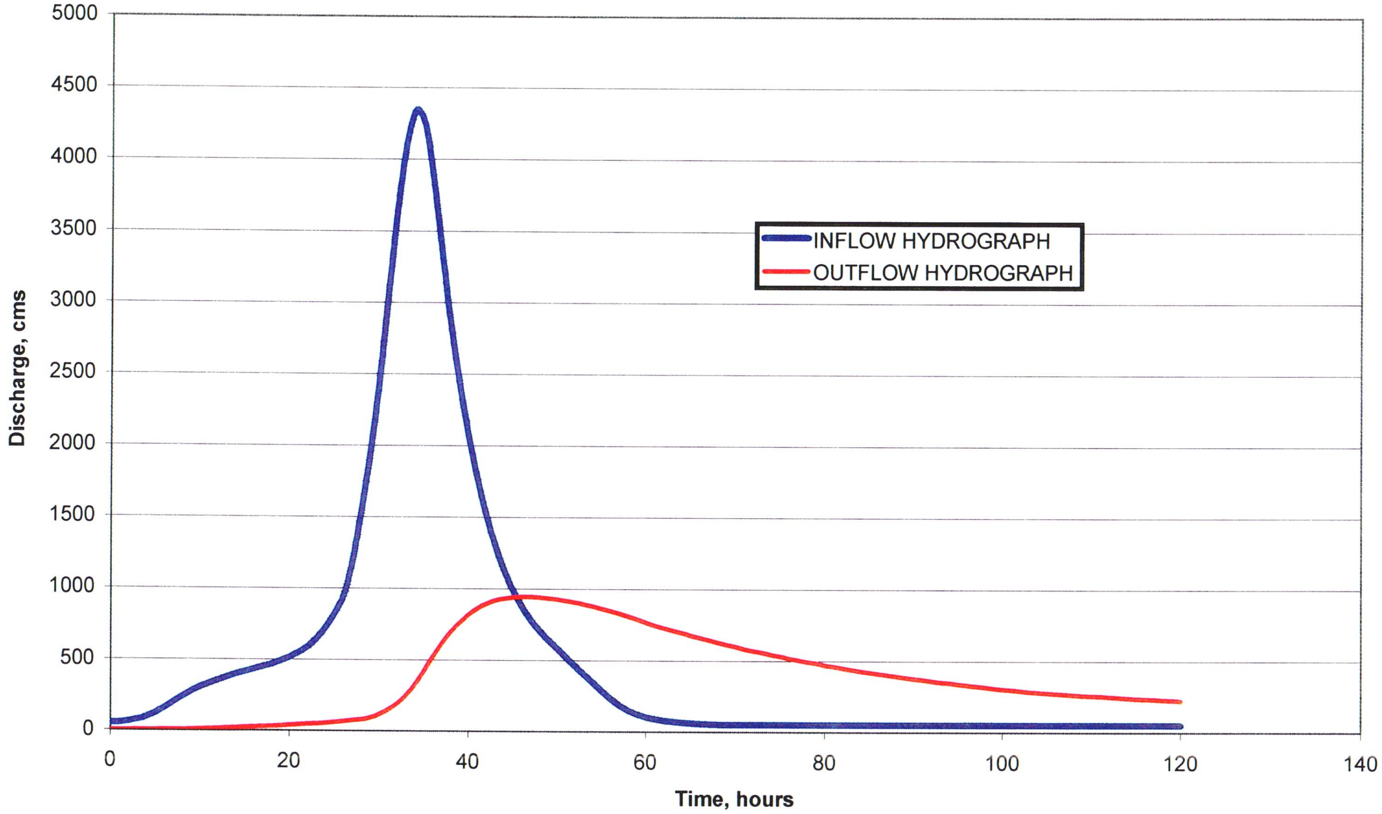
Drought Frequency at the Rio Indio Dam Site

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 3-2

RIO INDIO AT DAM SITE - PMF INFLOW AND OUTFLOW



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

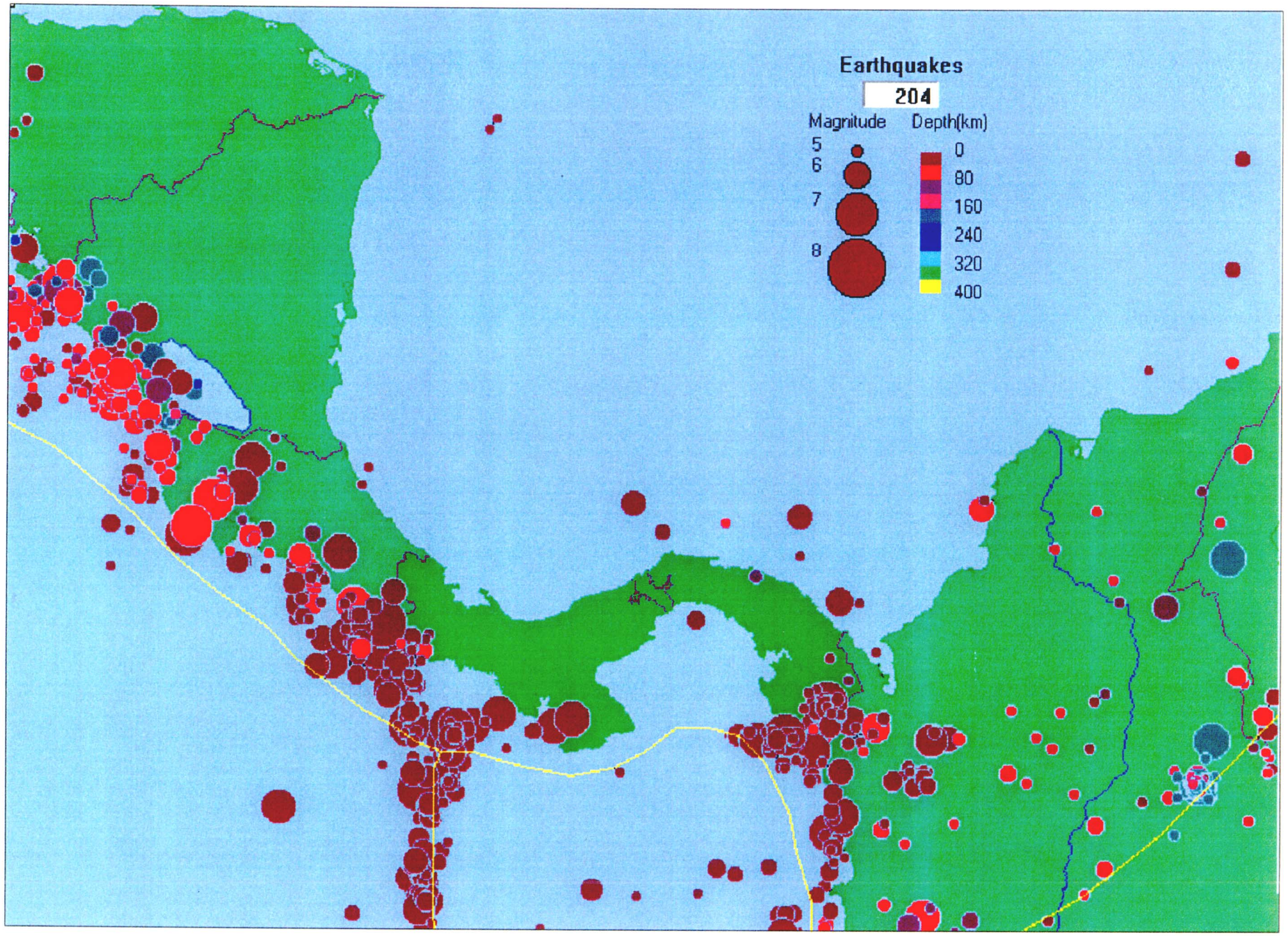
CONTRACT NO. CC-3-536
RÍO INDIO WATER SUPPLY PROJECT

Probable Maximum Flood at the Rio Indio Dam Site

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 3-3



NOTE:

PLOT OF ALL EARTHQUAKES >M = 3.0 IN 30-YEAR PERIOD JANUARY 1960 TO JANUARY 1990.
YELLOW LINES INDICATE PLATE MARGINS.

AUTORIDAD DEL CANAL DE PANAMA
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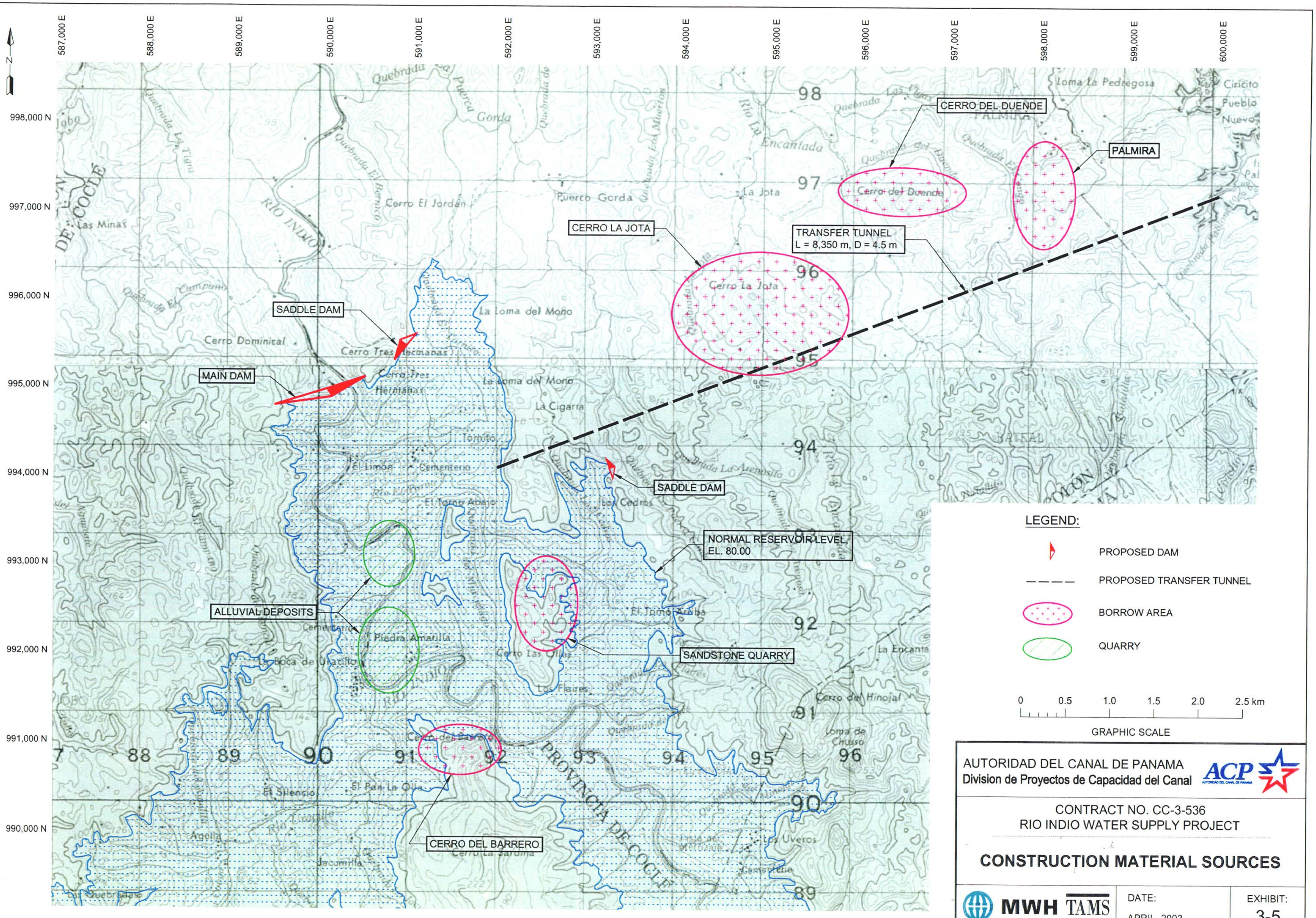
CONTRACT NO. CC-3-536
RÍO INDIO WATER SUPPLY PROJECT

Seismicity of Panama

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 3-4



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

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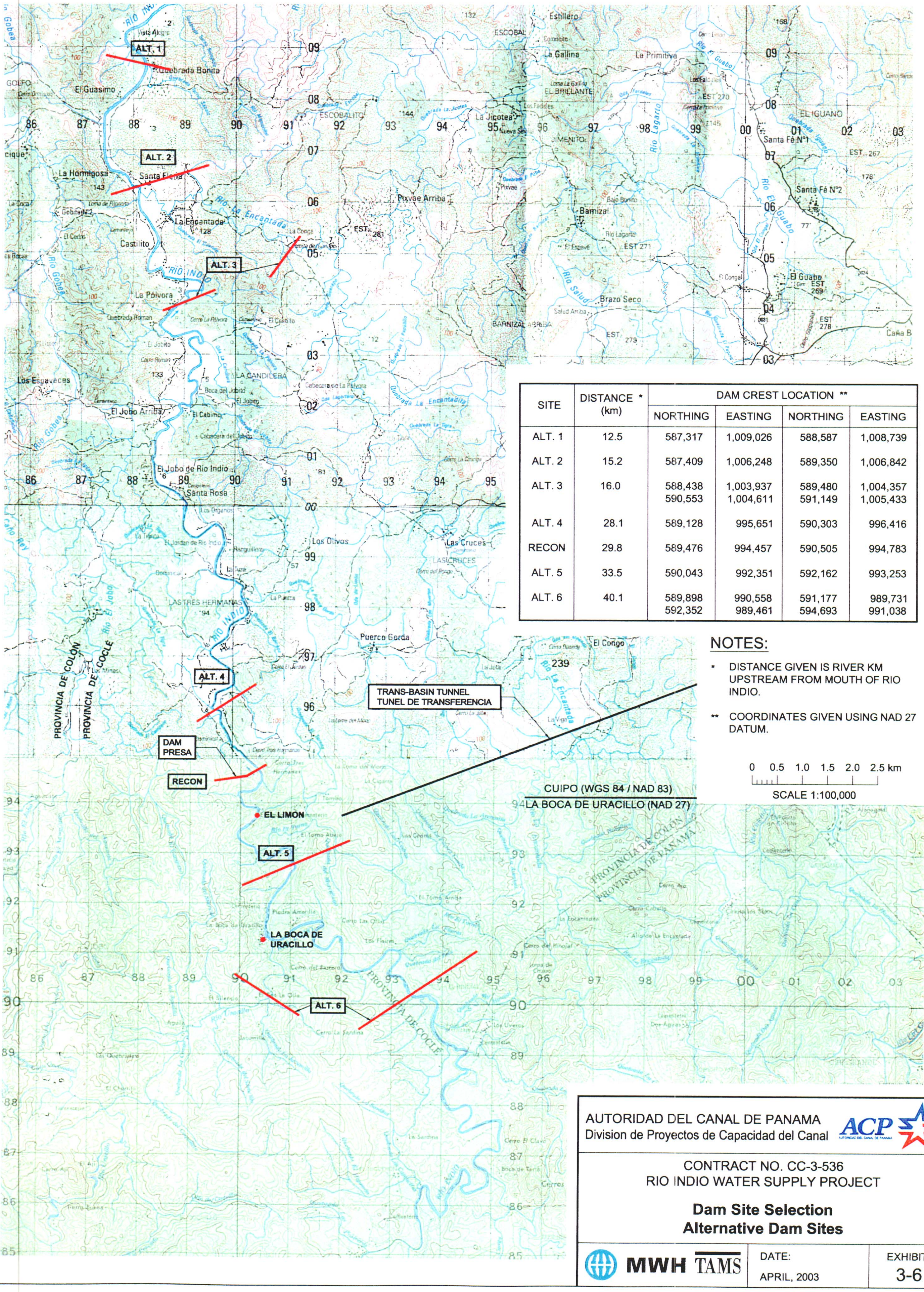
CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

CONSTRUCTION MATERIAL SOURCES

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 3-5



SITE	DISTANCE * (km)	DAM CREST LOCATION **			
		NORTHING	EASTING	NORTHING	EASTING
ALT. 1	12.5	587,317	1,009,026	588,587	1,008,739
ALT. 2	15.2	587,409	1,006,248	589,350	1,006,842
ALT. 3	16.0	588,438 590,553	1,003,937 1,004,611	589,480 591,149	1,004,357 1,005,433
ALT. 4	28.1	589,128	995,651	590,303	996,416
RECON	29.8	589,476	994,457	590,505	994,783
ALT. 5	33.5	590,043	992,351	592,162	993,253
ALT. 6	40.1	589,898 592,352	990,558 989,461	591,177 594,693	989,731 991,038

NOTES:

- * DISTANCE GIVEN IS RIVER KM UPSTREAM FROM MOUTH OF RIO INDIO.
- ** COORDINATES GIVEN USING NAD 27 DATUM.

0 0.5 1.0 1.5 2.0 2.5 km

SCALE 1:100,000

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

ACP

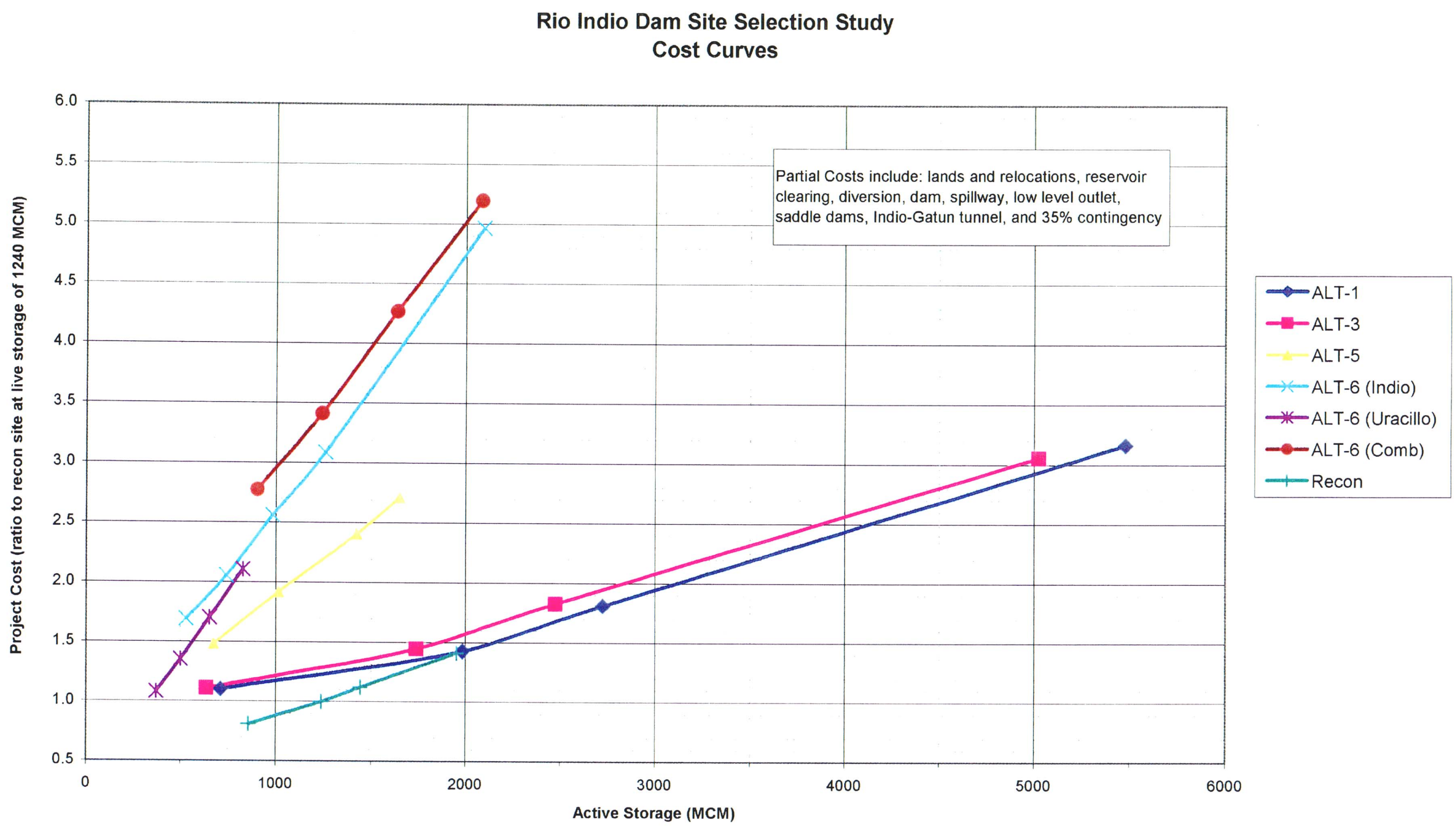
CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

Dam Site Selection
Alternative Dam Sites

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 3-6



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

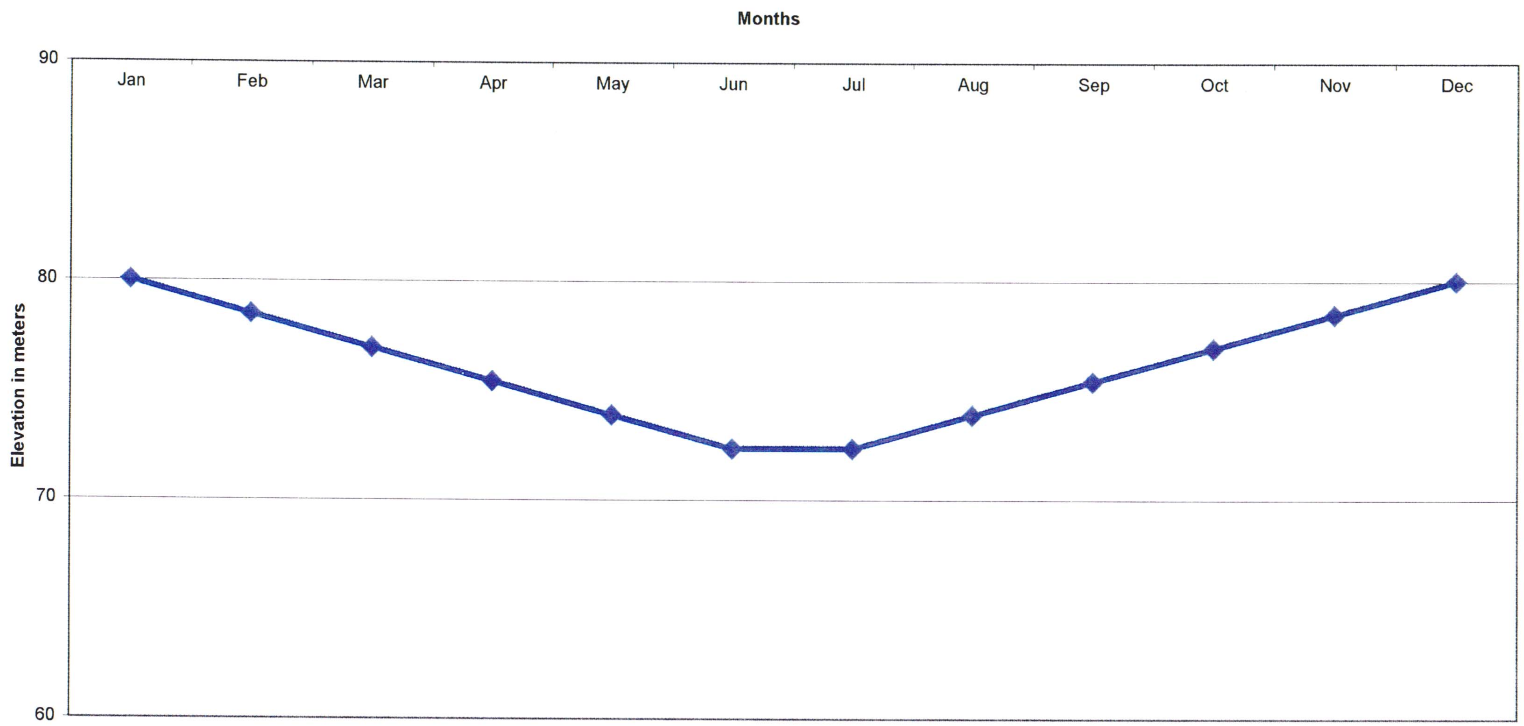
CONTRACT NO. CC-3-536
RÍO INDIO WATER SUPPLY PROJECT

Comparative costs of Alternative Dam Sites

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 3-7



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

ACP

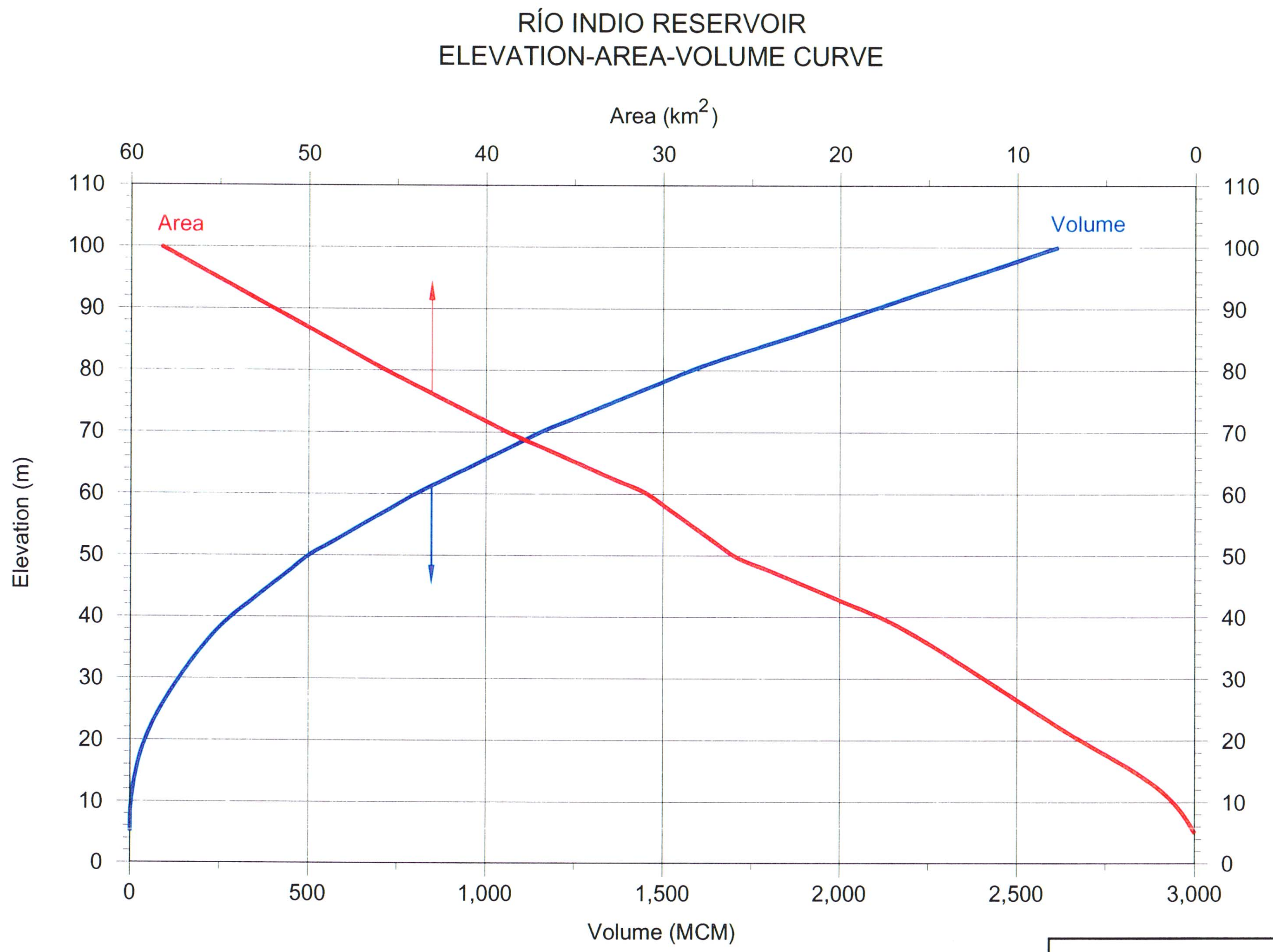
CONTRACT NO. CC-3-536
RÍO INDIO WATER SUPPLY PROJECT

Rio Indio Rule Curve

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 3-8



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

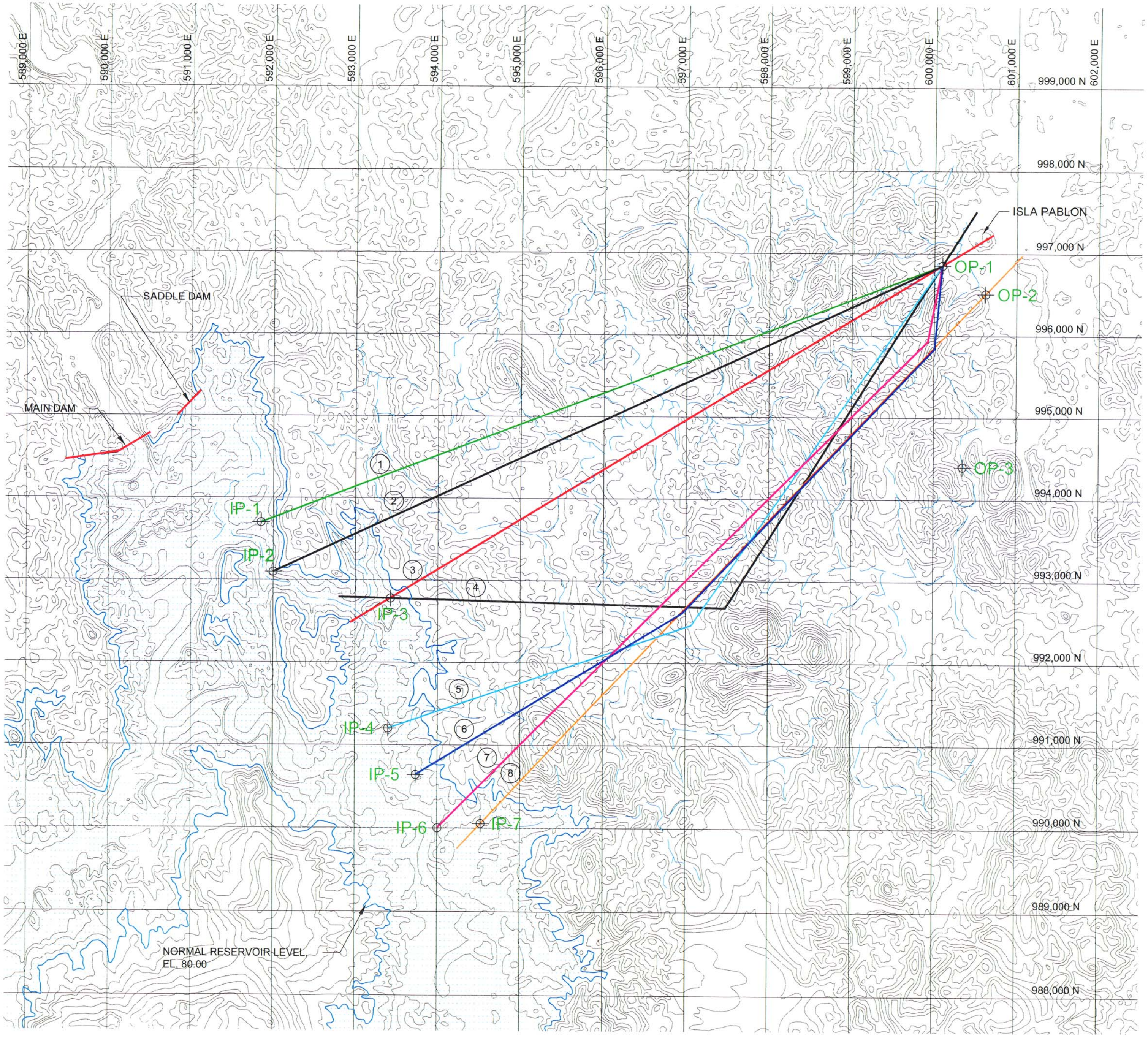
CONTRACT NO. CC-3-536
RÍO INDIO WATER SUPPLY PROJECT

AREA AND VOLUME CURVE

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 3-9



N

ALIGNMENT ALTERNATIVE	INLET PORTAL	OUTLET PORTAL
1	IP-1	OP-1
2	IP-2	OP-1
3	IP-3	OP-1
4	IP-3	OP-1
5	IP-4	OP-1
6	IP-5	OP-1
7	IP-6	OP-1
8	IP-7	OP-2

LEGEND:

QUEBRADAS

IP-1 – OP-1 TUNNEL ALIGNMENT

TRANS-BASIN TRANSFER TUNNEL

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

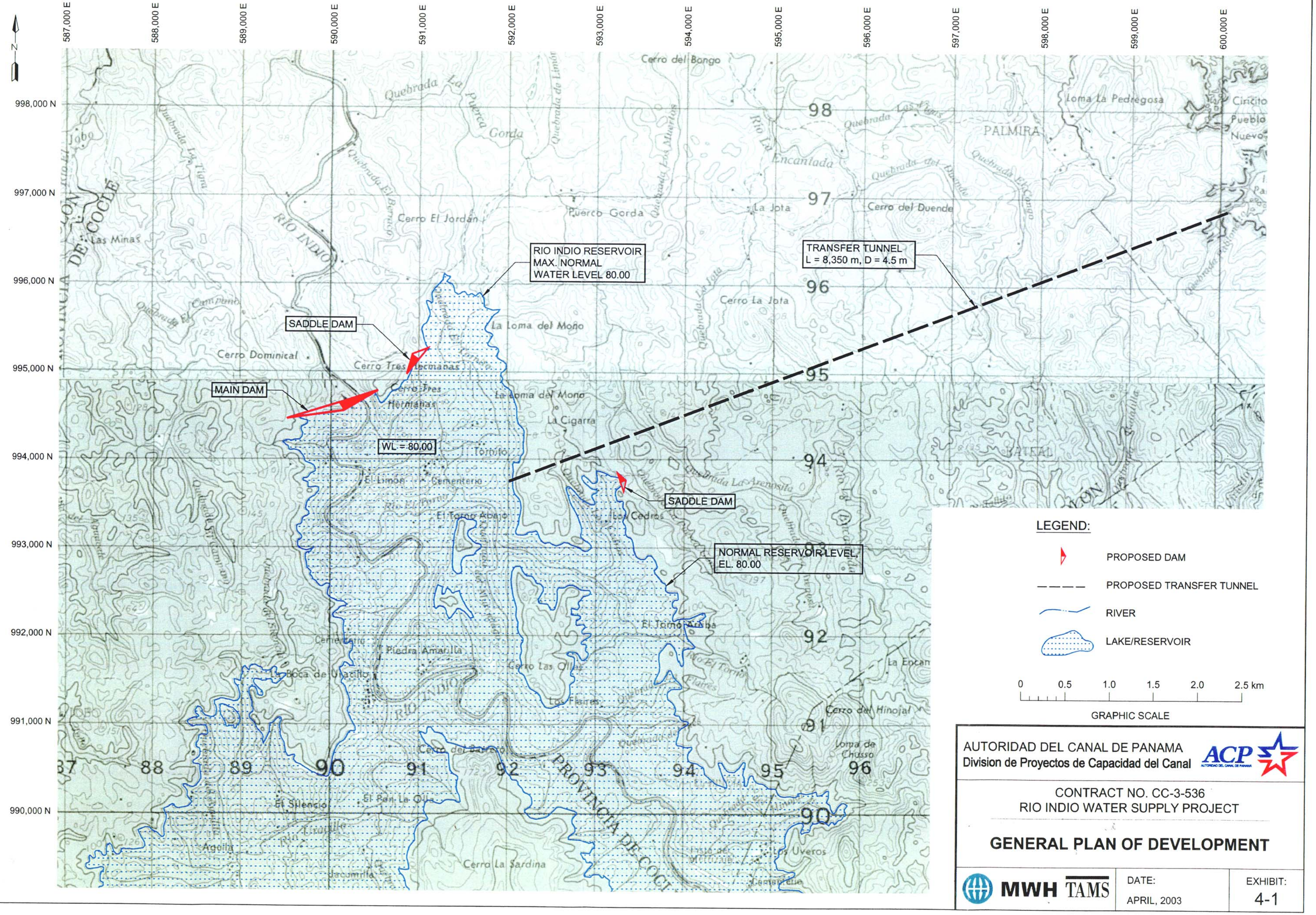
CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

POTENTIAL WATER TRANSFER ALIGNMENTS

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 3-10



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

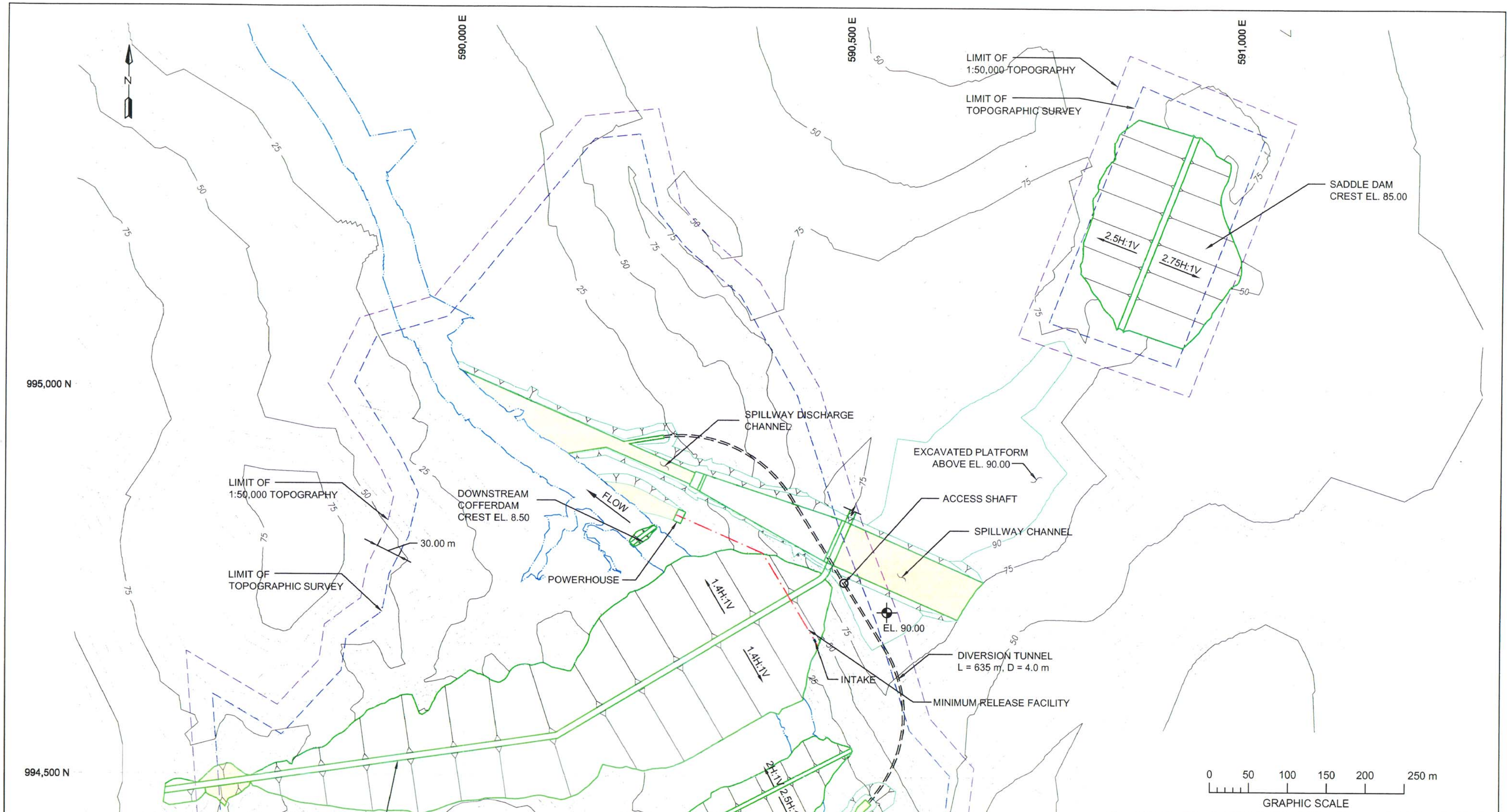
CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

GENERAL PLAN OF DEVELOPMENT

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 4-1



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

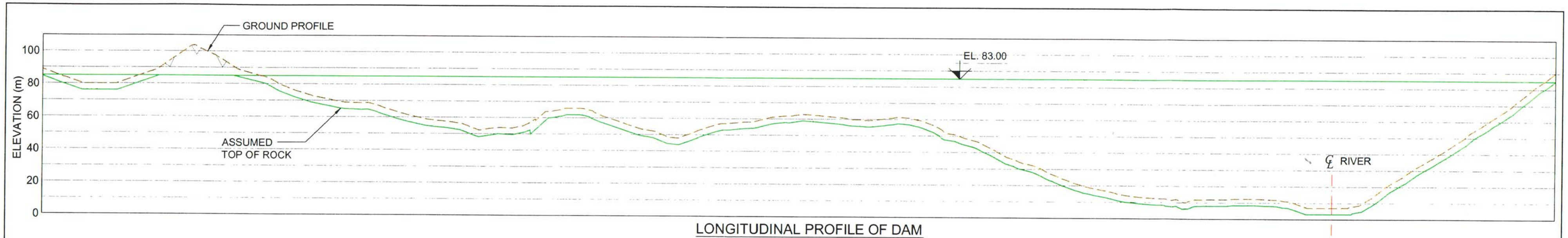
CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

RIO INDIO MAIN DAM AND SADDLE DAM PLAN

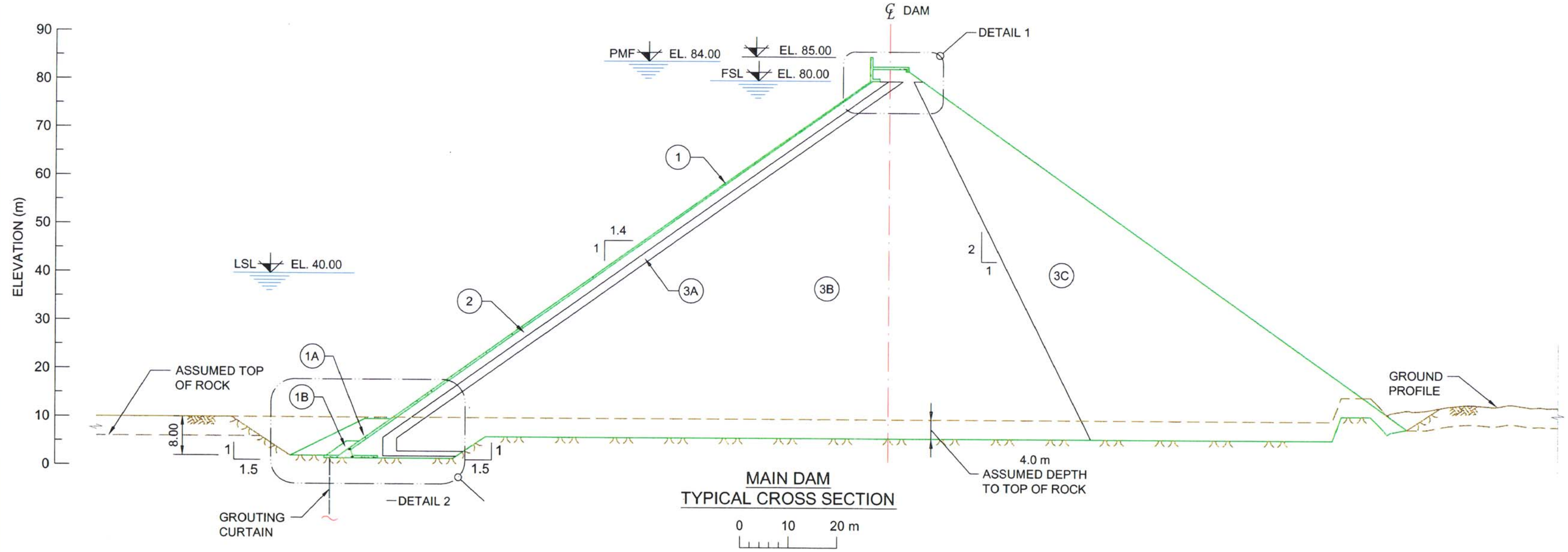
MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 4-2



LONGITUDINAL PROFILE OF DAM
(LOOKING DOWNSTREAM)

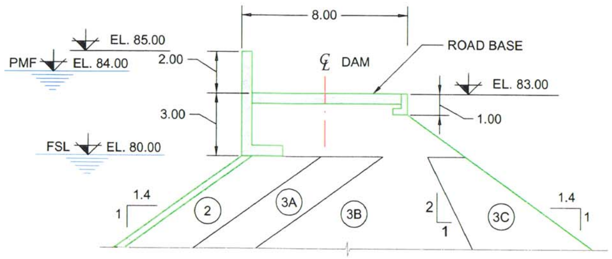


MAIN DAM TYPICAL CROSS SECTION

0 10 20 m
GRAPHIC SCALE

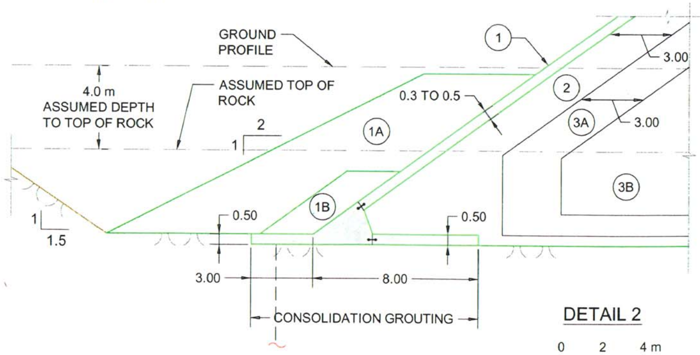
LEGEND:

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



DETAIL 2

0 2 4 m
GRAPHIC SCALE

0 50 100 150 200 250 m
GRAPHIC SCALE

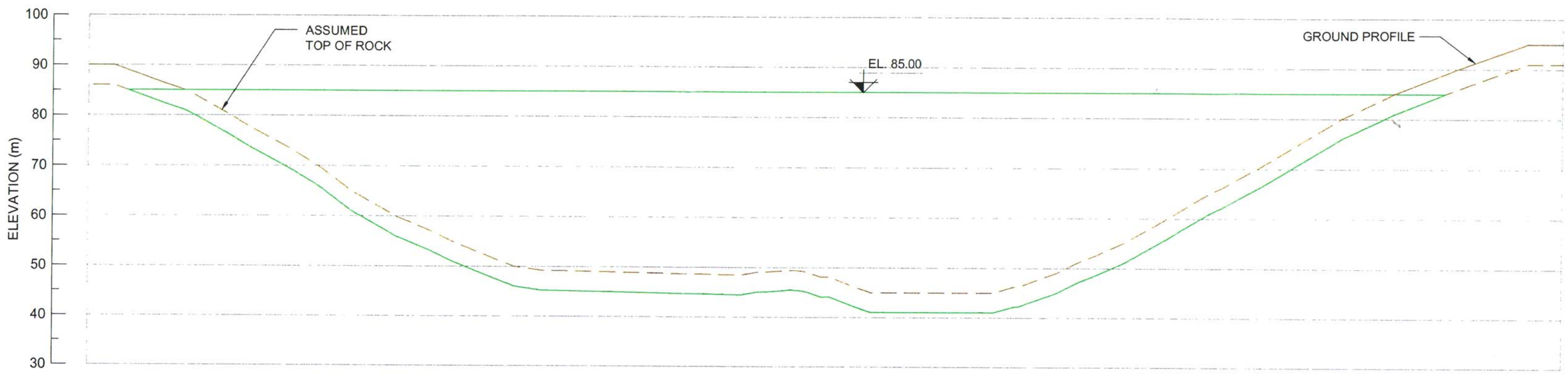
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal
ACP

CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

RIO INDIO MAIN DAM PROFILE AND TYPICAL CROSS SECTION

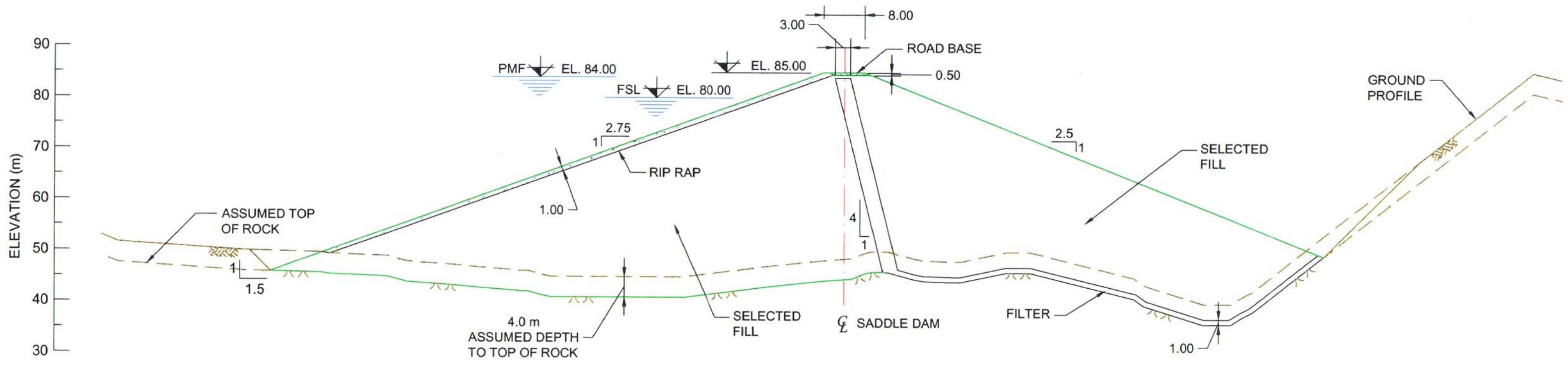
MWH TAMS

DATE:	EXHIBIT:
APRIL, 2003	4-3



LONGITUDINAL PROFILE OF SADDLE DAM

(LOOKING DOWNSTREAM)



SADDLE DAM

TYPICAL CROSS SECTION

0 10 20 m

GRAPHIC SCALE

0 25 50 75 100 125 m

GRAPHIC SCALE

AUTORIDAD DEL CANAL DE PANAMA

Division de Proyectos de Capacidad del Canal

ACP

CONTRACT NO. CC-3-536

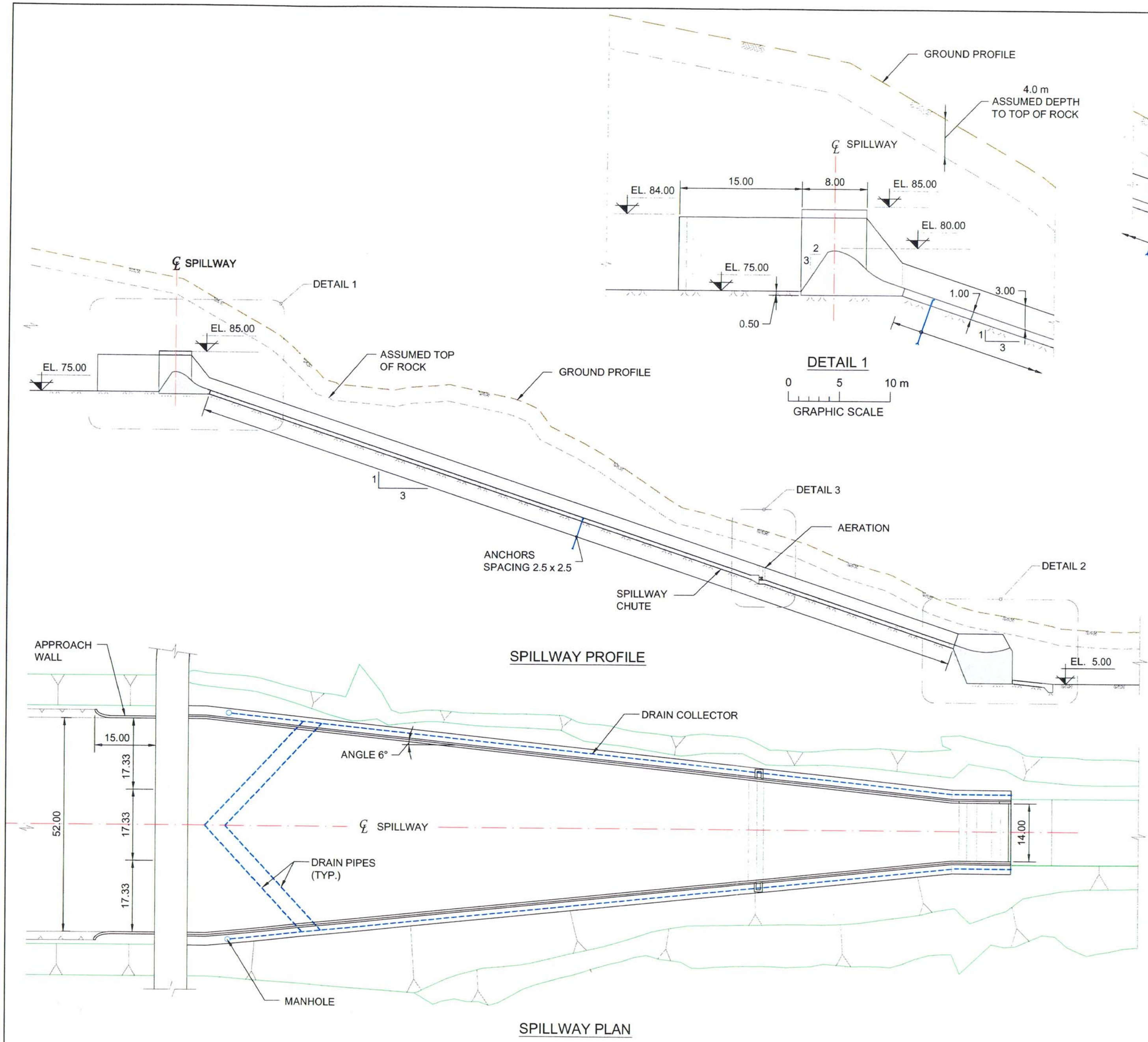
RIO INDIO WATER SUPPLY PROJECT

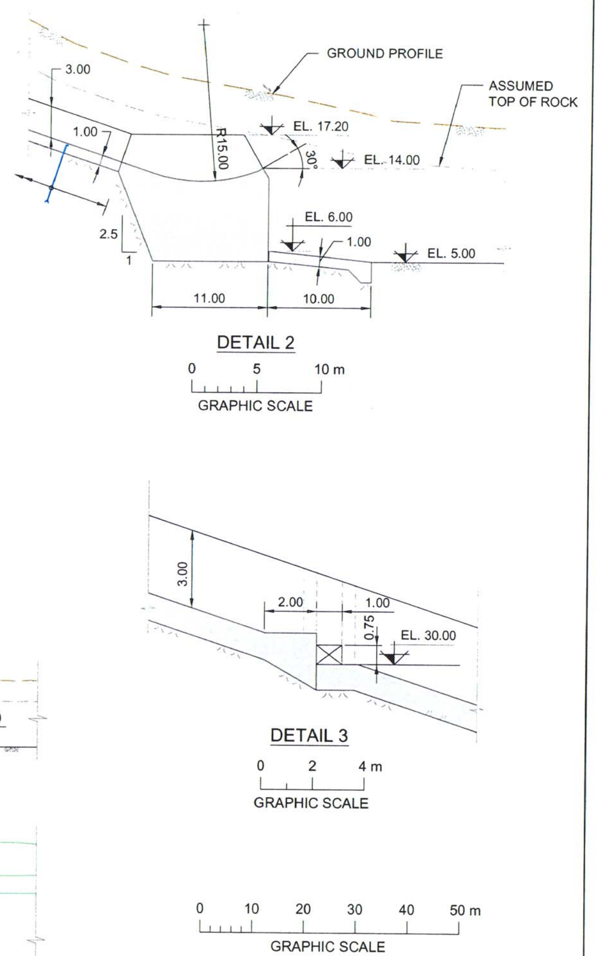
RIO INDIO SADDLE DAM

PROFILE AND TYPICAL CROSS SECTION

MWH TAMS

DATE:	EXHIBIT:
APRIL, 2003	4-4





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

ACP

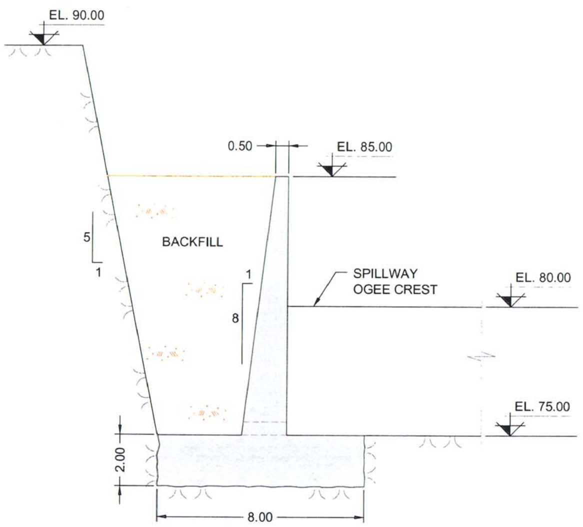
CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

SPILLWAY
PLAN, PROFILE AND DETAILS

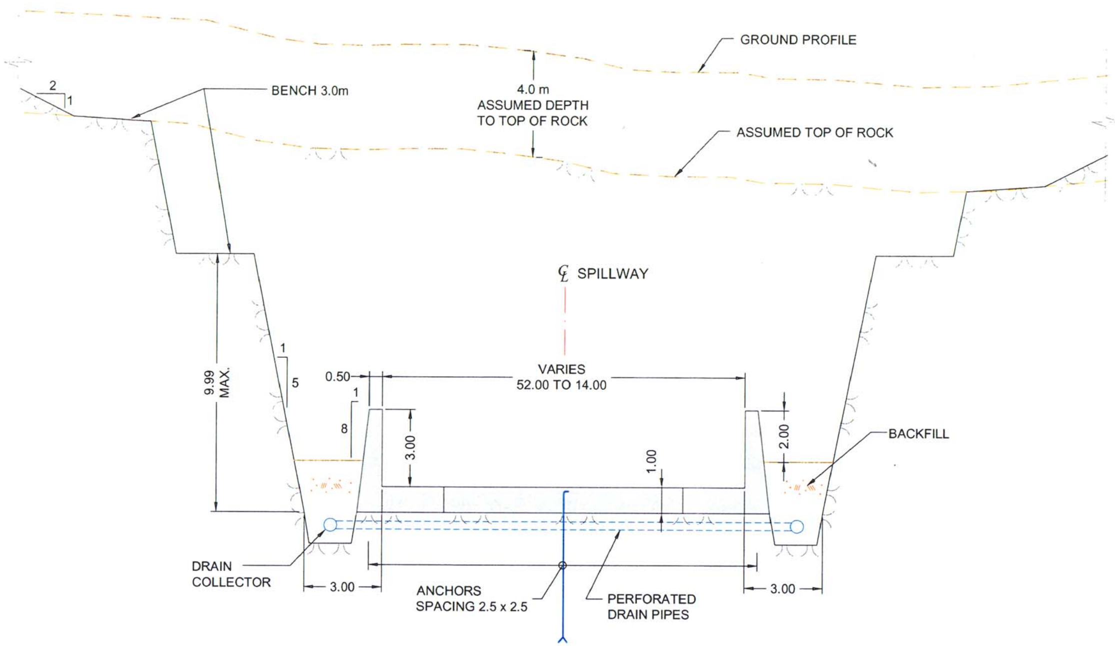
MWH TAMS

DATE: APRIL, 2003

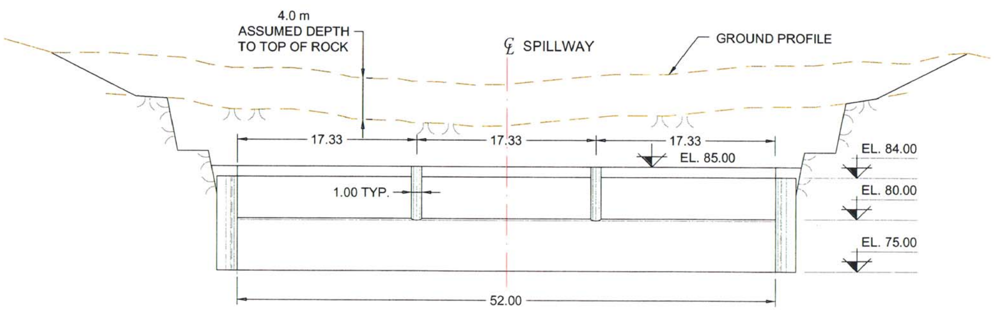
EXHIBIT: 4-5



SPILLWAY APPROACH WALL SECTION



SPILLWAY CHUTE TYPICAL CROSS-SECTION



SPILLWAY CONTROL STRUCTURE UPSTREAM VIEW

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

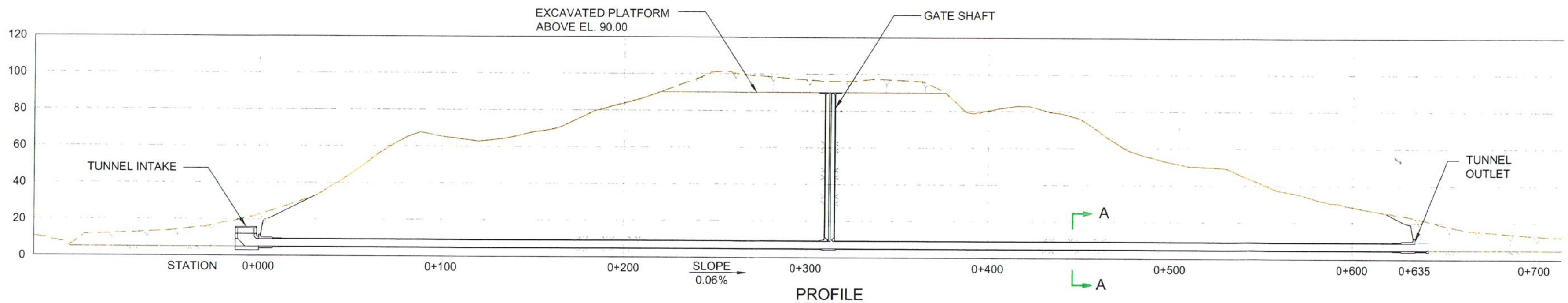
ACP

CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

SPILLWAY
SECTIONS AND UPSTREAM VIEW

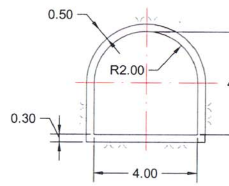
MWH TAMS

DATE:	EXHIBIT:
APRIL, 2003	4-6



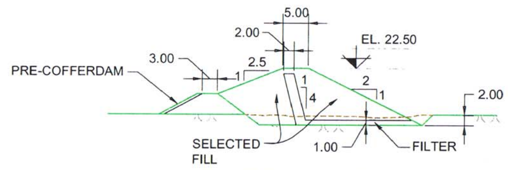
PROFILE
DIVERSION TUNNEL AND LOW LEVEL OUTLET

0 25 50 m
GRAPHIC SCALE



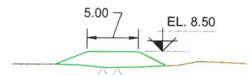
SECTION A

0 2 4 m
GRAPHIC SCALE



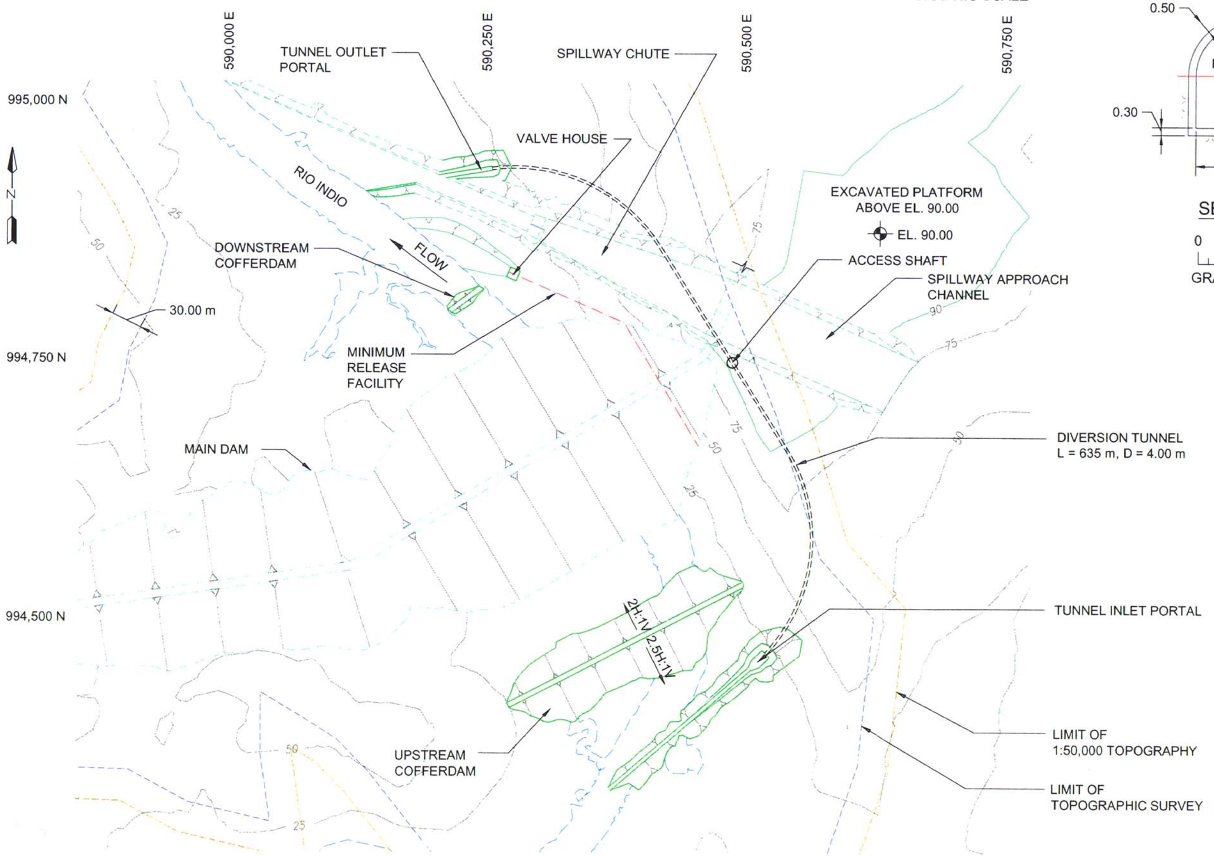
UPSTREAM COFFERDAM
TYPICAL CROSS SECTION

0 10 20 m
GRAPHIC SCALE



DOWNSTREAM COFFERDAM
TYPICAL CROSS SECTION

0 10 20 m
GRAPHIC SCALE



PLAN

0 50 100 150 200 250 m
GRAPHIC SCALE

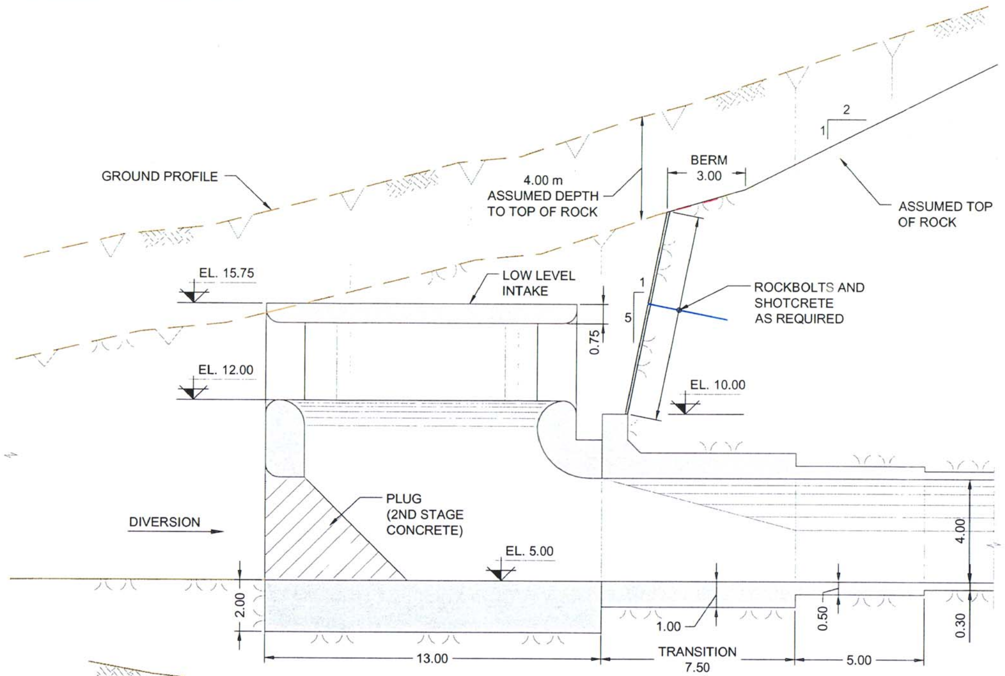
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

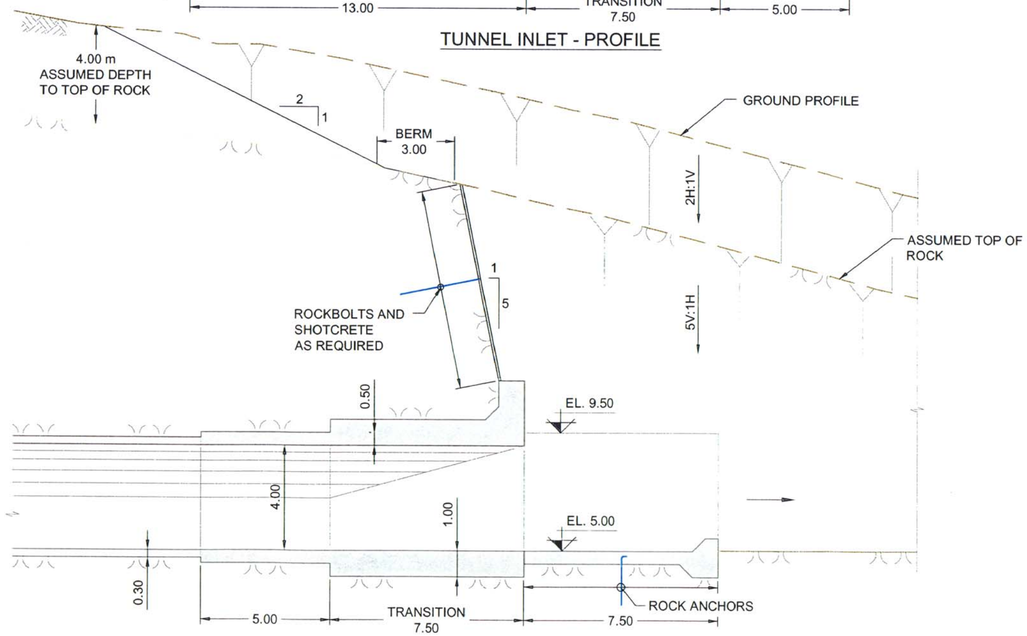
RIVER DIVERSION FACILITIES
PLAN, PROFILE AND SECTIONS

MWH TAMS

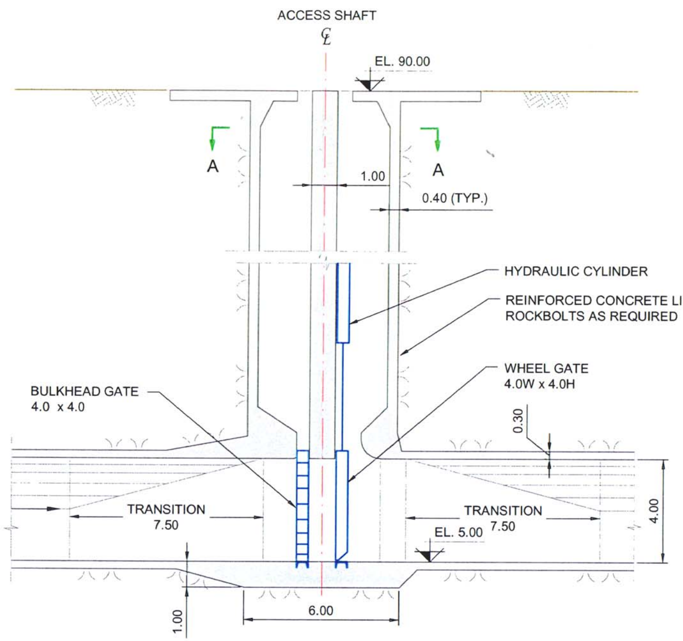
DATE:	EXHIBIT:
APRIL, 2003	4-7



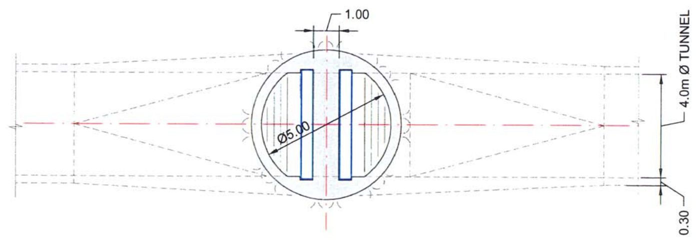
TUNNEL INLET - PROFILE



TUNNEL OUTLET - PROFILE



ACCESS SHAFT - PROFILE



ACCESS SHAFT - PLAN

0 2 4 6 8 10 m

GRAPHIC SCALE

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

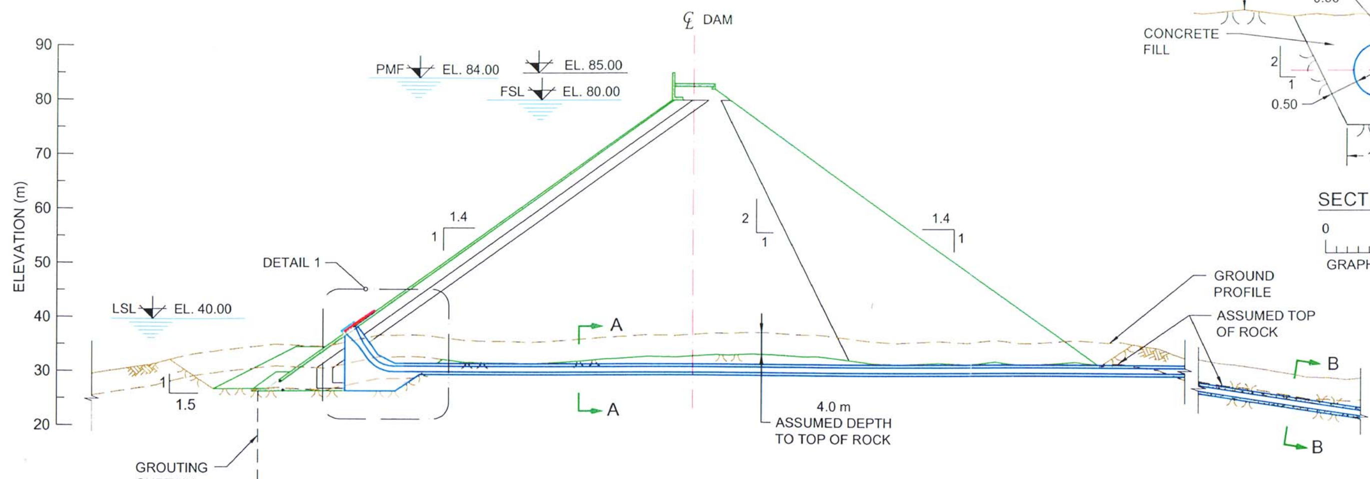
ACP

CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

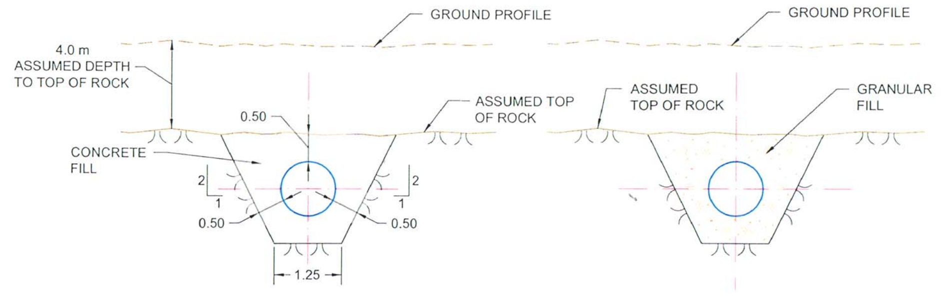
RIVER DIVERSION FACILITIES DETAILS

MWH TAMS

DATE:	EXHIBIT:
APRIL, 2003	4-8



MINIMUM RELEASE FACILITY
CROSS SECTION

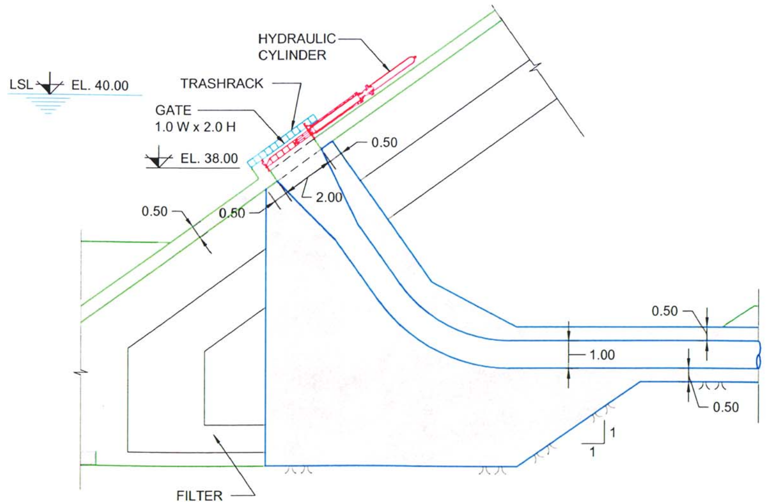


SECTION A - A

0 1 2 m
GRAPHIC SCALE

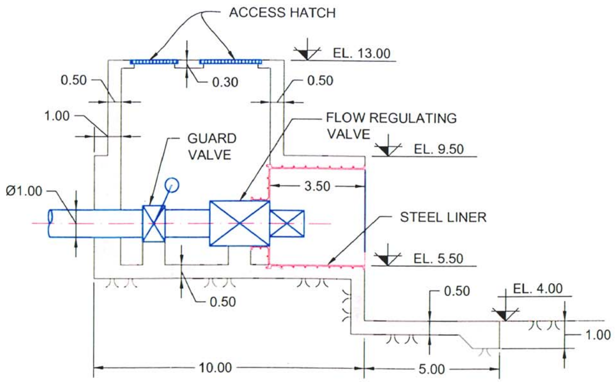
SECTION B - B

0 1 2 m
GRAPHIC SCALE



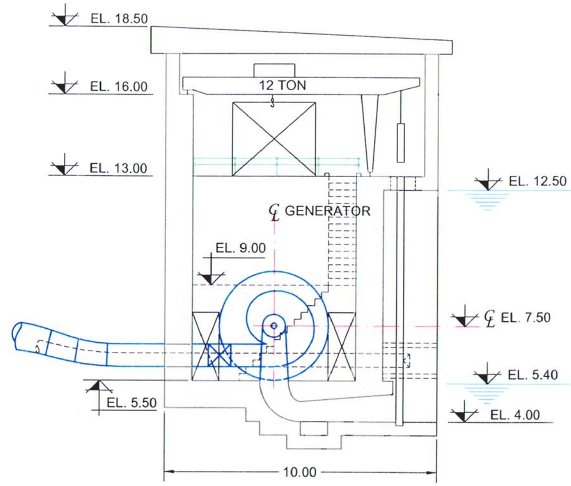
DETAIL 1

0 2 4 m
GRAPHIC SCALE



POWERHOUSE
SECTION THROUGH VALVE

0 2 4 m
GRAPHIC SCALE



POWERHOUSE
SECTION THROUGH TURBINE

0 2 4 m
GRAPHIC SCALE

0 10 20 30 40 50 m
GRAPHIC SCALE

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

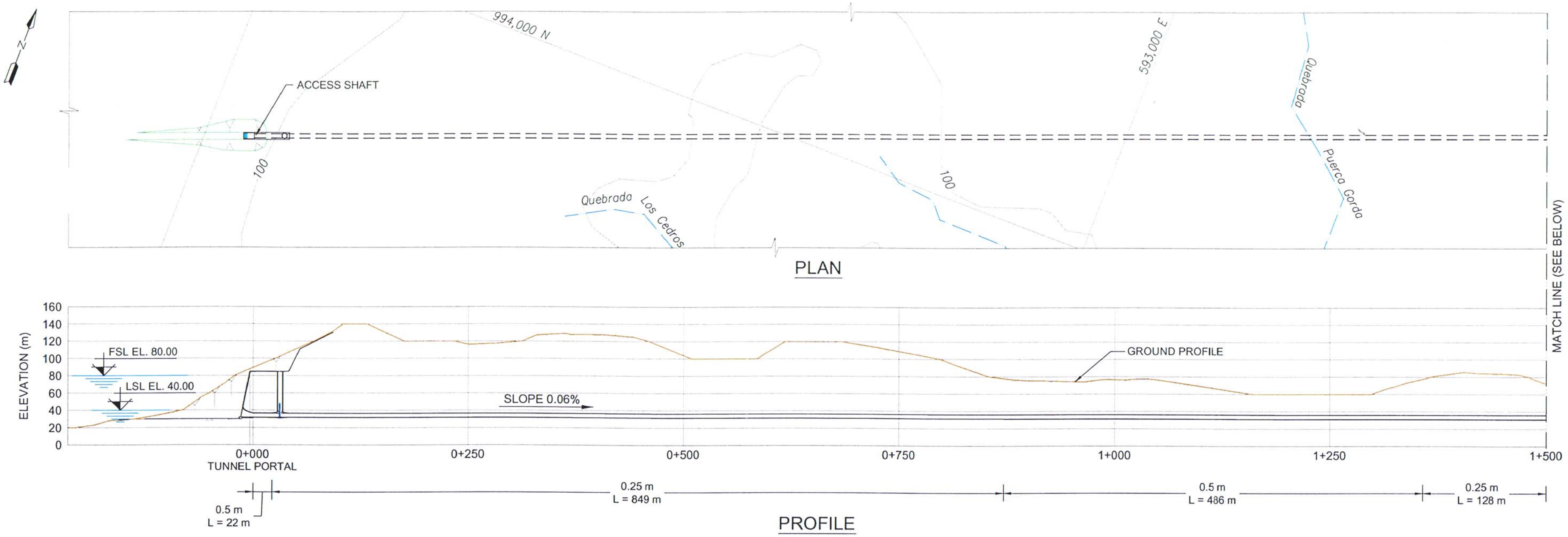
CONTRACT NO. CC-3-536
RÍO INDIO WATER SUPPLY PROJECT

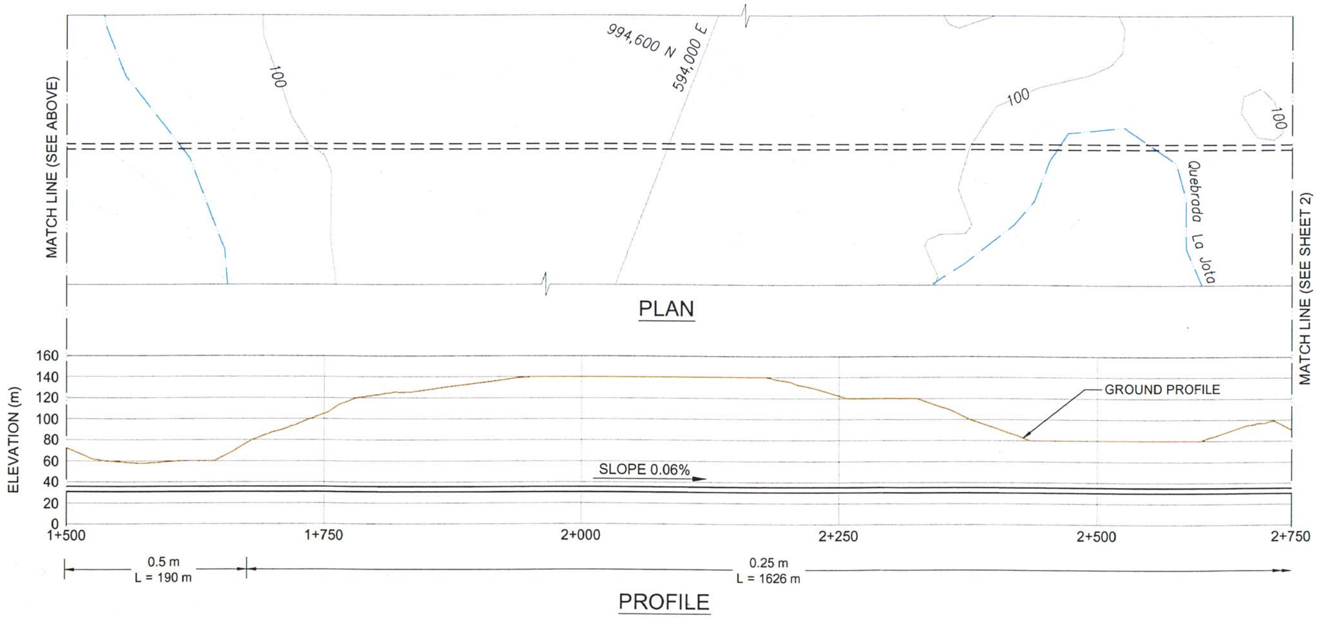
MINIMUM RELEASE FACILITY

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 4-9





NOTE:

0.25 m	- LINING THICKNESS
L = 856 m	- LENGTH OF INDICATED TUNNEL LINING THICKNESS

0 50 100 150 200 250 m

GRAPHIC SCALE

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

ACP

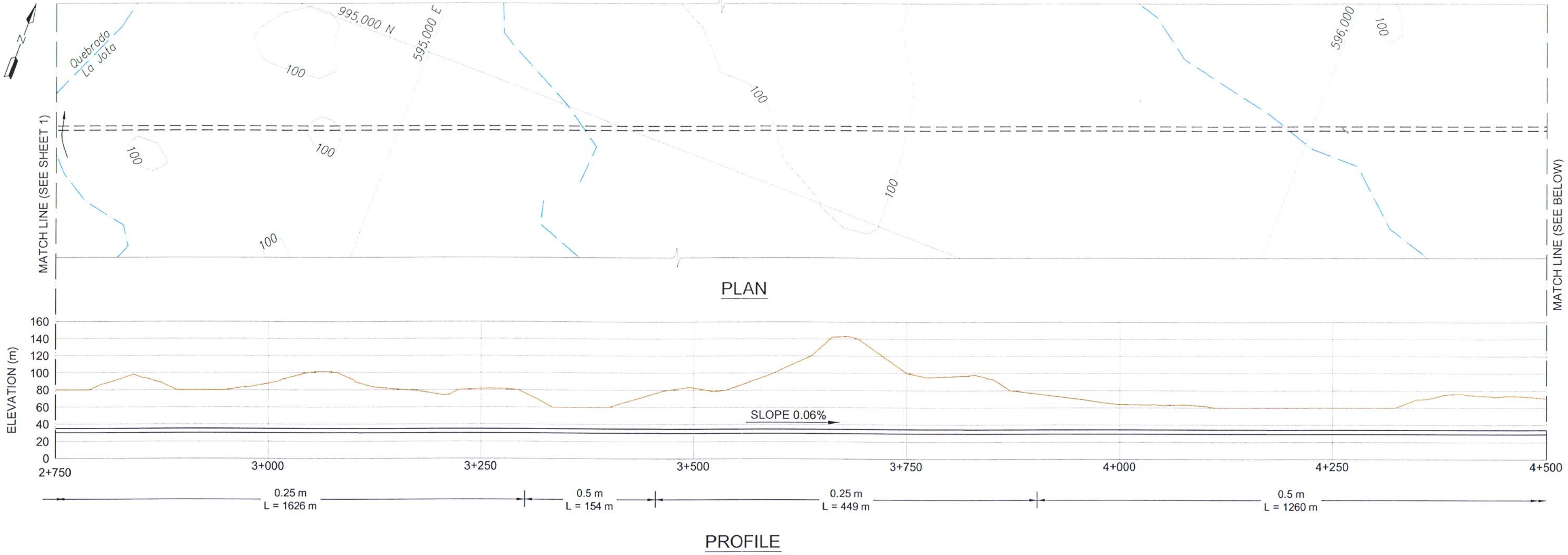
CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

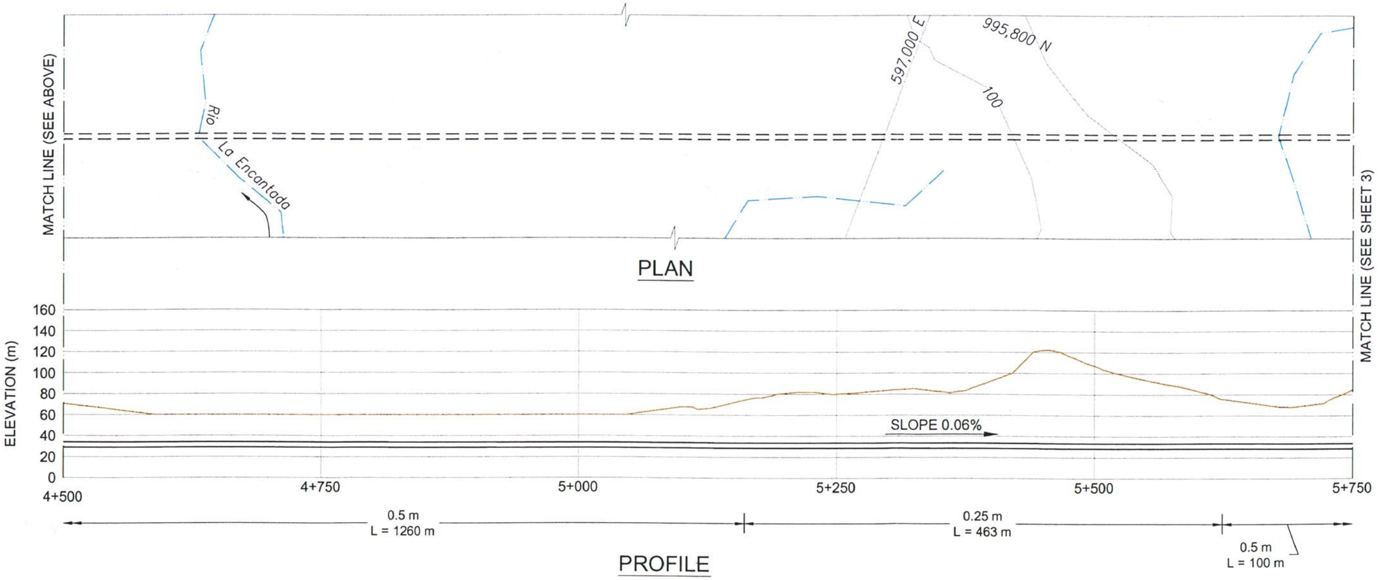
WATER TRANSFER TUNNEL
PLAN AND PROFILE - SHEET 1 OF 3

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 4-10





NOTE:

0.25 m - LINING THICKNESS
L = 856 m - LENGTH OF INDICATED TUNNEL LINING THICKNESS

0 50 100 150 200 250 m

GRAPHIC SCALE

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

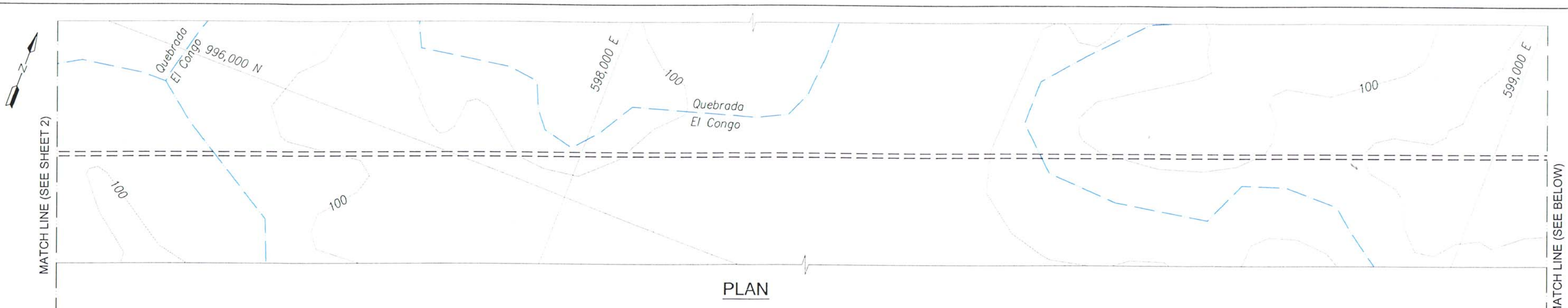
CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

WATER TRANSFER TUNNEL
PLAN AND PROFILE - SHEET 2 OF 3

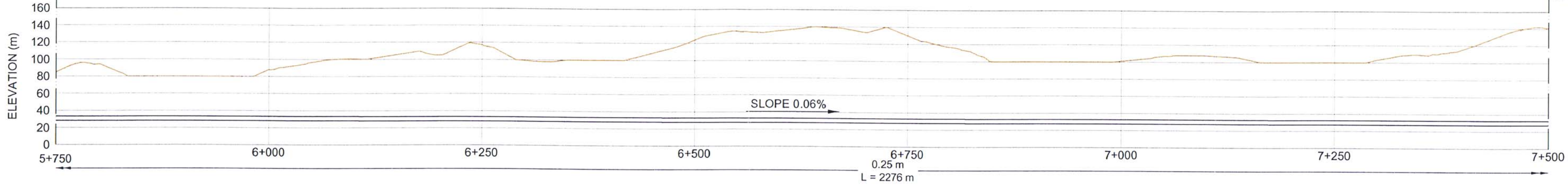
MWH TAMS

DATE: APRIL, 2003

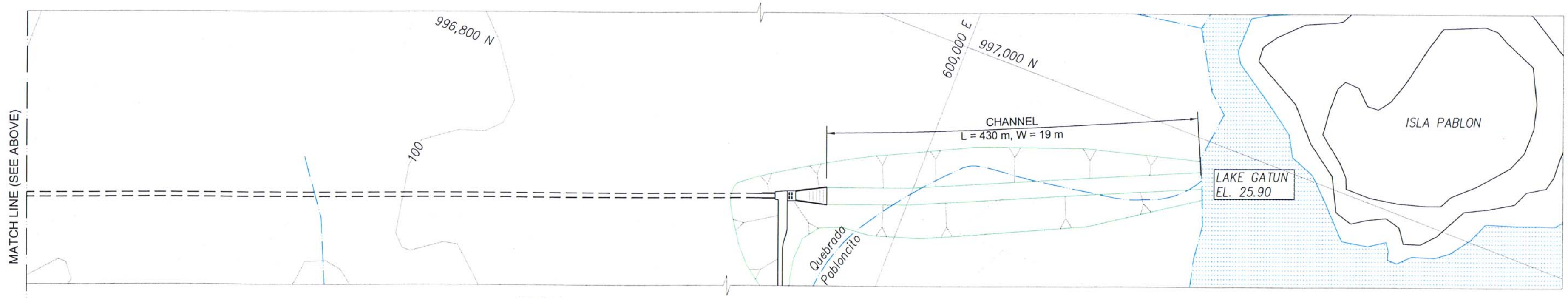
EXHIBIT: 4-10



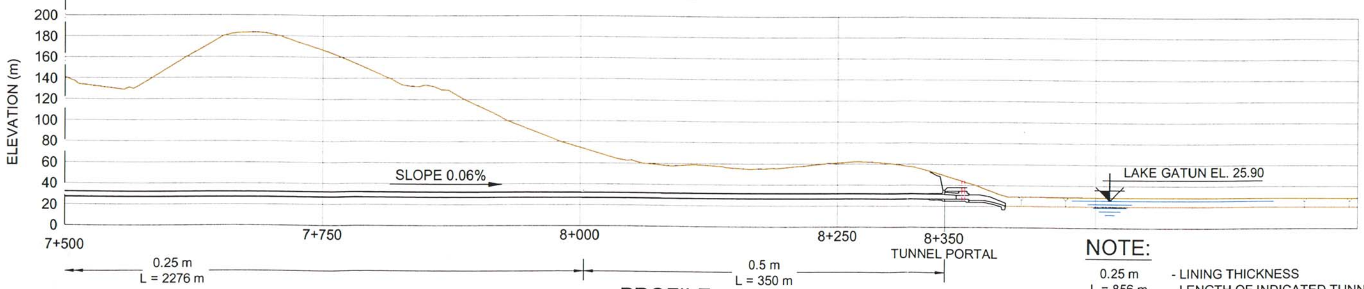
PLAN



PROFILE



PLAN



PROFILE

NOTE:

0.25 m - LINING THICKNESS

L = 856 m - LENGTH OF INDICATED TUNNEL LINING THICKNESS

0 50 100 150 200 250 m

GRAPHIC SCALE

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

ACP

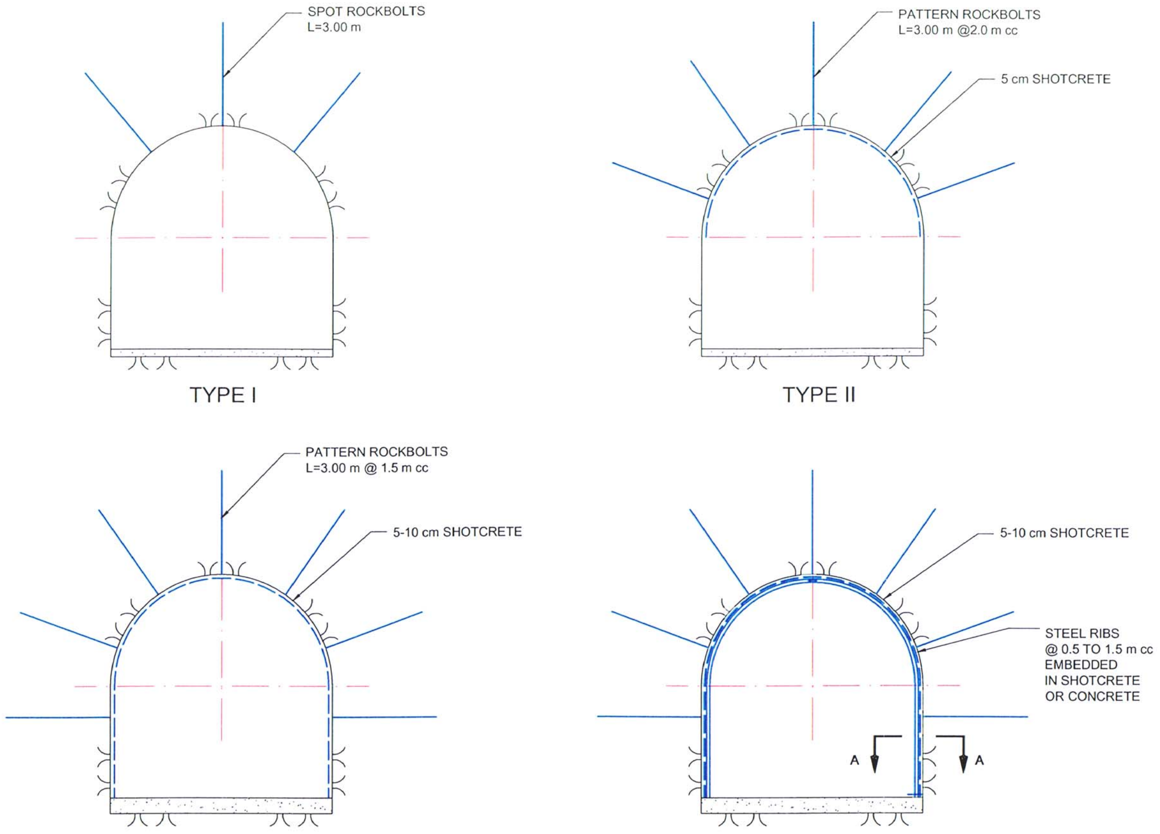
CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

WATER TRANSFER TUNNEL
PLAN AND PROFILE - SHEET 3 OF 3

MWH TAMS

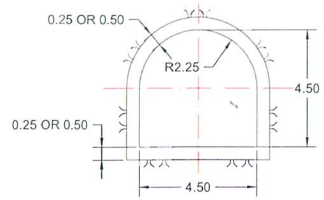
DATE: APRIL, 2003

EXHIBIT: 4-10



DRILL & BLAST SECTIONS

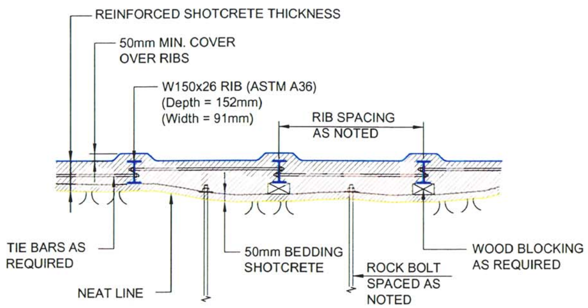
N.T.S.



FINISHED TUNNEL DIMENSIONS

0 2 m

GRAPHIC SCALE



SECTION A-A

N.T.S.

NOTE:

LINING THICKNESS VARIES TO MEET GROUND COVER CRITERIA.

ROCK CONDITION CATEGORIES:

TYPE I - BEST ROCK CONDITIONS, MINIMAL OVERBREAK, GENERALLY SELF-SUPPORTING OR REQUIRING MINIMAL SUPPORT WITH SHOTCRETE OR SPOT BOLTING, FULL FACE EXCAVATION WITH NORMAL ADVANCE.

TYPE II - GOOD TO FAIR ROCK CONDITIONS, MODERATE OVERBREAK WITH ROCKBOLTS AND SHOTCRETE; NORMAL ADVANCE POSSIBLE WITH PROPER BOLTING AND SHOTCRETING.

TYPE III - POOR ROCK CONDITIONS, WEATHERED OR WEAK ROCK, LOOSELY JOINTED, FULL FACE EXCAVATION WITH SLOWER SHORT ADVANCE AND LARGE OVERBREAKS. REQUIRES PROMPT SUPPORT WITH PATTERN ROCKBOLTING AND SHOTCRETE.

TYPE IV - VERY POOR ROCK CONDITIONS, FAULT AND SHEAR ZONES HIGHLY WEATHERED; PROMPT SUPPORT WITHIN THE OPEN FACE WITH STEEL RIBS AND LAGGING, BACKPACKING, REINFORCED SHOTCRETE; GROUTING MAY BE NECESSARY TO CONTROL WATER.

SHOTCRETE TO BE STEEL-FIBER REINFORCED OR INSTALLED WITH WIREMESH.

ALL ROCKBOLTS FULLY GROUTED, Ø 25 mm.

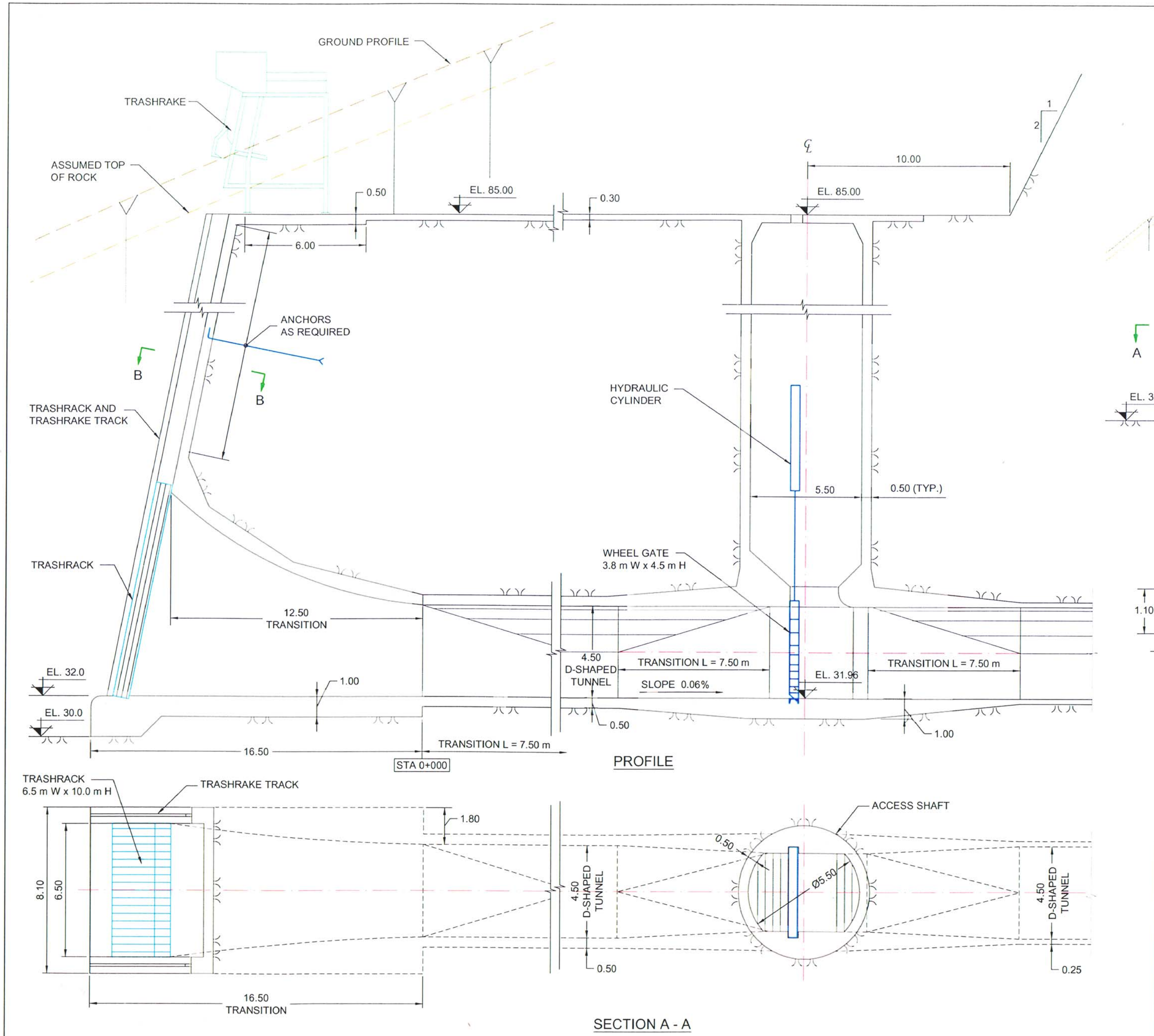
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

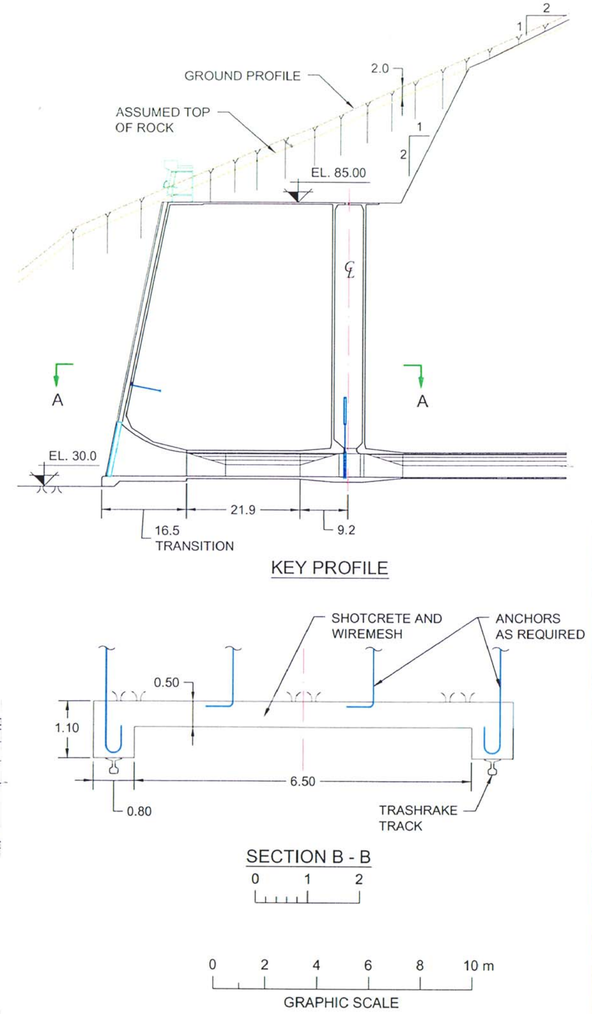
CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

WATER TRANSFER TUNNEL
TYPICAL CROSS SECTIONS

MWH TAMS

DATE:	EXHIBIT:
APRIL, 2003	4-11





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

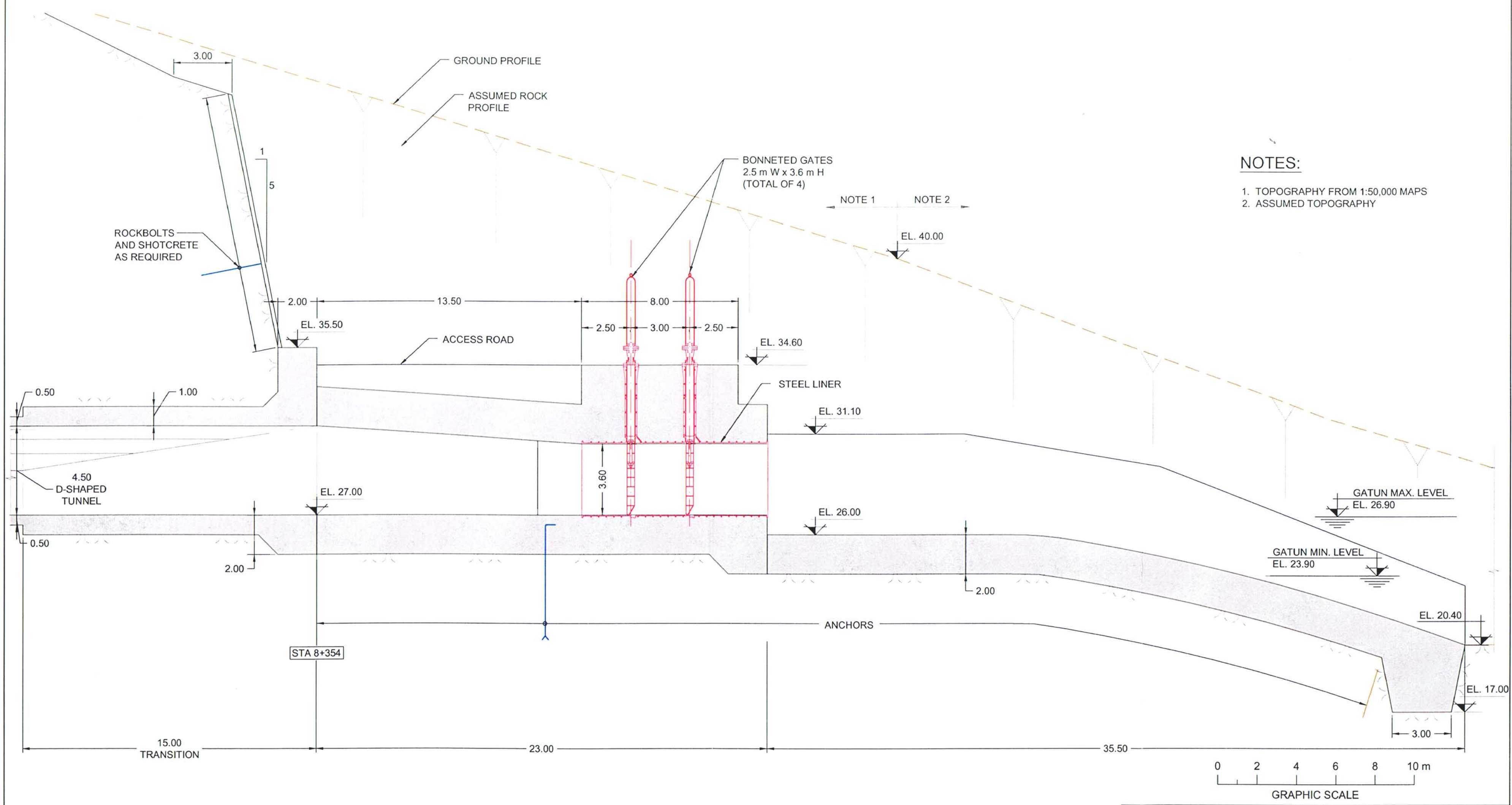
ACP

CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

WATER TRANSFER TUNNEL
INTAKE STRUCTURE AND ACCESS SHAFT

MWH TAMS

DATE:	EXHIBIT:
APRIL, 2003	4-12



NOTES:

1. TOPOGRAPHY FROM 1:50,000 MAPS
2. ASSUMED TOPOGRAPHY

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

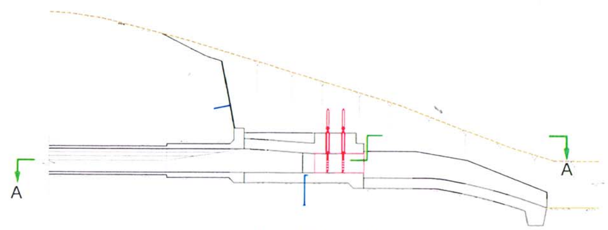
CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

WATER TRANSFER TUNNEL
OUTLET STRUCTURE - PROFILE

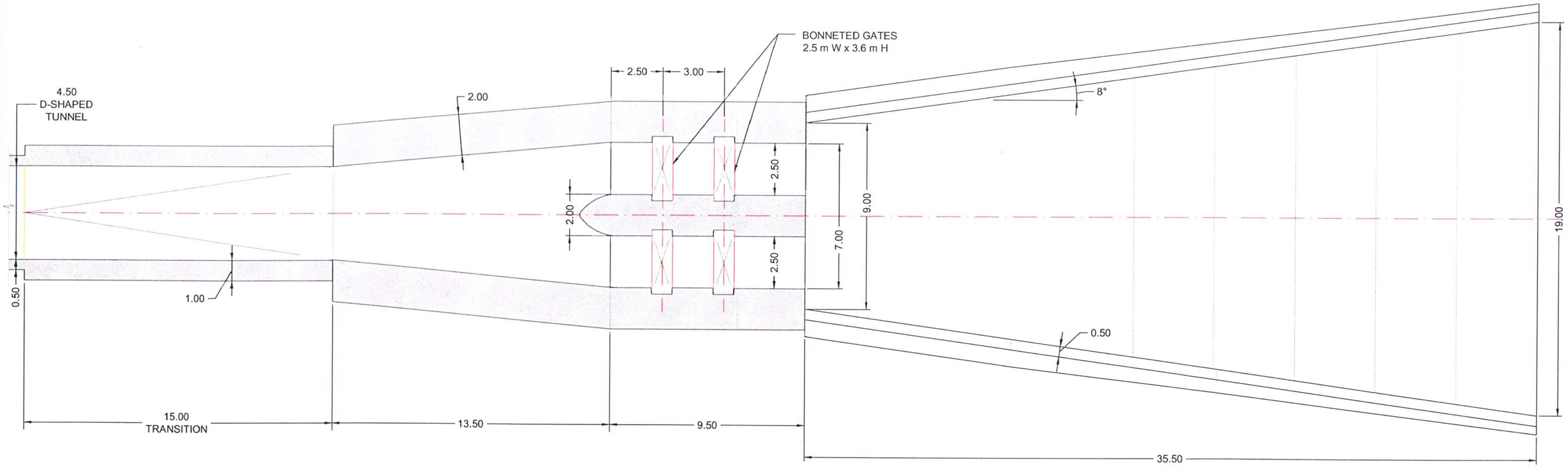
MWH TAMS

DATE: APRIL, 2003

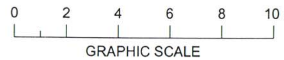
EXHIBIT: 4-13



KEY PROFILE



SECTION A - A



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

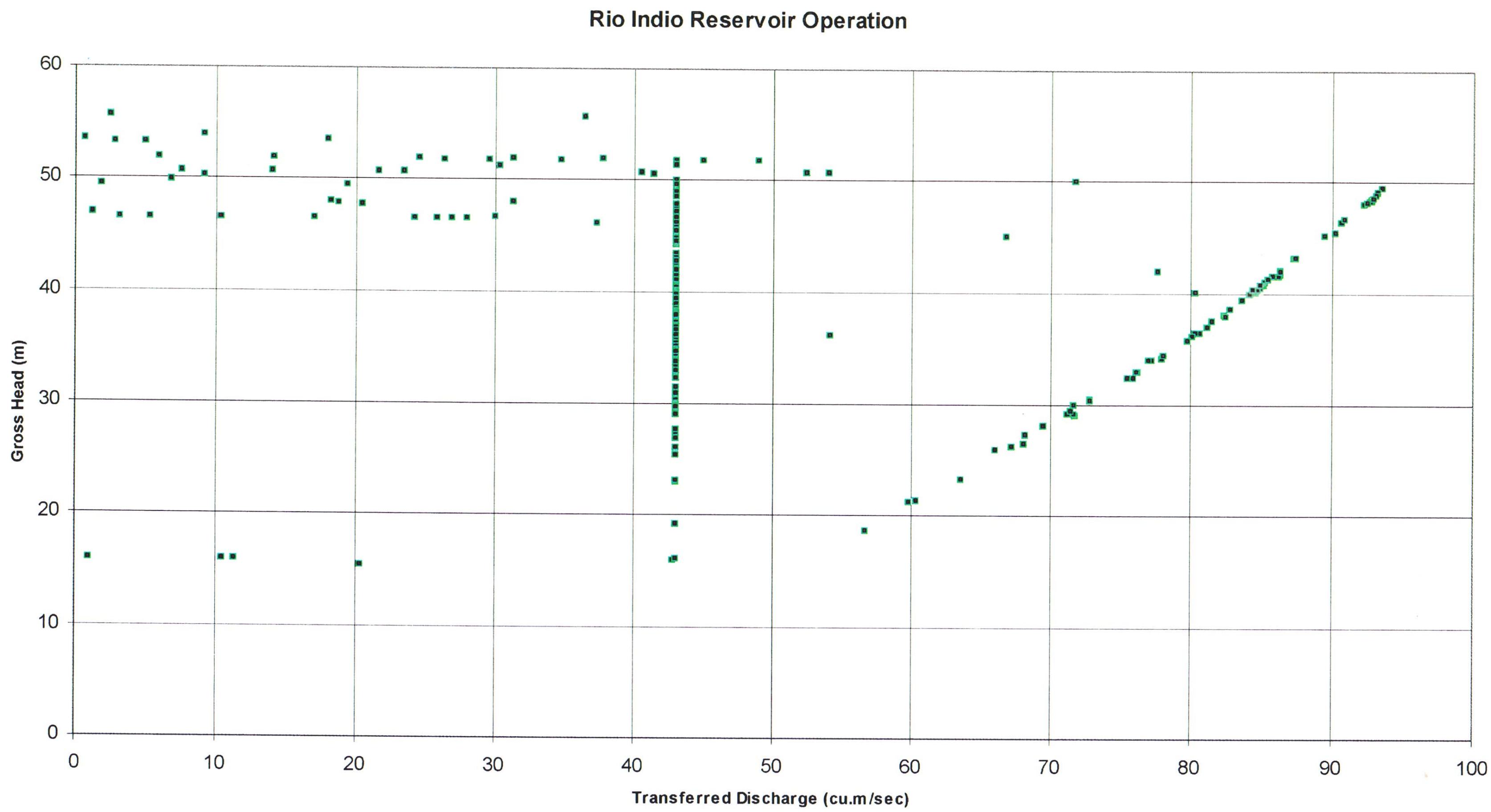
CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

WATER TRANSFER TUNNEL
OUTLET STRUCTURE - SECTION

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 4-14



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

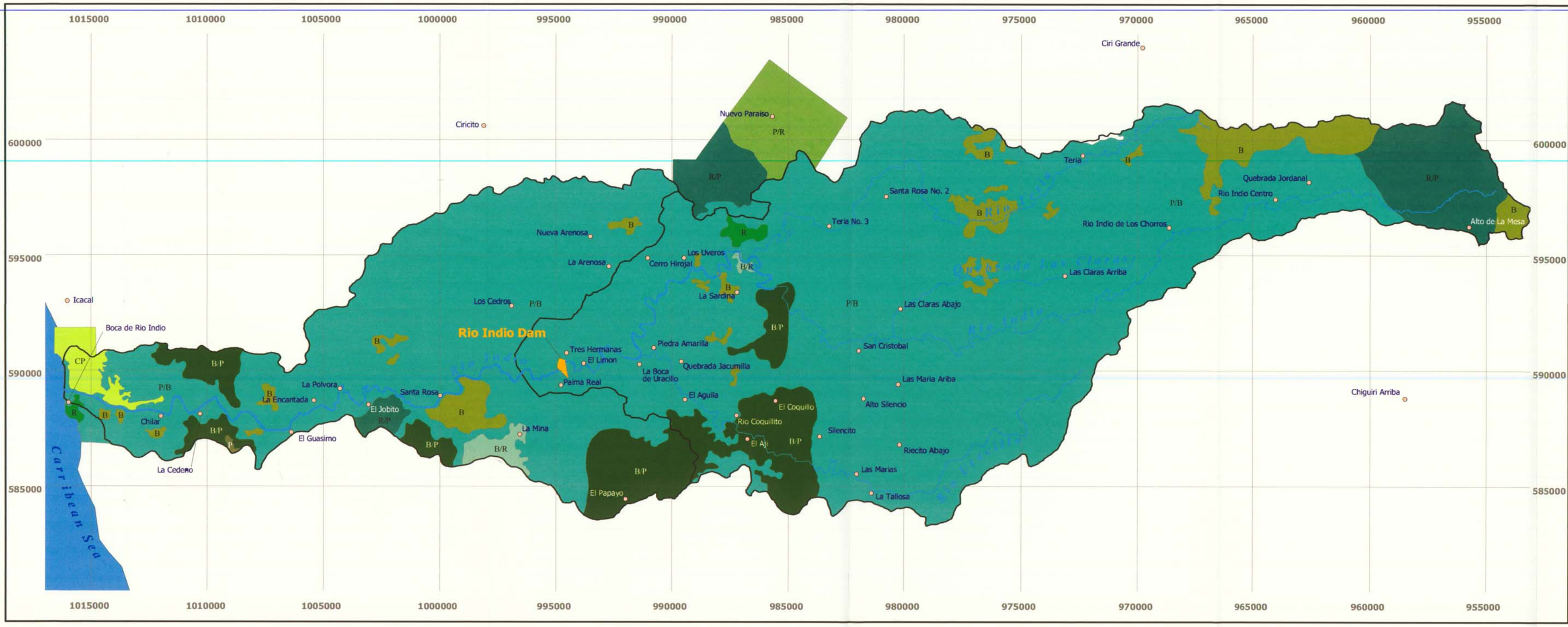
CONTRACT NO. CC-3-536
RÍO INDIO WATER SUPPLY PROJECT

Transferred Discharge

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 5-1



Land Use Map

Legend:

Symbol	Code	Description
	B	Forest
	B/P	Forest/Natural Pasture Lands
	B/R	Forest/Stubble
	P	Natural Pasture Lands
	P/B	Natural Pasture Lands/Forest
	P/R	Natural Pasture Lands/Stubble
	CP	Oil Palm
	R	Stubble
	R/P	Stubble/Natural Pasture Lands
		Watershed
		River
		Village/Hamlet

B - Forest
P - Pasture
R - Stubble
CP - Oil Palm Plantation

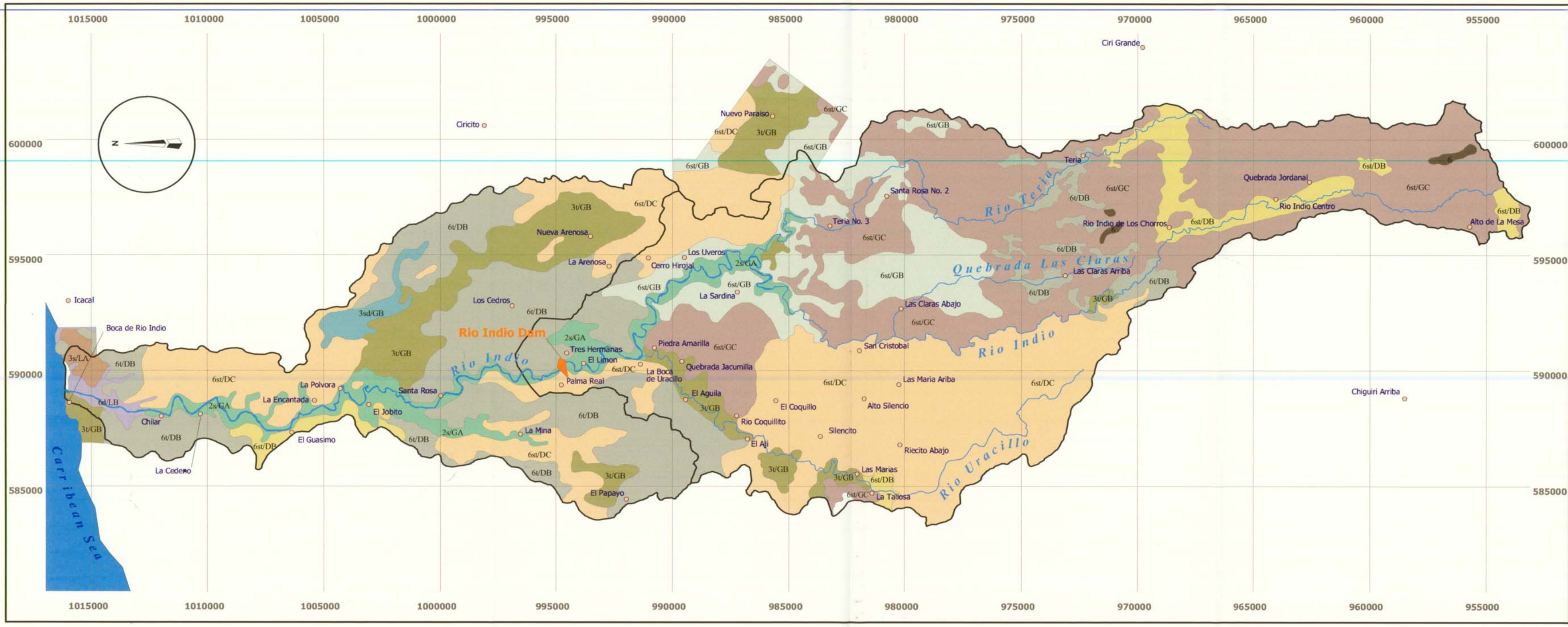
Notes: 1. The existing Agricultural Areas are located in the stubble areas and in the vicinity of the villages/hamlets.
2. A more detailed description is given in the report.
3. When two letters are present in a code, the first one indicates the predominant use.

3 0 5
Scale in Kilometers

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

CONTRACT NO. CC-5-536
Feasibility Design for the Rio Indio Water Supply Project
Agricultural and Irrigation Potential
Land Use Map

MWH | TAMS | **April 2003** | **Exhibit 6-1**



Land Capability for Irrigation Map

Legend:

Symbol	Class	Description / Limiting Factors
	2s/GA	Texture - moderately fine
	3s/LA	Texture - very fine
	3sd/GB	Texture - very fine, Internal Drainage - high water table
	3t/GB	Slope
	6	Bedrock
	6d/LB	External Drainage - inundation, Internal Drainage - high water table
	6st/DB	Soil Depth - shallow, slope
	6st/DC	Soil Depth - shallow, Slope & Stoniness
	6st/GB	Texture - very fine, Slope & Stoniness
	6st/GC	Soil Depth - shallow, Texture - very fine, Slope & Stoniness
	6t/DB	Texture - very fine
		Watershed
		River
		Village/Hamlet

2,3,6 - Land Class
t,s,d - Limiting Factors (Topography; Soil; Drainage)
L,D,G - Land Use (Cultivated, Non-irrigated; Stubble and Forest; Permanent Pasture, Non-irrigated)
A,B,C - Potential Productivity (High; Moderate; Low)

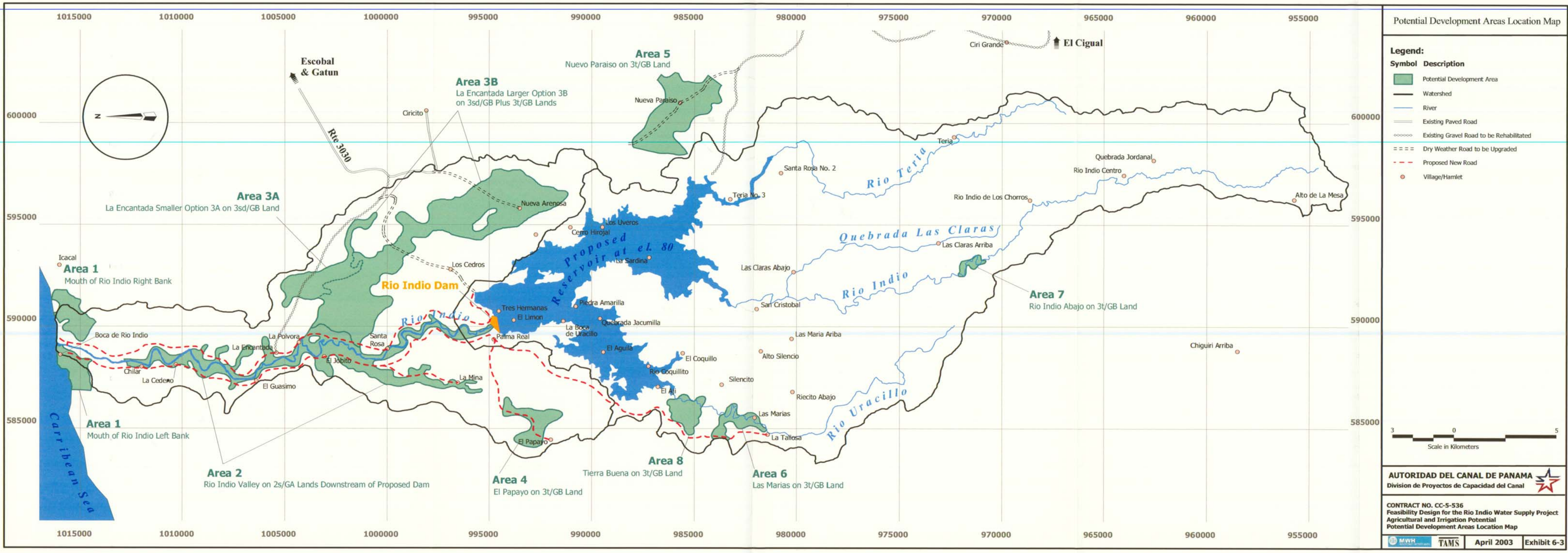
Note: Further description of land classes is given in the report.

3 0 5
Scale in Kilometers

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

CONTRACT NO. CC-5-536
Feasibility Design for the Rio Indio Water Supply Project
Agricultural and Irrigation Potential
Land Capability for Irrigation Map

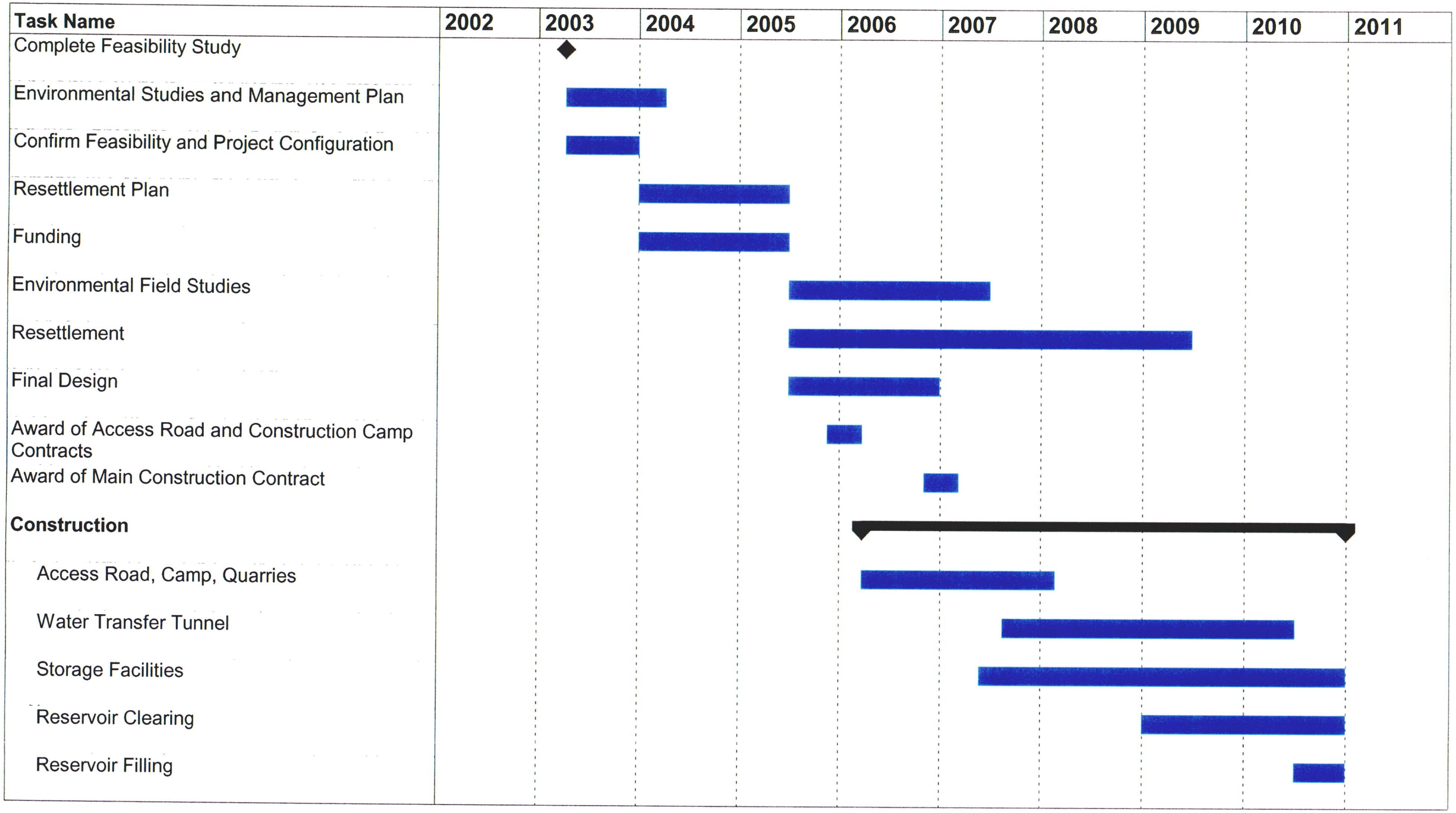
MWH | TAMS | **April 2003** | **Exhibit 6-2**



Potential Development Areas Location Map — Exhibit 6-3

Table 1 - Cropping Pattern Diagram

Crop	Month											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Rice DSR – TPR												
Rice TPR – TRP												
Beans												
Maize												
Plantain yr. 1												
Plantain yr. 2												
Cassava yr. 1												
Cassava yr. 2												
Vegetables (blend)												
Yams												
Pasture - Field												
SEEDBED Pasture												
NURSERY Organic Coffee;												
Pinus caribaea;												
Acacia mangium;												
Byrsonima cras.;												
Anacardium occ.;												



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

CONTRACT NO. CC-3-536
RÍO INDIO WATER SUPPLY PROJECT

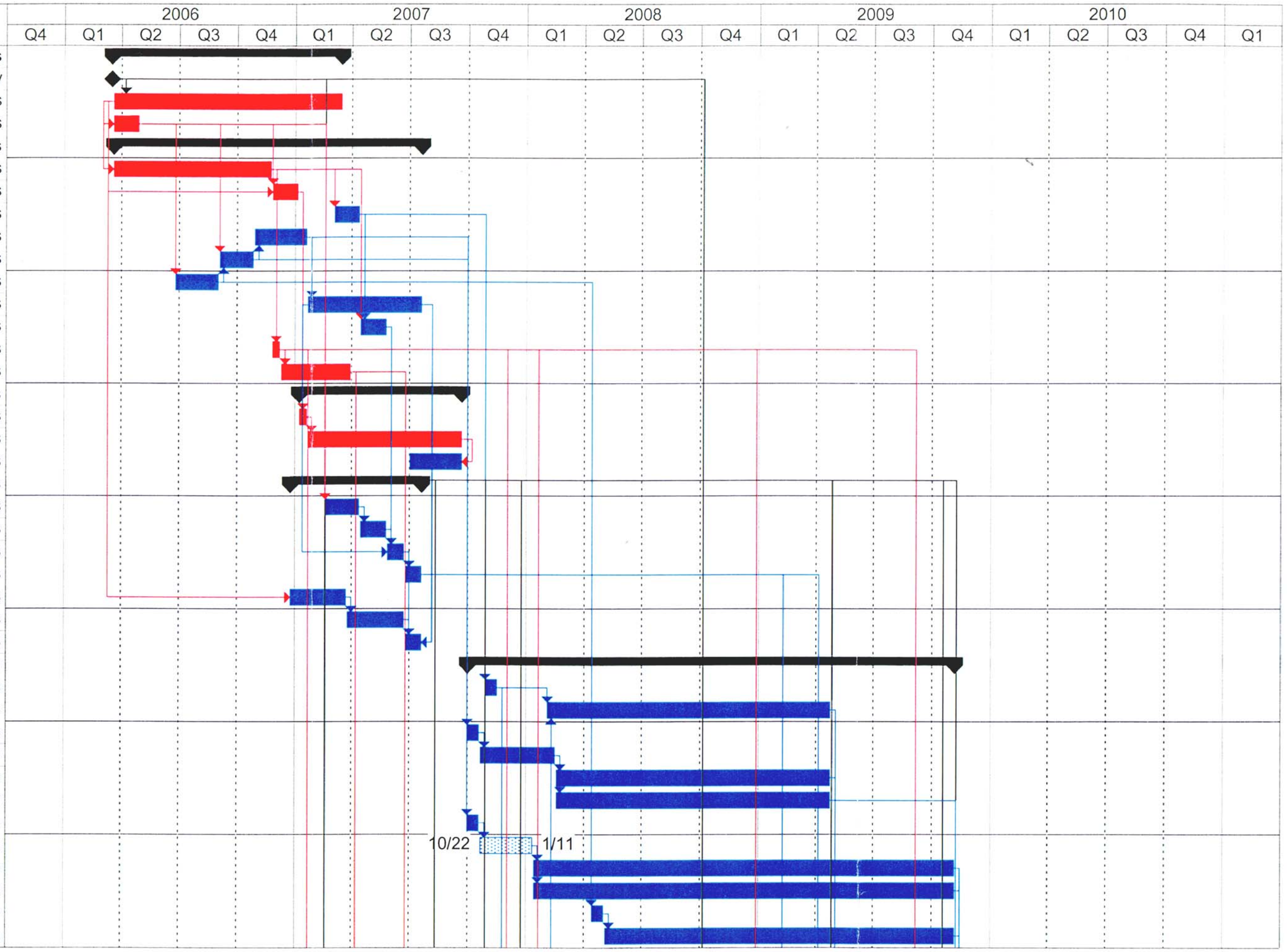
IMPLEMENTATION SCHEDULE

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 7-1

Task Name	Duration
Mobilization	**52.2 wks**
Notice to Proceed	1 day
Staffing and Personnel Mobilization	52 wks
Road Subcontractor Mobilization	6 wks
Access Roads	**70 wks**
Improve Access from Tres Hermanas to Junction	36 wks
Access to Construction Camp	6 wks
Access to Western Portal	6 wks
Access to Adit No.1	12 wks
Access to Adit No.2	8 wks
Access to Eastern Portal	10 wks
Access to Rock Quarry No.1 (Cerro La Jota)	26 wks
Access to Rock Quarry No.2 (Cerro Las Ollas)	6 wks
Access to dam site	2 wks
Bridge to Rio Indio Left Bank	16 wks
Construction Camp and Offices	**37 wks**
Clearing, Surveying and Siting	2 wks
House Construction	35 wks
Camp Infrastructures and Utilities	12 wks
Establish Quarries	**30 wks**
Geotechnical Investigation	8 wks
Surveying and Mapping	6 wks
Clearing & Grubbing	4 wks
Overburden Excavation	4 wks
Design and Purchase Crushing Plant	13 wks
Shipping of Crushing Plant	13 wks
Crushing Plant Installation	4 wks
Transfer Tunnel Excavation	**110 wks**
Western Portal Excavation	3 wks
Excavation from Western Portal	64 wks
Adit No.1 Portal	3 wks
Adit No.1 Excavation	17 wks
Excavation West from Adit No.1	62 wks
Excavation East From Adit No.1	62 wks
Adit No.2 Portal	3 wks
Adit No.2 Excavation	12 wks
Excavation West from Adit No.2	95 wks
Excavation East from Adit No.2	95 wks
Eastern Portal	3 wks
Excavation from Eastern Portal	79 wks



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

CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

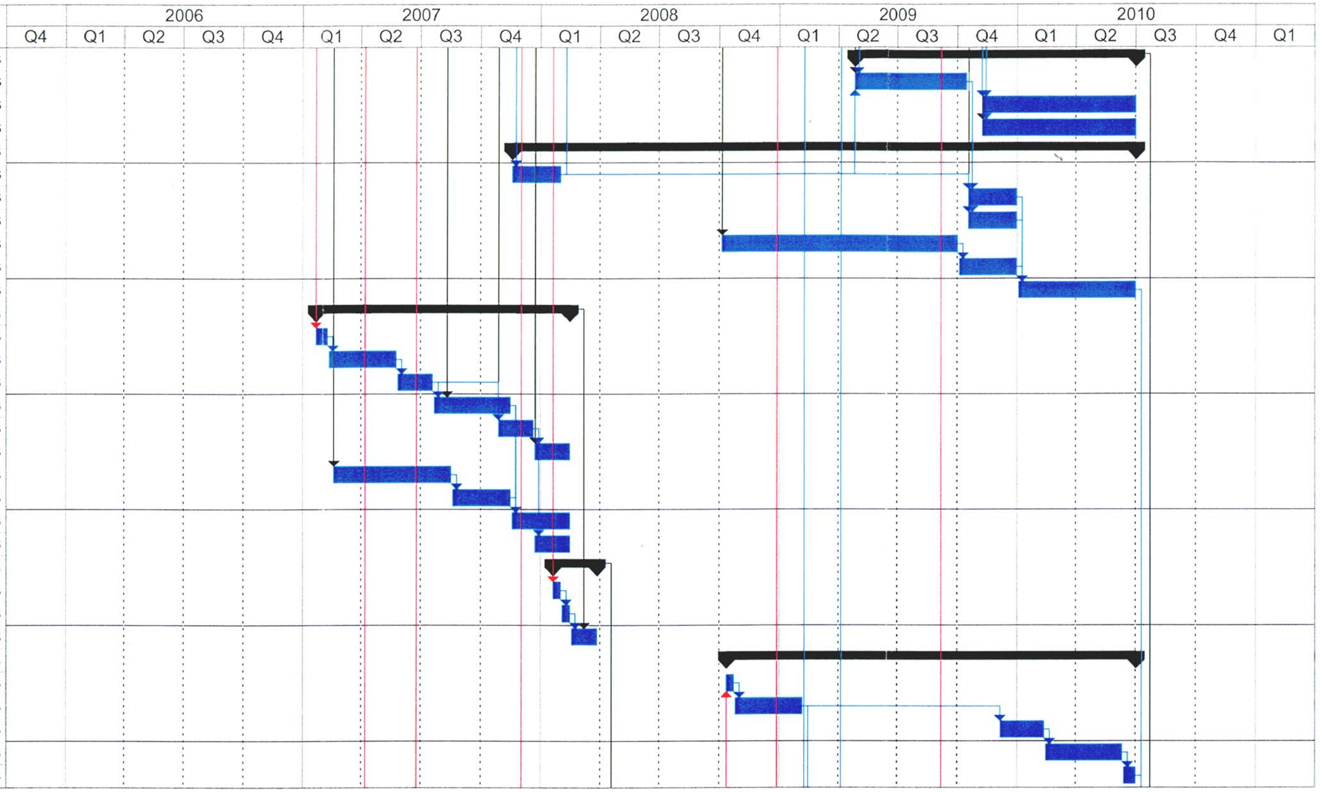
CONSTRUCTION SCHEDULE
SHEET 1 OF 3

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 7-2

Task Name	Duration
Transfer Tunnel Lining	**62 wks**
Lining between Western Portal and Adit No.1	25 wks
Lining between Adit No.1 and Adit No.2	34 wks
Lining between Eastern Portal and Adit No.2	34 wks
Transfer Tunnel Intake	**137 wks**
Gate Shaft Excavation	11 wks
Gate Shaft Concreting	11 wks
Intake Concreting	11 wks
Intake Equipment Design and Fabrication	52 wks
Intake Equipment Shipping	13 wks
Intake Equipment Installation	26 wks
Diversion Tunnel and Low Level Outlet	**56 wks**
Portal Excavation	3 wks
Tunnel Excavation	15 wks
Gate and Access Shaft Excavation	8 wks
Shaft Lining	17 wks
Tunnel Lining	8 wks
Intake Concreting	8 wks
Gate Design and Fabrication	26 wks
Gate Shipping	13 wks
Gate Installation	13 wks
Outlet Work	8 wks
Cofferdams	**10 wks**
Site Preparation	2 wks
Overburden Excavation	2 wks
Fill Material	6 wks
Spillway	**90 wks**
Overburden Excavation	2 wks
Rock Excavation	15 wks
Headworks and Bridge	10 wks
Chute and Flip Bucket	17 wks
Tailrace Channel	3 wks



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

CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

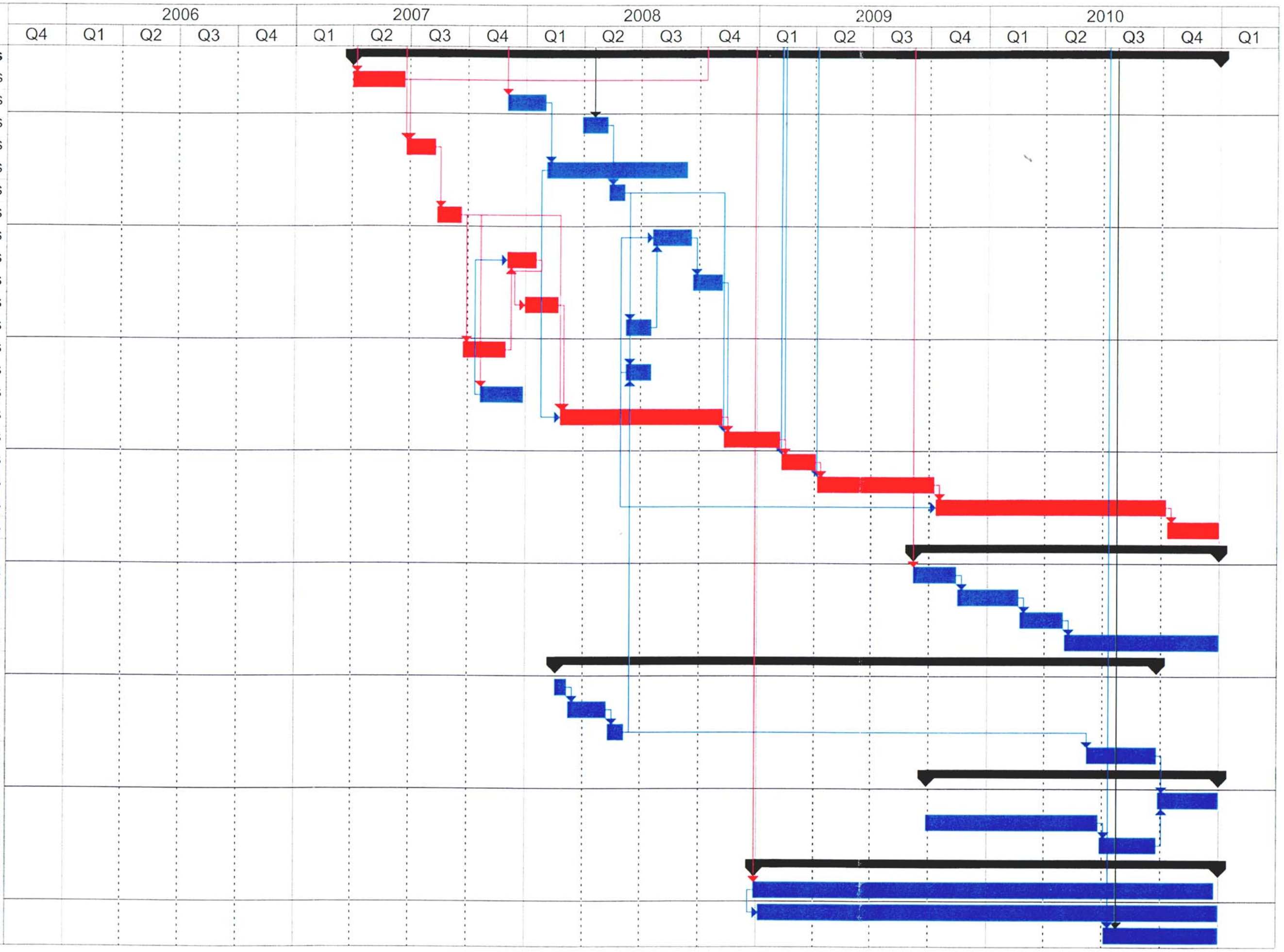
CONSTRUCTION SCHEDULE
SHEET 2 OF 3

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 7-2

Task Name	Duration
Rio Indio Dam	**196 wks**
Site Preparation	12 wks
Overburden Excavation - Abutment	9 wks
Overburden Excavation - River Section	6 wks
Overburden Excavation - Left Bank	7 wks
Rock Excavation - Abutment	32 wks
Rock Excavation - River Section	4 wks
Rock Excavation - Left Bank	6 wks
Grouting Curtain - River Section	9 wks
Grouting Curtain - Left Bank	7 wks
Consolidation Grouting - River Section	7 wks
Consolidation Grouting - Left Bank	8 wks
Dental Concrete - River Section	6 wks
Dental Concrete - Left Bank	10 wks
Plinth - River Section	6 wks
Plinth - Left Bank	10 wks
Rockfill Placement Left Bank	37 wks
Rockfill Placement River Section from Excav	13 wks
Rockfill Placement from Quarrie No.1	8 wks
Rockfill Placement from Quarrie No.2	27 wks
Concrete Face	52 wks
Parapets, Crest Road	12 wks
Saddle Dams	**69 wks**
Site Preparation	10 wks
Overburden Excavation, Foundation Preparation	14 wks
Cut-off Curtain	10 wks
Embankment Fill (incl. Filter, Riprap and Road)	35 wks
Rio Indio Minimum Release/Hydropower Facilities	**136 wks**
Trench Excavation	3 wks
Conduit Installation	9 wks
Conduit Concrete	4 wks
Powerhouse	16 wks
Rio Indio Minimum Release/Hydropower	**66 wks**
Equipment Installation	14 wks
Equipment Design and Fabrication	39 wks
Equipment Shipping	13 wks
Reservoir Area	**105 wks**
Reservoir Clearing	104 wks
Reservoir Mapping	104 wks
Reservoir Filling	26 wks



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

ACP

CONTRACT NO. CC-3-536
RIO INDIO WATER SUPPLY PROJECT

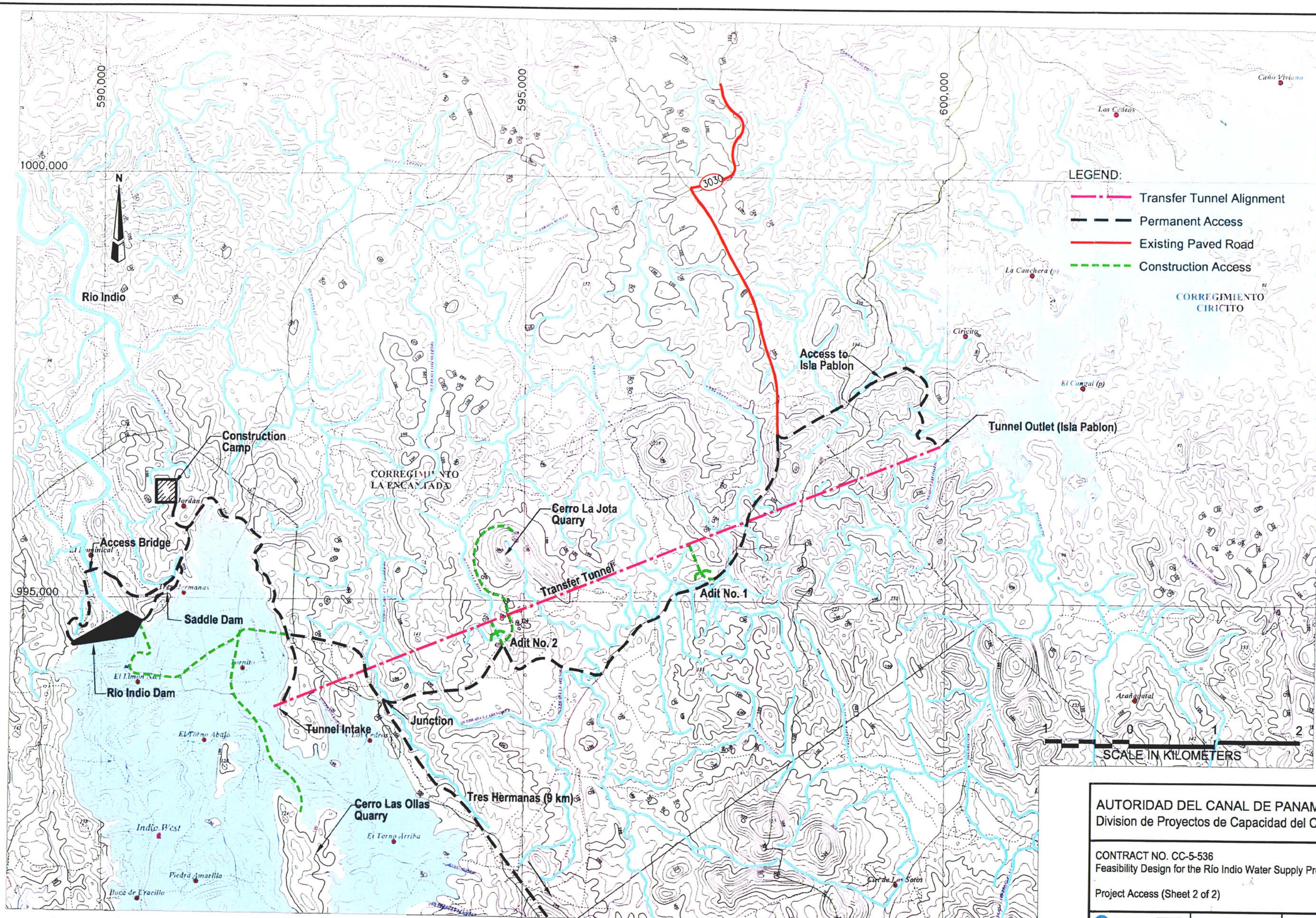
CONSTRUCTION SCHEDULE
SHEET 3 OF 3

MWH TAMS

DATE: APRIL, 2003

EXHIBIT: 7-2


LEGEND:
Paved Road
All Weather Gravel Road
Dry Weather Road
580,000
600,000
620,000
640,000
660,000
1020,000
1000,000
980,000
N
Cristobal
COLON
Gatun Locks
LAGO GATÚN
Supply Project
See Sheet 2 of 2
Isla Pablon
Rio Indio Dam Site
El Limon
Tres Hermanas
El Cigual
La Chorrera
Balboa
PANAMÁ
DISTRITO DE CHAGRES
PROVINCIA DE COLÓN
SCALE IN KILOMETERS
0
5
10
AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal
CONTRACT NO. CC-5-536
Feasibility Design for the Río Indio Water Supply Project
Project Access (Sheet 1 of 2)
MWH
TAMS
April 2003
Exhibit 7-3



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

CONTRACT NO. CC-5-536
Feasibility Design for the Río Indio Water Supply Project

Project Access (Sheet 2 of 2)

MWH TAMS	April 2003	Exhibit 7-3