Feasibility design for the Upper Chagres water supply project

Diseño de factibilidad para el proyecto de abastecimiento de agua de Alto Chagres

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Resumen Ejecutivo

EXECUTIVE SUMMARY

INTRODUCTION

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

The US Army Corps of Engineers (USACE) performed a reconnaissance study for the Panama Canal Commission to identify and evaluate potential water supply projects (1). The Upper Chagres Project was recommended as a feasible alternative for further consideration to develop a long-term water supply plan.

The Autoridad del Canal de Panama (ACP), formerly the Panama Canal Commission, has authorized Montgomery Watson Harza, formerly Harza Engineering Company, to perform an engineering feasibility study of the Upper Chagres Water Supply Project (Project) under Contract CC-3-536, Work Order 0011, dated September 11, 2001. A location map is shown on Exhibit 1.

OBJECTIVE OF THE STUDY

The original objective of this study was to determine the technical and economic feasibility of the Upper Chagres 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 decided by the ACP to implement the Upper Chagres Project only in conjunction with a plan to add new locks to the Panama Canal System. Under this condition, the demand for and benefits from developing the Upper Chagres Project could not be assessed at this time. Therefore, a determination of economic feasibility was not possible. The objective of the study was changed to an assessment of technical feasibility.

HYDROLOGY AND RIVER HYDRAULICS

Studies were performed to confirm the long-term streamflow sequence adopted for the Reconnaissance Study (1), and to estimate the spillway design flood and anticipated reservoir sedimentation.

The long-term streamflow sequence at the proposed Upper Chagres dam is based on data from the gage on the Río Chagres at Chico. Data were available for this study for the period from March 1933 to December 2000. Data were missing for November 1966 and from January 1968 to June 1971. The missing monthly data were developed by MWH using statistical procedures. As the proposed dam is located about 150 m upstream from the gage, the recorded flows are considered to be applicable to the damsite. The mean annual flow at the damsite is estimated to be 30.2 m^3/s. The monthly distribution of flow is shown below in cubic meters per second.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
25.5	14.9	12.4	15.7	27.6	29.6	32.3	35.3	34.1	39.8	49.3	46.4	30.2

The probable maximum flood (PMF), based on probable maximum precipitation (PMP) was adopted as the spillway design flood for the Upper Chagres Water Supply Project. Based on information presented in the National Weather Service publication of PMP dated 1978 and the Weather Bureau publication of depth-area-duration dated 1965, the PMP was estimated to be 657 mm. The results of storm transposition and maximization procedures resulted in a slightly lower estimate.

The PMP was transformed to a PMF using the HEC-1 computer model. For a base flow of 50 m^3/s, estimated from an analysis of five major floods at the Rio Chico gage, the probable maximum flood hydrograph has an estimated peak discharge of 9,940 m^3/s and a 3-day volume of 271 MCM.

The impact of sediment deposition on storage in the reservoir was evaluated using data from Lake Madden and other sources. After 100 years, it is expected that sediment deposition will reduce the gross storage by about 10 percent and the live storage by about 5 percent.

GEOLOGIC CONDITIONS

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

Geology of the Damsite

Overburden at the damsite consists primarily of residual soils and colluvium. In the riverbed and lower 5 to 10 m of the valley sides, overburden consists of alluvial deposits ranging from sand to boulders.

Bedrock units in the Alto Río Chagres project area consist largely of Cretaceous rocks of volcanic origin. Based upon regional relations and similarities with geologic units observed in the Canal Area, bedrock units in the Alto Río Chagres project area are thought to belong to the Igneous Basement Complex.

The volcanic rock along the Río Chagres in the vicinity of the damsite has been identified in the field and referred to as andesite. Several zones of agglomerate were also observed in surface exposures and in boreholes. Observations made during the mapping and drilling program indicate that the stratigraphic relationship between the andesite and agglomerate is highly variable. The agglomerate appears to be an interflow feature of individual andesite flows, with clasts being incorporated from existing surficial deposits and from volcanic activity (explosions, debris flows).

The valley floor in the vicinity of the damsite is on the order of 50 meters wide and contains alluvial terraces and gravel and boulder bars. The alluvial terraces are mainly found on the inside of meanders, while the gravel and boulder bars are typically found along straight sections of the river channel.

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

- Maximum Design Earthquake (MDE) = 0.20 g
- Operating Basis Earthquake (OBE) = 0.14 g

The Upper Chagres dam was analyzed for stability for 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.

Construction Materials

The construction of the Upper Chagres Project will require appropriate aggregate for the roller compacted concrete (RCC) mix, concrete aggregate, and random material for the initial upstream and the downstream cofferdams.

All aggregates (including coarse and fine aggregates for concrete and the RCC mix) need to be manufactured from quarried sources. These aggregates will be manufactured from local andesite in a quarry located immediately to the west of the confluence of the Río Chico and the Río Chagres.

The diversion cofferdams will be constructed from locally available random fill obtained from required excavation at the dam.

DESCRIPTION OF THE UPPER CHAGRES WATER SUPPLY PROJECT

The major elements that comprise the Upper Chagres Water Supply project include:

- A roller compacted concrete dam and appurtenant works at the Río Chico site,
- A gated spillway sized to protect the dam against the probable maximum flood,
- Temporary river diversion facilities, which include two-culverts that will be converted to incorporate the emergency drawdown facilities, and
- A 56 MW power station that is also used to supply the minimum release.

A general plan of development and a plan of the dam and appurtenant works are shown on Exhibits 2 and 3.

The dam will impound a reservoir with a gross storage capacity of 530 MCM at El. 210, the full supply level. Live storage between El. 210 and El. 155 will be 450 MCM. The resultant dead storage is sized to accommodate 100 years of sediment deposition. The reservoir area at the full supply level is 13.9 square kilometers.

Upon completion of the project, the yield of the water supply system for the Panama Canal will be increased by about 400 million cubic meters per year with a reliability of 99.6%. This is equivalent to about 5.3 additional lockages per day in the present canal system.

The Upper Chagres Dam will be made of a low to medium cement content concrete mix with aggregate taken from a quarry located upstream of the site along the Río Chico near its confluence with the Río Chagres. The dam will be about 140 m high from the deepest foundation excavation to the top of the dam.

A gated chute spillway will be located in the left-center portion of the dam. The discharge under PMF conditions will be 6,300 m^3/s using a surcharge of 2.9 m above the full supply level. Control will be afforded by 6 radial gates, each 8-m wide by 12-m high. A flip bucket will discharge the flood flows into a plunge pool, which will be formed in competent rock, pre-excavated to El. 63 about 200 m downstream from the flip bucket.

The facilities for the river diversion during construction will consist of cofferdams upstream and downstream from the damsite and two 7 m by 7 m conduits located on the right side of the river channel. The conduits will serve to pass the 25-year flood during construction, control the rate of initial reservoir filling, and provide for emergency evacuation of the reservoir.

Emergency drawdown will be accomplished using the spillway and one of the diversion conduits. For emergency drawdown, an intake tower with a 4 m by 4 m shaft will be constructed on the face of the dam. Two 3-m wide by 4-m high gates will be installed with sills at El. 115.

The power facilities consist of a power intake, a vertical shaft and horizontal tunnel leading to the powerhouse, which will house one 8-MW and three 16-MW Francis turbines direct connected to synchronous generators for a total installed capacity of 56 MW. A 115-kV switchyard will be located about 200 meters from the powerhouse and a 21.2 km 115-kV transmission line will connect with the national grid at the existing 115-kV Panama-Colon line near the Madden dam. The minimum release will be discharged through the powerhouse either as a part of the power operation or, if the units are shut down, through a bypass.

Operation facilities are required for the hydropower facilities, the spillway gates, and the other gates and valves. These facilities will include a SCADA system for remote monitoring and operation of the project, instrumentation, security and lighting, and landscaping and drainage.

COST OF THE PROJECT

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

A summary of the construction cost is shown below.

Item	Estimated Cost
Land Acquisition and Mitigation	$9,100,000
General Costs including Construction Camps and Permanent Access Roads	$13,030,000
River Diversion Works	$9,170,000
Main Dam	$107,230,000
Spillway	$12,830,000
Emergency Drawdown Facilities	$1,550,000
Power Intake and Tunnel	$9,460,000
Powerplant	$18,420,000
Transmission System	$5,170,000
Operation Facilities	$900,000
Subtotal Direct Cost	**$190,580,000**
Contingency	$27,720,000
Direct Cost	**$218,300,000**
Engineering and Administration	$32,700,000
Construction Cost (Jan 2003 price level)	**$251,000,000**

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

Item	Annual Cost
O&M	$1,034,000
Replacement	$520,000
Admin and General Expenses	$193,000
Insurance	$243,000
Resettlement Administration	$80,000
Watershed Management	$150,000
Mitigation Plan Implementation	$100,000
Total (rounded)	**$2,320,000**

PROJECT IMPLEMENTATION

It is estimated that implementation of the Project will required about 6.5 years including environmental studies, funding, design, contractor selection, and construction.

Construction alone will require 4 years. An implementation schedule is shown on Exhibit 4.

CONCLUSIONS AND RECOMMENDATIONS

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

- The Upper Chagres Water Supply Project is technically feasible.
- The damsite selected in the Reconnaissance Report is a suitable site for the development of the water resources of the Upper Chagres Basin.
- A roller compacted concrete dam is suitable for the site and is the most cost effective arrangement.
- The yield of the Panama Canal system will increase by about 400 MCM/yr (about 5.3 L/d) with the addition of the Upper Chagres Project.
- The addition of a 56 MW hydropower plant to the Project is warranted.
- The project is estimated to cost about $251 million in 2003 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 $307 million.
- The economic cost of water is higher for the Upper Chagres Project than for either the Río Indio Project or the Caño Sucio project.

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

The Upper Chagres Water Supply Project not be considered as a source of water for any canal expansion in the near or intermediate term unless expansion to the Western Watersheds is not possible.

TABLE OF SIGNIFICANT DATA

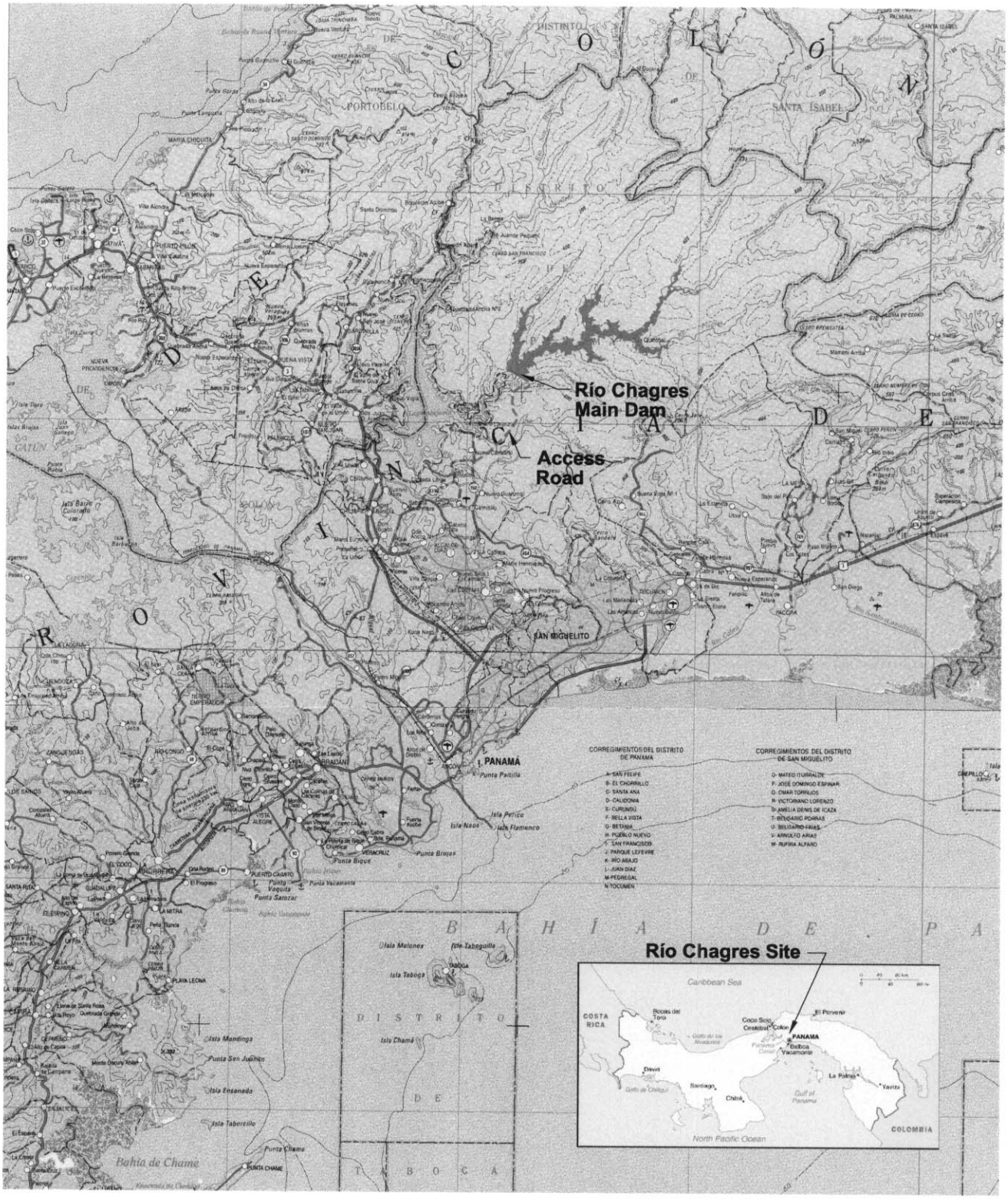
Project Setting: Upper Río Chagres Basin; east of Lake Madden		
Hydrology		
Average Annual Precipitation	3,250	mm
Average Annual Streamflow	30.2	m^3/s
Storage Facilities		
Reservoir		
Drainage Area	414	km^2
Normal Maximum Water Level	El. 210	msl
Active Storage		
Initial Volume (rounded)	530	MCM
Initial Operating Range	El 210- El 155	
Volume after 100 years (rounded)	480	MCM
Operating Range after 100 years	El 210-El 145	
Surface Area	13.9	km^2
Minimum Pool Level	El. 155	msl
Volume	80	MCM
Surface Area	3.8	km^2
Live Storage	450	MCM
Sediment (Dead) Storage	80	MCM
Dam		
Type of Dam	Roller Compacted Concrete (RCC)	
Crest Elevation	216	m
Crest Length	915	m
River Bed Elevation	86	m
Foundation Elevation	76	m
Hydraulic Height	130	m
Structural Height	140	m
Upstream and Downstream Slope	Vertical, 0.75H:1V	
Concrete Volume (rounded)	1,900,000	m^3

TABLE OF SIGNIFICANT DATA, cont.

Storage Facilities, cont.		
Spillway		
Type of Spillway	Gated ogee	
Spillway Gates	6 No. 12 m high by 8 m wide	
Spillway Crest Length	63	m
Spillway Crest Elevation	El 198	m
Spillway Design Flood		
Peak Inflow	9,940	m^3/s
3-day Volume	271	MCM
Peak Outflow	6,300	m^3/s
Surcharged Reservoir Level	212.9	msl
Diversion During Construction		
Section Shape	7 m by 7 m concrete culvert	
Number of Culverts	2	
Length	140	m
Diversion Flood (25-year)	2,110	m^3/s
Discharge Capacity	1,430	m^3/s
Pre-Cofferdam Height (hydraulic)	3	m
Main Cofferdam Height (hydraulic)	35	m
Downstream Cofferdam Height (hydraulic)	5	m
Cofferdam RCC Fill Volume	98,000	m^3
Cofferdam Embankment Fill Volume	5,000	m^3
Minimum Release Facility	Included in power facilities	
Power Facilities		
Installed Capacity	56	MW
Firm Capacity	56	MW
Average Annual Energy Production	254	GWh
Unit Information		
Number of Units and Capacity	3-16 MW	1-8 MW
Design Head	115 m	105 m
Rotational Speed	450 rpm	600 rpm
Generator Rating	17,800 kVA	8,900 kVA
Generator Frequency	60 Hz	
Power Factor	0.9	

TABLE OF SIGNIFICANT DATA, cont.

Power Facilities, cont.		
Physical Data		
Powerplant Type		Surface
Power Tunnel Length	200	m
Power Tunnel Diameter	4.2	m
Estimated Project Cost		
Construction Cost		$251,000,000
Annual Operating Cost		$2,320,000
Estimated Project Yield		
Volumetric Reliability	99.6	%
Yield L/d	5.3	L/d
Yield MCM/year	400	MCM/yr



5 0 5 10 15 20 km

GRAPHIC SCALE

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

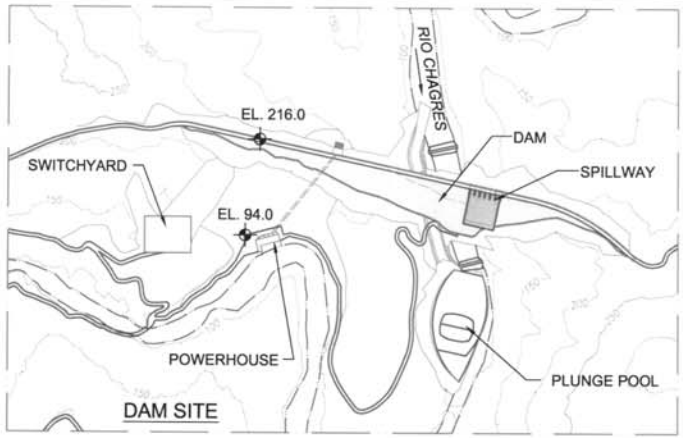
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT

Location Map

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 1



668,000 E
670,000 E
672,000 E
674,000 E
676,000 E
678,000 E
680,000 E
1,032,000 N
UPPER CHAGRES RESERVOIR FSL 210.0
1,030,000 N
1,028,000 N
1,026,000 N
1,024,000 N
PROPOSED DAM SITE
662,000 E
694,000 E
696,000 E
N
0 0.5 1 1.5 2 2.5 km
GRAPHIC SCALE

NOTE:
TOPOGRAPHY PROVIDED BY ACP FROM IFSAR SURVEY.

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

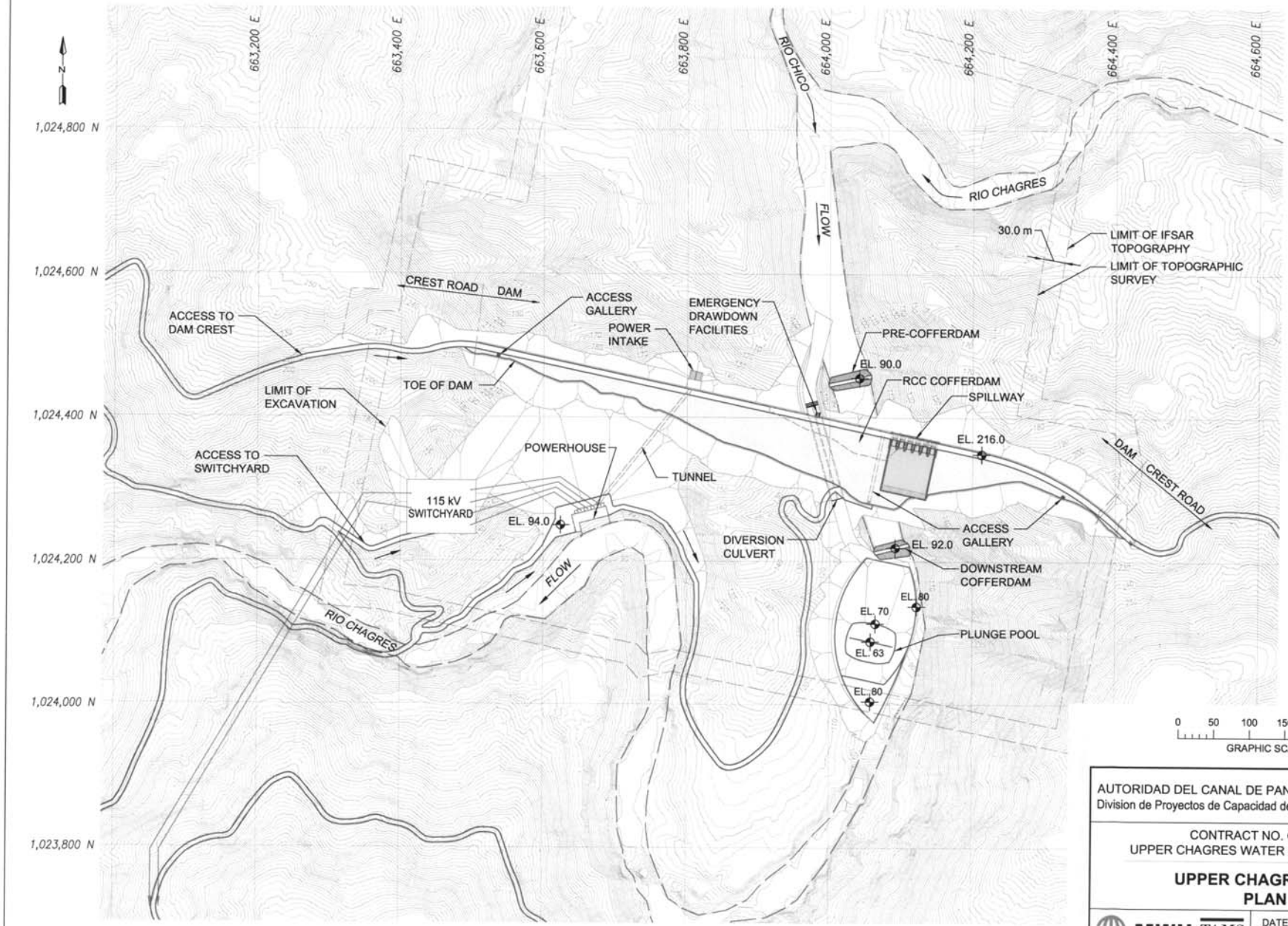
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT

GENERAL PLAN OF DEVELOPMENT

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 2



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

ACP

CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT

UPPER CHAGRES DAM
PLAN

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 3

Task Name	2003				2004				2005				2006				2007				2008				2009				2	
	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	
Completion of Feasibility Study	◆ Sep 5 '03																													
Environmental Baseline Studies																														
Feasibility Confirmation and Project Configuration																														
Funding																														
Environmental Field Studies																														
Environmental Mitigation Planning and Implementation																														
Design and Contractor Procurement																														
Construction Contract Awards																														
Access Roads and Construction Camp																														
Water Supply and Power Facilities																														
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AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

ACP

CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT

IMPLEMENTATION SCHEDULE

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 4