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

THE PANAMA CANAL

ENGINEERING SERVICES

Work Order No. 11
Upper Chagres Water Supply Project

Feasibility Study

Volume 3 APPENDICES C-F

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MWH
In association with
TAMS Consultants, Inc.
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Feasibility Design For
The Upper Chagres Water Supply Project

Volume	Title
1	Main Report
2	Appendix A – Hydrology, Meteorology and River Hydraulics Appendix B – Geology, Geotechnical and Seismological Studies
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FEASIBILITY DESIGN FOR THE UPPER CHAGRES WATER SUPPLY PROJECT

APPENDIX C

OPERATION SIMULATION STUDIES

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TAMS
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AUTORIDAD DEL CANAL DE PANAMA

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FEASIBILITY DESIGN FOR THE UPPER CHAGRES WATER SUPPLY PROJECT

APPENDIX C – OPERATION SIMULATION STUDIES

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INTRODUCTION

The evaluation of the production of the Upper Chagres Project was established by simulating the operation of the existing system and the existing system plus the Upper Chagres Project. The U.S. Army Corps of Engineers, Hydrologic Engineering Center developed HEC-5, Simulation of Flood Control and Water Conservation Systems Computer Program was used as the basis for the operation simulations. The simulations were preformed using English units. The model was operated by the ACP.

The operation simulation studies were performed by:

Ms. T. Atencio – Operations Specialist

Under the directions of:

Mr. J. Pascal, Task Order Manager, and
Mr. Jorge de la Guardia, Manager, Canal Capacity Projects Division

The basic input requirements of the model consist of physical data, operational data, and hydrologic time-series data consisting primarily of flow data. The physical and operational data were either developed by the ACP or carried over from the Reconnaissance Study. The hydrologic data was confirmed or re-developed by MWH and are presented in Appendix A.

In the Reconnaissance Report, the concept of hydrologic reliability was introduced. Hydrologic reliability was defined as the ability of the Panama Canal system to provide sufficient water for unrestricted operation. It is represented by a ratio of the volume of water provided to the volume of water demanded for canal operations during the designated period with no draft restrictions. The base level of reliability was taken as 99.6%, which was derived by operating the existing system (without improvements to Lake Gatun) over the period from 1919 to 1999 with a demand equal to an average of the lockages provided over the 5-year period from 1993-1997. As a part of the operation simulation studies, other reliability estimates were considered.

The same model was used to assess the potential for adding hydropower. In addition to the base case runs, operation rules to favor hydropower also were evaluated. The results of the hydropower operation studies are presented in Appendix E, Part 2.

In the attachments to this appendix, we have presented the ACP synopsis of the operation simulation studies, data and a curve for active storage versus yield, and a sample output from the HEC-5 model.

ATTACHMENTS

ATTACHMENT 1

ACP SYNOPSIS OF THE OPERATION SIMULATION STUDIES

HEC-5, Simulation of Flood Control and Water Conservation System

INTRODUCTION

The HEC-5 reservoir system model was developed by the U.S. Army Corps of Engineers' Hydrologic Engineering Center in Davis, California. The existing system model (base model) was developed in order to evaluate the capability of the present ACP system and to evaluate the effectiveness of proposed alternatives to improve the system capability and reliability.

This model performs a sequential simulation of reservoir operations given a time-series of flow. The reservoirs are defined by their storage and outflow capability. The reservoir storage is allocated to operational zones (levels) that define their usage (rule curves). The flood control zone is only used to store excess inflow, the conservation zone is used to store water to meet future demands, and the inactive zone, (dead storage) is where no releases can be made. 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 a reservoir model system.

BASE MODEL DATA

The base model represents the existing ACP water supply system. Madden and Gatun reservoirs are the primary elements of the system. HEC-5 can only process one diversion from each reservoir. The municipal water supply and the lockages for Gatun and Pedro Miguel were combined into one diversion from Gatun.

All data are in foot-pound units. The simulation time-interval is one month. However, this model could operate at time steps as small as one-hour. Given the monthly time-step, the seasonally varying data are all defined over the 12 months. There is no river-reach routing data required for the monthly time step.

The average-monthly flow data are input to Madden and Gatun. The inflow is assigned as incremental-local flow, which means that the inflow to Gatun only represents the catchment not controlled by Madden.

Madden Reservoir

The model begins with a Madden Reservoir (location 50) which receives basin inflow, provides M&I water supply, and releases flow to Gatun. Reservoir releases are assumed to pass through the hydroelectric facility and energy generation is computed up to the limits of power capacity. The outflow from Madden is "routed" to Gatun reservoir. The channel capacity was set to 1,415 m^3/s (50,000cfs) based on operation manual

information; however, that value should not be a controlling factor in the monthly simulation.

Elevation-Storage: HEC-5 defines the reservoir with a set of storage-based relationships. Reservoir outflow capacity, elevation, and area are defined as a function of storage. The data between elevations 57.9m and 82.3 m (190 and 270 feet) were input on a 0.60m (two-foot interval), except for the 60.9m to 67.1 m (200 to 220 feet) range where data input is on 0.30 m (one-foot) interval. Data below elevation 57.9 m (190 feet) and above 80.5m (264 feet) were estimated by extrapolation. There are two reasons for this: one is that the reservoir operating range is between elev. 57.9m and 76.8m (190 and 252 ft), so that information within this range should be more accurate. The other reason is that the program interpolates on a straight line between points, and in order to be more precise in the part of the curve where the slope changes more rapidly, closer points will be needed.

Outflow Capacity. The outflow capacity is a constraint on releases in HEC-5. The program does not simulate gate openings, it only ensures that the release does not exceed the maximum outflow capacity of the reservoir.

Reservoir guide-curve. The guide curve for the top-of-conservation is defined by the target storage at the end of each month. The reservoir guide curve has changed over the years. Since this analysis is for the existing system, the current guide-curve was used in the model. The guide curve is a data input supplied by ACP, more information will be given on its development in following sections.

Reservoir evaporation. The evaporation for Madden is the computed reservoir evaporation, in inches, provided by ACP.

Hydropower data: The total installed capacity is 36 MW, 3 x 12 MW units; no overload is assumed. The tailwater was set at 27.1m (89 feet). The efficiency was set at 83%, based on turbine testing data and an assumed generator efficiency of 96%. No hydropower requirements were specified. A leakage value of $0.6m^3/s$ (20 cfs) was used, as determined by the Meteorological & Hydrographic Branch (Met & Hyd) of ACP. The program will pass that value as a minimum and that flow will not be used for energy computation.

M&I Diversions: The municipal and industrial water supply is diverted from Madden to nowhere, i.e. the diverted flow leaves the system. Average monthly values for the 5-year period 1993-1997 were used. These were the last 5 complete years of information available when the base model was set in late 1998.

Gatun Reservoir

Gatun (location 40) is the next location below Madden. The input flow data to Gatun is the uncontrolled flow downstream from Madden. The total inflow is the sum of Madden

releases and input flow data. The release from Gatun routes to the Caribbean Sea. As with Madden, the reservoir releases will be used to generate electrical energy. Flow diversion from Gatun includes municipal water supply and the combined lockages for Gatun and Pedro Miguel Locks.

Elevation-Storage. HEC-5 defines the reservoir same as with Madden. The data between elevations 23.5m and 27.4m (77 and 90 feet) were input on 0.30m (one-foot) interval. The data were not defined below elevation 23.5 and above elevation 27.4m, so that data was estimated by extrapolating the given curves. Reasoning for this same as that for the Madden reservoir storage data.

Outflow capacity: Criteria is the same as that for Madden. The outflow capacity was taken from information by ACP for all 14 gates open from an elevation of 23.8m to 28.0m (78 to 92 feet). Outflow capacity for elevations 21.3m and 23.5m (70 and 77 feet) were estimated using the weir equation and a coefficient of 3.0.

Reservoir Guide-Curves and Reservoir evaporation. Same considerations as those for Madden.

Hydropower data. The total installed capacity is 24 MW, 3 x 3 MW units and 3 x 5 MW units. No overload is assumed. The tailwater elevation was set at 2.7m (9 feet), based on tailwater data from unit testing. The efficiency was set at 85%, based on turbine testing data and an assumed generator efficiency of 96%. No hydropower requirements were specified. A leakage value of $0.8m^3/s$ (27 cfs) is used, information provided by ACP`s Met & Hyd Branch.

Gatun and Pedro Miguel Locks: The diversions from Gatun include the combined flow for lockages.

M&I Diversions: The diversion from Gatun for municipal and industrial water supplies is included with the flow for locks as the diversion from Gatun. Average monthly values for the 5-year period 1993 to 1997 were used. These were the last 5 years of complete information available since the base model was set in late 1998.

Flow data:

It is a requirement of the model to define the starting storage values and the corresponding date for each reservoir.

BASE MODEL VALIDATION

To validate the model configuration and data, a simulation was performed with the outflow and the inflow defined. With all the inflow and outflow defined, the simulation should yield the same results as historically recorded. A simulation run was made for the

period of January 1970 to December 1997. For both reservoirs, the validation model elevations are essentially the same as the observed elevations, therefore, the model configuration is consistently accounting for the water in the system.

RESERVOIR GUIDE CURVES (RULE CURVES)

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.

Though the current set of curves was mostly developed on an empirical base, a study was conducted on April 1999 by Manuel B. Vilar from the Met & Hyd Branch of ACP to validate them. The study consisted on two distinctive approaches in simulating lake operations with the daily data from 1965 to 1994. They are an historical analysis and a stochastical analysis. The study concluded that "...it was verified that the existing rule curve has about a lower decile probability of requiring draft restrictions. That is, that about 10% of the historical events....will produce draft restrictions..."

UPPER CHAGRES RESERVOIR

A series of operation cases were performed to assess the relationship between yield and reliability and yield and active storage.

Yield versus reliability was evaluated for three operating ranges as follows:

Operating Range	Active Storage MCM	Range of SystemYields Locks/day
El 184-El 150	184	38.68 – 77.36
El 240-El 150	1,026	38.68 – 77.36
El 230-El 180	649	38.68 – 77.36

To evaluate the relationship between yield and active storage and the impact of the location of the active storage within the bounds of the development, the following operation runs were performed.

Reservoir Operation Range	Active Storage MCM
El 240 – El 150	1,026
El 230 – El 180	649
El 220 – El 150	619
El 220 – El 180	465
El 210 – El 150	465
El 200 – El 180	184
El 184 – El 150	184

The results of these runs are presented in Attachments 2.

The top of dam was set 5 meters above the normal pool elevation for each case.

Inflow/Outflow: The Upper Chagres Lake (location 60) would receive a monthly average runoff of 30 m^3/s from approximately 414 km^2 of the upper portion of the watershed. The calculated discharge at the Upper Chagres dam site is obtained from streamflow data of the Chico Hydrologic station. The inflows to Madden Lake are then adjusted by substracting the inflows at Chico from the Madden Lake Inflows historical records.

The outflows from the Upper Chagres Lake (60) goes to control point 50 (Madden Lake). No routing was performed. A minimum desired flow of 3 m^3/s (10% of the average flow) is released from Upper Chagres during the months February through May. Reservoir releases are assumed to pass through the hydroelectric facility located at the downstream toe of the Upper Chagres dam. The energy generation is computed up to the limits of power capacity. No derivations were considered from Upper Chagres Lake.

Elevation-Storage: HEC-5 defines the reservoir with a set of storage-based relationships. Reservoir outflow capacity, elevation, and area are defined as a function of storage.

Outflow Capacity. The outflow capacity is a constraint on releases in HEC-5. The program does not simulate gate openings, it only ensures that the release does not exceed the maximum outflow capacity of the reservoir.

Reservoir guide-curve. The guide curve for the top-of-conservation is defined by the target storage at the end of each month. As proposed by th ACP, the curve is at the top of the conservation pool in December, at 75% of the conservation pool in June and July, and stepped in even increments for the intervening months.

Reservoir evaporation. Because of the proximity of Upper Chagres to Madden Lake, and because of the absence of site specific information, the monthly evaporation rates established for Madden Lake were considered appropriate for the evaporation rates of Upper Chagres lake.

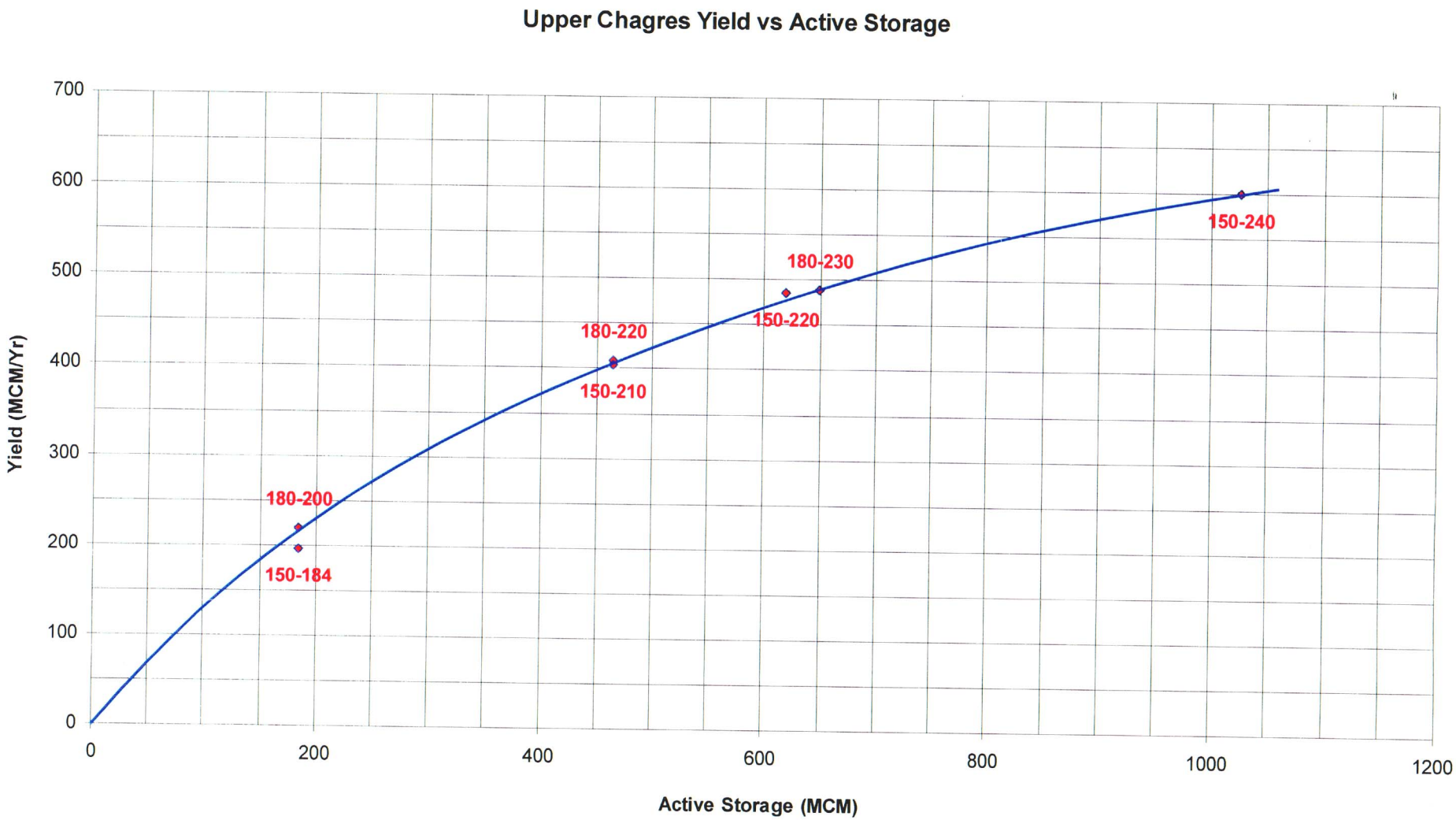
Flood flow. An uncontrolled ogee spillway was considered to the release of flood events. It was designed assuming a maximum water level of 4 meters above the spillway crest, a C value of 3.5 and a design flow for a return period of one thousand years. The maximum discharge was derived from IRHE report "Analisis Regional de Crecidas Maximas" and estimated as 156,300 cfs.

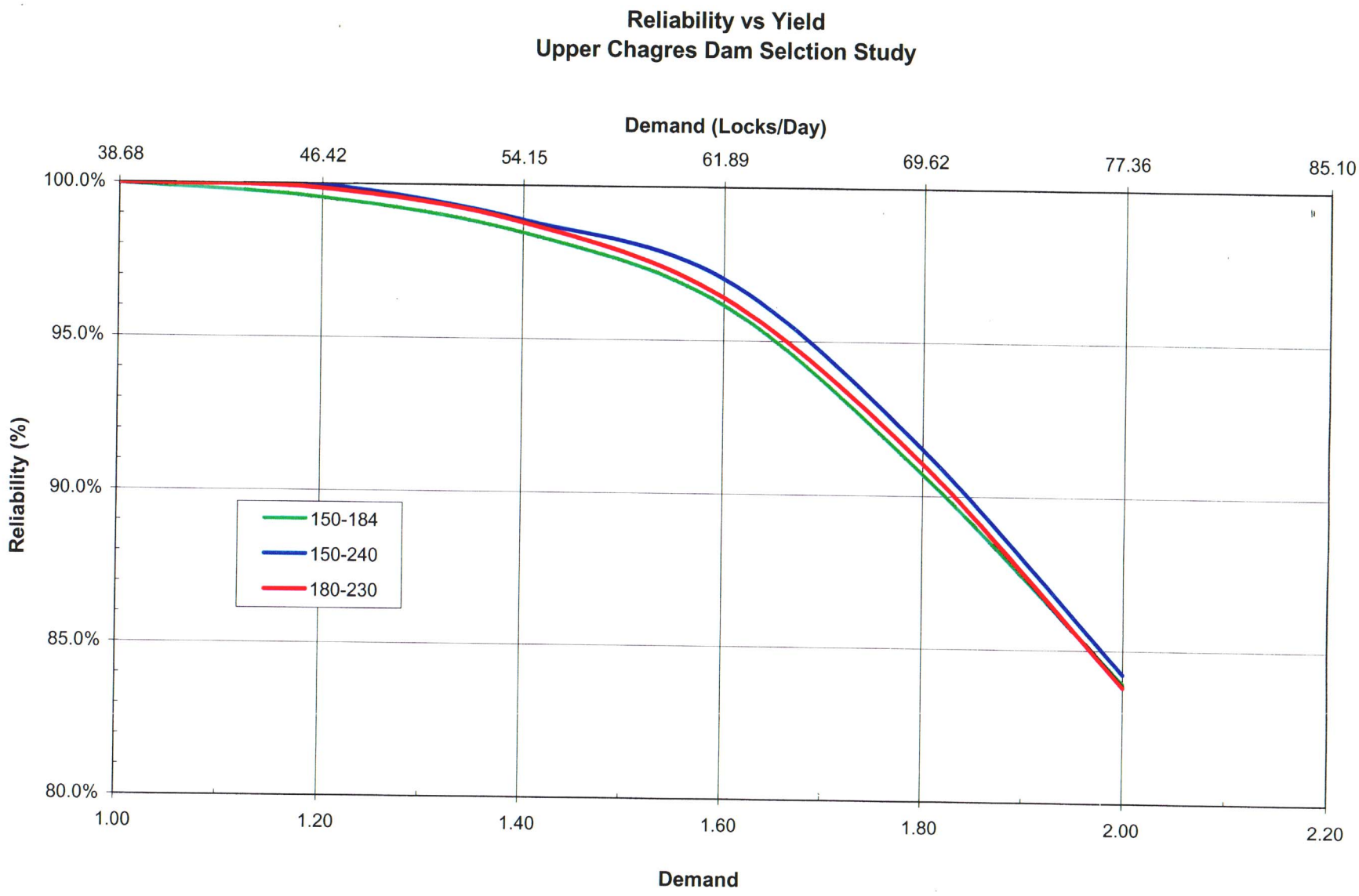
Hydropower data: HEC-5 runs were executed considering a 34.5 MW hydropower plant at the dam. The only limitation of power output was the powerplant rated capacity. No overload was assumed. A tailwater elevation of 100 m. was assumed. The power peaking capability function was not used. The efficiency was set at 86%. A fixed head loss of 1 ft was assumed.

A maximum flow (non-damaging channel capacity) of 3500 cfs was assumed

ATTACHMENT 2

STORAGE - YIELD AND RELIABILITY-YIELD DATA


Upper Chagres Yield vs Active Storage
Yield (MCM/Yr)
Active Storage (MCM)
0
100
200
300
400
500
600
700
0
200
400
600
800
1000
1200
180-200
150-184
180-220
150-210
180-230
150-220
150-240


Reliability vs Yield
Upper Chagres Dam Selction Study
Demand (Locks/Day)
38.68
46.42
54.15
61.89
69.62
77.36
85.10
100.0%
95.0%
90.0%
85.0%
80.0%
Reliability (%)
150-184
150-240
180-230
1.00
1.20
1.40
1.60
1.80
2.00
2.20
Demand

ATTACHMENT 3

TYPICAL HEC-5 OUTPUT FILE

```
************************************************************
* HEC-5 SIMULATION OF FLOOD CONTROL AND CONSERVATION SYSTEMS *
*                                                          *
*              Version 8.0 RJH;  40 Oct  1998              *
*                                                          *
*      Run Date: 17 APR 03      Time: 11:31:05              *
************************************************************
```

```
*****************************************************
*            U.S. ARMY CORPS OF ENGINEERS           *
*            Hydrologic Engineering Center          *
*            609 Second Street, Suite A             *
*            Davis, California  95616-4687          *
*  (530) 756-1104   http://www.hec.usace.army.mil   *
*****************************************************
```

```
X     X  XXXXXXX   XXXXX          XXXXXX
X     X  X     X  X     X         X
X     X  X        X               X
XXXXXXX  XXXXX    X        XXXXX  XXXXXX
X     X  X        X                     X
X     X  X     X  X     X         X     X
X     X  XXXXXXX   XXXXX          XXXXXX
```

```
*****************************************************************************************
*                                                                                       *
*                                                                                       *
*                          MODELING CAPABILITIES OF THIS VERSION ARE:                   *
*                                                                                       *
*                        Flood Control,  Water Supply,  and  Hydropower                  *
*                                                                                       *
*                                                                                       *
*                              MAXIMUM LIMITS FOR THIS VERSION ARE:                     *
*                                                                                       *
*            Reservoirs = 40,   Control Points = 80,   Diversions = 40,   Power Plants = 35 *
*                                                                                       *
*   Model Data Records (T1-ED)  =1000     Reservoir Levels     = 40     Flow Sequence Sets (BF-EJ)=     80  *
*   J8+JZ Output/DSS Records    =  80     Seasonal Storages    = 36     Periods per Flow Sequence =   2000  *
*   Res Physical Values (RS-RE) =  60     Seasons (CS Record)  = 36     Dynamic Dimen. (DM array) =1350000  *
*                                                                                       *
*                                                                                       *
*****************************************************************************************
```

1

HEC-5 SIMULATION OF FLOOD CONTROL AND CONSERVATION SYSTEMS

Version 8.0 RJH; 40 Oct 1998

```
T1    Panama Canal Capacity Study: Period - of Record Analysis  (CHAGRES1.DAT)
T2    Based on POR Model: Existing System with Average Lockage & Municipal Qs
T3    Upper Chagres Model developed by A.Bal, July, 1999. Modified by M.Echevers
C
C  THIS IS UPPER CHAGRES LAKE CASE 8 MODEL.
C  NORMAL POOL ELEVATION = 210 M (689.01 FEET) (MONTH OF DECEMBER)
C  MINIMUM POOL ELEVATION = 155 M (508.56 FEET)
C  IT IS BUILT AROUND THE EXISTING WATERSHED MODEL AS DEVELOPED BY RICHARD HAYES
C  OF HEC ON JANUARY 1999 (PCCBASE.DAT).  THAT MODE
C  Existing System with Average Lockage & Municipal Qs.
C  INFLOWS ARE READ FROM FILE PCCMONQ.DSS.
C  FLOWS WERE OBSERVED AT CHICO STATION.  MISSING FLOWS WERE DERIVED BY A
C  CORRELATION WITH BOQUERON RIVER.
C  I=CHAGRES1.DAT O=CHAGRES1.OUT DSSI=PCCMONSS.DSS  DSSO=CHAGRES1.DSS
C
J1     0       1       5       3       4       2
J2    24     1.0             132
J3     5                                      1                       1
C
C  BASIN MONTHLY NET EVAPORATION (INCHES) FOR LAKE CHAGRES IS ASSUMED TO BE THE
C  SAME AS THE HISTORICAL EVAPORATION FROM MADDEN LAKE.  EVAPORATION FROM PCC
C  COMPUTED VALUES ARE INPUT AS EV DATA.
J6 4.406   4.615   5.226   4.858   3.586   3.128   3.293   3.148   3.075   3.133
J6 2.827   3.307
C  OPTIMIZE THE DIVERSION SCHEDULE ON QD RECORDS BASED ON TOP OF BUFFER LEVEL
C  (LEVEL 2)
C  J7 200.4                                0                                6
J8 60.09   60.10   60.11   60.12   60.13   60.21   60.22
J8 40.03   40.30   40.31   40.22   40.10   40.09   40.13
J8 50.10   50.12   50.13   50.22   50.09   50.31   50.32
J8200.04  200.01
C   +++++++ Write Diversion Shortages To DSS File (Madden and Gatun Sum) +++++++
C  DATA SAVED TO DSS
C   .01=FLOW-LOC CUM       .03=FLOW-DIV         .04=FLOW-REG       .21=EVAP-NET
C   .09=FLOW-RES IN        .10=FLOW-RES OUT     .22=ELEV
C   .32=FLOW-SPILL         .16=ENERGY-GEN       .35=PLANT FACTOR
JZ 40.31   40.10   40.22   50.22   50.10   50.31   40.03   50.03   50.30   40.30
JZ 40.21   50.21   40.13   50.13   40.11   50.16   40.16   50.33   50.35   40.35
JZ 60.09   60.10   60.12   60.13   60.16   60.21   60.22   60.32   60.33   60.35
C ============== LAKE UPPER CHAGRES ==========================================
C  CONTROL POINT TITLES
C  60 UPPER CHAGRES DAM.  OUTFLOWS GO TO MADDEN LAKE.
C  50 MADDEN DAM.  OUTFLOWS GO TO GATUN LAKE.  M&I DIV. GOES TO DUMMY NODE 99.
C  40 GATUN DAM.  FLOWS GO TO DUMMY NODE 99.
C  99 DOWNSTREAM OF GATUN DAM.  M&I DIVERSION FROM MADDEN GO TO THIS POINT.
C 200 END NODE OF THE RUN
C
C  RESERVOIR LEVELS
C  5.  Top-of-dam                = Elev. 215.0 m (705.42 ft)
```

```
C  LEVELS 3 AND 4 HAVE A RESERVOIR RULE CURVE ASSOCIATED TO THEM.
C  THE LEVEL INDICATED CORRESPONDS TO THE MONTH OF DECEMBER.
C  4.  Top-of-flood (spill curve)  = Elev. 210.0 m (689.01 ft)
C  3.  Top-of-conservation        = Elev. 210.0 m (689.01 ft)
C  2.  Top-of-buffer                 = Elev. 155.10 m (508.88 ft) (No M&I deman
C  1.  Top-of-inactive               = Elev. 155.0 m (508.56 ft)
C
C  THE RULE CURVES WERE DERIVED USING MADDEN DAM'S RULE CURVE AS A GUIDE.
C  DEPENDING ON THE RESERVOIR SIZE AND ELEVATION, THEY WERE PLACED IN THE
C  RIGHT ELEVATION AND FLATTENED ACCORDINGLY.  THE RULE CURVES WERE OBTAINED
C  FROM THE BASE MODEL ON THE PANAMA CANAL DEVELOPED BY HEC IN FEBRUARY 1999.
C
C  STARTING STORAGE IN RESERVOIR (1000 ACRE-FEET) IS IN TOP OF CONSERVATION
C  LEVEL (210 METERS OR 689.01 FEET IN THE MONTH OF JANUARY)
C  CUMMULATIVE RESERVOIR CAPACITIES FOR EACH RESERVOIR LEVEL (acre-feet)
C
C  CASE OF VARIABLE RULE CURVES IN UPPER CHAGRES
```

Period	Date:	CHA Inflow (CFS)	CHA Outflow (CFS)	CHA EOP Stor (AC-FT)	CHA Case	CHA Level	CHA Evaporat (CFS)	CHA EOP Elev (FT)
605	1May 1998	1397.00	1137.20	80391.00	0.06	2.08	4.83	524.28
606	1Jun 1998	848.00	1107.62	64714.00	0.05	2.00	3.84	508.02
607	1Jul 1998	1093.00	1089.45	64714.00	0.05	2.00	3.55	508.02
608	1Aug 1998	1198.00	105.00	131645.00	0.00	2.28	4.49	563.62
609	1Sep 1998	1206.00	1251.50	128505.00	0.06	2.24	7.26	561.63
610	1Oct 1998	1182.00	105.00	194281.00	0.00	2.43	7.28	600.56
611	1Nov 1998	1360.00	105.00	268484.00	0.00	2.62	8.00	634.59
612	1Dec 1998	1936.00	1422.51	299583.00	0.06	2.65	7.71	646.80
613	1Jan 1999	1086.00	105.00	359103.00	0.00	2.88	13.01	667.53
614	1Feb 1999	848.00	105.00	399387.00	0.00	4.00	17.67	680.36
615	1Mar 1999	524.00	1483.27	339198.00	0.06	2.97	19.59	661.19
616	1Apr 1999	619.00	717.82	332483.00	0.05	3.18	14.03	659.05
617	1May 1999	906.00	1447.08	298516.00	0.06	3.38	11.34	646.38
618	1Jun 1999	1279.00	1430.33	288972.00	0.06	3.13	9.05	642.63
619	1Jul 1999	1598.00	1430.42	298668.00	0.06	3.27	9.89	646.44
620	1Aug 1999	1900.00	1445.02	325989.00	0.06	3.35	10.65	656.99
621	1Sep 1999	1562.00	1427.20	333305.00	0.03	3.00	11.86	659.32
622	1Oct 1999	1429.00	791.09	371772.00	0.05	3.29	12.31	671.57
623	1Nov 1999	1840.00	1454.03	394063.00	0.03	3.00	11.37	678.67
624	1Dec 1999	4477.00	3902.80	428740.00	0.06	4.04	10.23	689.63

Period	Date:	CHA Inflow	CHA Outflow	CHA EOP Stor	CHA Case	CHA Level	CHA Evaporat	CHA EOP Elev
	Sum =	659289.00	651548.19	**********	25.59	1952.63	10708.21	409352.56
	Max =	4477.00	3902.80	428740.00	0.06	4.52	37.48	689.63
	Min =	169.00	105.00	64714.00	0.00	2.00	3.55	508.02
	PMax=	624.00	624.00	624.00	4.00	401.00	87.00	624.00
	Avg =	1056.55	1044.15	330764.50	0.04	3.13	17.16	656.01
	PMin=	567.00	9.00	604.00	9.00	604.00	607.00	604.00

Period	Date:	GAT Diversio (CFS)	GAT Div Requ (CFS)	GAT Div Shor (CFS)	GAT EOP Elev (FT)	GAT Outflow (CFS)	GAT Inflow (CFS)	GAT Level
605	1May 1998	3506.62	3977.34	470.72	78.50	0.00	447.00	1.00
606	1Jun 1998	3790.58	3790.58	0.00	79.38	27.00	1830.27	2.12
607	1Jul 1998	3788.01	3788.01	0.00	79.52	27.00	618.77	2.14
608	1Aug 1998	3842.10	3842.10	0.00	82.60	27.00	5382.60	2.65
609	1Sep 1998	3733.91	3733.91	0.00	83.15	27.00	1435.23	2.70
610	1Oct 1998	3982.50	3982.50	0.00	85.57	27.00	4567.98	2.95
611	1Nov 1998	3818.92	3818.92	0.00	86.12	27.00	1385.12	2.86
612	1Dec 1998	3968.33	3968.33	0.00	87.75	519.33	3707.08	3.00
613	1Jan 1999	4283.89	4283.89	0.00	86.18	27.00	-2186.06	2.90
614	1Feb 1999	4282.60	4282.60	0.00	85.77	27.00	-147.80	2.93
615	1Mar 1999	4292.90	4292.90	0.00	83.56	27.00	-3124.96	2.72
616	1Apr 1999	4164.10	4164.10	0.00	83.26	27.00	-46.08	2.76
617	1May 1999	3977.34	3977.34	0.00	84.28	27.00	2183.20	2.93
618	1Jun 1999	3790.58	3790.58	0.00	84.70	3902.19	5008.48	3.00
619	1Jul 1999	3788.01	3788.01	0.00	84.70	2890.45	3281.54	3.00
620	1Aug 1999	3842.10	3842.10	0.00	85.23	4550.00	5833.71	3.29
621	1Sep 1999	3733.91	3733.91	0.00	85.00	3921.40	3958.63	3.00
622	1Oct 1999	3982.50	3982.50	0.00	85.90	1569.39	3545.56	3.00
623	1Nov 1999	3818.92	3818.92	0.00	87.40	4617.73	7680.13	4.00
624	1Dec 1999	3968.33	3968.33	0.00	87.75	15537.57	16465.93	3.00

Period	Date:	GAT Diversio	GAT Div Requ	GAT Div Shor	GAT EOP Elev	GAT Outflow	GAT Inflow	GAT Level
	Sum =	2482180.75	2492109.25	9928.56	52928.81	947154.00	1313448.38	1813.39
	Max =	4292.90	4292.90	3905.46	87.75	18195.19	19470.42	4.00
	Min =	387.45	3733.91	0.00	78.50	0.00	-3792.90	1.00
	PMax=	3.00	3.00	603.00	12.00	228.00	228.00	23.00
	Avg =	3977.85	3993.76	15.91	84.82	1517.88	2104.89	2.91
	PMin=	603.00	9.00	1.00	355.00	355.00	351.00	355.00

Period	Date:	MAD Outflow (CFS)	MAD Case	MAD Level	MAD EOP Elev (FT)	MAD Inflow (CFS)	MAD Div Shor (CFS)	MAD Q-Spill (CFS)
605	1May 1998	1585.96	0.09	2.00	190.10	1608.20	0.00	0.00
606	1Jun 1998	2065.81	0.09	2.00	190.10	2083.48	0.00	0.00
607	1Jul 1998	500.00	0.00	2.85	213.75	2808.30	0.00	0.00
608	1Aug 1998	3600.00	0.01	2.21	198.67	2043.14	0.00	0.00
609	1Sep 1998	500.00	0.00	2.79	221.91	3251.64	0.00	0.00
610	1Oct 1998	2682.55	0.05	2.46	215.89	1928.16	0.00	0.00
611	1Nov 1998	500.00	0.00	2.49	224.33	1695.58	0.00	0.00
612	1Dec 1998	500.00	0.00	2.86	245.88	4122.81	0.00	0.00
613	1Jan 1999	500.00	0.00	2.95	246.98	765.72	0.00	0.00
614	1Feb 1999	3600.00	0.01	2.67	229.87	364.86	0.00	8.66
615	1Mar 1999	500.00	0.00	3.18	236.83	1695.55	0.00	0.00
616	1Apr 1999	3600.00	0.01	3.10	223.91	1560.10	0.00	0.00
617	1May 1999	3600.00	0.01	3.02	217.57	2778.07	0.00	0.00
618	1Jun 1999	3600.00	0.01	3.04	216.50	3487.19	0.00	0.00
619	1Jul 1999	3319.87	0.03	3.00	217.00	3411.27	0.00	0.00
620	1Aug 1999	3214.43	0.03	3.00	222.00	3908.16	0.00	0.00
621	1Sep 1999	1304.65	0.05	3.29	233.32	3104.34	0.00	0.00
622	1Oct 1999	2184.74	0.03	3.00	236.00	2668.24	0.00	0.00
623	1Nov 1999	2124.60	0.03	3.00	247.00	4219.62	0.00	0.00
624	1Dec 1999	8639.07	0.03	3.00	252.00	9661.10	0.00	5285.57

Period	Date:	MAD Outflow	MAD Case	MAD Level	MAD EOP Elev	MAD Inflow	MAD Div Shor	MAD Q-Spill
	Sum =	1426109.38	12.31	1864.86	143576.44	1456993.25	0.00	26510.93
	Max =	8639.07	0.09	4.00	252.00	9661.10	0.00	5285.57
	Min =	500.00	0.00	2.00	190.10	-139.72	0.00	0.00
	PMax=	624.00	115.00	85.00	24.00	624.00	1.00	624.00
	Avg =	2285.43	0.02	2.99	230.09	2334.93	0.00	42.49
	PMin=	4.00	4.00	317.00	317.00	112.00	1.00	2.00

Period	Date:	END Flow Reg (CFS)	END Local Cu (CFS)
605	1May 1998	246.01	0.00
606	1Jun 1998	269.14	0.00
607	1Jul 1998	269.14	0.00
608	1Aug 1998	267.86	0.00
609	1Sep 1998	267.86	0.00
610	1Oct 1998	258.84	0.00
611	1Nov 1998	261.42	0.00
612	1Dec 1998	755.04	0.00
613	1Jan 1999	265.28	0.00
614	1Feb 1999	269.14	0.00
615	1Mar 1999	271.72	0.00
616	1Apr 1999	271.72	0.00
617	1May 1999	273.01	0.00
618	1Jun 1999	4144.34	0.00
619	1Jul 1999	3132.59	0.00
620	1Aug 1999	4790.85	0.00
621	1Sep 1999	4162.25	0.00
622	1Oct 1999	1801.23	0.00
623	1Nov 1999	4852.15	0.00
624	1Dec 1999	15773.27	0.00

Period	Date:	END Flow Reg	END Local Cu
	Sum =	1097113.13	0.00
	Max =	18430.89	0.00
	Min =	238.28	0.00
	PMax=	228.00	1.00
	Avg =	1758.19	0.00
	PMin=	601.00	1.00

Period	Date:	GAT Div Shor (CFS)	GAT Outflow (CFS)	GAT EOP Elev (FT)	MAD EOP Elev (FT)	MAD Outflow (CFS)	MAD Div Shor (CFS)	GAT Diversio (CFS)	MAD Diversio (CFS)	MAD Div Requ (CFS)	GAT Div Requ (CFS)
605	1May 1998	470.72	0.00	78.50	190.10	1585.96	0.00	3506.62	246.01	246.01	3977.34
606	1Jun 1998	0.00	27.00	79.38	190.10	2065.81	0.00	3790.58	242.14	242.14	3790.58
607	1Jul 1998	0.00	27.00	79.52	213.75	500.00	0.00	3788.01	242.14	242.14	3788.01
608	1Aug 1998	0.00	27.00	82.60	198.67	3600.00	0.00	3842.10	240.86	240.86	3842.10
609	1Sep 1998	0.00	27.00	83.15	221.91	500.00	0.00	3733.91	240.86	240.86	3733.91
610	1Oct 1998	0.00	27.00	85.57	215.89	2682.55	0.00	3982.50	231.84	231.84	3982.50
611	1Nov 1998	0.00	27.00	86.12	224.33	500.00	0.00	3818.92	234.42	234.42	3818.92
612	1Dec 1998	0.00	519.33	87.75	245.88	500.00	0.00	3968.33	235.70	235.70	3968.33
613	1Jan 1999	0.00	27.00	86.18	246.98	500.00	0.00	4283.89	238.28	238.28	4283.89
614	1Feb 1999	0.00	27.00	85.77	229.87	3600.00	0.00	4282.60	242.14	242.14	4282.60
615	1Mar 1999	0.00	27.00	83.56	236.83	500.00	0.00	4292.90	244.72	244.72	4292.90
616	1Apr 1999	0.00	27.00	83.26	223.91	3600.00	0.00	4164.10	244.72	244.72	4164.10
617	1May 1999	0.00	27.00	84.28	217.57	3600.00	0.00	3977.34	246.01	246.01	3977.34
618	1Jun 1999	0.00	3902.19	84.70	216.50	3600.00	0.00	3790.58	242.14	242.14	3790.58
619	1Jul 1999	0.00	2890.45	84.70	217.00	3319.87	0.00	3788.01	242.14	242.14	3788.01
620	1Aug 1999	0.00	4550.00	85.23	222.00	3214.43	0.00	3842.10	240.86	240.86	3842.10
621	1Sep 1999	0.00	3921.40	85.00	233.32	1304.65	0.00	3733.91	240.86	240.86	3733.91
622	1Oct 1999	0.00	1569.39	85.90	236.00	2184.74	0.00	3982.50	231.84	231.84	3982.50
623	1Nov 1999	0.00	4617.73	87.40	247.00	2124.60	0.00	3818.92	234.42	234.42	3818.92
624	1Dec 1999	0.00	15537.57	87.75	252.00	8639.07	0.00	3968.33	235.70	235.70	3968.33

Period	Date:	GAT Div Shor	GAT Outflow	GAT EOP Elev	MAD EOP Elev	MAD Outflow	MAD Div Shor	GAT Diversio	MAD Diversio	MAD Div Requ	GAT Div Requ
	Sum =	9928.56	947154.00	52928.81	143576.44	1426109.38	0.00	2482180.75	149958.83	149958.83	2492109.25
	Max =	3905.46	18195.19	87.75	252.00	8639.07	0.00	4292.90	246.01	246.01	4292.90
	Min =	0.00	0.00	78.50	190.10	500.00	0.00	387.45	231.84	231.84	3733.91
	PMax=	603.00	228.00	12.00	24.00	624.00	1.00	3.00	5.00	5.00	3.00
	Avg =	15.91	1517.88	84.82	230.09	2285.43	0.00	3977.85	240.32	240.32	3993.76
	PMin=	1.00	355.00	355.00	317.00	4.00	1.00	603.00	10.00	10.00	9.00

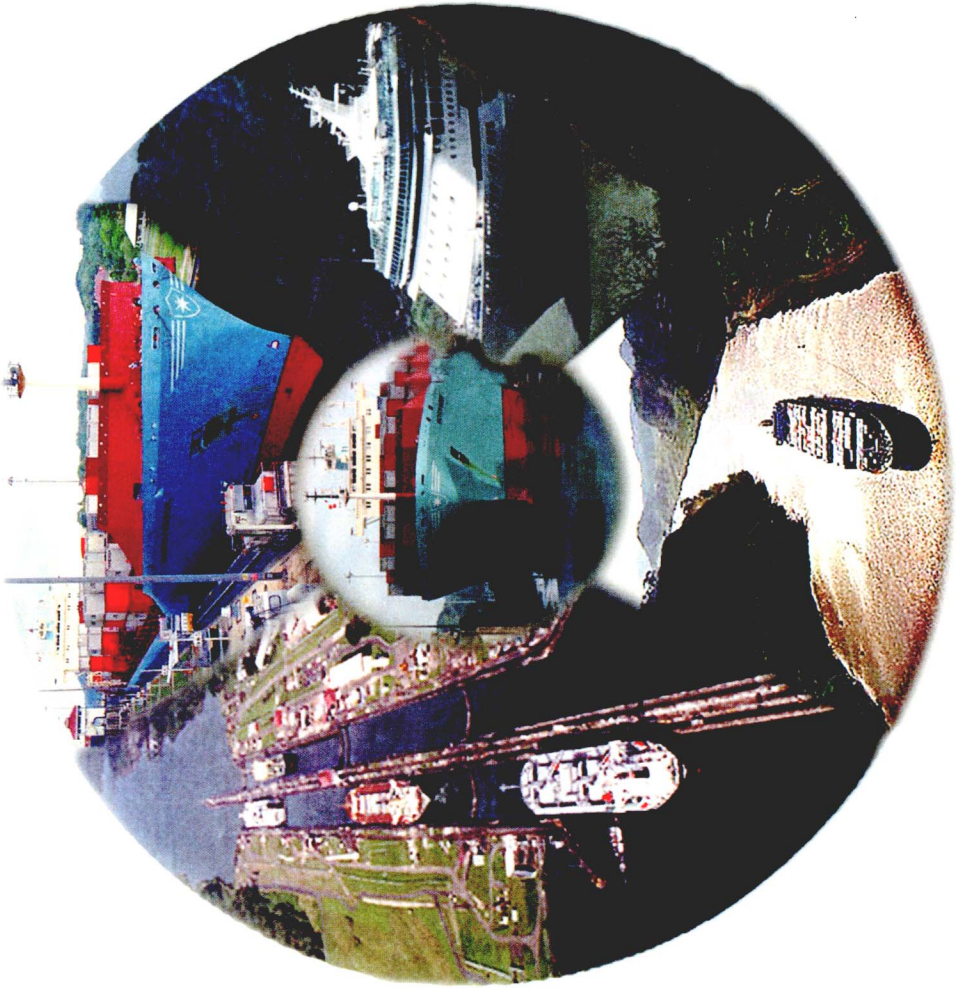
Period	Date:	GAT Evaporat (CFS)	MAD Evaporat (CFS)	GAT Level	MAD Level	GAT EOP Stor (AC-FT)	MAD Energy G 1000 kWh	GAT Energy G 1000 kWh	MAD Power He (FT)	MAD Plant Fa	GAT Plant Fa
605	1May 1998	447.00	22.23	1.00	2.00	3536150.00	8270.92	0.00	101.10	0.31	0.00
606	1Jun 1998	371.45	17.67	2.12	2.00	3621350.00	10456.77	0.00	101.10	0.40	0.00
607	1Jul 1998	376.86	23.60	2.14	2.85	3634565.00	2867.09	0.00	114.33	0.11	0.00
608	1Aug 1998	366.83	24.33	2.65	2.21	3941317.00	22021.04	0.00	117.74	0.82	0.00
609	1Sep 1998	464.92	34.78	2.70	2.79	3997448.00	2971.99	0.00	122.47	0.11	0.00
610	1Oct 1998	457.02	34.53	2.95	2.46	4248565.00	18080.66	0.00	129.99	0.68	0.00
611	1Nov 1998	398.02	29.98	2.86	2.49	4305696.00	3185.30	0.00	131.26	0.12	0.00
612	1Dec 1998	342.43	31.36	3.00	2.86	4480650.00	3682.85	2052.91	146.87	0.14	0.11
613	1Jan 1999	528.34	53.60	2.90	2.95	4312086.00	3947.73	0.00	157.43	0.15	0.00
614	1Feb 1999	592.26	60.36	2.93	2.67	4269485.00	25321.38	0.00	149.89	1.05	0.00
615	1Mar 1999	601.27	63.72	2.72	3.18	4038704.00	3621.57	0.00	144.42	0.14	0.00
616	1Apr 1999	433.58	47.01	2.76	3.10	4008555.00	25637.51	0.00	141.65	0.99	0.00
617	1May 1999	453.61	34.14	2.93	3.02	4113244.00	24652.54	0.00	131.81	0.92	0.00
618	1Jun 1999	373.98	26.81	3.00	3.04	4156820.00	23174.67	15146.09	128.04	0.89	0.88
619	1Jul 1999	391.09	29.16	3.00	3.00	4156820.00	22023.24	11596.88	127.75	0.82	0.65
620	1Aug 1999	388.13	31.65	3.29	3.00	4211888.00	21786.84	17856.00	130.55	0.81	1.00
621	1Sep 1999	436.99	38.70	3.00	3.29	4188100.00	9021.50	15346.92	138.90	0.35	0.89
622	1Oct 1999	436.05	42.08	3.00	3.00	4282800.00	16473.78	6308.62	145.67	0.62	0.35
623	1Nov 1999	373.55	39.90	4.00	3.00	4442800.00	16246.44	17280.00	152.69	0.63	1.00
624	1Dec 1999	312.80	37.13	3.00	3.00	4480650.00	28123.20	17856.00	160.52	1.05	1.00

Period	Date:	GAT Evaporat	MAD Evaporat	GAT Level	MAD Level	GAT EOP Stor	MAD Energy G	GAT Energy G	MAD Power He	MAD Plant Fa	GAT Plant Fa
	Sum =	371230.03	36538.88	1813.39	1864.86	**********	10037028.00	3174322.00	88198.23	381.92	179.86
	Max =	1026.55	132.44	4.00	4.00	4480650.00	28123.20	17856.00	163.00	1.05	1.00
	Min =	306.34	17.67	1.00	2.00	3536150.00	2686.32	0.00	101.10	0.10	0.00
	PMax=	592.00	87.00	23.00	85.00	12.00	1.00	12.00	85.00	1.00	12.00
	Avg =	594.92	58.56	2.91	2.99	4172128.75	16084.98	5087.05	141.34	0.61	0.29
	PMin=	598.00	606.00	355.00	317.00	355.00	597.00	2.00	603.00	353.00	2.00

Period	Date:	CHA Inflow (CFS)	CHA Outflow (CFS)	CHA Case	CHA Level	CHA Energy G 1000 kWh	CHA Evaporat (CFS)	CHA EOP Elev (FT)	CHA Q-Spill (CFS)	CHA Power He (FT)	CHA Plant Fa
605	1May 1998	1397.00	1137.20	0.06	2.08	11413.21	4.83	524.28	0.00	187.05	0.44
606	1Jun 1998	848.00	1107.62	0.05	2.00	10755.16	3.84	508.02	0.00	187.05	0.43
607	1Jul 1998	1093.00	1089.45	0.05	2.00	10454.57	3.55	508.02	0.00	178.92	0.41
608	1Aug 1998	1198.00	105.00	0.00	2.28	1077.12	4.49	563.62	0.00	209.46	0.04
609	1Sep 1998	1206.00	1251.50	0.06	2.24	15187.39	7.26	561.63	0.00	233.53	0.61
610	1Oct 1998	1182.00	105.00	0.00	2.43	1302.68	7.28	600.56	0.00	253.32	0.05
611	1Nov 1998	1360.00	105.00	0.00	2.62	1443.17	8.00	634.59	0.00	289.99	0.06
612	1Dec 1998	1936.00	1422.51	0.06	2.65	23824.39	7.71	646.80	0.00	311.59	0.93
613	1Jan 1999	1086.00	105.00	0.00	2.88	1691.61	13.01	667.53	0.00	328.95	0.06
614	1Feb 1999	848.00	105.00	0.00	4.00	1601.73	17.67	680.36	0.00	344.85	0.07
615	1Mar 1999	524.00	1483.27	0.06	2.97	25668.00	19.59	661.19	95.46	341.68	1.00
616	1Apr 1999	619.00	717.82	0.05	3.18	12273.87	14.03	659.05	0.00	331.02	0.49
617	1May 1999	906.00	1447.08	0.06	3.38	25200.00	11.34	646.38	0.00	323.95	0.98
618	1Jun 1999	1279.00	1430.33	0.06	3.13	23467.18	9.05	642.63	0.00	315.41	0.94
619	1Jul 1999	1598.00	1430.42	0.06	3.27	24253.24	9.89	646.44	0.00	315.44	0.94
620	1Aug 1999	1900.00	1445.02	0.06	3.35	25067.14	10.65	656.99	0.00	322.70	0.98
621	1Sep 1999	1562.00	1427.20	0.03	3.00	24428.46	11.86	659.32	0.00	329.05	0.98
622	1Oct 1999	1429.00	791.09	0.05	3.29	14220.74	12.31	671.57	0.00	336.34	0.55
623	1Nov 1999	1840.00	1454.03	0.03	3.00	24840.00	11.37	678.67	83.62	346.02	1.00
624	1Dec 1999	4477.00	3902.80	0.06	4.04	25668.00	10.23	689.63	2567.41	355.09	1.00

Period	Date:	CHA Inflow	CHA Outflow	CHA Case	CHA Level	CHA Energy G	CHA Evaporat	CHA EOP Elev	CHA Q-Spill	CHA Power He	CHA Plant Fa
	Sum =	659289.00	651548.19	25.59	1952.6310	731681.00	10708.21	409352.56	32846.37	204100.05	425.19
	Max =	4477.00	3902.80	0.06	4.52	25668.00	37.48	689.63	2567.41	372.06	1.00
	Min =	169.00	105.00	0.00	2.00	1077.12	3.55	508.02	0.00	178.92	0.04
	PMax=	624.00	624.00	4.00	401.00	1.00	87.00	624.00	624.00	1.00	1.00
	Avg =	1056.55	1044.15	0.04	3.13	17198.21	17.16	656.01	52.64	327.08	0.68
	PMin=	567.00	9.00	9.00	604.00	608.00	607.00	604.00	2.00	607.00	608.00

Part 1
Dam Type Selection



FEASIBILITY DESIGN FOR THE UPPER CHAGRES WATER SUPPLY PROJECT

APPENDIX D
PART 1

DAM TYPE SELECTION

Prepared by

MWH

In association with

TAMS
AN EARTH TECH COMPANY

FEASIBILITY DESIGN FOR THE UPPER CHAGRES WATER SUPPLY PROJECT

APPENDIX D, PART 1 – DAM TYPE SELECTION

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ATTACHMENTS

Attachment 1a	Hydraulic Analysis for Design of Diversion Tunnel and Cofferdam
Attachment 1b	Drawdown Analysis
Attachment 1c	Evaluation of Spillway Size
Attachment 2	Comparative Cost Estimate

FOREWORD

The studies described in this appendix have been performed in accordance with the scope of services for Contract CC-3-536 - Work Order 011, Feasibility Design and Related Services for the Upper Chagres Water Supply Projects entered into on June, 2000. This appendix covers the selection of the type of dam for the Upper Chagres project to be further evaluated in the feasibility studies.

These studies have been prepared using the following basic information:

- Reconnaissance Study: Identification, Definition, and Evaluation of Water Supply Projects, prepared by the U.S. Army Corps of Engineers, Mobile District, dated August 1999; Topographic mapping of areas of the proposed dam site prepared by Ingenieria Avanzada, S.A. under subcontract to MWH. Services were completed and submitted to the ACP under Contract CC-3-536, Task Order 10, Altimetric and Planimetric Survey of the Upper Chagres Damsite;
- Additional topographic mapping of the dam site developed by digitizing 1:50,000 scale maps obtained from Instituto Geografico Nacional (Tommy Guardia);
- The results of hydrology and meteorology studies presented in the companion Appendix A, and;
- Geological and geotechnical information obtained from two dam site exploration and mapping field programs, and a construction materials investigation program, including both test pit sampling and laboratory testing, as presented in the companion Appendix B.

1 INTRODUCTION

As part of a reconnaissance study, the Mobile District assisted ACP to identify and rank 17 water supply projects to augment the existing canal water supply system. The Upper Chagres Water Supply Project was identified as one of the highest ranked projects, and has been selected for study at the feasibility level. The dam site selected in the reconnaissance study is located about 5 km west of Lake Alajuela on the southwest-flowing Río Chagres, Exhibit 1. The location was selected to provide the maximum size reservoir. Two reservoir elevations were considered in the reconnaissance study: 200 m above mean sea level (El. 200) and 220 m above mean sea level (El. 220). The maximum reservoir elevation is limited to about El. 250 by topography at the dam site. For a normal pool level of El. 220, no saddle dams are required.

The dam type selected in the reconnaissance study was a center core rockfill dam with a crest at El. 225, providing a full supply level of El. 220.0, and a maximum reservoir flood level of El. 224. An ungated spillway was located on the right abutment. The proposed spillway had a crest width of 286.5 m and a capacity of 4,430 m^3/s. The spillway chute was proposed as a sloped and stepped natural rock cut channel.

The project also included a hydropower facility at the dam and a transmission line, as well as construction of access roads and other facilities required for this remote location. Exhibit 2 is an area map showing the reservoir.

2 DAM TYPES AND DEVELOPMENT CRITERIA

This section contains a description of the types of dams that have been considered and the criteria used in sizing the facilities and appurtenant features. Features common to all dam types are also identified, but not included in subsequent comparison.

2.1 General Criteria

General criteria have been established primarily for the dam type selection. It is anticipated that they will be modified as a result of additional studies performed to optimize the selected dam. The general criteria for dam type selection are as follows:

- The dam will be located at the damsite identified in the reconnaissance study;
- The reservoir full supply level will be at El. 220;
- The reservoir low supply level will be at El. 180;
- Ungated spillway widths of 50 m and 100 m were selected. These limit the flood surcharge to El. 228.4 and 226.9, respectively;
- The dam crest will be at El. 227.4 with an upstream parapet wall to EL. 229.4 for the 50-m wide spillway, and;
- The dam crest will be at El. 225.9 with an upstream parapet wall to EL. 227.9 for the 100-m wide spillway.

As a result of these criteria, the gross storage at full supply level will be 682 million cubic meters (MCM). The live storage between El. 220 and El. 180 is estimated to be 465 MCM. This is lower than the live storage of 519 MCM reported in the Reconnaissance Report.

2.2 Alternative Dam Types

The dam types considered for this study are the following:

Table 1: Alternative Dam Types

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

Alternatives 3 and 4 were considered, but not carried forward for study for the following reasons:

Alternative 3, Conventional Gravity Concrete Dam, will have the same basic geometry as Alternative 2, RCC. Experience over the last 15-20 years is that RCC gravity dam unit construction costs are lower than those for conventional gravity dams, primarily owing to the lower cement content (and therefore cost), as well as less formwork and faster construction. Cost comparisons performed for the Río Indio and the Río Cano Sucio Water Supply Project dams showed the RCC alternative to cost less than a conventional gravity concrete dam. Therefore, Alternative 2 is expected to provide the same benefits and reliability at lower cost. Consequently, a conventional gravity concrete dam was not considered further.

Alternative 4, Earth Core Rockfill Dam, requires a substantial source of suitable impervious material for the core, as well as a relatively long dry season construction period. As presented in Appendix B, Geology, and discussed in Section 3 of this appendix, suitable sources and quantities of impervious material were not located in the vicinity of the dam site. Some heterogeneous sources of impervious materials were identified near the site, and residual soils are available around the dam site. If of sufficient quantity, these sources would require a piece-meal exploitation procedure resulting in higher costs and unfavorable environmental consequences. The quality of the materials is also quite variable impacting the overall quality of any potential core constructed using them. Experience has shown that unless there are suitable sources of core material in

close proximity to the dam site, a CFRD is more economical than an ECRD. In addition, the average annual rainfall is approximately 3,200 mm, and the extended wet season of eight months, will result in a longer construction period for this type of dam than for a CFRD and at a higher cost. The longer construction period will require increased flood protection for similar levels of protection, also resulting in higher cost. The ECRD alternative was, therefore, discarded, and is not considered further.

2.3 Dam Site Location

The dam site is located on the Río Chagres about 500 m downstream of the confluence with the Río Chico and about 15 river km upstream of Lake Alhajuela (Lake Madden) It is located approximately 25 km north of Panama City and 30 km east of Lake Gatun.

The axis used for this study was selected primarily to maximize storage and for topographical considerations. It takes advantage of a relatively narrow reach of river valley to reduce the volume of the dam types. The space available for the upstream cofferdam and diversion facilities is restricted, however other potentially suitable axes located upstream and downstream of the selected axis would either eliminate a portion of the reservoir along the Río Chico, or require construction of a substantial saddle dam. There are no adverse access difficulties. The final alignment of the dam will be confirmed following the site investigation program during final design.

2.4 Spillway Design Flood

The spillway will be designed for the probable maximum flood (PMF). For a project whose failure would result in loss of human life and economic endeavor, it is customary to design the project for the worst conditions that could reasonably be postulated, i.e. the probable maximum precipitation (PMP) resulting in the PMF.

Estimating the PMF consists of analyzing the basic factors that cause the occurrences of great floods, maximizing these factors to their highest reasonable physical limits, and then combining them within acceptable conditions from a hydrologic point of view, in a manner which produces the maximum flood. The studies to determine the PMF are presented in Appendix A, Hydrology and Meteorology.

The maximum peak inflow of the PMF is estimated to be 9,940 m^3/s. The PMF has a 3-day volume of about 270 MCM.

2.5 Diversion Flood and Diversion Works

The selected diversion flood will impact the cost of the diversion tunnel(s) and cofferdams. For this dam type selection study, the following aspects of dam construction were taken into consideration:

1. Conversion of the diversion tunnel to a low level outlet for control of reservoir filling and emergency drawdown of the reservoir;
2. The length of time and cost of repair to critical components of the project that would be subject to damage due to flooding during construction, and;
3. Diversion structure cost differences for alternative dam types.

At this stage of study, the length of time at risk and cost of repair to components of the project that could be impacted by a flood during construction are not known with any certainty. Based on a preliminary assessment, both RCC and CFRD-type dams will be constructed to a level above the proposed upstream cofferdam elevations in one to two years after diversion facilities are completed respectively. There is less than a 5% probability that a flood greater in magnitude than the 50-year return period flood will occur in two years. Therefore, for dam type selection, the diversion flood adopted for the CFRD dam is the 50-year return period. For the dam type comparison, the RCC dam diversion flood is selected as the 25-year return period flood. For a flood-risk time that is one year less than the CFRD, this flood frequency results in the same probability of exceedance.

Flood peaks for selected return periods from Appendix A, and are presented below:

Table 2: Flood Peaks for Selected Return Periods

Return Period (Years)	Flood Peak (m^3/s)
2	955
5	1,400
10	1,710
20	2,000
25	2,110
50	2,420
100	2,740

Hydraulic analyses for several alternative diversion flood cases and diversion facilities have been prepared. They are presented in Attachment 1a, Hydraulic Analysis for Design of Diversion Tunnel and Cofferdam. The analysis includes development of a tailwater rating curve, diversion tunnel/culvert analysis and reservoir routing of the selected floods for several diversion tunnel capacities.

The flood routing analysis showed that the cofferdam does not significantly attenuate the large diversion flood, and that two diversion tunnels will be required. Tunnel size/cofferdam height optimization studies show that reducing the tunnel capacity will require high cofferdams, over 30 m. Given the short dry season (from January to April), the maximum practical cofferdam height and size is limited.

For both the CFRD and RCC Dam alternatives, conventional dumped/compacted embankment fill cofferdams were considered. Layout studies showed that the cofferdam could not be constructed for the CFRD without severely impacting the tunnel diversion arrangement. Therefore, an alternative cofferdam plan is proposed utilizing a small dry season cofferdam to divert flow through the diversion tunnels, while a RCC cofferdam is constructed. The RCC cofferdam can be constructed to the required height within the dry season, and will then be permanently incorporated into the CFRD as the upstream plinth.

The RCC dam could be constructed behind a conventional cofferdam. However, at a minimum, construction of the upstream portion of the RCC dam can be accomplished within the three-month dry season. Therefore, the selected diversion plan for the RCC

dam includes construction of a cofferdam that will form part of the final dam, thereby eliminating the need for an embankment fill cofferdam.

Provision of drawdown capability is most easily and cost effectively achieved by conversion of the diversion facilities to a low level outlet. For this dam type selection study the following criteria and assumptions were adopted for sizing the emergency drawdown facilities:

1. Drawdown requirements were adopted for a significant hazard, significant risk dam in accordance with U.S.B.R. ACER Technical Memorandum No. 3, 1982;
2. The average annual inflow is 30.2 m^3/s;
3. A provision for sediment build-up will be made.

Emergency drawdown studies are presented in Attachment 1b, Drawdown Analysis. Drawdown studies showed these requirements are met by one of the double tunnels required for diversion. Therefore, one of the two diversion tunnels will be constructed to serve as an emergency drawdown facility.

Preliminary layouts have been prepared for both the CFRD and the RCC dam. The dam site topography favors diversion tunnels through the right abutment. The design flood and diversion facilities selected for the dam type study are listed below.

For the CFRD,

1. A 50-year event, with a peak inflow of 2,420 m^3/s, is selected as the design flood;
2. The diversion tunnels will be two 8.0-m diameter, D-shaped tunnels, 520-m long tunnels. An access shaft adjacent at the dam crest centerline on the right abutment will provide access to the emergency drawdown gates installed in one of the two tunnels;
3. Maximum discharge of the diversion tunnels will be 1,680 m^3/s, and;
4. The upstream cofferdam will have a crest at El. 121.0;
5. A minimal downstream cofferdam is required of one or two meters height.

For the RCC dam,

1. A 25- year event with a peak inflow of 2,110 m^3/s, is selected as the design flood;
2. The diversion tunnels will be two 7.0-m diameter, D-shaped tunnels, 410-m long tunnels. An access shaft adjacent at the dam crest centerline on the right abutment will provide access to the emergency drawdown gates installed in one of the two tunnels.
3. Maximum discharge of the diversion tunnels will be 1,340 m^3/s;
4. The upstream cofferdam will have a crest at El. 122.0 m, and;
5. A minimal downstream cofferdam is required of one or two meters height.

2.6 Spillways

In the reconnaissance study, the USACE selected an ungated spillway located on the left abutment. It was proposed with a crest width of 286.5 m (measured as the open width of the control structure) and a capacity of 4,430 m^3/s and a sloped and/or stepped natural rock cut channel spillway chute. Review of the supporting cost information showed this to be a relatively expensive spillway arrangement.

ACP has indicated a preference for an ungated spillway because of its lower operation and maintenance costs. From earlier studies of spillways for the similar Río Indio Water Supply Project, ungated and gated spillways of this capacity were determined to have substantially the same initial construction cost for CFRD dams. The RCC dam alternative was also of similar cost for both ungated and gated spillways.

Therefore, for this dam type selection analysis, an ungated spillway was used. For the selected alternative, a gated option will be evaluated to see if there are any significant cost savings. The crest of the ungated spillway was set at El. 220.0, and flood routing performed for several widths with hydraulic widths varying from 25 m to 350 m (to bracket the width selected for the Reconnaissance study). These are presented in Attachment 1c, Evaluation of Spillway Size.

The flood routing analysis showed that the difference in surcharge between a 286-m wide spillway and a 100-m wide spillway is about 2 m. The flood routing studies showed that

the flood surcharge begins to increase rapidly for spillway widths less than about 100 m. Based on this information and topographic conditions at the site, a 100-m spillway width was selected for use in this study for the CFRD.

Layout studies for RCC dam led to selection of a narrower spillway width and correspondingly higher dam crest elevation. A 100-m wide ungated spillway over the RCC dam required a plunge pool that was wider than the river channel, resulting in major excavation in the river channel abutments. An ungated spillway width of 50-m reduced plunge pool related excavation. Therefore two different spillway widths were selected for the CFRD and RCC alternatives.

For the dam type selection study, an ungated crest width of 100 m is selected for the CFRD alternative, with a corresponding maximum water surface at El.226.9. An ungated crest width of 50 m is selected for the RCC alternative, with a corresponding maximum water surface at El.228.4. Additional dam height and spillway width optimization will be performed as part of the selected dam type optimization.

2.6.1 Ungated Spillway for CFRD Alternative

Layouts for an ungated spillway adjacent to the CFRD showed the right abutment to have preferable topographical characteristics. The left abutment is considerably steeper and higher than the right abutment, which would, if possible, require excavating a significant portion of the hillside and would result in more difficult construction access. In addition, the chute would terminate at an unfavorable angle to the downstream river channel, would require a stilling basin, or would need to be increased in length.

The chute spillway would include an approach channel excavated to El. 213. The spillway ogee crest would be at El. 220.0, the reservoir full supply level. The selected open spillway width to pass the PMF is 100.0 m. The maximum discharge is 4,158 m^3/s. A spillway bridge will span the ogee from the dam crest to the right abutment. The spillway chute will taper to 48 m at the flip bucket. The chute will have an overall length of about 450 m, and a drop of approximately 120 m. A smooth concrete chute will be provided with training walls of about 4 m. The flip bucket will have a lip at El. 93 that is one meter above the expected maximum tailwater elevation under PMF conditions. All spillway structures will be constructed of conventional mass or reinforced concrete

founded on rock. Anchors and drains under the spillway chute are also provided. The spillway will discharge back into the Río Chagres by means of a short excavated discharge channel.

2.6.2 Ungated Spillway for RCC Alternative

The ungated spillway for the RCC alternative will be located on the dam and aligned to discharge into the Río Chagres. It will include a crest at EL. 220.0 m and an open crest width of 50 m. The crest road will be supported by means of two piers. A smooth chute of conventional concrete will be provided with training walls. The spillway chute will terminate in a flip bucket at El. 115.

A smaller spillway width of 50 m was used for the RCC alternative due to the width of the river channel and the orientation of the dam axis with respect to the river channel. The river channel is approximately 50 m wide downstream of the dam in the area where the spillway jet will impact. Topographic conditions at the abutments required the dam axis being positioned such that it is approximately 20 degrees from perpendicular to the river channel and abutment slopes. The spillway was positioned along the dam axis such that the discharge jet impact zone and required plunge pool excavation will not impinge on the steep left abutment slope and potentially lead to slope instability.

2.7 Other Features

In addition to the dam and spillway, there are a number of other features that comprise or are required for construction of the Upper Chagres Water Supply Project including:

- Cofferdams;
- Saddle Dams;
- Multi-level Outlet Structure;
- Hydropower Facilities;
- Access, and;
- Construction Area (laydown and around dam).

These are described below together with how they are addressed in the dam type selection study.

2.7.1 Cofferdams

Cofferdams will be constructed upstream and downstream of the project works and will be of sufficient height to protect the working area against flooding during the selected diversion flood. Due to space limitations, the upstream cofferdam will be constructed of RCC founded on competent bedrock, and will be incorporated into the structure of the main dam. A gallery will be constructed within the cofferdam for construction of the grout and drainage curtains. The downstream cofferdam will be constructed of random fill.

2.7.2 Saddle Dams

Creation of a reservoir with a normal full supply level at El. 220 m will not require construction of saddle dams.

2.7.3 Minimum Release Facility

Provisions for a minimum release facility are required for the Upper Chagres Water Supply Project to provide control of downstream releases to maintain water quality and ecological flows between the project and Lake Alhajuela. The outlet structure will be sized to provide the minimum release equivalent to 10% of the mean annual flow or 3.0 m^3/s. It is anticipated that a multi-level intake will not be required for this facility based on water quality modeling for Lake Gatun, Lake Alajuela and at the Rio Indio Water Supply Project. A separate minimum release facility will only be required if a hydropower plant is not included in the project, as the minimum release would be made through the hydropower facility.

The relatively small structure will be constructed on the upstream face of the RCC and CFRD dam type alternatives, or incorporated into one of the diversion tunnels. Slide gates or valves will be housed in the intake structure. Discharge will be through the intake structure to a steel pipe located at dam foundation elevation or in the diversion tunnel. The required pipe diameter will be about 2.0 m. The pipe will terminate at a

flume and control valve for measurement and variation of required minimum releases. Differences in complexity and cost of a minimum release facility for a CFRD compared with a RCC dam are too small to be captured in this dam type comparison study. Therefore, the minimum release facility is not included in the dam type selection cost comparison.

2.7.4 Hydropower Facilities

The project has been planned with provision for incorporating hydroelectric generation. On-going studies are being performed to identify the generation potential and the hydropower facilities that will be constructed at the Upper Chagres dam.

For the dam type selection studies, the principal cost difference is the intake structure and power tunnel required for the CFRD alternative. The hydropower tunnel will not be larger than the diversion tunnels, therefore one of the tunnels could be adapted for hydropower for either the CFRD or the RCC dam. The RCC dam could also be constructed with intakes for a hydropower facility, with the powerhouse located immediately downstream of the dam. If an RCC dam is selected, additional studies will be performed to evaluate the two alternatives. However, for the dam type study, both dam types are assumed to have the same costs for addition of hydropower.

2.7.5 Access

New access roads (and bridges) to the dam site and to quarries will be required. Access roads are not specifically included in the dam type selection study as cost differences are small and have not been defined.

2.7.6 Construction

Construction camps and facilities will be required prior to commencement of the main Upper Chagres dam and facilities construction contract. For the dam type selection study, they have been estimated to be similar and have not been included in comparative cost estimates. The RCC dam will require specific installations for material storage and handling and the costs of these installations are included in the general costs of the RCC.

3 GEOLOGIC AND GEOTECHNICAL CHARACTERISTICS

Geologic and geotechnical information used as the basis for input to the dam type selection process was obtained during a visit to the proposed Upper Chagres dam site in May 2002. Investigations included general reconnaissance of the project area, basic geologic mapping at the damsite, identification of potential construction material sources, and material sampling and testing. Additional investigations to explore subsurface conditions were carried out during June and July, 2002. The program involved drilling 8 boreholes to investigate subsurface conditions in the dam abutments and along the proposed diversion tunnels. The program also included water pressure testing and laboratory testing of soil and rock samples collected during the program. The results of these investigations are presented in Appendix B, Geology, Geotechnical and Seismological Studies, of the main report.

Only those geologic and geotechnical characteristics pertinent to the dam selection studies are addressed in this section. A more detailed description of the local geology and geotechnical characteristics is contained in Appendix B.

3.1 Site Geology

Bedrock units at the Río Chagres dam site area consist of Cretaceous age volcanic rocks, mostly andesite flows with minor agglomerate units, belonging to the Igneous Basement Complex. Other volcanic and intrusive igneous formations also belonging to Igneous Basement Complex occur in the reservoir area. Sedimentary rock units also occur in the Upper Chagres region near the outlet into Lake Alajuela, but based on site reconnaissance, there is no evidence that they occur in the dam site area.

The damsite on the Río Chagres is located approximately 500 meters downstream of its confluence with the Río Chico. At the damsite, the Río Chagres flows south in a deeply incised meanders that form an asymmetrically shaped valley exhibiting nearly 300 meters of relief. The meanders seem to be controlled by structural features in the rock mass. Relatively steep slopes on the left abutment contrast with more gradual slopes of the right abutment. The valley floor in the vicinity of damsite is on the order of 50 meters wide

and contains alluvial terraces and gravel and boulder bars. Bedrock is exposed almost continuously along the riverbanks, and in several places along the river bed.

Both abutments are densely vegetated with primary and secondary forest growth, and are almost entirely covered with residual soils and colluvium. Most of the dam site area is characterized by a moderately deep weathered profile with locally thick soil cover typical of the sub-tropical climate.

Rock outcrops can be observed throughout the site area on both abutments, especially along the river bank and in side gullies. Bedrock at the dam site is found to consist mostly of fine-grained andesite and less commonly of andesitic agglomerate. The andesite is thick-bedded to massive in nature. Based upon reconnaissance mapping subsurface exploration, it is considered that the same rock types occur in the foundation areas of all proposed principal structures and on both sides of the river. It is also interpreted that sound, strong bedrock.

Alluvial terrace deposits are found along the river in many locations. Terrace deposits consisting primarily of clean sands and gravels are mainly found on the inside of meander bends, while the gravel and boulder bars are typically found along straight sections of the river channel. Several boulder bars can be observed at places where apparently more resistant rock controls the river gradient. The terrace deposits are located up to 5 to 10 m above the present river level.

3.2 Materials Available for Construction

Materials available in the vicinity of the proposed dam site include alluvial deposits in terraces and the river bottom, overburden, and rockfill from quarry operations.

Alluvial Deposits. Deposits of clean alluvial sands and gravels were observed along much of the Río Chagres; mainly as terraces and bar deposits on the inside of meander bends and along the sides of the river channel, and as bed load in the river channel. These deposits are locally of small volume and limited in extent. Sufficient quantities of these materials were not identified within reasonable distance of the dam site to warrant their use as a construction material. They are therefore not considered a suitable or economic material resource for the

construction of the project, although they may be used for road construction and construction camp construction.

Colluvial and Residual Soils. Most of the bedrock in the project area is covered by well-developed horizons of colluvial and residual soils. These materials were tested in the laboratory and were found to be suitable for use as impervious fill. However, its use as core material in ECRD construction is inconvenient because of its high moisture content.

Andesite. The exploration carried out to date shows that the andesite rock is covered by a thick mantle of residual soil, saprolite, and highly weathered rock. Development of a quarry will require the removal of about 20 m or more of these materials. The andesite rock is hard and durable, and preliminary information indicates it could be used for filters, concrete aggregate, and rockfill. The drilling results indicated a rather high degree of fracturing in some areas; however, observations at the site indicated a strong competent rock. It the rock mass is highly fractured, flatter slopes may be required for the CFRD.

Material for construction of diversion cofferdams will be obtained from locally available random fill exploited from the immediate vicinity of the dam site. Materials for coarse and fine concrete aggregates, filters and drains will need to be manufactured from quarried material, or imported from sources off-site. Quarries can be developed in the local andesite, or farther away from basalt necks. This quarry or quarries will also be available to exploit material for any required rockfill.

3.3 Geotechnical and Geologic Design Considerations

Generally, the geologic and geotechnical factors that most influence selection of dam type fall into the following categories:

- General foundation bedrock acceptability, including sliding resistance and deformation characteristics of foundation;
- Required excavation depths to achieve acceptable foundation materials;

- Measures required to treat the foundation to improve physical properties and control leakage;
- Long-term performance of the foundation under normal operation conditions and extreme events, especially earthquake; and
- Availability of suitable construction materials.

Such geological and geotechnical factors can have direct influence on the development of comparative construction costs and were taken into consideration during the study of dam type alternatives.

- **Foundation Bedrock Characteristics**. In general, the andesite foundation bedrock at the site should provide an excellent foundation for all types of structures being considered. This type of foundation material is not expected to present any significant constraints on project development that cannot be taken care of with appropriate design details and construction practices.

  - *Bearing Capacity*. The andesite bedrock at the site is strong and is expected to present adequate bearing capacity to support any of the structures being considered. Differential settlements should not be a concern with this type of foundation. Additional data from subsurface investigation and testing will be needed to develop design and construction details for foundation treatment.
  - *Resistance to Sliding*. The andesite should provide adequate resistance to sliding along discontinuities and at foundation-structure interfaces, provided excavation depths are sufficient to achieve fresh sound bedrock.

- **Excavation Depths**. Based upon preliminary subsurface investigations and observations made at the site an average overburden thickness (depth to top of weathered rock) varying from about 5 m in the river channel to about 13 m in the upper abutments can be assumed. The depth to the top of competent rock varies between about 10 m in the river bottom to about 25 m in the upper abutments. These values can be used in the development of preliminary layouts and in the computation of quantity takeoffs for cost estimates.

- **Foundation Improvement, Treatment, and Long-Term Performance**. No special foundation improvement or treatment measures are expected for the Río Chagres site that would influence selection of one dam type over another. Similarly, the andesite bedrock is expected to perform satisfactorily over the lifetime of the project without adverse deterioration.

- **Natural Slope Stability**. No large mass movements are expected to affect the reservoir, but the effect of saturation, say after intense rainfall, on the stability of residual soils and saprolites needs to be properly evaluated. This could be significant in design of safe spillway cuts.

Geotechnical design criteria used for developing preliminary layouts and cost estimates for dam type selection are presented in Table 3, following:

Table 3: Summary of Geotechnical Design Parameters

Parameter	Selected Design Criteria
Thickness of overburden (top of weathered rock)	Varies; 5 m in river channel to 12.5 m in abutments
Depth to top of competent rock	Varies; 10 m in river channel to 25 m in abutments
Rock Excavation Slopes	0.2H : 1V, 3-m-wide benches every 10 m vertically
Soil Excavation Slopes – Permanent	1.5H : 1V, 3-m-wide benches every 10 m vertically. Bench at soil-rock contact
Soil Excavation Slopes – Temporary	1H : 1V, 3-m-wide benches every 10 m vertically. Bench at soil-rock contact

4 ALTERNATIVE DAM TYPE LAYOUTS

This section gives a brief description of both of the alternative dam type development concepts and highlights the pertinent differences between them.

4.1 Concrete Face Rockfill Dam

A site plan of the concrete faced rockfill dam (CFRD) is presented in Exhibit 3. The general arrangement shows the dam, cofferdams, diversion tunnel alignments and spillway. Exhibit 4 shows a profile and sections through the CFRD. Exhibits 5 and 6 show the plan, profile and sections through the diversion tunnels and spillway, respectively.

The centerline of the dam alignment was selected to minimize excavation and fill volume. The upstream and downstream cofferdams were located to provide adequate construction and laydown areas while minimizing the length of diversion tunnels. Because of the height and space limitations upstream of the dam, an embankment fill upstream cofferdam could not be developed for the proposed diversion tunnel alignments. Therefore, an RCC cofferdam has been developed that can be incorporated into the main structure of the dam. A pre-cofferdam will be constructed upstream of the RCC cofferdam to allow for dewatering of the site for foundation excavation and consolidation grouting. A gallery will be included within the cofferdam for construction of the required grouting curtain and drains at the toe of the main dam. In addition to consolidation grouting beneath the plinth of the CFRD and the heel of the RCC dam alternatives, a grout curtain cutoff will be constructed to a depth of 40% of the hydraulic head. A small (2 m high) downstream cofferdam will be located at a distance downstream of the dam so as to allow sufficient space for construction access and laydown areas.

The CFRD will be constructed of selected rockfill obtained from nearby rock quarries. For the dam type selection, the slopes of both the upstream and downstream faces are 1.4H:1.0V, reflecting the relatively low seismicity of the location. These slopes will be optimized during subsequent studies when stability analyses are performed. An upstream parapet wall extending 2 m above the fill, and a downstream retaining wall of 1 m, will form the dam crest respectively.

The dam will be constructed with a conventional reinforced concrete upstream facing as an impermeable membrane. It will be designed to have (1) low permeability, (2) sufficient durability against weathering, and (3) sufficient flexibility to tolerate small expected embankment settlement. The concrete facing will be constructed of panels with intermediate vertical waterstops. A zone of fine gravel and sand will be placed beneath the concrete face to provide continuous support for the concrete facing. The gravel prevents movement of the sand bedding material that supports the concrete facing into the main rockfill. The zone will be about 3 m thick. It is expected that this support zone will be placed using an upstream-extruded concrete curb to provide confinement during compaction and protection against erosion during construction.

A reinforced concrete plinth, or toe slab (also used as the grouting platform), will be placed upstream and under the toe of the concrete facing. This plinth will be extended downstream, as needed, to lengthen the seepage path as required by the rock encountered. The plinth will be founded on competent rock.

The upstream cofferdam will be constructed of RCC and will be incorporated into the structure of the main dam. It will be founded on competent rock. The pre-cofferdam and downstream cofferdam will be constructed of random fill that will be obtained from portions of the required excavation for the main dam and spillway. The diversion tunnels will be located in the right abutment. They will be aligned to minimize tunnel length, and to facilitate conversion to a low level outlet for emergency drawdown. One diversion tunnel will be converted into a low-level outlet; a portion of this tunnel may require steel lining where it passes through a zone of relatively low cover beneath the upstream face of the dam. The alignment permits construction of an access shaft in the right abutment from the dam crest to an outlet control gate chamber in the diversion/low level outlet tunnel. The access shaft has been located just downstream of the dam crest.

Pertinent data is provided in Table 4, below.

Table 4: CRFD Design Parameters

Feature	Parameter	Selected Design Criteria
Dam Section		
	CFRD	
	Alignment	See Plan
	Crest elevation	225.9 m
	Parapet elevation	227.9 m
	Reservoir full supply level	220.0 m
	Crest width	8 m
	Upstream slope	1.4 H : 1 V
	Downstream slope	1.4 H : 1 V
	Concrete face thickness	0.3 - 0.5m, 0.4 m, av.
	Transition fill thickness	3 m
	Plinth width	4 m
	Foundation	
	Plinth	Competent rock
	Embankment	Weathered rock
	Material Volumes, m^3	
	Rockfill	9,469,000
	Filter	535,000
	Concrete	216,000
	Foundation excavation	3,219,000
Cofferdams		
	Upstream cofferdam	
	Type	RCC
	Alignment	See Plan
	Crest Elevation	121.0 m
	Fill Volume, m^3	100,500
	Foundation	Competent rock
	Upstream slope	Vertical
	Downstream slope	0.75 H : 1 V
	Downstream cofferdam	
	Type	Earth embankment
	Alignment	See Plan
	Crest Elevation	3 m
	Distance from dam	25 m (min)
	Upstream slope	2.5 H : 1 V
	Downstream slope	2.0 H : 1 V
	Crest width	5 m
	Freeboard	0.2 m

4.1.1 Ungated Spillway

The ungated spillway will be located in the right abutment. A crest road access bridge will span the spillway channel over the control structure. The spillway, chute and flip bucket are described in Section 2.6.1 Ungated Spillway for CFRD Alternative.

4.2 Roller Compacted Concrete Dam

The site plan, profile and sections for the RCC dam are presented on Exhibits 7 and 8; sections through the diversion tunnels are presented on Exhibit 9; and the plan and sections through the spillway are shown on Exhibit 10. The centerline of the dam is located on an axis that is slightly different from that of the CRFD. The cross section has been selected to provide adequate stability under the prevailing site conditions (low-to-moderate seismicity and moderate foundation strength) based on experience. The selected cross section will include a vertical upstream slope, and a downstream slope of 0.75H:1V. The crest will be 8-m-wide at El. 227.4, with a parapet wall to El. 229.4. An upstream cut-off grout curtain and an under-drainage system will be constructed. Pertinent data is provided in Table 5.

The current alternative assumes low-medium paste RCC, utilizing bedding mixes, as required, particularly at the rock-concrete interface, and at the upstream end of each lift, and an upstream impervious membrane, and drainage system. The impervious membrane and drainage system will be connected to a conventional reinforced concrete gallery situated above tailwater adjacent to the upstream toe. This gallery will be used for construction of the grout curtain and drainage curtain.

4.2.1 Ungated Spillway

As described in Section 2.6, Spillways, the ungated spillway will be smaller and have less hydraulic capacity than the CFRD ungated spillway. It will be located on the RCC dam to discharge directly by means of a chute and flip bucket into the existing Río Chagres channel. As discussed earlier, the Río Chagres channel is relatively narrow downstream of the dam, imposing width limitations on the ungated spillway. Therefore, to prevent downstream abutment instability, excavation of a plunge pool will be required in the right bank where the spillway jet will impact. A crest access bridge is provided across the

spillway. The spillway will be constructed of conventional reinforced concrete structurally connected to the RCC dam.

Table 5: RCC Design Parameters

Feature	Parameter	Selected Design Criteria
Dam Section		
	RCC and gravity	
	Alignment	See Plan
	Crest elevation	227.4 m
	Parapet Elevation	2 m
	Reservoir Full Supply Level	220.0 m
	Crest width	8 m
	Upstream slope	0 H : 1 V
	Downstream slope	0.75 H : 1 V
	RCC uncompacted section downstream	0.5 m
	Foundation	Competent rock
	Material Volumes, m^3	
	RCC	2,685,000
	Conventional concrete	121,000
	Foundation excavation	1,679,000
Cofferdams		
	Upstream cofferdam	
	Type	RCC
	Alignment	See Plan
	Crest Elevation	22.5 m
	Fill Volume, m^3	100,500
	Downstream cofferdam	
	Type	Earth embankment
	Alignment	See Plan
	Crest Elevation	3 m
	Distance from dam	25 m (min)
	Crest width	5 m
	Freeboard	1 m
	Upstream slope	Vertical
	Downstream slope	0.75 H : 1 V
	Foundation	
	Impervious Element	2 m
	Shells	2 m

5 EVALUATION OF THE ALTERNATIVE DAM TYPES

The objective of the dam type evaluation is to select the dam type to be included in the project arrangement. The evaluation process will also be used to identify specific aspects of the selected dam type that require additional study.

5.1 Factors Considered in Dam Type Selection

The evaluation of the alternative dam types is based on the following factors:

1. Construction cost;
2. Construction considerations;
3. Foundation considerations, and;
4. Operation and Maintenance considerations.

Both dam types have been developed to provide the same level of performance. The dam types have been developed to:

- Minimize the initial construction cost of the project by minimizing the dam size for the selected design parameters;
- Minimize technical difficulties that might be encountered in project construction through project configuration;
- Account for potential foundation related difficulties that might become apparent during future investigation programs, and;
- Minimize project operation and maintenance costs, or the possibility of encountering unique and difficult to solve remedial costs.

The alternative that best satisfies the stated objectives, and any other specific owner requirements, will be the recommended alternative.

5.1.1 Initial Construction Costs

To develop the initial construction costs for each alternative, preliminary quantities and costs have been prepared. Only quantities and costs that are judged to vary by alternative have been estimated. The following common costs are not included in the cost estimates:

1. Access Roads;
2. Construction Facilities;
3. Reservoir clearing;
4. Environmental and socio-economical costs, and;
5. Contingencies.

Unit costs have been estimated for use at this preliminary cost comparison level. Attachment 2, Comparative Cost Estimate presents the costs for diversion and care of water, the dam, the spillway and the low level outlet for selected quantities and unit costs together with the basis for the unit costs.

Table 6 below summarizes the resulting cost estimates for the alternatives considered, and presents the comparative cost estimates in US $ millions (rounded).

Table 6: Summary of Comparative Costs

Component	CFRD Ungated	RCC Ungated
	US$ x million, 2002	
Diversion and Care of Water	12.2	10.1
Dam	147.0	160.1
Spillway	23.3	5.4
Low Level Outlet	8.6	4.4
Total	**191.1**	**180.0**

The comparative cost estimate shows the RCC alternative to be over $10 million lower in cost, 6% lower than the CFRD alternative. The RCC dam type alternative is primarily dependent on the unit cost of RCC. Historic RCC unit costs for a dam of this volume range from $35/m^3 to $75/m^3. The unit cost developed for this comparison is $46.5/m^3. A sensitivity analysis showed that the unit cost of RCC would need to be increased by 9% (from $46.5/m^3 to $50.5/m^3) for the construction cost of the RCC alternative to be equal to the construction costs of the CFRD alternative.

The CFRD alternative requires more costly diversion for the longer at flood risk construction period. It also requires a significantly more costly spillway (large separate structure) and low level outlet works (steel reinforcing). The cost of these components is greater than the cost advantage of the CFRD over the RCC dam, resulting in a lower overall cost for the RCC alternative for the Upper Chagres Project.

Addition of a hydropower facility to the Upper Chagres project has not yet been studied. The two diversion tunnels will allow conversion of one tunnel to a power tunnel at later stages of construction when the main dam is above the cofferdam height. In this case, there will not be a significant difference in cost. However, construction of an integral intake and powerhouse with the RCC dam may be the optimum arrangement, again favoring the RCC dam type alternative.

The difference in initial construction cost between the RCC alternative and the CFRD alternative favor the RCC alternative. Contingencies have not been included on either quantities or unit costs. For the feasibility level estimate, contingency allowances will be included for the following:

1. Uncertainties attributable to unforeseeable adverse geological conditions;
2. Variations in the cost of permanent equipment and resources for construction due to changing market conditions;
3. Modifications in design resulting in an increase in construction cost;
4. Minor items not detailed at this time, and;
5. Overlooked and unforeseen items that may not be included in the present feasibility level quantity estimates.

The application of contingencies to provide reasonable coverage for item one will not favor either the CFRD alternative or the RCC alternative. Site investigation information has been utilized in developing appropriately conservative foundation elevations and foundation characteristics for both alternatives. These are reflected in the dam arrangements and quantities. Contingencies for items two-five will be similar for either dam type. Therefore, application of contingencies to the dam-type comparison costs will not favor either dam type.

5.1.2 Construction Considerations

Construction considerations have been evaluated on the basis of the following objectives:

- Minimize the need for off-site materials;
- Minimize the duration of the construction activities;
- Minimize the consequences of flooding due to streamflow in excess of the diversion dam floods, and;
- Maximize the use of available construction technology, specifically in Panama.

Construction considerations do not clearly favor either of the dam alternatives, as discussed below.

- The CFRD alternative takes more advantage of local materials. Basically all materials used for construction of the dam are found at relatively close distance to the site of construction. Construction of the RCC dam requires importation of the substantially larger quantities of cement from an offsite factory, or even from outside of the country, and its transportation to the site. However, this is reflected in the development of the unit cost for the RCC.

- The total quantity of RCC to be placed is estimated at about 2.7 million m^3 at an average weekly production of 24,000 m^3, it corresponds to approximately 26 months of construction. The overall construction of the RCC dam is anticipated to take approximately 48 months with 12 months for preparation, including, the diversion tunnel, cofferdams, quarrying aggregate, foundation preparation, etc., and 10 months for finishing works.

- The construction of the CRFD will require the excavation of nearly 9.5 million m^3 of rock from either required excavation or quarry excavation. This is anticipated to take approximately 50 months. Preparatory works of 12 months including cofferdam, diversion and low-level outlet, and finishing works of 6 to 9 months will result in an overall construction period of approximately five to six years.

- The effect of flooding during construction does not clearly favor either of the alternatives. The RCC dam is resistant to damage by overtopping but its vital placement equipment, processing plant and material stockpiles may be damaged during the flood, if not adequately protected or located. The CFRD can be designed and constructed to withstand overtopping almost as effectively as an RCC dam. Interruption in placement of the CFRD would have less impact.

- The CFRD alternative has a definite advantage when previous local experience is considered. Fortuna dam is a 100-m-high CFRD, and was commissioned a few years ago, and the Barrigon dam, a 60-m-high CFRD, part of the Esti Hydroelectric Project, is currently under construction. No RCC dams have been constructed in Panama.

5.1.3 Foundation Considerations

Foundation considerations have been evaluated on the basis of the following objectives:

- Minimize impact of potential adverse foundation conditions resulting from future investigations;
- Minimize concerns relating to the foundation strength characteristics;
- Minimize potential for differential deformation, and;
- Minimize potential for seepage through the foundation.

The foundation is an integral part of any dam, as it provides support to the dam body, and continuity to the water-tightness element of the dam. To perform these functions, the foundation material should have certain minimal attributes:

- The foundation should have a strength comparable or superior to the strength of the material being placed on top, and
- The foundation should be of low permeability, or else, it should be possible to treat it by grouting or other means to reach a low permeability.

The known characteristics of the site equally favor the selection of either dam alternative. The rock formation found in outcrop, and found to extend throughout the site is suitable for both dam types. The competency and frequency of observed outcrops supported by the drilling program results indicate relatively deep foundation levels.

Should foundation conditions be more or less favorable than anticipated, it is not apparent which dam type would be less impacted. A CFRD does not need to be completely founded on competent rock, only the plinth (toe slab) and the upstream end of the fill need to be founded on competent rock. Recently, appropriately designed CFRD dams have been founded on weathered rock and low compressibility saprolites. Additionally, in designing fill dams, such as a CFRD, it is easier to accommodate differential deformations associated with less competent foundations. However, it is not anticipated this inherent capability of CFRD will offer a significant advantage at this damsite. If the proposed site exploration program reveals poorer rock foundations than currently anticipated, while the CFRD dam would be less impacted, the larger dam volume and topographical limitations could result in similar cost impacts compared to the RCC dam type. In addition, the RCC dam foundation levels, varying from 10 m to 25 m below ground level have been selected to be in the strong andesite bedrock. More favorable foundation conditions, particularly in the abutments, will allow the RCC dam size to be reduced.

In conclusion, the subsurface information at this time does not favor selection of either alternative dam type. Any unexpected subsurface conditions can be handled relatively easily for both dam types within the planned (large) foundation excavation and treatment programs. The competent rock footprint required for the RCC dam is no larger than the competent rock footprint required for the CFRD.

5.1.4 Operating and Maintenance Considerations

The operation and maintenance considerations of the project have been evaluated on the basis of the following:

- Minimize uncontrolled leakage through the dam or its foundation;
- Minimize the need for maintenance of the dam and the potential for difficult remedial measures, and;
- Minimize the need for maintenance of the spillway and the potential for difficult remedial measures.

Operation and maintenance considerations tend to favor selection of an RCC dam alternative, although owner's preferences usually override any reasoning on this issue. CFRD's and RCC dams are usually both safe and reliable but the upstream grouting and drainage gallery built-in in the RCC dams allow execution of remedial grouting and foundation drainage, if required.

Leakage through either type of dam should be negligible. Although some early RCC dams experienced leakage problems, more recent designs and construction techniques have virtually eliminated this problem. CFRD's may be subject to cracking of the concrete facing if poor quality control of concrete placement occurs, or subsidence causes cracking. The general experience is that appropriate design and specification requirements coupled with construction inspection has resulted in CFRD's that do not leak any more than other types of dam.

5.2 Recommendation

CFRD and RCC dam types are both technically feasible at this site. The comparative cost evaluation favors the RCC alternative over the CFRD alternative. While the RCC alternative cost estimate is more sensitive to a cost increase as a result of higher unit cost for RCC, the unit costs selected for the dam type comparison are considered appropriate, and a more detailed development of RCC costs may reduce the overall cost.

Based on the available information, the dam type recommended for the Upper Río Chagres Water Supply Feasibility Studies is the RCC alternative for the following reasons:

1. Project development costs are lower;
2. The construction schedule is one to two years less;
3. There are no known foundation conditions that favor either type of dam, and;
4. Addition of hydropower will be similar for both dam types if constructed as part of the diversion facilities, or more favorable for RCC if an integrated powerhouse is found to be the optimum development.

The selection of the RCC alternative should be confirmed following the completion of proposed additional site investigation programs if the investigations show foundation conditions that are unfavorable for RCC dams. Spillway type and size should also be re-evaluated once operation levels are selected.

EXHIBITS

EXHIBIT 1 Location Map

EXHIBIT 2 Reservoir Area Map

EXHIBIT 3 CFRD – Plan

EXHIBIT 4 CFRD – Profile and Sections

EXHIBIT 5 CFRD Diversion – Plan, Profile and Sections

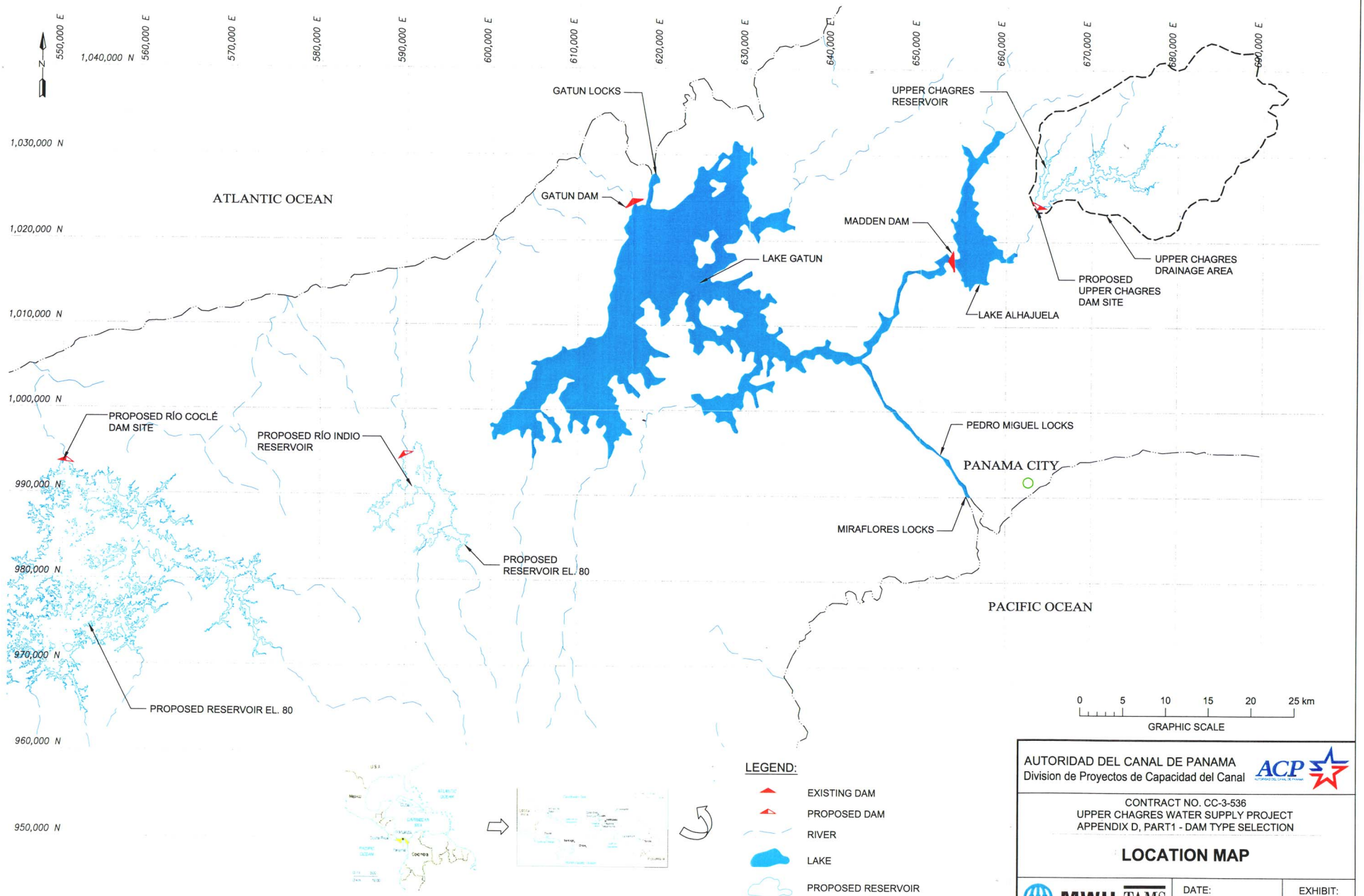
EXHIBIT 6 CFRD Spillway – Plan, Profile and Sections

EXHIBIT 7 RCC Dam – Plan

EXHIBIT 8 RCC Dam – Profile and Sections

EXHIBIT 9 RCC Diversion – Plan, Profile and Sections

EXHIBIT 10 RCC Spillway – Plan, Section and Elevation



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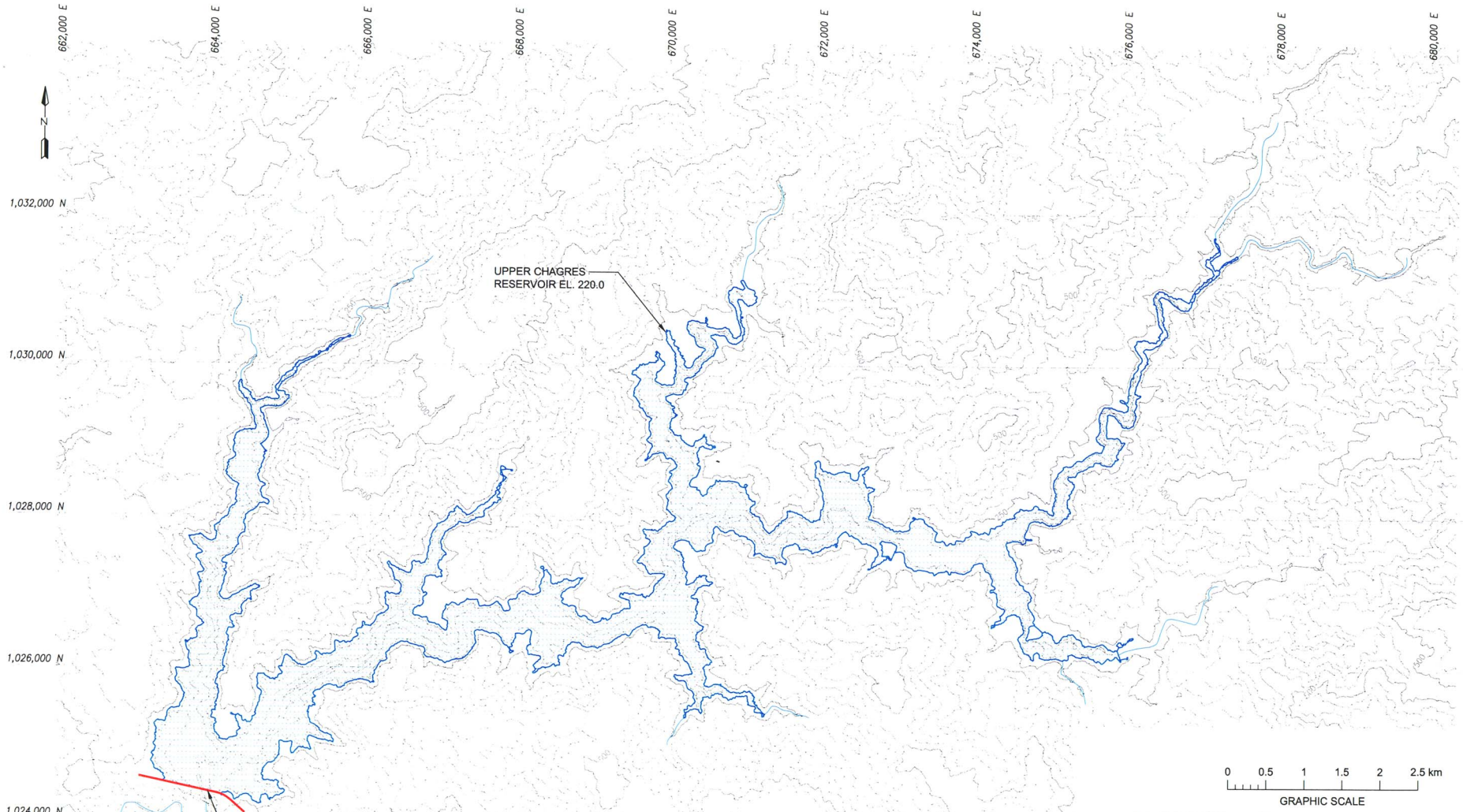
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX D, PART1 - DAM TYPE SELECTION

LOCATION MAP

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 1



NOTE:

TOPOGRAPHY PROVIDED BY ACP FROM IFSAR SURVEY.

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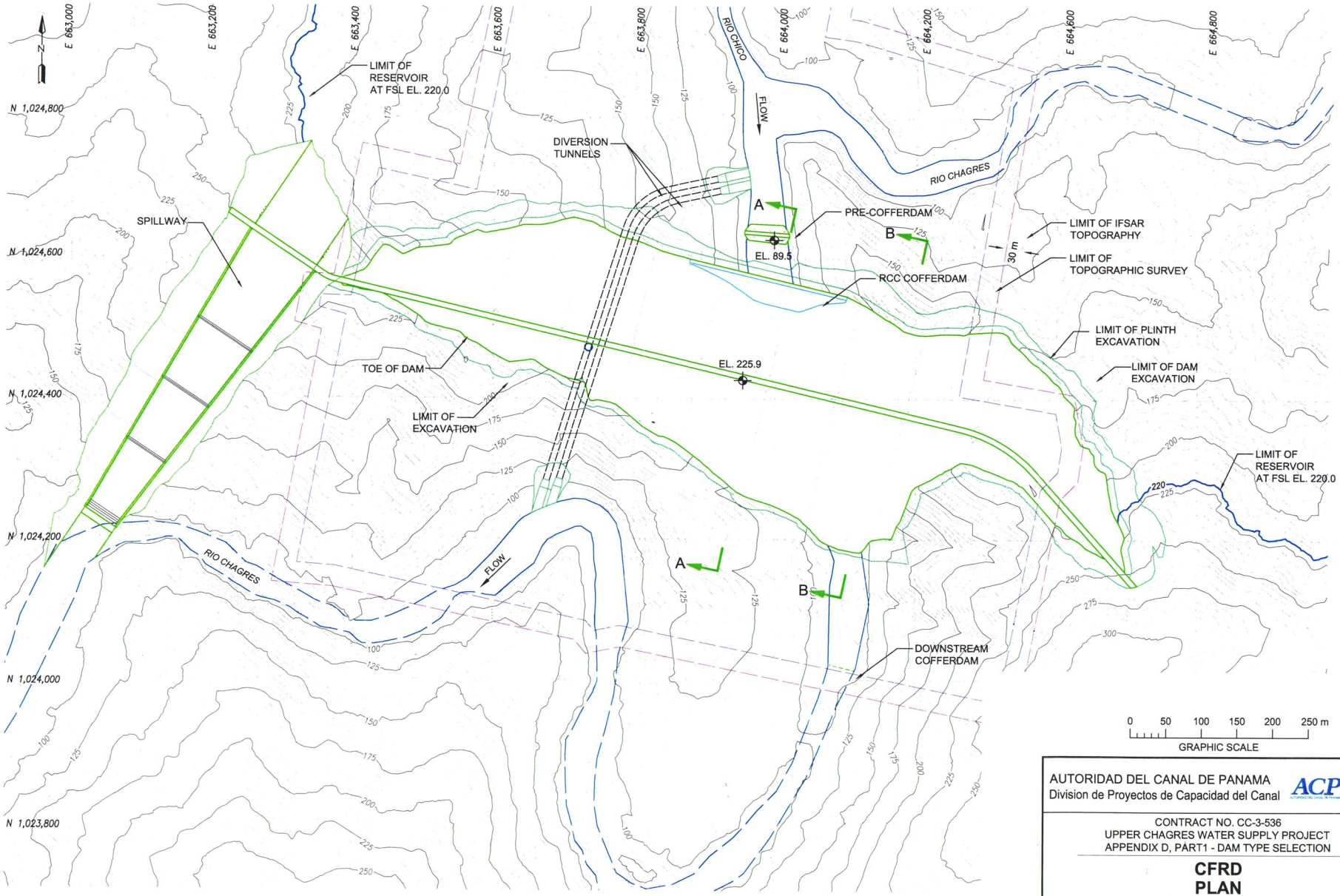
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX D, PART1 - DAM TYPE SELECTION

RESERVOIR AREA MAP

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 2



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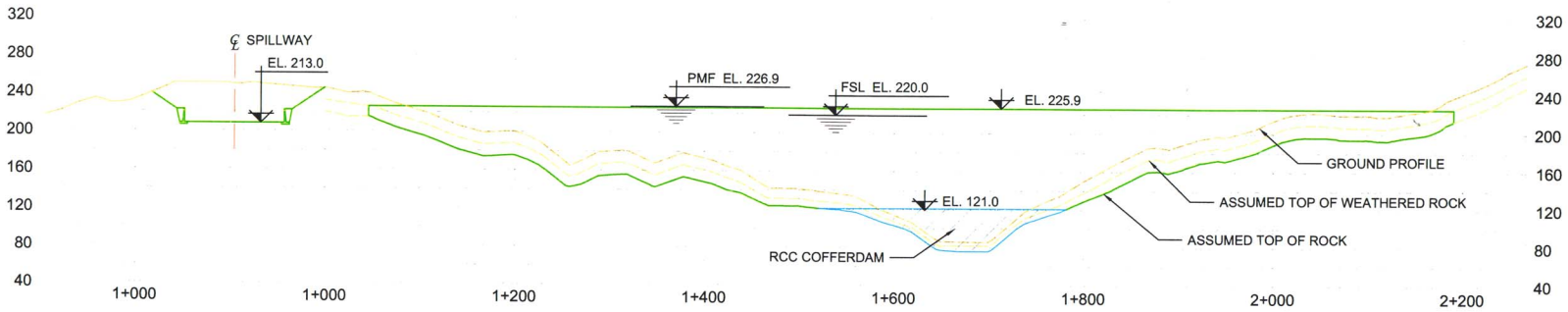
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX D, PART1 - DAM TYPE SELECTION

CFRD
PLAN

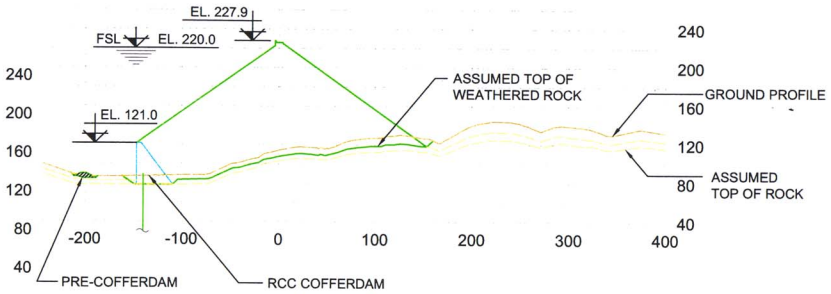
MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 3

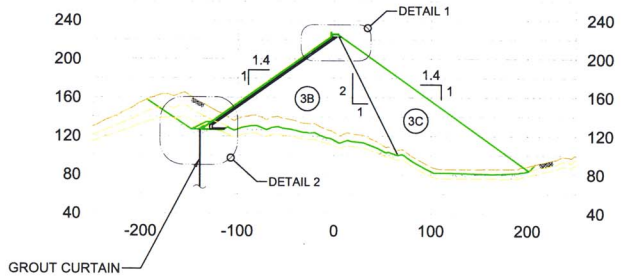


DAM PROFILE



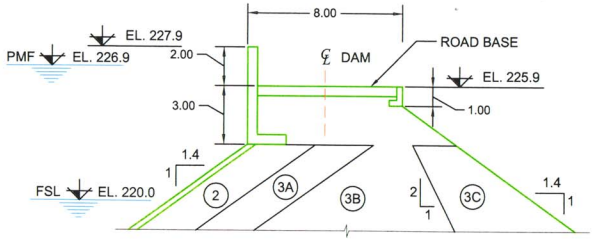
SECTION A - A

SEE EXHIBIT 3



SECTION B - B

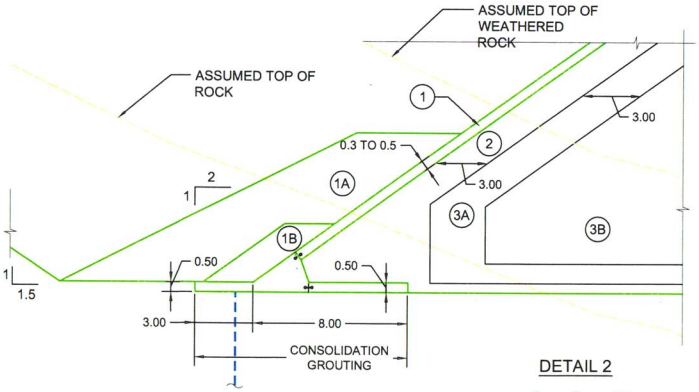
SEE EXHIBIT 3



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

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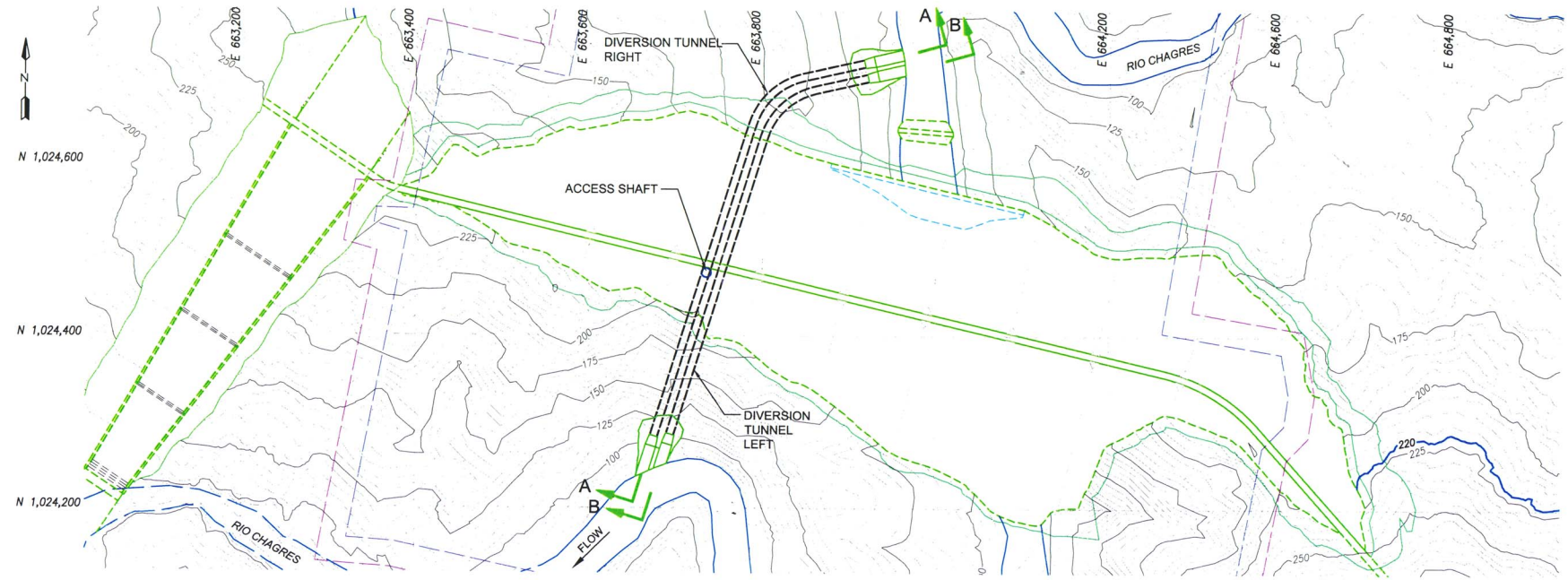
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX D, PART1 - DAM TYPE SELECTION

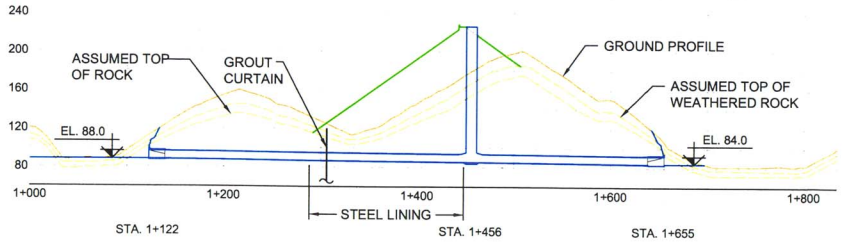
CFRD
PROFILE AND SECTIONS

MWH TAMS

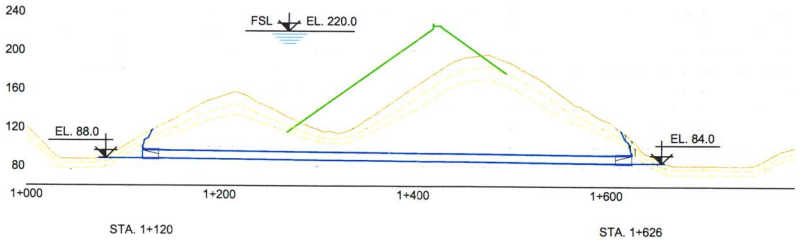
DATE:	EXHIBIT:
SEPTEMBER, 2003	4



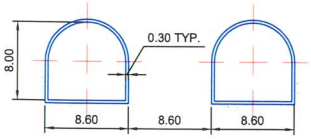
PLAN



DIVERSION TUNNEL AND LOW LEVEL OUTLET - RIGHT
SECTION A - A



DIVERSION TUNNEL AND LOW LEVEL OUTLET - LEFT
SECTION B - B



TYPICAL SECTION THROUGH TUNNELS

0 5 m

0 50 100 150 200 250 m
GRAPHIC SCALE

AUTORIDAD DEL CANAL DE PANAMA
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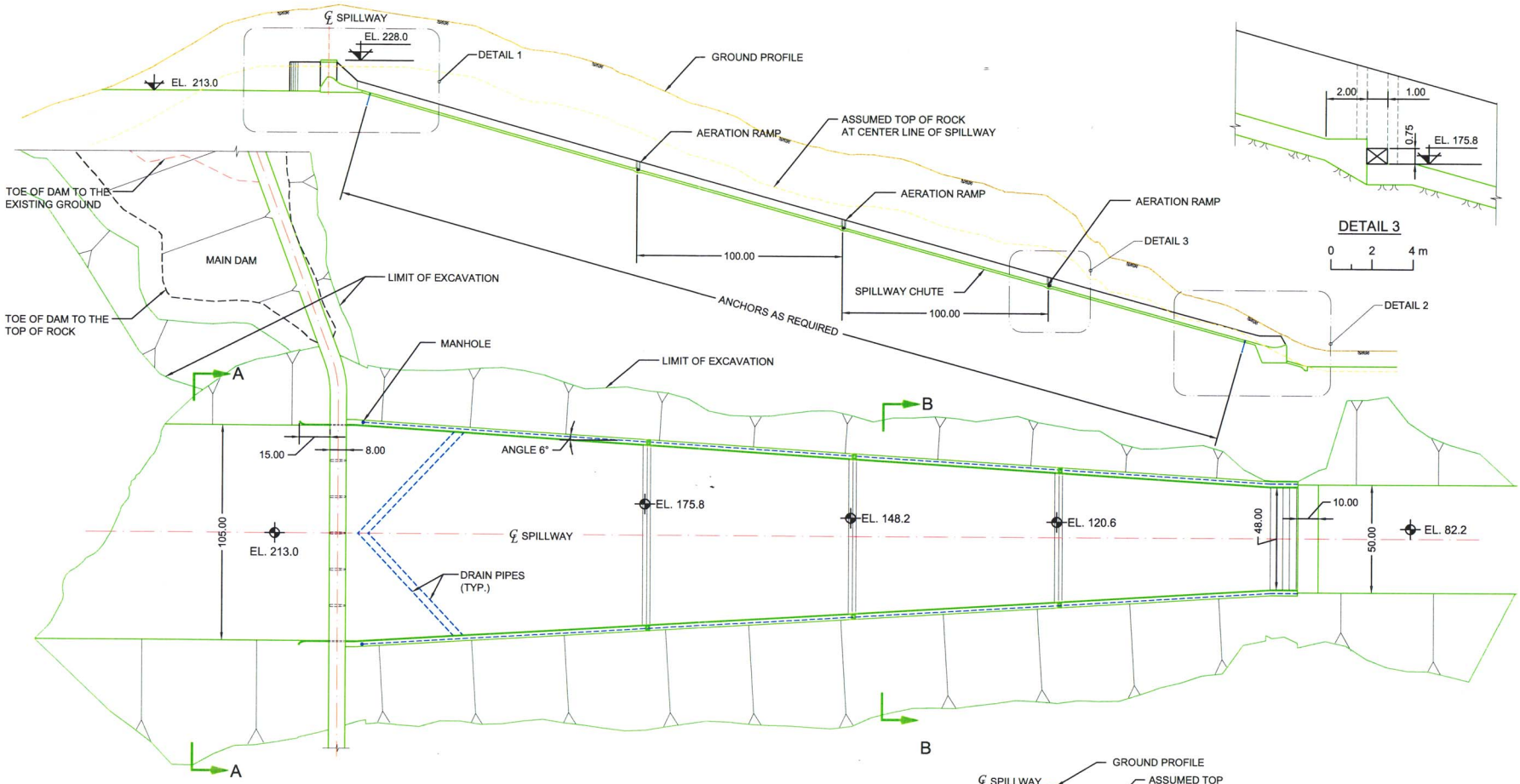
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX D, PART1 - DAM TYPE SELECTION

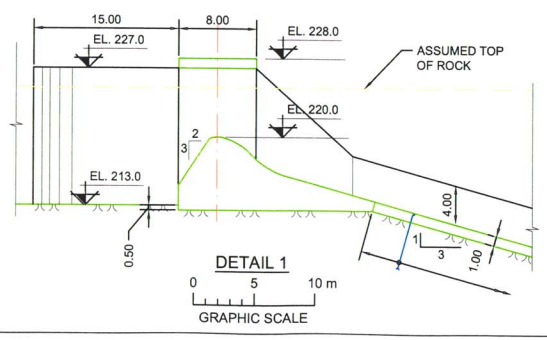
CFRD DIVERSION
PLAN, PROFILE AND SECTIONS

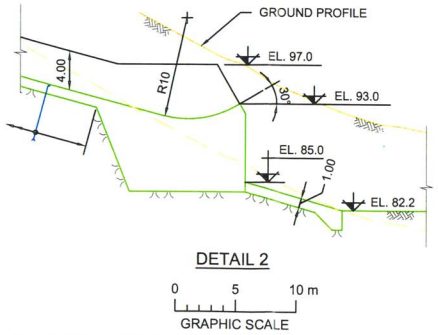
MWH TAMS

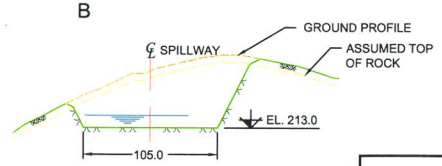
DATE: SEPTEMBER, 2003

EXHIBIT: 5









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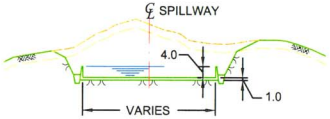
(NTS)



SECTION B - B (TYP.)
(NTS)

0 10 20 40 60 80 100 m
GRAPHIC SCALE

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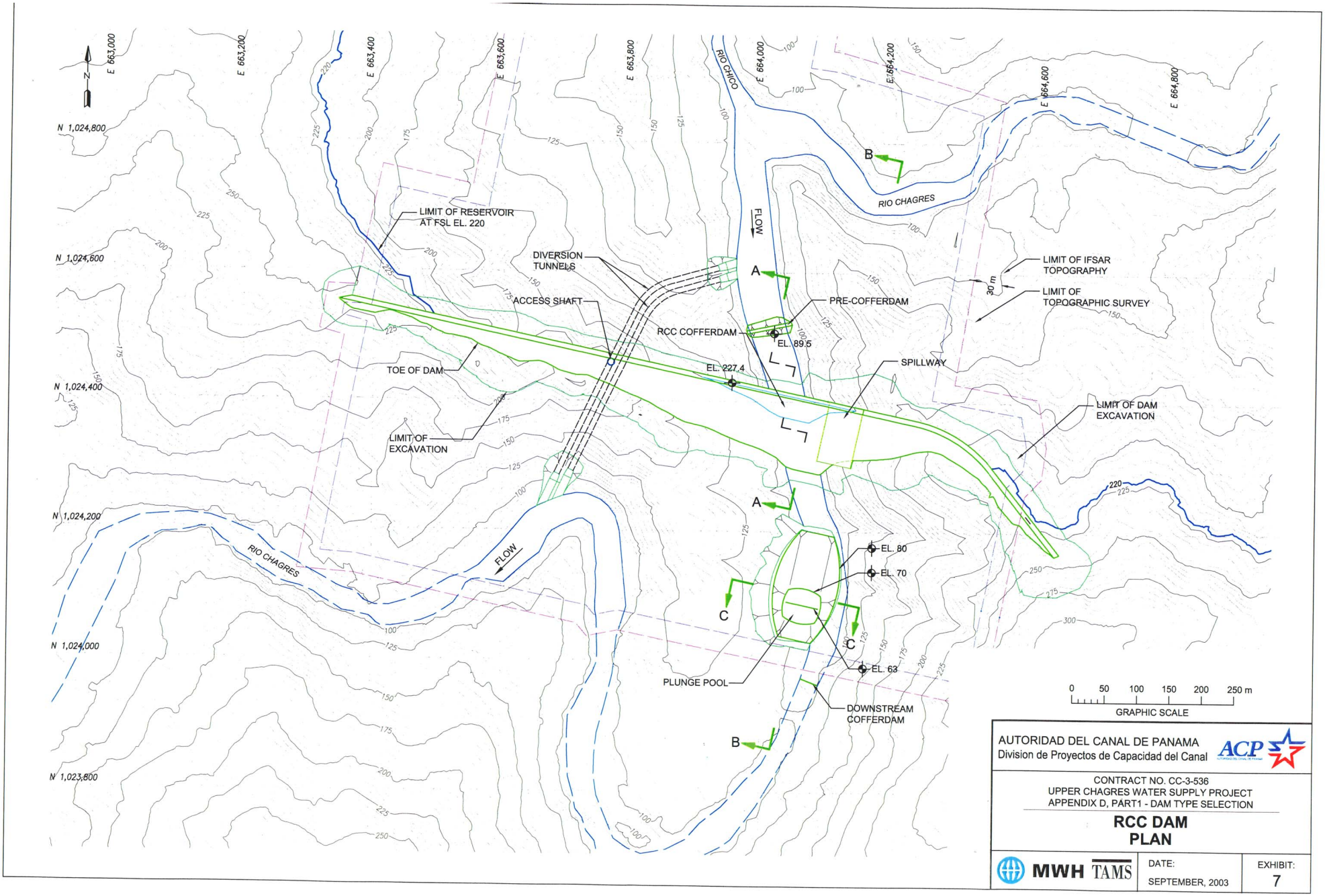
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX D, PART1 - DAM TYPE SELECTION

CFRD SPILLWAY
PLAN, PROFILE AND DETAILS

MWH TAMS

DATE:	EXHIBIT:
SEPTEMBER, 2003	6



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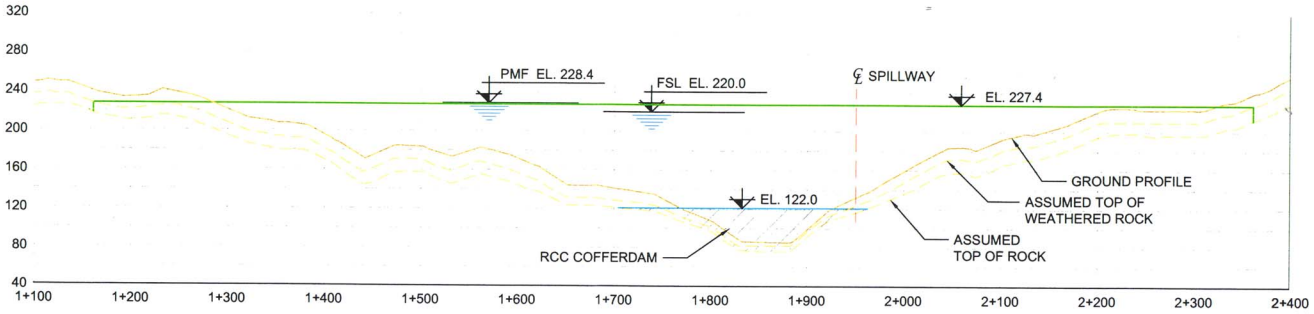
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX D, PART1 - DAM TYPE SELECTION

RCC DAM
PLAN

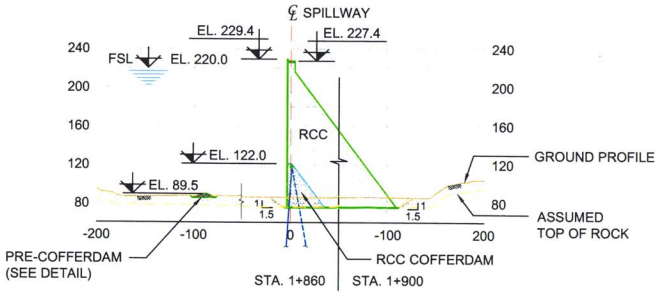
MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 7

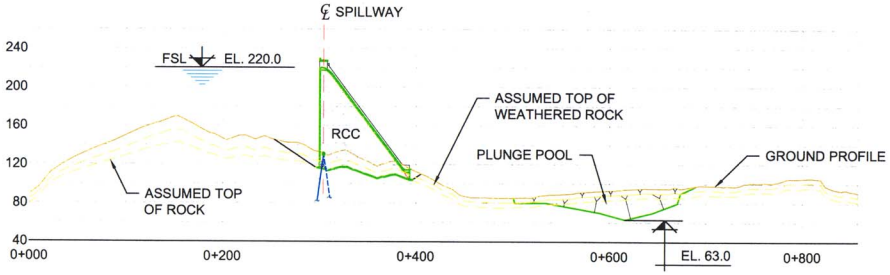


DAM PROFILE



SECTION A - A

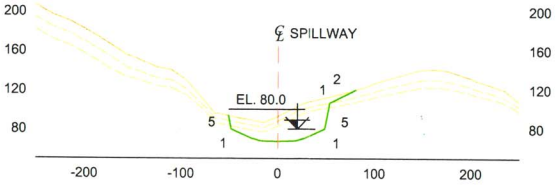
SEE EXHIBIT 7



SECTION B - B

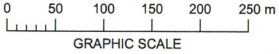
PROFILE THROUGH SPILLWAY ALIGNMENT

SEE EXHIBIT 7



SECTION C - C

SEE EXHIBIT 7



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

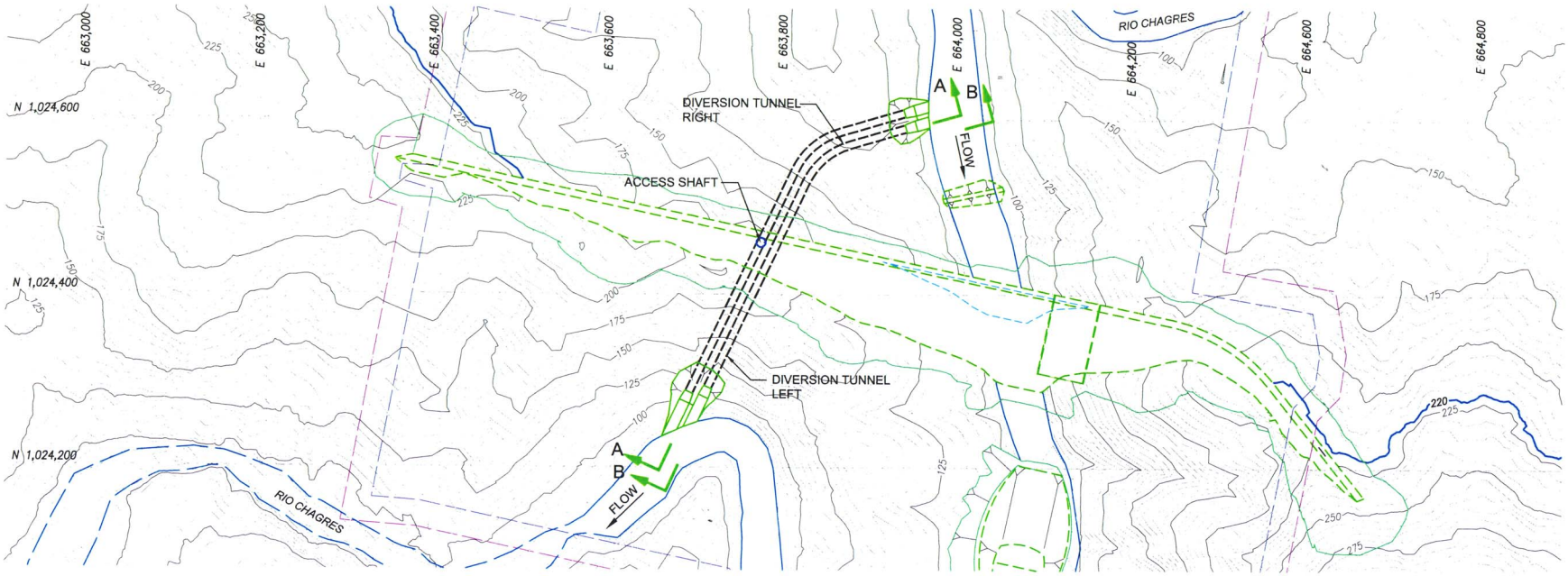
CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX D, PART1 - DAM TYPE SELECTION

RCC DAM
PROFILE AND SECTIONS

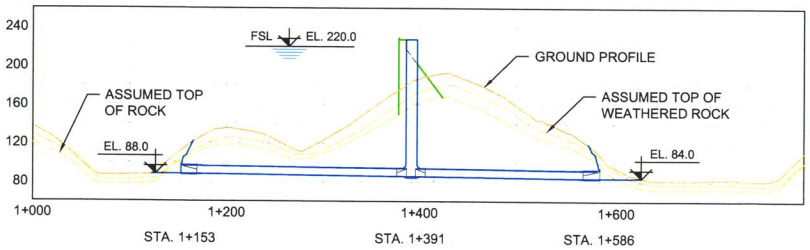
MWH TAMS

DATE: SEPTEMBER, 2003

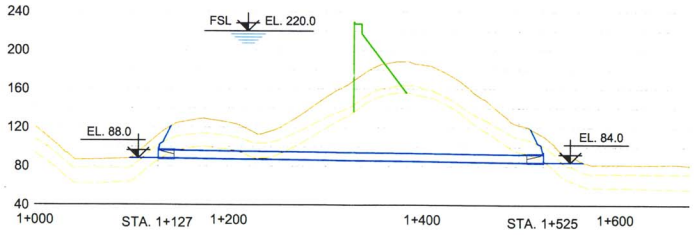
EXHIBIT: 8



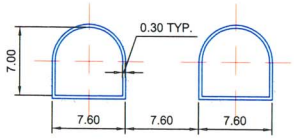
PLAN



DIVERSION TUNNEL AND LOW LEVEL OUTLET - RIGHT
SECTION A - A



DIVERSION TUNNEL - LEFT
SECTION B - B



TYPICAL SECTION THROUGH TUNNELS

0 5 m

0 50 100 150 200 250 m

GRAPHIC SCALE

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

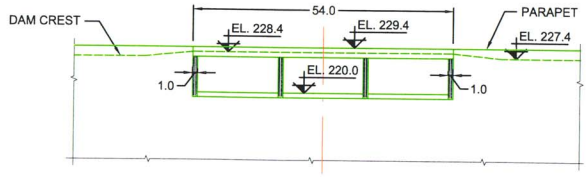
ACP

CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX D, PART1 - DAM TYPE SELECTION

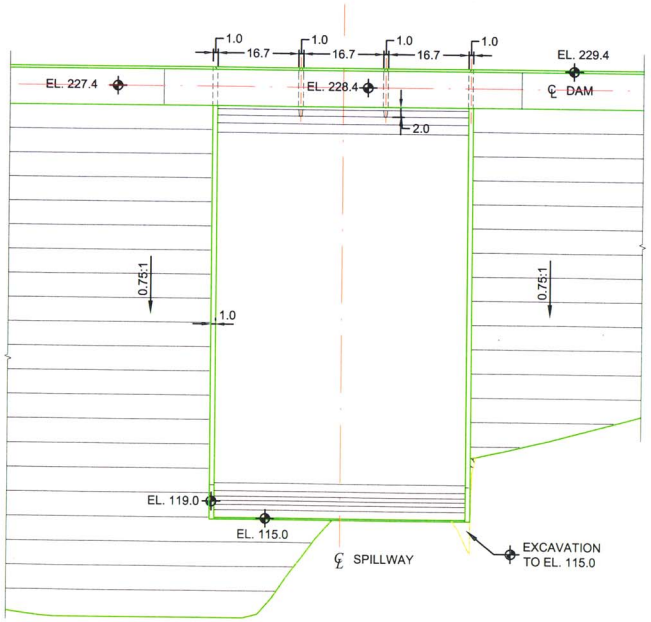
RCC DIVERSION
PLAN, PROFILES AND SECTIONS

MWH TAMS

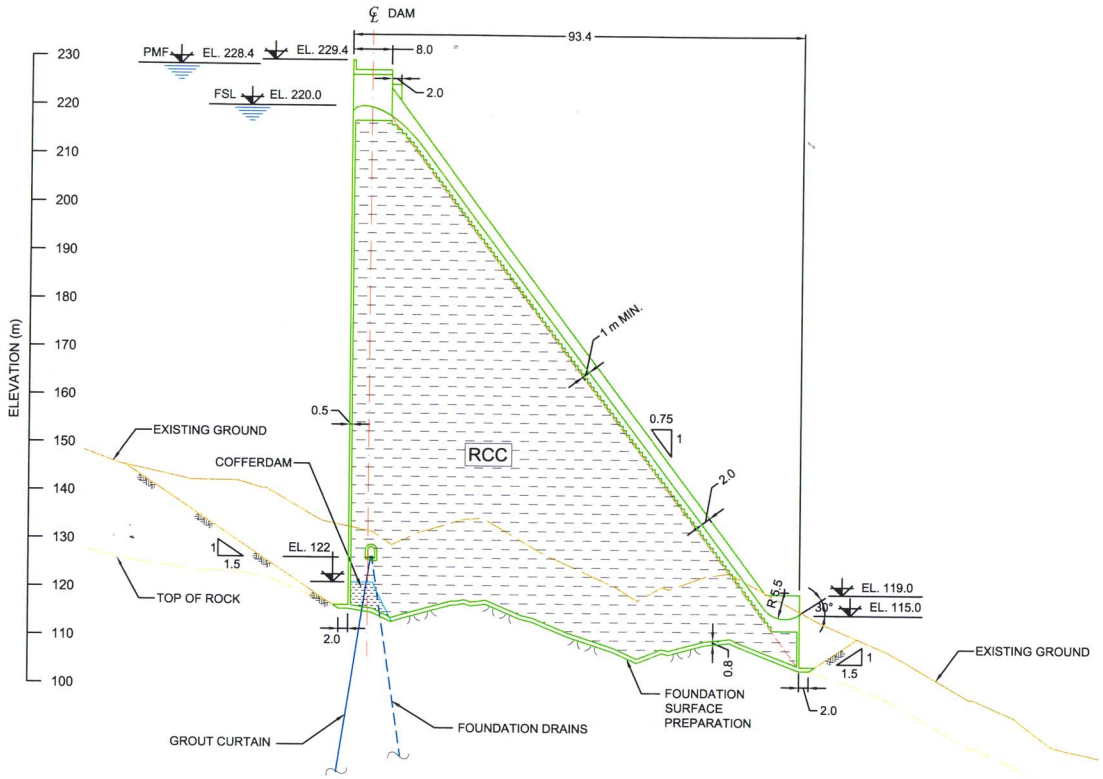
DATE:	EXHIBIT:
SEPTEMBER, 2003	9



UPSTREAM ELEVATION



PLAN



SPILLWAY SECTION

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
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX D, PART1 - DAM TYPE SELECTION

RCC SPILLWAY
PLAN, SECTION AND ELEVATION

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: 10

ATTACHMENTS

Attachment 1a	Hydraulic Analysis for Design of Diversion Tunnel and Cofferdam
Attachment 1b	Drawdown Analysis
Attachment 1c	Evaluation of Spillway Size
Attachment 2	Comparative Cost Estimate

Attachment 1a – Hydraulic Analysis for Design of Diversion Tunnel and Cofferdam

MWH
MONTGOMERY WATSON HARZA

MWH ENERGY & INFRASTRUCTURE, INC.
PRIVATIZATION AND PROJECT DEVELOPMENT

Location Chicago Office **Date** May 29, 2003

To Michael Newbery

From Paul M. Kanellopoulos

Subject Upper Chagres Water Supply Feasibility Study
Hydraulic Analysis for Design of Diversion Tunnel and Cofferdam

Introduction

This memorandum summarizes the procedures and results of the hydraulic analysis performed for the design of the cofferdam and diversion tunnel for the Upper Chagres Dam. The analysis includes:

- Development of tailwater rating curve;
- Estimation of cofferdam height upstream and downstream of the proposed dam with 600 m long D-shaped diversion tunnels for 25-yr and 50-yr flows;
- Estimation of cofferdam height upstream and downstream of the proposed dam with 150 m long box culverts for 25-yr flow; and
- Estimation of closure dike height at Sections 1 and 4 for low flow conditions (15, 20, 25 m^3/s).

Basic data used in the analysis is discussed. Results are provided as tables.

Computer Model

The Full-Equations (FEQ) modeling system of one-dimensional, unsteady, open-channel flow was used for the hydraulic analysis of the Upper Chagres Dam. FEQ is based on the full Saint-Venant equations. This modeling system, developed by Delbert Franz of Linsley, Kraeger Associates, Ltd., Mountain View, CA is widely used by engineers and hydrologists in county and state agencies and consulting firms, and has been accepted by the Federal Emergency Management Agency (FEMA) for use in floodplain studies. It is used in a variety of applications such as flood studies, design studies for dam spillways, dam break analyses, and legal cases. The

program supports a wide variety of structures including bridges, culverts, dams, level-pool reservoirs, spillways, weirs, sluice gates, pumps, side weirs, expansions, contractions, drop structures, and flow over roadways. The hydraulic features of the stream system, such as channel cross-sectional properties, are incorporated into the model. FEQ is capable of simulating flow conditions in a network of open channels and storm sewers. The flow conditions are simulated in terms of water-surface elevation, water velocity, and discharge at any point in the system.

Introduction

The main purpose of this study is to determine the size of the diversion tunnel to pass the 25-yr and 50-yr flows as well as the resulting cofferdam heights upstream and downstream of the dam. The main components of the model include the tabulation of the 25-yr and 50-yr hydrographs, shown in Tables 1 and 2 respectively, the reservoir capacity curve, shown in Table 3, and the cross sectional data, included in Appendix I.

Table 1. 25-Year Flood Hydrograph in Upper Chagres

Time (hrs)	0	1	2	3	4	5	6	7
Flow (cms)	102	149	269	747	1644	2113	1942	1494
Time (hrs)	8	9	10	11	12	13	14	15
Flow (cms)	1046	747	598	448	359	329	299	269
Time (hrs)	16	17	18	19	20	21	22	23
Flow (cms)	242	228	214	200	186	172	158	144
Time (hrs)	24	25	26	27	28	29	30	31
Flow (cms)	130	116	102	102	102	102	102	102

Table 2. 50-Year Flood Hydrograph in Upper Chagres

Time (hrs)	0	1	2	3	4	5	6	7
Flow (cms)	117	171	308	856	1884	2421	2226	1712
Time (hrs)	8	9	10	11	12	13	14	15
Flow (cms)	1199	856	685	514	411	377	342	308
Time (hrs)	16	17	18	19	20	21	22	23
Flow (cms)	278	262	246	230	214	197	181	165
Time (hrs)	24	25	26	27	28	29	30	31
Flow (cms)	149	133	117	117	117	117	117	117

Table 3. Reservoir Capacity Curve at Upper Chagres

Elevation (m)	Area (km^2)	Volume (MCM)
88	-	-
90	0.02	0.01
95	0.09	0.26
105	0.21	1.72
112	0.42	3.87
120	0.76	8.50
130	1.27	18.53
135	1.67	25.85
145	2.68	47.41
155	3.75	79.40
165	5.05	123.23
175	6.44	180.55
185	8.17	253.44
195	10.24	345.30
205	12.61	459.33
215	15.28	598.53
225	18.49	767.09
235	22.14	969.96
245	26.07	1210.75

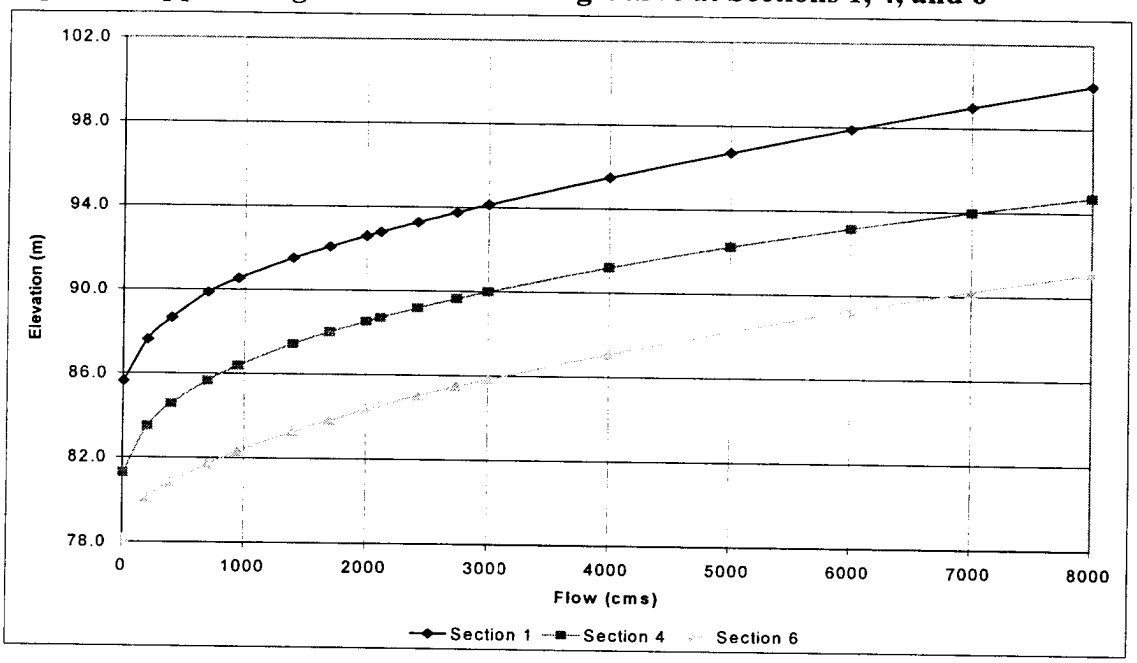
Tailwater Analysis

The objective of the tailwater analysis is to develop a tailwater-rating curve for the proposed Upper Chagres Dam site. Six cross-sections downstream of the Upper Chagres dam were used. The first cross section is located 400 m downstream of the dam and the last cross section is located 3175 m downstream of the dam. ACP provided the station-elevation data for the 6 surveyed cross-sections. The average slope of the 2775 m channel reach is 0.26 %. The Manning's roughness coefficients for the study reach is 0.035 for the channel portion and 0.045 for the over-bank portion. In the first three cross-sections downstream of the dam, the over-bank flow is at an elevation of 90 m and above. In the last three cross-sections downstream of the dam, the over-bank flow is at an elevation of 85 m and above. As mentioned earlier, Appendix I lists the station-elevation data for the six cross-sections. The resulting tailwater rating curves for cross-sections 1 (400 m d/s dam), 4 (1685 m d/s dam), and 6 (3175 m d/s dam) are tabulated in Table 4 and plotted in Figure 1.

Table 4. Tailwater Rating Curve

Flow (m^3/s)	Tailwater Elevation at Section 1 (m)	Tailwater Elevation at Section 4 (m)	Tailwater Elevation at Section 6 (m)
5	85.62	81.26	78.18
200	87.62	83.48	80.07
400	88.65	84.56	80.81
700	89.87	85.65	81.68
950	90.54	86.37	82.29
1400	91.51	87.43	83.24
1700	92.07	88.01	83.80
2000	92.59	88.53	84.33
2115	92.78	88.72	84.52
2420	93.26	89.19	85.01
2740	93.75	89.64	85.47
3000	94.12	89.99	85.82
4000	95.48	91.20	87.08
5000	96.72	92.23	88.21
6000	97.89	93.15	89.25
7000	98.98	93.97	90.21
8000	100.03	94.71	91.12

Figure 1. Upper Chagres Tailwater Rating Curve at Sections 1, 4, and 6



Evaluation of Diversion Tunnel Size (D-Shaped Tunnels)

Several diversion tunnel sizes were modeled in order to determine the cofferdam height upstream and downstream of the proposed dam. Tunnel sizes considered are D-shaped with 6, 7, 8, and 10 m diameters, a length of 600 m and an invert elevation of 88m at both ends. Both single and double barrels were considered. A Manning's coefficient of 0.014 was used for the concrete-lined tunnels. The entrance and exit loss coefficients are 0.5 and 1.0, respectively. Bend losses were assumed to be negligible. The diversion tunnel exit is located at Section 4, 1685 m downstream of the dam.

Cofferdam heights are analyzed based on the 25 and 50-yr hydrographs shown earlier. The water surface elevations for the different tunnel configurations under 25-year and 50-year flow conditions are summarized in Tables 5a and 5b, respectively. This information is used to select the most cost-effective cofferdam alternative. One alternative that was strongly considered is the double barrel, 8 m diameter tunnel. Figure 2 shows the rating curve for this configuration.

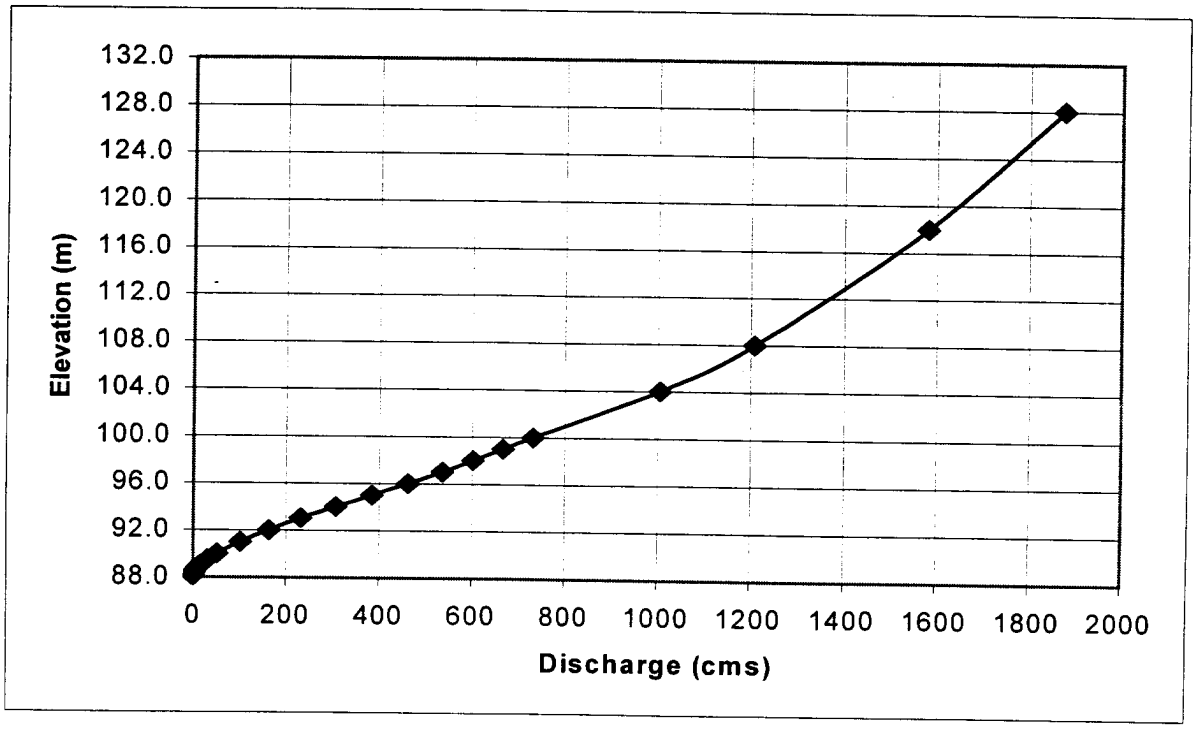
Table 5a. Diversion Tunnel Analysis for Upper Chagres (D-shaped, 25-yr Flow)

Tunnel Diameter (m)	Tunnel Length (m)	Peak Discharge (cms)	Upstream Water Surface Elevation (m)	Downstream Water Surface Elevation (m)
7	600	731	131.0	85.8
8	600	933	127.7	86.3
10	600	1338	121.5	87.3
6 (2 tunnels)	600	982	126.5	86.5
7 (2 tunnels)	600	1279	122.0	87.2
8 (2 tunnels)	600	1555	117.3	87.7

Table 5b. Diversion Tunnel Analysis for Upper Chagres (D-shaped, 50-yr Flow)

Tunnel Diameter (m)	Tunnel Length (m)	Peak Discharge (cms)	Upstream Water Surface Elevation (m)	Downstream Water Surface Elevation (m)
6	600	558	136.7	85.2
8	600	977	131.1	86.4
8 (2 tunnels)	600	1664	120.8	87.9
10	600	1412	124.5	87.5

Figure 4. Rating Curve for 2-8m D-Shaped Tunnels, L=600 m



Evaluation of Diversion Tunnel Size (Box Culverts)

Another option considered in the diversion tunnel and cofferdam analysis was to use 150 m long twin box culverts that discharge into Section 1, 400m downstream of the dam. These culverts have an invert elevation of 88m at the upstream end and 87m at the downstream end. A Manning's roughness coefficient of 0.014 was used. The results of this analysis for 25-year flow are presented in Table 6. The results show that box culverts have a higher discharge capacity than D-shaped tunnels of similar size.

Table 6. Diversion Tunnel Analysis for Upper Chagres (Twin Box Culverts, 25-yr Flow)

Tunnel Dimensions (m)	Tunnel Length (m)	Combined Peak Discharge (m^3/s)	Upstream Water Surface Elevation (m)	Downstream Water Surface Elevation (m)
5 by 5	150	836	129.0	90.3
6 by 6	150	1126	124.0	90.9
7 by 7	150	1430	119.9	91.6

Analysis of Low Flows

Additional runs were made with constant flows of 15, 20, and 25 m^3/s in order to determine the height of the temporary closure dikes used during the construction of the cofferdams. Table 7a-c summarizes the peak water surface elevations for 4 D-shaped tunnel configurations during low flow conditions.

Table 7a. Low Flow Analysis (15 m^3/s)

Tunnel Diameter (m)	Upstream Water Surface Elevation (m)	Downstream Water Surface Elevation (Section 4) (m)	Downstream Water Surface Elevation (Section 1) (m)
6	89.7	81.6	85.9
8	89.5	81.6	85.9
8 (2 barrels)	89.0	81.6	85.9
10	89.3	81.6	85.9

Table 7b. Low Flow Analysis (20 m^3/s)

Tunnel Diameter (m)	Upstream Water Surface Elevation (m)	Downstream Water Surface Elevation (Section 4) (m)	Downstream Water Surface Elevation (Section 1) (m)
6	90.1	81.7	86.0
8	89.7	81.7	86.0
8 (2 barrels)	89.2	81.7	86.0
10	89.5	81.7	86.0

Table 7c. Low Flow Analysis (25 m^3/s)

Tunnel Diameter (m)	Upstream Water Surface Elevation (m)	Downstream Water Surface Elevation (Section 4) (m)	Downstream Water Surface Elevation (Section 1) (m)
6	90.3	81.9	86.1
8	90.0	81.9	86.1
8 (2 barrels)	89.3	81.9	86.1
10	89.7	81.9	86.1

Attachment 1b – Drawdown Analysis

MWH
MONTGOMERY WATSON HARZA

MWH ENERGY & INFRASTRUCTURE, INC.
PRIVATIZATION AND PROJECT DEVELOPMENT

Location Chicago Office **Date** August 11, 2003

To Michael Newbery

From Paul M. Kanellopoulos

Subject Upper Chagres Water Supply Feasibility Study
Drawdown Analysis

This memorandum summarizes the procedures and results performed for the Upper Chagres reservoir drawdown analysis. The purpose of this analysis is to determine the drawdown time to 25, 50, and 75% of full supply level. The modeled scenarios are as follows:

- Drawdown from full-supply level of 220.0 m using one 8m D-Shaped tunnel;
- Drawdown from full-supply level of 210.0 m using 2.5, 3.0, and 3.5 m diameter by-pass evacuation valves discharging at Section 4 (1685 m D/S of the dam);
- Drawdown from full-supply level of 210.0 m using a 2.5 m diameter by-pass evacuation valve discharging at Section 4 in conjunction with 6 12-by-8m spillways;
- Drawdown from full-supply level of 210.0 m using a 2.5 m diameter by-pass evacuation valve discharging at Section 1 (400 m D/S of the dam) in conjunction with 6 12-by-8m spillways; and
- Drawdown from full-supply level of 210.0 m using a 4-by-4m drop shaft with 2 orifices in conjunction with 6 12-by-8m spillways.

Basic data used in the analysis is discussed. Results are provided as tables.

Computer Model

The Full-Equations (FEQ) modeling system of one-dimensional, unsteady, open-channel flow was used for the hydraulic analysis of the Upper Chagres Dam. FEQ is based on the full Saint-Venant equations. This modeling system, developed by Delbert Franz of Linsley, Kraeger Associates, Ltd., Mountain View, CA is widely used by engineers and hydrologists in county and state agencies and consulting firms, and has been accepted by the Federal Emergency Management Agency (FEMA) for use in floodplain studies. It is used in a variety of applications

such as flood studies, design studies for dam spillways, dam break analyses, and legal cases. The program supports a wide variety of structures including bridges, culverts, dams, level-pool reservoirs, spillways, weirs, sluice gates, pumps, side weirs, expansions, contractions, drop structures, and flow over roadways. The hydraulic features of the stream system, such as channel cross-sectional properties, are incorporated into the model. FEQ is capable of simulating flow conditions in a network of open channels and storm sewers. The flow conditions are simulated in terms of water-surface elevation, water velocity, and discharge at any point in the system.

Introduction

The Upper Chagres reservoir drawdown analysis was conducted in order to meet U.S. Bureau of Reclamation requirements of:

- 75% water level in 30-40 days;
- 50% water level in 50-60 days; and
- 25% water level in 80-100 days.

Silt levels over the life of the dam were taken into account. During the drawdown, it was assumed that constant flows of 30.2 m^3/s or 47.9 m^3/s were flowing into the reservoir. These correspond to either the mean annual flow or mean November-December flow, respectively. The reservoir bottom is at 88 m above mean sea level and the reservoir full supply level is 210.0 m for most of the analyses. The reservoir capacity curve is presented in Table 1.

Table 1. Reservoir Capacity Curve at Upper Chagres

Elevation (m)	Area (km^2)	Volume (MCM)
88	-	-
90	0.02	0.01
95	0.09	0.26
105	0.21	1.72
112	0.42	3.87
120	0.76	8.50
130	1.27	18.53
135	1.67	25.85
145	2.68	47.41
155	3.75	79.40
165	5.05	123.23
175	6.44	180.55
185	8.17	253.44
195	10.24	345.30
205	12.61	459.33
215	15.28	598.53
225	18.49	767.09

Reservoir Drawdown Analysis

I. Drawdown using 8m D-Shaped Tunnel

One of the diversion tunnel alternatives is to build 2 8 m-diameter, 600 m long D-shaped tunnels that discharge at Section 4, located 1685 m downstream of the dam. The tunnel invert elevations correspond to the bottom of the reservoir, at 88 m. Table 2 shows the time to empty out the reservoir to 25, 50, and 75 % of the starting full supply level of 220.0 m with one of the two tunnels open and a constant inflow of 30.2 m^3/s.

Table 2. Time required to empty reservoir with a single 8m, 600m long D-Shaped tunnel

Full Reservoir Elevation (m)	Water Surface Elevation in Reservoir (m)	Elevation / Full Reservoir Elevation (%)	Time to Empty (Days)
220.0	187.0	75	2.89
220.0	154.0	50	4.54
220.0	121.0	25	5.27

II. Drawdown using By-pass Evacuation Valve at Section 4

One drawdown option is to attach a by-pass evacuation valve to the penstock. The flow through the valve is governed by the equation $Q = CA(2gH)^{1/2}$, where Q = flow (m^3/s), C = discharge coefficient, A = valve cross-sectional area (m^2), g = acceleration due to gravity, and H = head above the valve invert (m). The discharge coefficient in this case is 0.6. At Section 4, the water level rises to 93.4 m during the Probable Maximum Flood (PMF) with 6 12-by-8m gated spillways open. The by-pass valve invert is set at 94.0 m, slightly above this level. Although the water enters the penstock at an elevation of 150.0 m, the control point for head is the valve invert. The discharge coefficient C takes into account all the losses on the way. Table 3a-c shows the drawdown results for 3 different valve diameters with a constant inflow of 30.2 m^3/s and starting pool elevation of 210.0 m.

Table 3a. Time required to empty reservoir with a 2.5m diameter by-pass evacuation valve discharging at Section 4 (constant inflow = 30.2 m^3/s)

Full Reservoir Elevation (m)	Water Surface Elevation in Reservoir (m)	Elevation / Full Reservoir Elevation (%)	Flow Through Valve (m^3/s)	Time to Empty (Days)
210.0	210.0	100	140.5	0
210.0	180.0	75	121.0	35.5
210.0	150.0	50	97.6	57.6

Table 3b. Time required to empty reservoir with a 3.0 m diameter by-pass evacuation valve discharging at Section 4 (constant inflow = 30.2 m^3/s)

Full Reservoir Elevation (m)	Water Surface Elevation in Reservoir (m)	Elevation / Full Reservoir Elevation (%)	Flow Through Valve (m^3/s)	Time to Empty (Days)
210.0	210.0	100	202.3	0
210.0	180.0	75	174.2	22.6
210.0	150.0	50	140.6	36.3

Table 3c. Time required to empty reservoir with a 3.5 m diameter by-pass evacuation valve discharging at Section 4

Full Reservoir Elevation (m)	Water Surface Elevation in Reservoir (m)	Elevation / Full Reservoir Elevation (%)	Flow Through Valve (m^3/s)	Time to Empty (Days)
210.0	210.0	100	275.4	0
210.0	180.0	75	237.1	15.8
210.0	150.0	50	191.3	25.3

As seen in the previous tables, the 2.5m diameter valve is the optimum choice.

III. Drawdown using 2.5m By-pass Evacuation Valve at Section 4 in Conjunction with 6 12-by-8m Gated Spillways

After selecting the 2.5m by-pass evacuation valve discharging into Section 4, a drawdown analysis was conducted in which the valve is operating in conjunction with the 6 12-by-8m gated spillways, whose invert is 198.0 m. The spillway gates and valve are fully open from the start. The results of this drawdown analysis with a constant inflow of 30.2 and 47.9 m^3/s are presented in Tables 4a and 4b, respectively.

Table 4a. Time required to empty reservoir with a 2.5m diameter by-pass evacuation valve discharging at Section 4 in conjunction with 6 12-by-8 m gated spillways (constant inflow = 30.2 m^3/s)

Full Reservoir Elevation (m)	Water Surface Elevation in Reservoir (m)	Elevation / Full Reservoir Elevation (%)	Flow Through Spillway (m^3/s)	Flow Through Valve (m^3/s)	Time to Empty (Days)
210.0	210.0	100	4549	140.5	0
210.0	180.0	75	0	121	21.6
210.0	150.0	50	0	97.6	43.7

Table 4b. Time required to empty reservoir with a 2.5 m diameter by-pass evacuation valve discharging at Section 4 in conjunction with 6 12-by-8 m gated spillways (constant inflow = 47.9 m^3/s)

Full Reservoir Elevation (m)	Water Surface Elevation in Reservoir (m)	Elevation / Full Reservoir Elevation (%)	Flow Through Spillway (m^3/s)	Flow Through Valve (m^3/s)	Time to Empty (Days)
210.0	210.0	100	4549	140.5	0
210.0	180.0	75	0	121	26.1
210.0	150.0	50	0	97.6	54.5

As seen in the tables above, the drawdown criteria are met. It was also determined that it is preferable to use the more conservative constant flow value of 47.9 m^3/s .

IV. Drawdown using 2.5m By-pass Evacuation Valve at Section 1 in Conjunction with 6 12-by-8m Gated Spillways

Another option is to set the by-pass valve at Section 1, located 400 m downstream of the dam. The invert is set at 99.0 m, slightly above the 98.2 m water surface elevation obtained during the PMF with the 6 12-by-8 m gated spillways open. Table 5 shows the drawdown results for this case with a constant inflow of 47.9 m3/s. The starting reservoir elevation is 210.0 m. Initially, the discharge goes through the 6 12-by-8m gated spillways with gates fully open. Once the water surface elevation reaches 200.0 m, the valve is opened as well. The valve remains closed initially in order to minimize downstream flows.

Table 5. Time required to empty reservoir with a 2.5m diameter by-pass evacuation valve discharging at Section 1 in conjunction with 6 12-by-8m gated spillways (constant inflow = 47.9 m^3/s)

Full Reservoir Elevation (m)	Water Surface Elevation in Reservoir (m)	Elevation / Full Reservoir Elevation (%)	Flow Through Spillway (m^3/s)	Flow Through Valve (m^3/s)	Time to Empty (Days)
210.0	210.0	100	4549	closed	0
210.0	200.0	92	283.6	131.2	1.1
210.0	180.0	75	0	117.4	27.5
210.0	150.0	50	0	93.2	57.8

V. Drawdown using 4-by-4 m Drop Shaft in Conjunction with 6 12-by-8m Gated Spillways

The last drawdown alternative considered consists of a 4-by-4 m drop shaft connected to a single 150 m long 7-by-7 m box culvert that discharges into Section 1. The box culvert has an invert of 88 m at the entrance and 87 m at the exit. The drop shaft has 2 orifices 3m wide by 4m high with inverts at 145.4 m and 115.0 m. A discharge coefficient of 0.65 was assigned to the orifices,

corresponding to an orifice with a slightly rounded entrance. The head is relative to the orifice invert and the FEQ model takes into account possible submergence inside the drop shaft. Since a constant inflow of 47.9 m^3/s is entering the reservoir, the orifice acts like a sharp-crested weir (C = 1.71) once the reservoir empties out and steady state conditions are reached. Since a constant flow of 47.9 m^3/s creates a head of 4.6 m, the invert of the top orifice was set at 145.4 m to ensure that the water surface elevation will drop to 150.0 m, or the 50% level.

The drop shaft was designed in a way that attempts to minimize downstream flows, and in a way that the top orifice will be able to satisfy drawdown requirements once the bottom orifice becomes silted. Table 6a-b summarizes the results of the analysis. First during the drawdown, the 6 12-by-8 m gated spillways are fully open. When the water level reaches 200.0 m, the top orifice is also opened. The water level drops to 150.0 m in less than 50 days. This elevation corresponds to the 50% reservoir level. At this point, if the bottom orifice is closed, the top orifice acts like a weir with a constant flow of 47.9m^3/s. Once the bottom orifice opens, the water level drops to 120.0 m in less than 60 days. This corresponds to the 25% level. This is far less time than the 80-100 day requirement. However, what controls the design in this case is the surcharge created by the constant inflow. A larger gate results in a smaller surcharge. Lowering the invert further to get to the 120.0m requirement is not an option due to siltation.

Table 6a. Time required to empty reservoir with the top orifice discharging into Section 1 in conjunction with 6 12-by-8m gated spillways (constant inflow = 47.9 m^3/s)

Full Reservoir Elevation (m)	Water Surface Elevation in Reservoir (m)	Flow Through Spillway (m^3/s)	Flow Through Orifice, Shaft, and Tunnel (m^3/s)	Water Surface Elevation in Shaft (m)	Cumulative Time to Empty (Days)
210.0	210.0	4549	0 (closed)	88.0	0
210.0	200.0	283.3	248.2	95.8	1.1
210.0	180.0	0	195.7	94.7	13.0
210.0	150.0	0	47.9	90.6	49.8

Table 6b. Drawdown analysis after bottom orifice opens (top orifice remains open, constant inflow = 47.9 m^3/s)

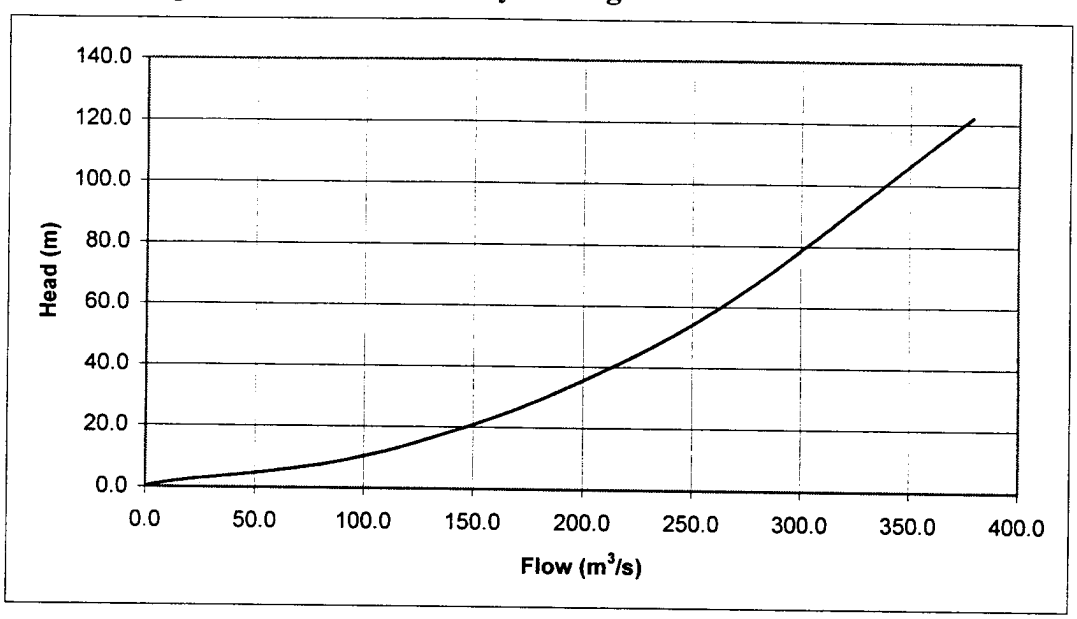
Full Reservoir Elevation (m)	Water Surface Elevation in Reservoir (m)	Flow Through Spillway (m^3/s)	Flow Through Orifice, Shaft, and Tunnel (m^3/s)	Water Surface Elevation in Shaft (m)	Cumulative Time to Empty (Days)
210.0	150.0	0	244.7	95.8	49.8
210.0	120.0	0	52.3	90.8	58.0

A different approach to determine siltation during the life of the dam shows that the silt level will be below 115.0 m. In this case, a single 3 m wide by 4 m high orifice can be used in the bottom, with an invert of 115.0 m. Table 6c shows the drawdown time for this case. Initially, the flow is entirely through the spillway, in order to minimize downstream flows. When the water surface elevation reaches 200.0 m, the orifice is opened. Figure 1 shows the rating curve for a 3-by-4m orifice.

Table 6c. Time required to empty reservoir with the bottom orifice discharging into Section 1 in conjunction with 6 12-by-8m gated spillways (constant inflow = 47.9 m^3/s)

Full Reservoir Elevation (m)	Water Surface Elevation in Reservoir (m)	Flow Through Spillway (m^3/s)	Flow Through Orifice, Shaft, and Tunnel (m^3/s)	Water Surface Elevation in Shaft (m)	Cumulative Time to Empty (Days)
210.0	210.0	4549	0 (closed)	88.0	0
210.0	200.0	283.3	310.2	97.1	1.1
210.0	180.0	0	273.2	96.3	9.6
210.0	150.0	0	196.8	94.7	18.9
210.0	120.0	0	52.3	90.8	27.3

Figure 1. Rating curve for a 3m-wide-by-4m-high orifice



Attachment 1c – Evaluation of Spillway Size

MWH
MONTGOMERY WATSON HARZA

MWH ENERGY & INFRASTRUCTURE, INC.
PRIVATIZATION AND PROJECT DEVELOPMENT

Location Chicago Office **Date** May 29, 2003

To Michael Newbery

From Paul M. Kanellopoulos

Subject Upper Chagres Water Supply Feasibility Study
Evaluation of Spillway Size

This memorandum summarizes the procedures and results performed for the Upper Chagres Dam spillway design. The analysis includes:

- Estimation of flood surcharges for an ungated Ogee spillway with length ranging from 25 to 350 m and a crest elevation of 220.0 m;
- Estimation of flood surcharges for an ungated Ogee spillway with a spillway length of 50 m and a starting full supply level ranging from 170.0 to 240.0 m; and
- Estimation of flood surcharges for a gated spillway of several gate dimensions with a 0.75:1 width to height ratio.

Basic data used in the analysis is discussed. Results are provided as tables.

Computer Model

The Full-Equations (FEQ) modeling system of one-dimensional, unsteady, open-channel flow was used for the hydraulic analysis of the Upper Chagres Dam. FEQ is based on the full Saint-Venant equations. This modeling system, developed by Delbert Franz of Linsley, Kraeger Associates, Ltd., Mountain View, CA is widely used by engineers and hydrologists in county and state agencies and consulting firms, and has been accepted by the Federal Emergency Management Agency (FEMA) for use in floodplain studies. It is used in a variety of applications such as flood studies, design studies for dam spillways, dam break analyses, and legal cases. The program supports a wide variety of structures including bridges, culverts, dams, level-pool reservoirs, spillways, weirs, sluice gates, pumps, side weirs, expansions, contractions, drop structures, and flow over roadways. The hydraulic features of the stream system, such as channel cross-sectional properties, are incorporated into the model. FEQ is capable of

simulating flow conditions in a network of open channels and storm sewers. The flow conditions are simulated in terms of water-surface elevation, water velocity, and discharge at any point in the system.

Introduction

A wide range of spillway sizes was evaluated by routing the probable maximum flood (PMF) through the Upper Chagres reservoir. The PMF and reservoir stage-volume data are listed in Tables 1 and 2, respectively. Ogee spillway coefficients vary with surcharge and range between 1.5 and 2.28. A design head of 3 m was used to determine these coefficients, which are listed in Table 3.

Table 1. Probable Maximum Flood at Upper Chagres

Time (hrs)	0	1	2	3	4	5	6	7
Flow (cms)	50	72	156	397	602	725	818	935
Time (hrs)	8	9	10	11	12	13	14	15
Flow (cms)	1135	1682	3214	6254	9555	9936	7571	5406
Time (hrs)	16	17	18	19	20	21	22	23
Flow (cms)	4068	3286	2756	2371	2095	1854	1620	1422
Time (hrs)	24	25	26	27	28	29	30	31
Flow (cms)	1255	1086	906	627	418	305	237	192
Time (hrs)	32	33	34	35	36	37	38	39
Flow (cms)	158	131	110	93	78	68	60	55
Time (hrs)	40	41	42	43	44	45	46	47
Flow (cms)	52	51	50	50	50	50	50	50

Table 2. Reservoir Capacity Curve at Upper Chagres

Elevation (m)	Area (km^2)	Volume (MCM)
88	-	-
90	0.02	0.01
95	0.09	0.26
105	0.21	1.72
112	0.42	3.87
120	0.76	8.50
130	1.27	18.53
135	1.67	25.85
145	2.68	47.41
155	3.75	79.40
165	5.05	123.23
175	6.44	180.55
185	8.17	253.44
195	10.24	345.30
205	12.61	459.33
215	15.28	598.53
225	18.49	767.09
235	22.14	969.96
245	26.07	1210.75

Table 3. Ogee Spillway Coefficients for a Design Head of 3m

Surcharge (m)	Coefficient
0.0	1.50
0.36	1.66
0.6	1.74
0.9	1.85
1.2	1.93
1.5	2.00
1.8	2.06
2.1	2.10
2.4	2.15
2.7	2.20
3.0	2.23
3.3	2.25
3.6	2.27
3.9	2.28
4.2	2.28
5.0	2.28
10.0	2.28

Evaluation of Spillway Size

I. Ungated Spillway

Results for surcharge as a function of spillway length are shown in Table 4. This includes spillway lengths ranging from 25-350 m with a starting pool elevation of 220.0 m. The top of dam is determined by adding 1m of freeboard to the maximum water surface elevation in the reservoir. Another analysis was done in which the spillway length is fixed at 50m and the starting full supply level varies between 170-240 m. Results are shown in Table 5.

Table 4. Surcharge for Several Spillway Lengths During PMF

Spillway Length (m)	Starting Full Supply Level (m)	Peak Discharge (m^3/s)	Surcharge (m)	Maximum Water Surface Elevation (m)	Top of Dam (m)
25	220.0	1750	9.8	229.8	230.8
50	220.0	2756	8.4	228.4	229.4
100	220.0	4158	6.9	226.9	227.9
150	220.0	5147	6.1	226.1	227.1
200	220.0	5910	5.5	225.5	226.5
250	220.0	6521	5.1	225.1	226.1
260	220.0	6635	5.0	225.0	226.0
300	220.0	6957	4.7	224.7	225.7
350	220.0	7293	4.4	224.4	225.4

Table 5. Surcharge Over the 50 m Spillway During the PMF for Various Starting Full Supply Levels

Starting Full Supply Level (m)	Peak Discharge (m^3/s)	Surcharge (m)	Maximum Water Surface Elevation (m)	Top of Dam (m)
170.0	5853	13.8	183.8	184.8
200.0	3738	10.3	210.3	211.3
210.0	3221	9.3	219.3	220.3
220.0	2756	8.4	228.4	229.4
240.0	1306	5.1	245.1	246.1

II. Gated Spillway

A gated spillway analysis was conducted with a starting full supply level of 210.0 m and a width to height ratio of approximately 0.75:1 for the gates. The goal is to determine which gate configuration will be needed to obtain a maximum water surface elevation of 219.3 m during the PMF, which corresponds to a 50 m spillway with a crest at 210.0 m as shown in Table 5. A total of 7 gated spillway configurations were analyzed. For each configuration, the spillway crest is computed by subtracting the gate height from the full supply level. The first step in developing the rating curves is to compute the flow through the spillway with the starting full supply level, which corresponds to the top of the gate. The flow is computed using the equation $Q = CLH^{1.5}$, where Q = flow (m^3/s), C = ogee spillway coefficient, or 2.28 for higher depths, L = length of spillway (m), and H = head above spillway crest (m). When flows into the reservoir exceed this amount, the head starts building up. Otherwise, inflow = outflow and the head remains constant. This can be observed in the rating curves for each gated spillway configuration shown in Table 6.

Peak flows and maximum water surface elevations for each of the 7 spillway configurations analyzed are summarized in Table 7. As noted in the table, the spillway configuration that most closely matches the required 219.3 m surcharge is the 2-gate, 9m high, 6.75m wide configuration. This can be further refined by interpolation. It can also be noted that to pass the PMF with no surcharge requires 6 16-by-12 m spillways.

Table 6. Rating Curves for Different Spillway Configurations in the Upper Chagres Dam

Head (m)	Flow (cms) 2, H=10.0m W=7.5m	Flow (cms) 2, H=7.5m W=5.6 m	Flow (cms) 2, H=7.0m W=5.25 m	Flow (cms) 6, H=10.0m W=7.5m	Flow (cms) 2, H=9.0m W=6.75m	Flow (cms) 6, H=12.0m W=8.0m	Flow (cms) 6, H=16.0m W=12.0m
7.0	-	-	0 - 443	-	-	-	-
7.5	-	0 - 524	492	-	-	-	-
8.0	-	578	542	-	-	-	-
8.5	-	633	593	-	-	-	-
9.0	-	689	646	-	0 - 831	-	-
9.5	-	748	701	-	901	-	-
10.0	0 - 1081	808	757	0 - 3244	973	-	-
10.5	1164	869	815	3491	1047	-	-
11.0	1248	932	873	3743	1123	-	-
11.5	1334	996	934	4001	1200	-	-
12.0	1422	1062	995	4265	1280	0 - 4549	-
12.5	1511	1129	1058	4534	1360	4837	-
13.0	1603	1197	1122	4809	1443	5130	-
13.5	1696	1267	1187	5089	1527	5428	-
14.0	1792	1338	1254	5375	1612	5733	-
14.5	1888	1410	1322	5665	1699	6043	-
15.0	1987	1484	1391	5961	1788	6358	-
15.5	2087	1558	1461	6261	1878	6678	-
16.0	2189	1634	1532	6566	1970	7004	0-10506
16.5	2292	1712	1605	6877	2063	7335	11003
17.0	2397	1790	1678	7192	2157	7671	11506
17.5	2504	1869	1753	7511	2253	8012	12018
18.0	2612	1950	1828	7835	2351	8358	12536
18.5	2721	2032	1905	8164	2449	8708	13062
19.0	2832	2115	1983	8497	2549	9064	13596
19.5	2945	2199	2061	8835	2650	9424	14136
20.0	3059	2284	2141	9177	2753	9789	14683
20.5	3174	2370	2222	9523	2857	10158	15237
21.0	3291	2457	2304	9874	2962	10532	15798
21.5	3409	2546	2387	10228	3069	10910	16365
22.0	3529	2635	2470	10587	3176	11293	16940
22.5	3650	2725	2555	10950	3285	11680	17520
23.0	3772	2817	2641	11317	3395	12072	18108
23.5	3896	2909	2727	11688	3506	12467	18701
24.0	4021	3002	2815	12063	3619	12867	19301
24.5	4147	3097	2903	12442	3733	13272	19907
25.0	4275	3192	2993	12825	3848	13680	20520

Table 7. Surcharge and Peak Flow for Various Gated Spillway Configurations

Spillway Config.	2 Gates H=10.0m W=7.5m	2 Gates H=7.5m W=5.6 m	2 Gates H=7.0m W=5.25m	6 Gates H=10.0m W=7.5m	2 Gates H=9.0m W=6.75m	6 Gates H=12.0m W=8.0m	6 Gates H=16.0m W=12.0m
Crest (m)	200.0	202.5	203.0	200.0	201.0	198.0	194.0
Full Supply Level (m)	210.0	210.0	210.0	210.0	210.0	210.0	210.0
Peak Flow (m^3/s)	2642	1887	1754	5435	2324	6265	9936
Max Water Surface Elevation (m)	218.1	220.1	220.5	214.1	218.9	212.9	210.0
Top of Dam (m)	219.1	221.1	221.5	215.1	219.9	213.9	211.0

Attachment 2 – Comparative Cost Estimate

Comparative Cost Estimates

Unit costs for major items of dam construction were developed. These items include: excavation (common and rock), fill placement, quarrying, concrete fabrication and placement, formwork, steel reinforcement and Roller Compacted Concrete. Other unit costs were estimated from experience on other project of similar nature. The major unit costs were developed using cost of labor, equipment and material.

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

Unskilled labor:	$5.50/hr
Skilled labor:	$6.60/hr
Equipment operator:	$7.90/hr
Truck driver:	$6.20/hr

In addition to the local labor a crew leader was generally included at the rate of $10.00/hr. For specialized activities, an engineer was included at the rate of $60.00 per hour.

Equipment rate were obtained from the publication of the US Army Corps of Engineers entitled "Construction Equipment Ownership and Operating Expense" (EP 1110-1-8), dated August 31, 2001. Equipment requirements and production rates were developed based on experience in similar type of project in tropical countries.

Materials including explosives, cement, and reinforcement steel are anticipated to be imported for the most part. International unit prices were used.

The build-up of the unit rates include also a margin of 30% to reflect the following items:

Contractor home office charges	7%
Bond and Insurance	4%
Project management and engineering	7%
Margin for risk	2%
Margin for profit	10%

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 they appear to be reasonable estimate for this type of construction.

The principal unit cost used for the dam comparison study at the Upper Chagres dam site are as follows:

Overburden Excavation	\$3.20 per m^3
Rock Excavation	\$8.75 per m^3
Concrete	\$115.00 per m^3
Formwork	\$46.20 per m^2
Steel Reinforcement	\$1,360 per metric ton
Roller Compacted Concrete	\$46.50 per m^3
Rock fill	\$10.25 per m^3
Filters/ Drains	\$15.90 per m^3

These unit costs are based on estimated production rate adjusted for site-specific conditions. For the RCC placement an average production rate of 250 m^3 per hour is estimated to be a reasonable rate under the climatic and topographic conditions of the site. Similarly the unit cost for rockfill takes into account the geological conditions as it is anticipated that approximately 20% of the rock will be obtained from required excavation (spillway and dam foundation) and the rest will be quarried less than one kilometer from the dam site. Access to the quarry located north of the confluence of Rio Chico and Rio Chagres will be gained through a crossing of Rio Chico to be built slightly upstream of the confluence.

Construction Schedule

The total quantity of RCC to be placed is estimated at about 2.7 million m^3 at an average weekly production of 24,000 m^3, it corresponds to approximately 26 months of construction. The overall construction of the RCC dam is anticipated to take approximately 48 months with12 months for preparation, including, the diversion tunnel, cofferdams, quarrying aggregate, foundation preparation, etc., and 10 months for finishing works.

The construction of the CRFD dam will require the excavation of about 9.5 million m^3 of rock from either required excavation or quarry excavation. This is anticipated to take approximately 50 months. Preparatory works of 12 months including cofferdam, diversion and low level outlet, and finishing works of 6 to 9 months will result in an overall construction period of approximately five to six years.

Panama Canal Authority
Contract CC-3-536
Task Order 11, Rio Chagres Water Supply Feasibility Study
Dam Type Alternative Study

CFRD **Ungated** **$ 191,131,451**

Quantity Take-Offs

Item	Description	Unit	Quantity		Unit Cost		Cost
DIVERSION							
1	Site Preparation	m^2	20,000	$	0.55	$	11,000
2	Diversion Tunnel Intake and Outlet Portals						
	2.1 Rock	m^3	48,483	$	8.75	$	424,229
	2.2 Shotcrete	m^2	4,594	$	45.90	$	210,882
	2.3 Rockbolts	l.m.	2,297	$	60.50	$	138,980
	2.4 Concrete	m^3	237	$	115.00	$	27,250
	2.5 Formwork	m^2	548	$	46.20	$	25,322
	2.6 Reinforcement	kg	9,289	$	1.36	$	12,632
3	Diversion Tunnel						
	3.1 Tunnel Ex.	m^3	68,599	$	72.00	$	4,939,125
	3.2 Shotcrete	m^2	15,907	$	45.90	$	730,123
	3.3 Rockbolts	l.m.	6,948	$	60.50	$	420,353
	3.4 Steel Ribs	kg	96,158	$	2.90	$	278,858
4	Cofferdams						
	4.1 Overburden Excavation	m^3	-	$	3.20	$	-
	4.2 Mass RCC	m^3	100,469	$	50.00	$	5,023,459
	Subtotal					$	12,242,215
DAM							
1	Site Preparation	m^2	360,000	$	0.55	$	198,000
2	Excavation						
	2.1 Overburden	m^3	2,146,308	$	3.20	$	6,868,187
	2.2 Rock	m^3	1,073,154	$	8.75	$	9,390,099
3	Grouting						
	3.1 Cut-off	m^2	62,113	$	46.00	$	2,857,185
	3.1 Consolidation	m	3,300	$	69.20	$	228,360
4	Rockfill						
	4.1 Mass	m^3	9,468,877	$	10.25	$	97,055,986
	4.2 Filter	m^3	535,252	$	15.90	$	8,510,499
	4.3 Drain	m^3	38,161	$	15.90	$	606,759
5	Concrete						
	5.1 Plinth	m^3	23,904	$	172.00	$	4,111,488
	5.2 Facing	m^2	178,417	$	80.00	$	14,273,374
	5.3 Parapet -US	m^3	5,495	$	252.00	$	1,384,784
	5.4 Parapet -DS	m^3	1,038	$	252.00	$	261,570
	5.5 Crest	m^3	7,327	$	175.00	$	1,282,208
Subtotal						$	147,028,498

CFRD **Ungated**

Quantity Take-Offs

Item	Description	Unit	Quantity		Unit Cost		Cost
SPILLWAY							
1	Site Preparation	m^2	150,000	$	0.55	$	82,500
2	Excavation						
	2.1 Overburden	m^3	1,715,000	$	3.20	$	5,488,000
	2.2 Rock	m^3	714,100	$	8.75	$	6,248,375
	2.3 Backfill	m^3	11,397	$	7.20	$	82,058
3	Headworks						
	3.1 Concrete	m^3	10,863	$	115.00	$	1,249,292
	3.2 Formwork	m^2	4,423	$	46.20	$	204,337
	3.3 Reinforcement	kg	363,513	$	1.36	$	494,378
4	Chute and Flip Bucket						
	4.1 Concrete	m^3	44,335	$	115.00	$	5,098,480
	4.2 Formwork	m^2	9,437	$	46.20	$	435,983
	4.3 Reinforcement	kg	1,888,279	$	1.36	$	2,568,059
	4.4 Drains	l.m.	11,564	$	9.00	$	104,076
	4.5 Anchors	l.m.	23,990	$	37.00	$	887,645
5	Bridge						
	5.1 Concrete	m^3	856	$	140.00	$	119,840
	5.2 Formwork	m^2	1,070	$	46.20	$	49,434
	5.3 Reinforcement	kg	134,221	$	1.36	$	182,540
Subtotal						$	23,294,999
LOW LEVEL OUTLET							
1	Shaft and Gate Structure						
	1.1 Excavation, Rock	m^3	6,226	$	295.00	$	1,836,756
	1.2 Shotcrete	m^2	2,185	$	45.90	$	100,276
	1.3 Rockbolts	l.m.	2,196	$	60.50	$	132,858
	1.4 Concrete	m^3	5,747	$	140.00	$	804,626
	1.5 Formwork	m^2	8,241	$	46.20	$	380,737
	1.6 Reinforcement	kg	225,295	$	1.36	$	306,402
2	Tunnel Lining						
	2.1 Concrete	m^3	4,739	$	115.00	$	544,991
	2.2 Formwork	m^2	10,962	$	10.00	$	109,619
	2.3 Reinforcement	kg	185,771	$	1.36	$	252,648
3	Intake Stucture						
	3.1 Concrete	m^3	2,304	$	115.00	$	264,960
	3.2 Formwork	m^2	2,016	$	46.20	$	93,139
	3.3 Reinforcement	kg	90,240	$	1.36	$	122,726
4	Steel Lining						
	3.1 Steel Liner	kg	1,130,000	$	3.20	$	3,616,000
Subtotal						$	8,565,739
Total						$	191,131,451

Panama Canal Authority
Contract CC-3-536
Task Order 11, Rio Chagres Water Supply Feasibility Study
Dam Type Alternative Study

RCC Ungated $ **179,908,556**

Quantity Take-Offs

Item	Description	Unit	Quantity		Unit Cost		Cost
DIVERSION							
1	Site Preparation	m^2	20,000	$	0.55	$	11,000
2	Diversion Tunnel Intake and Outlet Portals						
	2.1 Rock	m^3	57,817	$	8.75	$	505,900
	2.2 Shotcrete	m^2	5,232	$	45.90	$	240,140
	2.3 Rockbolts	l.m.	2,616	$	60.50	$	158,262
	2.4 Concrete	m^3	237	$	115.00	$	27,250
	2.5 Formwork	m^2	548	$	46.20	$	25,322
	2.6 Reinforcement	kg	9,289	$	1.36	$	12,632
3	Diversion Tunnel						
	3.1 Tunnel Ex.	m^3	42,848	$	72.00	$	3,085,075
	3.2 Shotcrete	m^2	11,132	$	45.90	$	510,963
	3.3 Rockbolts	l.m.	5,557	$	60.50	$	336,218
	3.4 Steel Ribs	kg	67,294	$	2.90	$	195,154
4	Cofferdams						
	4.1 Overburden Excavation	m^3	-	$	3.20	$	-
	4.2 Mass RCC	m^3	100,200	$	50.00	$	5,010,000
Subtotal						$	10,117,916
DAM							
1	Site Preparation	m^2	90,000	$	0.55	$	49,500
2	Foundation Excavation						
	2.1 Overburden	m^3	840,000	$	3.20	$	2,688,000
	2.2 Rock	m^3	839,300	$	8.75	$	7,343,875
3	Grouting						
	3.1 Cut-off	m^2	48,480	$	46.00	$	2,230,094
	3.2 Consolidation	m	14,150	$	69.20	$	979,180
4	RCC						
	4.1 Mass	m^3	2,660,000	$	46.50	$	123,690,000
	4.2 Uncompacted	m^3	24,762	$	44.00	$	1,089,541
	4.3 US/DS Facing	m^3	48,453	$	282.00	$	13,663,618
	4.4 Foundation	m^3	68,382	$	115.00	$	7,863,930
	4.5 Gallery	m^3	4,200	$	115.00	$	483,000
Subtotal						$	160,080,738

RCC **Ungated**

Quantity Take-Offs

Item	Description	Unit	Quantity		Unit Cost		Cost
SPILLWAY							
1	Headworks						
	1.1 Concrete	m^3	1,290	$	115.00	$	148,304
	1.2 Formwork	m^2	880	$	46.20	$	40,638
	1.3 Reinforcement	kg	40,141	$	1.36	$	54,591
2	Chute and Flip Bucket						
	2.1 Concrete	m^3	10,802	$	115.00	$	1,242,230
	2.2 Formwork	m^2	8,804	$	46.20	$	406,745
	2.3 Reinforcement	kg	417,166	$	1.36	$	567,346
3	Bridge						
	3.1 Concrete	m^3	432	$	140.00	$	60,480
	3.2 Formwork	m^2	540	$	46.20	$	24,948
	3.3 Reinforcement	kg	67,738	$	1.36	$	92,123
4	Plunge Pool Excavation						
	4.1 Rock	m^3	310,443	$	8.75	$	2,716,378
Subtotal						$	5,353,783
LOW LEVEL OUTLET							
1	Shaft and Gate Structure						
	1.1 Excavation, Rock	m^3	5,522	$	295.00	$	1,628,891
	1.2 Shotcrete	m^2	2,124	$	45.90	$	97,479
	1.3 Rockbolts	l.m.	2,080	$	60.50	$	125,840
	1.4 Concrete	m^3	5,294	$	140.00	$	741,227
	1.5 Formwork	m^2	7,614	$	46.20	$	351,760
	1.6 Reinforcement	kg	207,544	$	1.36	$	282,259
2	Tunnel Lining						
	2.1 Concrete	m^3	3,386	$	115.00	$	389,399
	2.2 Formwork	m^2	7,792	$	10.00	$	77,921
	2.3 Reinforcement	kg	132,734	$	1.36	$	180,519
2	Intake Stucture						
	2.1 Concrete	m^3	2,304	$	115.00	$	264,960
	2.2 Formwork	m^2	2,016	$	46.20	$	93,139
	2.3 Reinforcement	kg	90,240	$	1.36	$	122,726
Subtotal						$	4,356,119
Total						$	179,908,556

FEASIBILITY DESIGN FOR THE UPPER CHAGRES WATER SUPPLY PROJECT

APPENDIX D

PART 2

PROJECT COMPONENT CONFIGURATION

Prepared by

MWH

In association with

TAMS

AN EARTH TECH COMPANY

FEASIBILITY DESIGN FOR THE UPPER CHAGRES WATER SUPPLY PROJECT

APPENDIX D – PART 2
PROJECT COMPONENT CONFIGURATION

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ATTACHMENTS

Attachment 1	Hydraulic Studies for Gated Spillways
Attachment 2	Comparative-Level Cost /Height Curve
Attachment 3	RCC Dam Stability and Bearing Capacity Analysis

1 INTRODUCTION

With the selection of an RCC dam as the type of dam to be carried forward in the feasibility study, several additional studies were performed to confirm or improve the configuration of the project. These are:

1. Development of area and volume curves;
2. Confirm the type, location, and size of the spillway;
3. Confirm the type, location, and size of the diversion facilities;
4. Confirm the type, location, and size of the low level outlet facilities, and
5. Check the dam stability.

2 AREA/VOLUME VERSUS ELEVATION

This section presents the rationale for the definition of the area and volume versus elevation relationships for the Upper Chagres Reservoir. The procedures used by the Panama Canal Authority (ACP) and the US Army Corps of Engineers, Mobile District (USACE) to estimate the area and volume of the proposed Upper Chagres reservoir are compared against with the procedures used by MWH. The comparison shows that the ACP/USACE areas and volumes are on the order of 10 percent higher than those estimated by MWH. It is recommend that the area and volume estimates developed by MWH be used for feasibility study. It is further recommended that additional surveying be performed to confirm the area and volume of the proposed Upper Chagres Reservoir if studies proceed beyond the feasibility level.

Topography for the Upper Chagres reservoir was taken from digital contour maps provided to MWH by ACP in *.dgn* format (Microstation/Inroads). The topographic survey was made using IFSAR (Interferometric Synthetic Aperture Radar) data; the contours provided in the *.dgn* files are at 10-m intervals. The IFSAR data represents the 'top-of-trees' topography and not the actual ground surface.

Topography of the proposed dam site was generated from a ground survey performed during November and December 2001 by Ingenieria Avanzada, S.A. (IASA). IASA provided MWH the raw data from the survey and contours generated from the raw data.

Based on an index, the proposed dam site and reservoir are located on the following 1:50,000 topographic quad sheets:

1. Buena Vista (4243-I) – dam site
2. S/N (4343-IV) – majority of reservoir
3. name unknown (4344-III) – reservoir above contour El. 240 m

We were not able to obtain these sheets and are not sure that they exist. We have been provided with a photocopy of part of the Buena Vista sheet, which covers the proposed dam site. We also have a *.dxf* file of the sheet. These data were not used.

MWH has been provided aerial photographs of the proposed dam site but not of the reservoir area.

MWH estimated area by measuring the planimetric area of individual contours. Each of the contours forming the reservoir boundary was joined into a single line; the area bounded by each contour was computed using the 2-D AutoCAD *area* command. This was performed for all contours at 10-m intervals between El. 90 and El. 260.

The topographic survey made at the proposed dam site by IASA in 2001 indicates that the ground surface elevation at the dam site is approximately 88 m; this was used as the zero-area elevation.

ACP/USACE area and volume estimates were provided to MWH in an Excel file named *Elev-vol_AB -Mobile.xls*; the computations appear to have been completed around May-June, 1999. The computations are based on area measurements made at six elevations: 100, 150, 180, 200, 220 and 250 meters. The zero-area elevation used is El. 96.62, which was reportedly determined by linear extrapolation of the area curve.

The areas estimated by MWH and ACP/USACE are generally not in agreement (see Table 1 below). ACP/USACE area estimates are on the order of 10 percent (or more) greater than those made by MWH.

Table 1 Comparison of Upper Chagres Reservoir Contour Areas with Elevation (top-of-tree topography)

Contour Elevation	Area (km^2) ACP/USACE Estimate	Area (km^2) MWH Estimate	Difference (from MWH estimate)
88 m	--	0	--
96.62 m	0	--	--
100 m	0.124	0.091	+ 36 %
150 m	1.958	1.673	+ 17 %
180 m	5.504	5.048	+ 9.0 %
200 m	8.837	8.169	+ 8.2 %
220 m	13.862	12.606	+ 10.0 %
250 m	24.205	22.144	+ 9.3 %

We do not know why the areas are different. It is possible that the difference in the areas is due to the way in which they were measured. In making reservoir area estimates for Río Indio and Coclé del Norte, MWH noted that the areas estimated using 3-D surfaces models in *AutoCAD Land Development Desktop* (ACAD LDD) tended to be greater than those estimated by planimetering off the areas directly from the contours. Maurice James (USACE, Mobile District) indicated that the program *Inroads* (similar to ACAD LDD) was used to generate dam layouts for the Reconnaissance Study. If *Inroads* was also used for making area estimates from a 3-D surface model, then this could explain the differences in the area estimates.

MWH recommends that reservoir area estimates be made by planimetering areas directly from individual contours or using a 2-D model. Use of 3-D surfaces to estimate areas adds an additional level of approximation to the process; the difference between planimetered areas and areas from a 3-D surface varies as a function of the topographic expression and is difficult to quantify.

The initial estimates of area were computed using 'top-of-trees' topography based on the IFSAR data.

The ACP/USACE subtracted a maximum of 15 m from the initial area estimates to account for tree cover in order to correct the reservoir contours to ground elevations. This was performed for each of the contours above El. 150; i.e. uncorrected elevations El. 150 to El. 250 correspond to corrected elevations El. 135 to El. 235. The correction factor decreased from 15 m at El. 135 to 0 m at El. 96.6.

MWH concurs with the 15-m correction based on the following:

- Observations made during a visit to the proposed dam site and the area upstream made by the Hydrologist, Task Manager and Project Manager generally confirm the assumption.
- Consideration of published literature discussing the types of trees present within the Canal Area and in the Bayano river watershed, generally confirms the assumption. It is noted in the literature that there are generally two tree strata present, the lower stratum averaging 8 to 12 m in height and the upper stratum averaging 23 to 30 m in height. The two tree strata are variably intermixed.

- With the additional topographic survey data collected by IASA at the dam site, it is possible to evaluate the appropriateness of the 15-m correction factor for tree height. This is perhaps the most quantitative method for evaluating the correction factor

ACP made a comparison between IFSAR data and the 1:50,000 topo for the proposed Río Indio reservoir area. Reportedly, the data did not compare well. A part of the problem was attributed to a substantial amount of clearing that is present within the Indio reservoir area. Since IFSAR data represents the top of trees, it was difficult to make a blanket correction for the Indio Reservoir area when a significant portion of the area has been cleared. Reportedly there has been very little clearing in the Upper Chagres reservoir area, so it is anticipated that a correction can be made to the estimated reservoir area.

A comparison was made between the IFSAR topography and the topography generated from the IASA ground survey. Three-dimensional surfaces of the IFSAR and survey topographies were generated in ACAD LDD. A comparison was made by cutting sections through the surfaces at 50-m intervals.

The sections included the IFSAR surface, the 'corrected' IFSAR surface (-15 m), and the survey surface. Comparison of the sections shows that general shape of the topography is similar, however the difference in the elevations for the corrected IFSAR and survey surfaces ranges between about –30m to +30m. The elevation correspondence between the two surfaces is variable along the sections.

A comparison was also made by subtracting both the uncorrected and corrected IFSAR surfaces from the survey surface. This yielded the following results:

Survey – uncorrected IFSAR:	11,595,000 CM net cut
Survey – corrected IFSAR	360,500 CM net fill

Using a 2-D area of the surfaces of 830,500 SM, the uncorrected IFSAR surface is an average of 14 m higher than the survey surface; the corrected IFSAR surface is on average 0.4 m lower than the survey topography. An elevation-band plot of the height difference between the corrected IFSAR and survey surfaces indicates that the elevation

difference between the two surfaces is less than 10 m for more than half of the survey area. Locations where the greatest elevation difference between the two surfaces (on the order of 30 to 40 m) occurs appears to be in the vicinity of the steeper slopes, particularly in the SE corner of the survey area.

Based on these results, it appears that the 15-m correction factor for tree height is appropriate. It should be noted, however, that the area over which the surfaces were directly compared represents only a very small portion of the reservoir area.

The following procedure was used by ACP/USACE to generate reservoir volume estimates:

1. Fit a third-order polynomial to 'corrected' areas at five elevations: 96.62, 135, 165, 185, 205 and 235 m. Areas from this fit are referenced in Recon report.
2. Estimate volumes from the five elevations listed in (1) using the equation given below.
3. Fit a third-order polynomial to the five volume points. Volumes from this fit are referenced in the Recon report.

The equation used for volume estimates is (H is elevation, A is area):

$$Volume = \frac{1}{3}(H_1 - H_2)(A_1 + A_2 + \sqrt{A_1 A_2})$$

MWH volume estimates were made with MWH area data using the above equation and a smooth curve was drawn through the data. The same equation was used by MWH for estimating volumes for the Río Indio, Caño Sucio and Coclé Del Norte reservoirs. Generally, the ACP/USACE volumes are on the order of 10 percent greater than those estimated by MWH. A comparison of the two estimates is shown in Table 2.

Table 2 Comparison of Upper Chagres Reservoir Cumulative Volumes with Elevation

Contour Elevation	Volume (MCM) USACE Estimate	Volume (MCM) MWH Estimate	Difference (from MWH estimate)
130 m	21.08	18.53	+ 13.8 %
135 m	28.53	25.85	+ 10.3 %
165 m	128.51	123.23	+ 4.3 %
185 m	272.66	253.44	+ 7.6 %
205 m	504.11	459.33	+ 9.7 %
225 m	844.51	767.09	+ 10.1 %
235 m	1,062.36	969.96	+ 9.5 %

It is concluded that:

1. The ACP/USACE and MWH area-volume estimates for the proposed Upper Chagres reservoir differ by approximately 10 percent, with the ACP/USACE values being the higher of the two estimates.
2. Based on the available information, the 15-m correction factor for tree height appears to be appropriate.

It is recommended that:

1. The curve prepared by MWH be adopted for use in the feasibility level studies
2. Additional surveying of the reservoir be performed during any design studies to confirm the estimated topography.

The area and volume data are presented in Table 3 and on Figures 1 and 2. Additional backup and calculations relating to the MWH and ACP/USACE estimates of area and the topography comparison for the reservoir area correction are available in the project files.

Table 3 Recommended Upper Chagres Reservoir Area-Volume Data

Elevation (m)	Area (km^2)	Cumulative Volume (MCM)
88	0	0
90	**0.02**	**0.01**
95	**0.09**	**0.26**
100	0.12	0.15
105	**0.21**	**1.72**
110	0.33	3.60
120	**0.76**	**8.50**
125	1.00	12.0
130	**1.27**	**18.53**
135	**1.67**	**25.85**
140	2.14	36.0
145	**2.68**	**47.41**
150	3.20	61.0
155	**3.75**	**79.40**
160	4.38	100.0
165	**5.05**	**123.23**
170	5.72	151.0
175	**6.44**	**180.55**
180	7.26	215.0
185	**8.17**	**253.44**
190	9.14	296.0
195	**10.24**	**345.30**
200	11.39	399.0
205	**12.61**	**459.33**
210	13.89	526.0
215	**15.28**	**598.53**
220	16.82	680.0
225	**18.49**	**767.09**
230	20.25	864.0
235	**22.14**	**969.96**
240	24.05	1087.0
245	**26.07**	**1,210.75**

Values in **BOLD** indicate measured contour data; all other values interpolated from curve

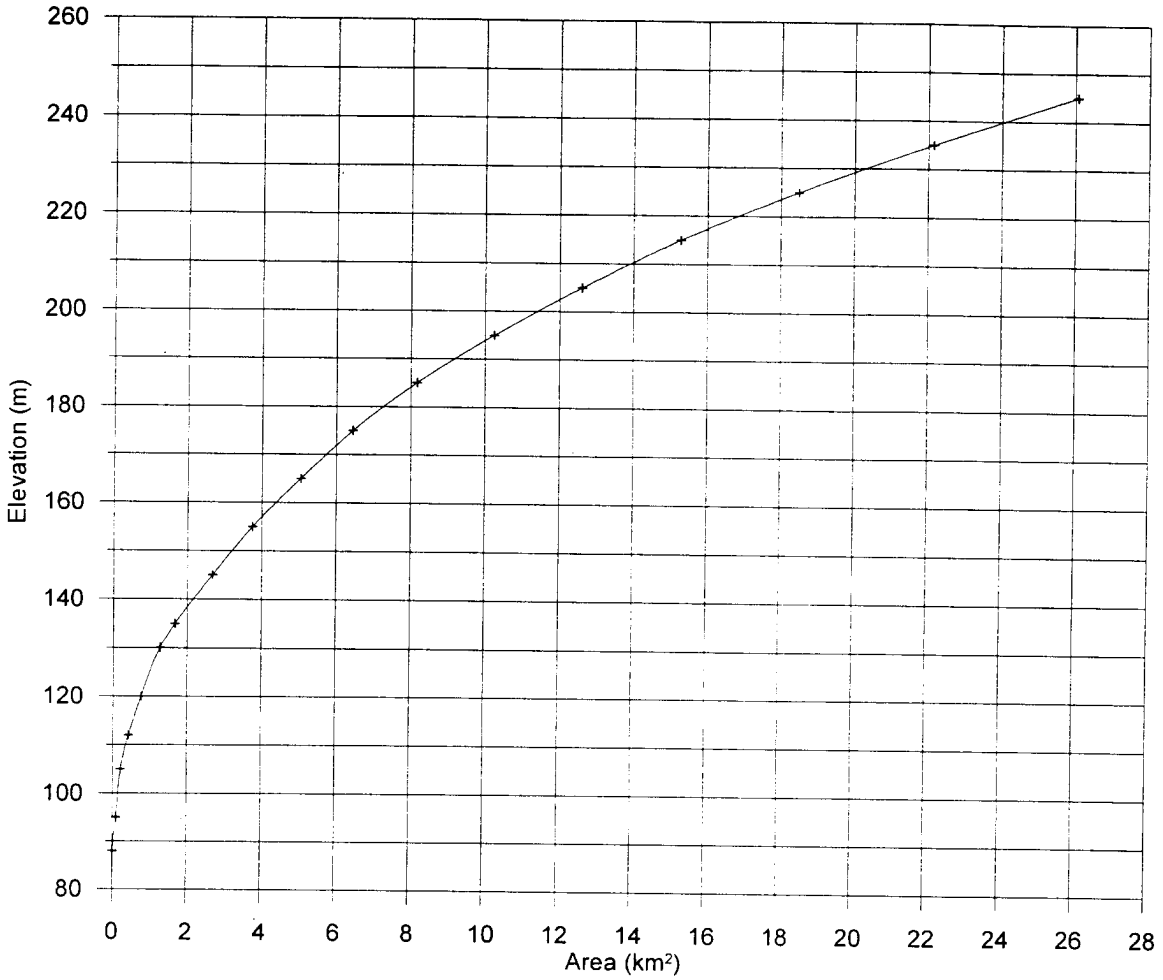


Figure 1. Recommended Upper Chagres Elevation-Area Curve

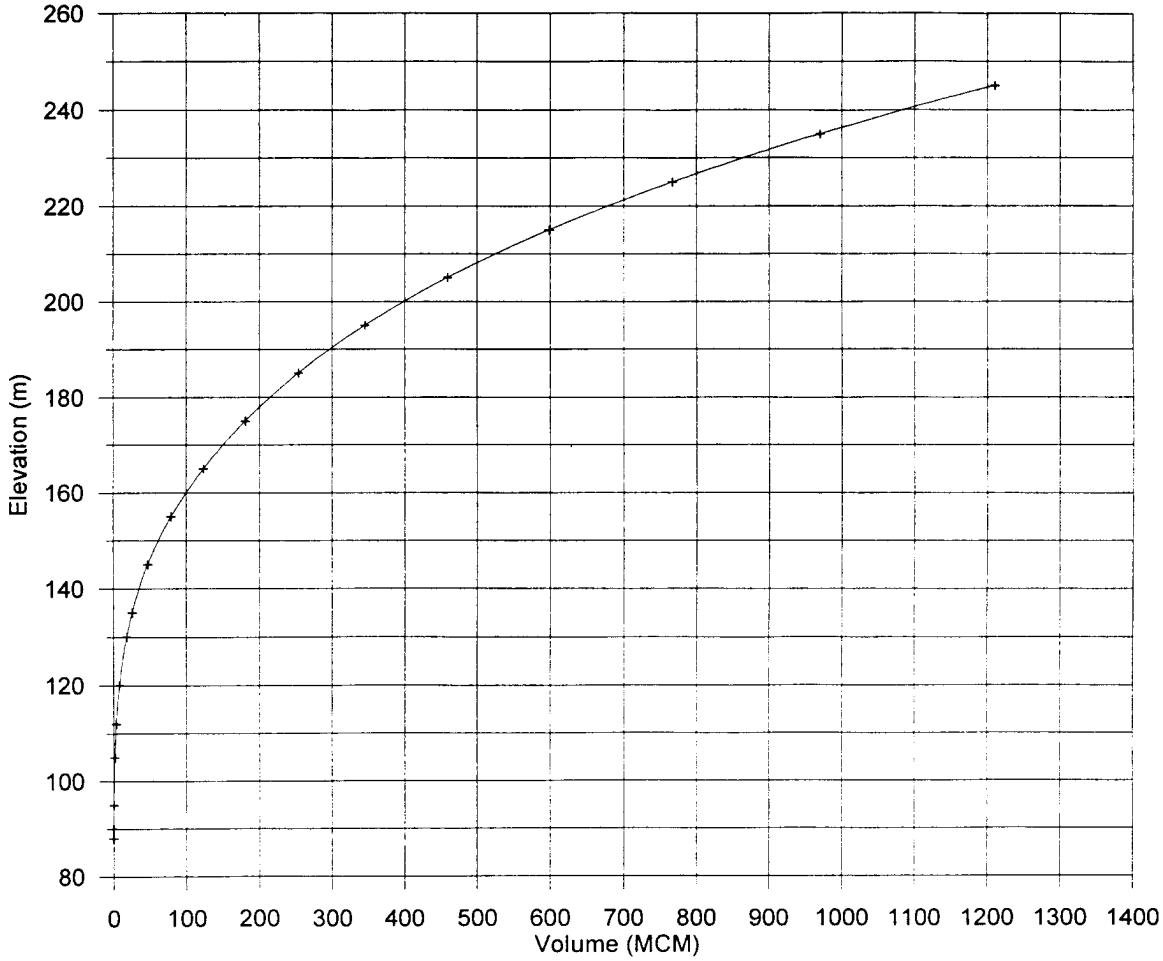


Figure 2. Recommended Upper Chagres Elevation-Volume Curve

3 SPILLWAY DESIGN

As a part of the dam-type selection studies, a roller compacted concrete dam was selected. In the selection analysis, an ungated spillway, located about in the center of the dam, was assumed. The spillway width was set at 50 m to limit it to the approximate width of the river downstream of the dam in the area where the spillway jet will impact. The spillway was located along the axis so that the plunge pool would not destabilize the steep left abutment.

As a result of the drilling program, it became apparent that a significant quantity of excavation would be required under the dam to reach suitable rock. While this did not change the adoption of an RCC dam, it did add to the cost. In an attempt to reduce this cost, it was decided to investigate a gated spillway.

The study compared the ungated spillway to a gated spillway to determine if the concept of reducing cost with a gated spillway was valid. The final study resulted in the selection of the number and size of the gates. Due to a slight re-orientation of the dam axis, it was determined that the maximum width of the spillway could be increased to about 60 m. In addition, as a result of an analysis of the reservoir operating level and live storage, the full supply level was changed from El. 220, which was used in the dam type studies, to El. 210.

Hydraulic studies were performed to determine the flood surcharge required for a series of gated configurations. Details of the studies are presented in Attachment 1 and the results are shown below:

Table 4 Surcharge and Peak Flow for Various Gated Spillway Configurations

	2 Gates H=10.0m W=7.5m	2 Gates H=7.5m W=5.6 m	2 Gates H=7.0m W=5.25m	6 Gates H=10.0m W=7.5m	2 Gates H=9.0m W=6.75m	6 Gates H=12.0m W=8.0m	6 Gates H=16.0m W=12.0m
Crest(m)	200.0	202.5	203.0	200.0	201.0	198.0	194.0
Full Supply Level (m)	210.0	210.0	210.0	210.0	210.0	210.0	210.0
Peak Flow (m^3/s)	2642	1887	1754	5435	2324	6265	9936
Max Water Surface Elevation (m)	218.1	220.1	220.5	214.1	218.9	212.9	210.0
Top of Dam (m)	219.1	221.1	221.5	215.1	219.9	213.9	211.0

In addition, a cost-height curve was developed for the dam, which is presented on Attachment 2.

A comparison of the dam plus spillway costs was made for an ungated configuration similar to the configuration used in the dam type analysis and a gated arrangement with six 8-m wide by 12-m high radial gates. The estimated costs are presented in Table 5.

Table 5 Comparison of Ungated and Gated Arrangement Cost

Item	Ungated Spillway	Gated Spillway
Dam Crest Elevation	220	214
Maximum Water Surface	219	213
Full Supply Level	210	210
Dam Cost	$137.0 million	$119.5 million
Spillway Cost	$5.0 million	$11.5 million
Total	**$142 million**	**$131 million**

There would be significant cost savings associated with a gated spillway and, therefore, a gated spillway was adopted for the project.

There would be significant cost savings associated with a gated spillway and, therefore, a gated spillway was adopted for the project.

The gated arrangement considered in the comparison with the ungated arrangement was then compared to two other gated configurations; six 12-m wide by 16-m high gates and six 7-5-m wide by 10-m high gates. The larger gate alternative was rejected because it resulted in a chute width larger than considered acceptable. A cost comparison for the two remaining alternatives is shown.

Table 6 Comparison of Alternative Gated Spillway Arrangements

Gate Size	Six 7.5-m wide by 10-m high	Six 8-m wide by 12-m high
Dam Crest Elevation	215	214
Maximum Water Surface	214	213
Full Supply Level	210	210
Dam Cost	$123.0 million	$119.5 million
Spillway Cost	$9.9 million	$11.5 million
Total	**$132.9 million**	**$131.0 million**

On this basis, the arrangement with six 8x12 gates was adopted. It is realized that this analysis does not constitute an optimization of spillway size. However, the configuration is acceptable and the cost closely approximates optimum.

4 DIVERSION FACILITIES

The objective of this study is to compare tunnel and conduit alternatives for the diversion and emergency drawdown functions of the project. The selected project operation levels are from a full supply level of El. 210 to a minimum supply level of El. 155. Streambed is assumed to be about El. 86.

Because it is an RCC dam, a flood with a return interval of 25 years was adopted and routed through the project for a range of tunnel and conduit sizes. Headwater and tailwater elevations are:

Table 7 Headwater, Tailwater, and Discharge for Diversion Alternatives

	Upstream WS Elevation	Downstream WS Elevation	Peak Discharge (m^3/s)
Tunnel Diameter – m			
7	131.0	85.8	731
8	127.7	86.3	933
10	121.5	87.3	1,338
Two 6	126.5	86.5	982
Two 7	122.0	87.2	1,279
Two 8	117.3	87.7	1,555
Two-Barrel Box Culverts – m			
5 by 5	129.0	90.3	836
6 by 6	124.0	90.9	1,126
7 by 7	119.9	91.6	1,430

For the diversion tunnel schemes, it was assumed that the upstream cofferdam would be constructed of RCC and incorporated into the structure of the main dam because of space limitations. For the conduit schemes, the cofferdam also was incorporated into the main dam to limit the length of the conduits. The height of the cofferdam was constrained by the volume of material that could be place in the short dry season (from January through April). As a result, the height of the cofferdam was limited to about El. 121.

The two 8-m diameter and two 7-m diameter alternatives resulted in acceptable cofferdam configurations. As the cofferdam would be incorporated into the dam, the smallest diameter (lowest cost) tunnel configuration was adopted. It was initially determined that one tunnel would be used as a low-level outlet and the other as a power tunnel. The concept of using one of the diversion tunnels for power was later rejected because it extended the construction period by a significant period of time.

Hydraulic studies for the conduit alternatives indicated that two 7 m by 7 m conduits would also result in an acceptable height cofferdam and this arrangement was adopted. No analysis was done of larger conduits because, as mentioned above, a smaller cofferdam would not reduce the cost of the dam; nor were any studies done of more than two conduits because, intuitively, two conduits would be less expensive than three smaller conduits providing the same cross sectional area.

Selection between the tunnel and conduit alternatives was based on the least cost for the emergency drawdown arrangement. For the tunnel arrangement, a shaft and gate chamber are required to provide for the emergency drawdown. For the conduit scheme, an intake is required on the face of the dam. Based on a comparative level estimate, the conduit arrangement was the least expensive and was adopted. The details of this comparison are presented in the next section.

5 EMERGENCY DRAWDOWN FACILITIES

Emergency drawdown requirements are derived from U.S.B.R. ACER Technical Memorandum No. 3, 1982. The guidelines adopted for the Upper Chagres reservoir drawdown are as follows:

Drawdown to	Elev.	Time (days)
75% of hydraulic height	180	30-40
55% of hydraulic height	150	50-60
25% of hydraulic height	120	80-100

Selection between the tunnel diversion and conduit diversion was based on a comparison of the costs of the diversion facilities plus the additional facilities for emergency drawdown and power development.

The tunnel diversion would be accomplished through two 7-m diameter unlined tunnels. In addition to supporting diversion of the river during construction, one tunnel would be used for power development and the other for the low-level outlet through which emergency drawdown would occur. For a comparative cost, it is necessary to add an intake tower, a power intake, and to line the diversion tunnel. The conduit diversion would be accomplished though a two concrete conduits with each conduit dimensioned at 7m by 7 m. The emergency drawdown would be accomplished through one of the conduits. However, the power development would require separate facilities. For a comparative cost of the conduit diversion, it is necessary to add an intake tower and a series of gates, and a power intake, shaft, and manifold.

On the basis of a comparative-level cost, the two alternatives are essentially the same as shown in Table 8.

Table 8 Comparison of Emergency Drawdown Facilities Using the Conduit and Tunnel Diversion

Item	Conduit Diversion (x $1000)	Tunnel Diversion (x $1000)
Conduits	$4,300	
Diversion Tunnels		$5,100
LL Outlet Tower and Gates	$1,700	$3,200
Tunnel Liner		$700
Power Intake	$8,000	$8,000
Shaft, Tunnel, Manifold	$3,800	
Manifold		$1,800
TOTAL	**$17,800**	**$18,800**

The conduit diversion was selected because it is slightly less expensive, the foundation conditions are better known, it is easier to arrange for drawdown to 25% of the hydraulic height, and there are schedule and other advantages during construction of having the power facilities separate from the diversion.

The gate arrangement in the low-level outlet intake tower was based on hydraulic studies and anticipated sediment conditions. Reservoir inflow during the emergency drawdown conditions was assumed to equal the average of the two highest mean monthly flow values or about 48 m^3/s. It was decided to include two sets of gates with each set including an emergency gate and an operating gate. With two sets, the reservoir can be drawn down to the 25% level in the early years and, once the lower set of gates in silted in, the upper-level gates can provide a measure of drawdown capability.

The upper gate set was located with its sill at El. 150 to remain open when sediment reaches El. 155, the estimated 100-year level. It is expected that periodic operation of the gates will keep a flow path open. With 3 m wide by 4 m high gates, the reservoir can be drawn down to El. 154.6 in 55 days assuming the lower set of gates has been silted in. At this elevation, the flow through the gates equals the design reservoir inflow. If it is desired to bring the level down to El. 150 to strictly match the guidelines, the sill of the gates would be at El. 145. At this level, it will be more difficult to keep the gates open

under the projected 100-year sediment deposition conditions. For this study, the gate sills were set at El. 150.

The lower gates were assumed to be the same size to minimize spare parts. The sills of the gate set were established at El. 115 to maintain the reservoir at the 25% level while passing the design reservoir inflow.

In the hydraulic studies, it was assumed that the spillway, which is operable down to El. 198 and the high gate set were operated together. To minimize releases in the channel downstream, the lower gate set was not opened until the water level reached the minimum afforded by the upper gate set. The drawdown times for the various conditions are presented in Table 9.

Table 9 Drawdown Times for Various Reservoir Levels

Reservoir Level (%of FSL)	Reservoir Elevation	Allowable Time to Reach Elevation (days)	Computed Time to Reach Allowable Elevation (days)
75	180	30-40	13
50	154.6 (1)	50-60	50
50	150 (2)	50-60	54
25	120	80-100	58

(1) Sill at El. 150
(2) Sill at El. 145

The lower gate set provides the required drawdown much faster that is called for in the guidelines. A smaller gate would increase the time and be less expensive. However, to maintain the level at 120 for the required design reservoir inflow, the sill would have to be set lower thus shortening the period of time the gates will be open and available as a result of sediment deposition.

6 DAM STABILITY

A preliminary sliding stability analysis and a foundation bearing capacity analysis were performed for the proposed RCC gravity dam on the Upper Río Chagres. A more detailed discussion of the analyses is included in Attachment 3.

Stability Analysis

The dam section selected for analysis is the highest section through the river channel. The loading assumptions used in the analysis are listed below.

Reservoir FSL:	210 m
PMF El.:	212.9 m
Normal Tailwater El.:	86 m
PMF Tailwater El.:	98 m
Drainage Efficiency:	67%
Silt El.:	115 m
Seismic Acceleration:	0.13 g (use 2/3 of MDE acceleration, 0.20 g, for pseudo-static analysis)

The loading cases considered in the analysis together with the required factors of safety are listed in the table below. The loading cases and factors of safety are based on a combination of recommendations taken from the U.S. Army Corps of Engineers Engineering and Design Manual for Gravity Dam Design (USACE, 1995), and the FERC *Engineering Guidelines for the Evaluation of Hydropower Projects* (FERC, 2002). The required factors of safety are based on the FERC guidelines for an analysis performed assuming the foundation material has no cohesion (i.e. friction only).

Table 10 Loading Conditions for Dam Stability Analysis

Loading Case	Reservoir El. (m)	Tailwater El. (m)	Silt El. (m)	Seismic Acceleration (g)	Required Factor of Safety
Usual	210	86	115	0	1.5
Unusual	212.9	98	115	0	1.3
Extreme	210	86	115	0.13	1.3

Material strength parameters selected for use in the stability analyses are based on rock mass strength estimates developed using the Hoek-Brown failure criterion (Hoek, et al., 2002).

The nature of the rock at the site spans a wide range of conditions ranging from altered, soft rock to fresh, hard rock (as exposed in the rock outcrops). As a result, two rock mass strengths were developed to represent upper and lower bound strengths. No differentiation was made between the andesite and agglomerate rock types because the relative strengths appear to be more of a function of the state of weathering and/or alteration rather than the lithology.

Because the selected method of analysis is one that assumes no cohesion for the foundation material, a series of linear fits was made to the non-linear Hoek-Brown failure envelopes in order to estimate an appropriate strength for use in the stability analyses. The linear fits are based on an anticipated range of normal stresses beneath the dam, which is between about 0.5 and 2.5 MPa. The selected strengths are listed in Table 11; a graph of the strength envelopes is contained in Attachment 2.

Table 11 Selected Material Strength Parameters

Rock Type	Friction Angle (deg)	Cohesion (MPa)
Andesite/Agglomerate (Low)	35	0
Andesite/Agglomerate (High)	69	0
Selected for Analysis	*52*	*0*

Factors of safety against sliding were computed using the following expression:

$$Factor\ of\ Safety = \frac{F_{ver} \cdot \tan\phi}{F_{hor}}$$

Vertical forces considered in the analysis are due to the weight of the dam and to hydrostatic uplift at the base of the dam. Horizontal forces considered are due to the reservoir, tailwater, silt load, and for the Extreme loading case, seismic acceleration.

The computed factors of safety for each of the three loading conditions are listed in the table below. The results of the preliminary stability analysis indicate that the dam meets the required factors of safety and will be stable under the assumed loading conditions.

Table 12 Stability Analysis Results

Case	Computed Factor of Safety	Required Factor of Safety	Criteria Satisfied?
Usual – Normal Pool	1.9	1.5	Yes
Unusual – Flood Pool	1.7	1.3	Yes
Extreme – Earthquake	1.4	1.3	Yes

Bearing Capacity Analysis

A preliminary foundation bearing capacity analysis was performed using a procedure recommended by Goodman (1989) for rock foundations. The range of bearing capacities estimated for the rock at the damsite are listed in the table below.

Rock Type	Friction Angle (deg)	Allowable Bearing Capacity (MPa)
Andesite/Agglomerate (Low)	35	9.4
Andesite/Agglomerate (High)	69	602

ATTACHMENTS

Attachment 1 – Hydraulic Studies For Gated Spillways

Factors of safety against sliding were computed using the following expression:

$$Factor\ of\ Safety = \frac{F_{ver} \cdot \tan\phi}{F_{hor}}$$

Vertical forces considered in the analysis are due to the weight of the dam and to hydrostatic uplift at the base of the dam. Horizontal forces considered are due to the reservoir, tailwater, silt load, and for the Extreme loading case, seismic acceleration.

The computed factors of safety for each of the three loading conditions are listed in the table below. The results of the preliminary stability analysis indicate that the dam meets the required factors of safety and will be stable under the assumed loading conditions.

Table 12 Stability Analysis Results

Case	Computed Factor of Safety	Required Factor of Safety	Criteria Satisfied?
Usual – Normal Pool	1.9	1.5	Yes
Unusual – Flood Pool	1.7	1.3	Yes
Extreme – Earthquake	1.4	1.3	Yes

Bearing Capacity Analysis

A preliminary foundation bearing capacity analysis was performed using a procedure recommended by Goodman (1989) for rock foundations. The range of bearing capacities estimated for the rock at the damsite are listed in the table below.

Rock Type	Friction Angle (deg)	Allowable Bearing Capacity (MPa)
Andesite/Agglomerate (Low)	35	9.4
Andesite/Agglomerate (High)	69	602

The maximum foundation loads due to the three dam loading conditions are given in the table below. The minimum allowable bearing capacity is taken as that computed for the lower bound andesite/agglomerate, however, it is anticipated that much of the foundation will have a higher allowable bearing capacity. The results of the analysis indicate that the foundation bearing capacity is sufficient for the proposed RCC dam.

Case	**Maximum Bearing Pressure (MPa)**	**Minimum Allowable Bearing Capacity (MPa)**	**Criteria Satisfied?**
Usual – Normal Pool	2.7	9.4	Yes
Unusual – Flood Pool	2.6	9.4	Yes
Extreme – Earthquake	1.7	9.4	Yes

Attachment 1

This memorandum summarizes the procedures and results performed for the Upper Chagres Dam spillway design to estimate flood surcharges for a gated spillway of several gate dimensions with a width to height ratio of between 0.65 to 0.75.

Computer Model

The Full-Equations (FEQ) modeling system of one-dimensional, unsteady, open-channel flow was used for the hydraulic analysis of the Upper Chagres Dam. FEQ is based on the full Saint-Venant equations. This modeling system, developed by Delbert Franz of Linsley, Kraeger Associates, Ltd., Mountain View, CA is widely used by engineers and hydrologists in county and state agencies and consulting firms, and has been accepted by the Federal Emergency Management Agency (FEMA) for use in floodplain studies. It is used in a variety of applications such as flood studies, design studies for dam spillways, dam break analyses, and legal cases. The program supports a wide variety of structures including bridges, culverts, dams, level-pool reservoirs, spillways, weirs, sluice gates, pumps, side weirs, expansions, contractions, drop structures, and flow over roadways. The hydraulic features of the stream system, such as channel cross-sectional properties, are incorporated into the model. FEQ is capable of simulating flow conditions in a network of open channels and storm sewers. The flow conditions are simulated in terms of water-surface elevation, water velocity, and discharge at any point in the system.

Introduction

A wide range of spillway sizes was evaluated by routing the probable maximum flood (PMF) through the Upper Chagres reservoir. The PMF and reservoir stage-volume data are listed in Tables 1 and 2, respectively. Ogee spillway coefficients vary with surcharge and range between 1.5 and 2.28. A design head of 3 m was used to determine these coefficients, which are listed in Table 3.

Table 1. Probable Maximum Flood at Upper Chagres

Time (hrs)	0	1	2	3	4	5	6	7
Flow (cms)	50	72	156	397	602	725	818	935
Time (hrs)	8	9	10	11	12	13	14	15
Flow (cms)	1135	1682	3214	6254	9555	9936	7571	5406
Time (hrs)	16	17	18	19	20	21	22	23
Flow (cms)	4068	3286	2756	2371	2095	1854	1620	1422
Time (hrs)	24	25	26	27	28	29	30	31
Flow (cms)	1255	1086	906	627	418	305	237	192
Time (hrs)	32	33	34	35	36	37	38	39
Flow (cms)	158	131	110	93	78	68	60	55
Time (hrs)	40	41	42	43	44	45	46	47
Flow (cms)	52	51	50	50	50	50	50	50

Table 2. Reservoir Capacity Curve at Upper Chagres

Elevation (m)	Area (km^2)	Volume (MCM)
88	-	-
90	0.02	0.01
95	0.09	0.26
105	0.21	1.72
112	0.42	3.87
120	0.76	8.50
130	1.27	18.53
135	1.67	25.85
145	2.68	47.41
155	3.75	79.40
165	5.05	123.23
175	6.44	180.55
185	8.17	253.44
195	10.24	345.30
205	12.61	459.33
215	15.28	598.53
225	18.49	767.09
235	22.14	969.96
245	26.07	1210.75

Table 3. Ogee Spillway Coefficients for a Design Head of 3m

Surcharge (m)	Coefficient
0.0	1.50
0.36	1.66
0.6	1.74
0.9	1.85
1.2	1.93
1.5	2.00
1.8	2.06
2.1	2.10
2.4	2.15
2.7	2.20
3.0	2.23
3.3	2.25
3.6	2.27
3.9	2.28
4.2	2.28
5.0	2.28
10.0	2.28

Spillway Discharge

A gated spillway analysis was conducted with a starting full supply level of 210.0 m and a width to height ratio of approximately 0.75:1 for the gates. The goal is to determine which gate configuration will be needed to obtain a maximum water surface elevation of 219.3 m during the PMF, which corresponds to a 50 m spillway with a crest at 210.0 m as shown in Table 5. A total of 7 gated spillway configurations were analyzed. For each configuration, the spillway crest is computed by subtracting the gate height from the full supply level. The first step in developing the rating curves is to compute the flow through the spillway with the starting full supply level, which corresponds to the top of the gate. The flow is computed using the equation $Q = CLH^{1.5}$, where Q = flow (m^3/s), C = ogee spillway coefficient, or 2.28 for higher depths, L = length of spillway (m), and H = head above spillway crest (m). When flows into the reservoir exceed this amount, the head starts building up. Otherwise, inflow = outflow and the head remains constant. This can be observed in the rating curves for each gated spillway configuration shown in Table 4.

Peak flows and maximum water surface elevations for each of the 7 spillway configurations analyzed are summarized in Table 5. As noted in the table, the spillway configuration that most closely matches the required 219.3 m surcharge is the 2-gate, 9m high, 6.75m wide configuration. This can be further refined by interpolation. It can also be noted that to pass the PMF with no surcharge requires 6 16-by-12 m spillways.

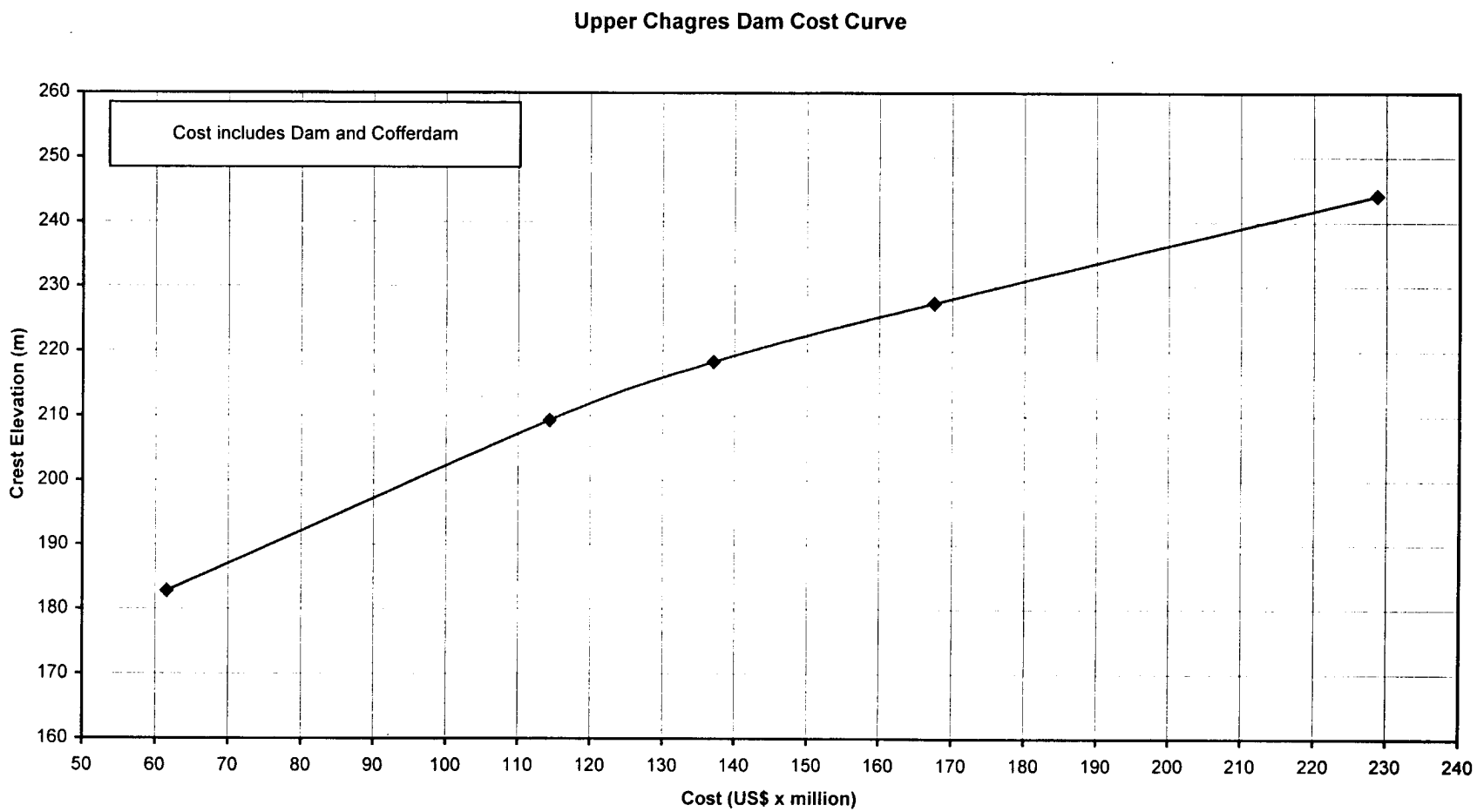
Table 4. Rating Curves for Different Spillway Configurations in the Upper Chagres Dam

Head (m)	Flow (cms) 2 Gates H=10.0m W=7.5m	Flow (cms) 2 Gates H=7.5m W=5.6 m	Flow (cms) 2 Gates H=7.0m W=5.25 m	Flow (cms) 6 Gates H=10.0m W=7.5m	Flow (cms) 2 Gates H=9.0m W=6.75m	Flow (cms) 6 Gates H=12.0m W=8.0m	Flow (cms) 6 Gates H=16.0m W=12.0m
7.0	-	-	0 - 443	-	-	-	-
7.5	-	0 - 524	492	-	-	-	-
8.0	-	578	542	-	-	-	-
8.5	-	633	593	-	-	-	-
9.0	-	689	646	-	0 - 831	-	-
9.5	-	748	701	-	901	-	-
10.0	0 - 1081	808	757	0 - 3244	973	-	-
10.5	1164	869	815	3491	1047	-	-
11.0	1248	932	873	3743	1123	-	-
11.5	1334	996	934	4001	1200	-	-
12.0	1422	1062	995	4265	1280	0 - 4549	-
12.5	1511	1129	1058	4534	1360	4837	-
13.0	1603	1197	1122	4809	1443	5130	-
13.5	1696	1267	1187	5089	1527	5428	-
14.0	1792	1338	1254	5375	1612	5733	-
14.5	1888	1410	1322	5665	1699	6043	-
15.0	1987	1484	1391	5961	1788	6358	-
15.5	2087	1558	1461	6261	1878	6678	-
16.0	2189	1634	1532	6566	1970	7004	0-10506
16.5	2292	1712	1605	6877	2063	7335	11003
17.0	2397	1790	1678	7192	2157	7671	11506
17.5	2504	1869	1753	7511	2253	8012	12018
18.0	2612	1950	1828	7835	2351	8358	12536
18.5	2721	2032	1905	8164	2449	8708	13062
19.0	2832	2115	1983	8497	2549	9064	13596
19.5	2945	2199	2061	8835	2650	9424	14136
20.0	3059	2284	2141	9177	2753	9789	14683
20.5	3174	2370	2222	9523	2857	10158	15237
21.0	3291	2457	2304	9874	2962	10532	15798
21.5	3409	2546	2387	10228	3069	10910	16365
22.0	3529	2635	2470	10587	3176	11293	16940
22.5	3650	2725	2555	10950	3285	11680	17520
23.0	3772	2817	2641	11317	3395	12072	18108
23.5	3896	2909	2727	11688	3506	12467	18701
24.0	4021	3002	2815	12063	3619	12867	19301
24.5	4147	3097	2903	12442	3733	13272	19907
25.0	4275	3192	2993	12825	3848	13680	20520

Table 5. Surcharge and Peak Flow for Various Gated Spillway Configurations

Spillway Config.	2 Gates H=10.0m W=7.5m	2 Gates H=7.5m W=5.6 m	2 Gates H=7.0m W=5.25m	6 Gates H=10.0m W=7.5m	2 Gates H=9.0m W=6.75m	6 Gates H=12.0m W=8.0m	6 Gates H=16.0m W=12.0m
Crest (m)	200.0	202.5	203.0	200.0	201.0	198.0	194.0
Full Supply Level (m)	210.0	210.0	210.0	210.0	210.0	210.0	210.0
Peak Flow (m^3/s)	2642	1887	1754	5435	2324	6265	9936
Max Water Surface Elevation (m)	218.1	220.1	220.5	214.1	218.9	212.9	210.0
Top of Dam (m)	219.1	221.1	221.5	215.1	219.9	213.9	211.0

Attachment 2 – Comparative-Level Dam Cost/Height Curve


Upper Chagres Dam Cost Curve
Cost includes Dam and Cofferdam
Crest Elevation (m)
260
250
240
230
220
210
200
190
180
170
160
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
Cost (US$ x million)

Attachment 3 - RCC Dam Stability and Bearing Capacity Analysis

MWH
MONTGOMERY WATSON HARZA

Intra-Company Correspondence

MWH AMERICAS, INC.
HYDROPOWER

Location: Chicago

August 27, 2003

To: Michael Newbery

From: Rori Green

Subject: Upper Chagres RCC Dam Stability and Bearing Capacity Analysis

Preliminary sliding stability and bearing capacity analyses were performed for the proposed RCC gravity dam on the Upper Río Chagres. The results indicate that the dam is stable based on the assumed loading and foundation conditions.

I. SLIDING STABILITY ANALYSIS

Section Description and Loading Conditions

The dam section selected for analysis is the highest section through the river channel.

Dam Section Description:

Crest El.:	216 m
Upstream Slope:	Vertical
Downstream Slope:	0.75H:1V
Foundation El.:	76 m

Loading Assumptions:

Reservoir FSL:	210 m
PMF El.:	212.9 m
Normal Tailwater El.:	86 m
PMF Tailwater El.:	98 m
Drainage Efficiency:	67%
Silt El.:	115 m
Seismic Acceleration:	0.13 g (use 2/3 of MDE acceleration, 0.20 g, for pseudo-static analysis)

The loading cases considered in the analysis together with the required factors of safety are listed in the table below. The loading cases and factors of safety are based on a combination of recommendations taken from the U.S. Army Corps of Engineers Engineering and Design Manual for Gravity Dam Design (USACE, 1995), and the FERC *Engineering Guidelines for the*

Evaluation of Hydropower Projects (FERC, 2002). The required factors of safety are based on the FERC guidelines for an analysis performed assuming the foundation material has no cohesion (i.e. friction only).

Loading Case	Reservoir El. (m)	Tailwater El. (m)	Silt El. (m)	Seismic Acceleration (g)	Required Factor of Safety
Usual	210	86	115	0	1.5
Unusual	212.9	98	115	0	1.3
Extreme	210	86	115	0.13	1.3

Method for Estimating Material Strength Parameters

The material strength parameters used for the analysis are based on rock mass strength estimates developed using the Hoek-Brown failure criterion (Hoek, et al., 2002). The Hoek-Brown criterion is a widely used method for estimating the strength of rock masses based on the properties of the rock mass, including the compressive strength of the intact rock blocks, the degree of fracturing, and the nature of the joint surfaces and infillings. The rock mass is classified according to these characteristics using the Rock Mass Rating (RMR) classification system (Bieniawski, 1976) and is then input into the Hoek-Brown criterion. The result is a non-linear failure envelope representing the strength of the rock mass. Typically a line is fit to the non-linear envelope over the range of anticipated normal stresses in order to estimate a linear Mohr-Coulomb strength parameters, friction angle and cohesion. These latter parameters are then typically used as the inputs for stability analyses.

Selection of Material Strength Parameters

The nature of the rock at the site spans a wide range of conditions ranging from altered, soft rock to fresh, hard rock (as exposed in the rock outcrops). As a result, two rock mass strengths were developed to represent an upper and lower bound strength; these upper and lower bounds are designated *Low* and *High* to represent the relative lower (low strength) and upper (high strength) bounds. A description of the rock masses corresponding to these bounds is given below.

> *Andesite/Agglomerate (Low)*: Strongly weathered and/or altered; highly fractured with RQD's less than 25 percent; soft rock with a very low unconfined compressive strength in the range of about 5 to 30 MPa; joint surfaces are altered and slickensided and may contain fault gouge.
>
> *Andesite/Agglomerate (High)*: Unaltered or weakly altered; fresh to slightly weathered; moderately fractured with RQD's in the range of 25 to 50 percent; hard rock with unconfined compressive strengths in the range of 80 to 150 MPa; joint surfaces are rough, tight and have little to no infilling.

No differentiation was made between the andesite and agglomerate rock types because the relative strengths appear to be more of a function of the state of weathering and/or alteration rather than the lithology.

The rock mass strength parameters developed for the Upper Chagres dam site are listed in the table below. A graph showing the non-linear failure envelopes with the linear fits is presented in Figure 1. The linear fits are based on an anticipated range of normal stresses beneath the dam, which is between about 0.5 and 2.5 MPa.

Rock Type	Friction Angle (deg)	Cohesion (MPa)
Andesite/Agglomerate (Low)	29	0.2
Andesite/Agglomerate (High)	61	1.2

Material Strength Parameters for Stability Analysis

Because the selected method of analysis is one that assumes no cohesion for the foundation material, an additional set of linear fits was made to the non-linear failure envelopes in order to estimate an appropriate strength for use in the stability analyses. The selected strengths are listed in the following table, and a graph of the strength envelopes is shown on Figure 2.

Rock Type	Friction Angle (deg)	Cohesion (MPa)
Andesite/Agglomerate (Low)	35	0
Andesite/Agglomerate (High)	69	0
Selected for Analysis	*52*	*0*

Method of Analysis

Factors of safety against sliding were computed using the following expression:

$$Factor\ of\ Safety = \frac{F_{ver} \cdot \tan\phi}{F_{hor}}$$

Vertical forces considered in the analysis are due to the weight of the dam and to hydrostatic uplift at the base of the dam. Horizontal forces considered are due to the reservoir, tailwater, silt load, and where applicable, seismic acceleration.

Results of Stability Analysis

The computed factors of safety for each of the three loading conditions are listed in the table below. The results of the preliminary stability analysis indicate that the dam meets the required factors of safety and will be stable under the assumed loading conditions.

Case	Computed Factor of Safety	Required Factor of Safety	Criteria Satisfied?
Usual – Normal Pool	1.9	1.5	Yes
Unusual – Flood Pool	1.7	1.3	Yes
Extreme – Earthquake	1.4	1.3	Yes

II. BEARING CAPACITY ANALYSIS

The foundation bearing capacity was analyzed using the method described in Goodman (1989) for estimating the bearing capacity of rock foundations. The equation for estimating the bearing capacity are given by the following:

$$q_f = q_u(N_\phi + 1)$$

where

$$N_\phi = \tan^2\left(45 + \frac{\phi}{2}\right)$$

q_u = uniaxial compressive strength
q_f = ultimate bearing capacity
ϕ = friction angle

The allowable bearing capacity is computed using a factor of safety of 5, such that:

$$q_{allowable} = \frac{q_f}{5}$$

Bearing capacities estimated for the andesite/agglomerate at the damsite are presented in the table below.

Rock Type	Friction Angle (deg)	Allowable Bearing Capacity (MPa)
Andesite/Agglomerate (Low)	35	9.4
Andesite/Agglomerate (High)	69	602

Stresses, or bearing pressures, at the foundation were computed as part of the sliding stability analyses described in Section I. The maximum bearing pressures for each of the three cases are listed in the table below. The minimum allowable bearing capacity is taken as that computed for the lower bound andesite/agglomerate, however, it is anticipated that much of the foundation will have a higher allowable bearing capacity.

Case	Maximum Bearing Pressure (MPa)	Minimum Allowable Bearing Capacity (MPa)	Criteria Satisfied?
Usual – Normal Pool	2.7	9.4	Yes
Unusual – Flood Pool	2.6	9.4	Yes
Extreme – Earthquake	1.7	9.4	Yes

The results indicate that the foundation has sufficient bearing capacity for the proposed dam on the Upper Río Chagres.

References

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Goodman, R.E. (1989). *Introduction to Rock Mechanics, Second Edition.* John Wiley and Sons.

Hoek, E., Carranza-Torres, C.T., and Corkum, B. (2002) Hoek-Brown failure criterion – 2002 edition. *Proc. North American Rock Mechanics Society meeting in Toronto in July 2002.*

U.S. Army Corps of Engineers. (1995). *Gravity Dam Design.* EM 1110-2-2200.

Figure 1

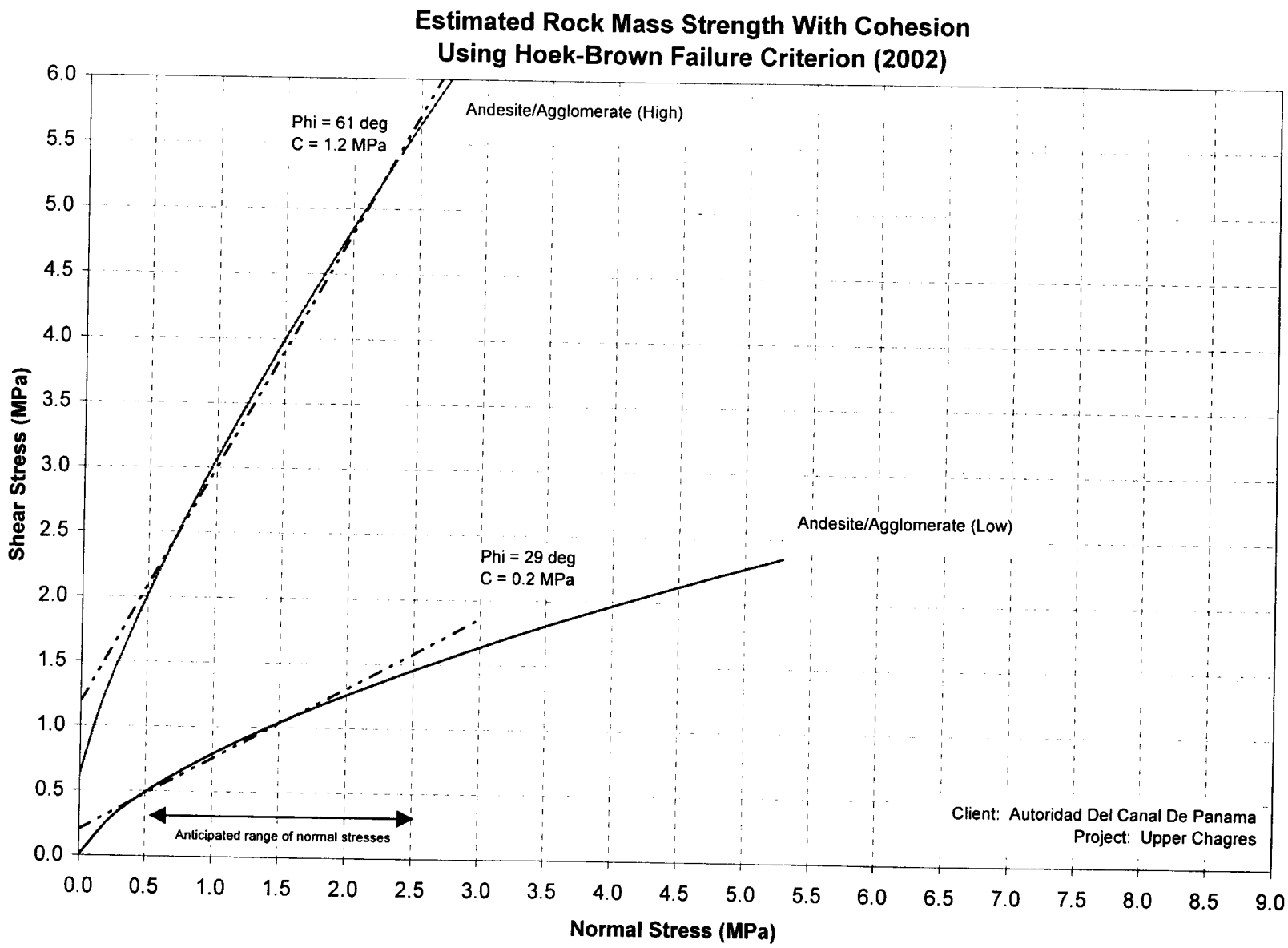
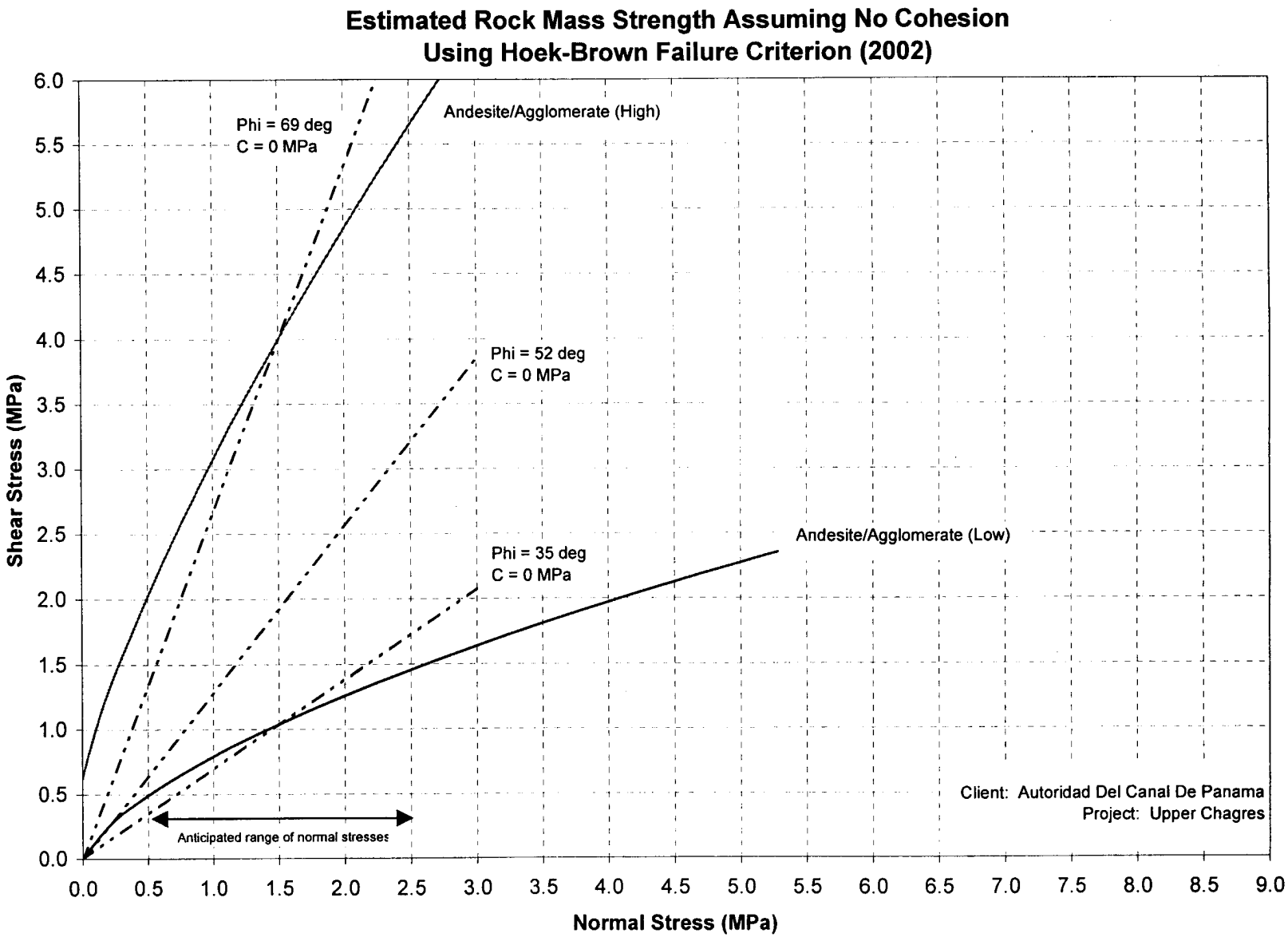

Estimated Rock Mass Strength With Cohesion
Using Hoek-Brown Failure Criterion (2002)
Shear Stress (MPa)
Normal Stress (MPa)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
Phi = 61 deg
C = 1.2 MPa
Andesite/Agglomerate (High)
Andesite/Agglomerate (Low)
Phi = 29 deg
C = 0.2 MPa
Anticipated range of normal stresses
Client: Autoridad Del Canal De Panama
Project: Upper Chagres

Figure 2


Estimated Rock Mass Strength Assuming No Cohesion
Using Hoek-Brown Failure Criterion (2002)
Phi = 69 deg
C = 0 MPa
Andesite/Agglomerate (High)
Phi = 52 deg
C = 0 MPa
Phi = 35 deg
C = 0 MPa
Andesite/Agglomerate (Low)
Anticipated range of normal stresses
Client: Autoridad Del Canal De Panama
Project: Upper Chagres
Shear Stress (MPa)
Normal Stress (MPa)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0

Sample Stability Calculations

STABILITY ANALYSIS

Upper Chagres
RCC Gravity Dam Stability Analysis - Normal Operating Case (Usual)

PROGRAM DESCRIPTION SECTION

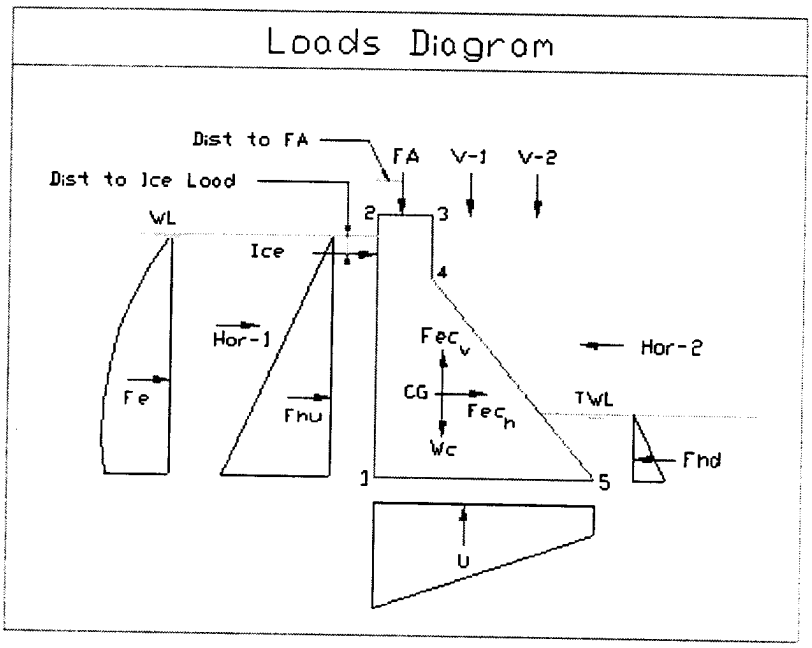
Stabil-1.mcd is a Mathcad file which calculates factors of safety against sliding and overturning for any shaped structure.

Features

- metric or imperial units
- ice, anchor, hydrostatic and gravity loads
- crack analysis (with modified uplift for load cases other than seismic)
- calculates percentage of effective base
- bearing pressures
- volume and position of center of gravity of structure (including voids)
- summary of forces and moments (including resultant and eccentricity)
- additional point loads (eg. backfill, vertical hydrostatic, etc.)
- hydrodynamic forces by Westergaard
- equivalent horizontal and vertical inertia forces on structure during earthquake
- results in any units (including user defined)

Assumptions and Limitations

- 2-dimensional
- horizontal base only
- vertical hydrostatic and backfill loads must be input as point loads
- lowest point on structure is level of base
- all vertical point loads are referenced to most upstream point of structure



INPUT SECTION

Unit System

1 - metric
2 - imperial

Select unit system

Ψ $\quad units := 1$ <... select unit system

$unL := if(units = 1, 1 \cdot m, 1 \cdot ft)$

$unM := if(units = 1, 1 \cdot kN, 1 \cdot lb)$

Geometry of Structure defined by perimeter coordinates

There is no need to "close" the perimeter ,i.e, so that last point equal to first point

Ψ $\quad X := \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0.5 \\ 0.5 \\ 8 \\ 8 \\ 102.7 \end{pmatrix} \cdot unL \qquad Y := \begin{pmatrix} 76 \\ 210.0 \\ 216.0 \\ 216.0 \\ 216.0 \\ 216.0 \\ 202.2 \\ 76 \end{pmatrix} \cdot unL$ <... input X & Y coordinaytes

Ψ $\quad Length_Base := 102.7$ <... length of the base of the structure

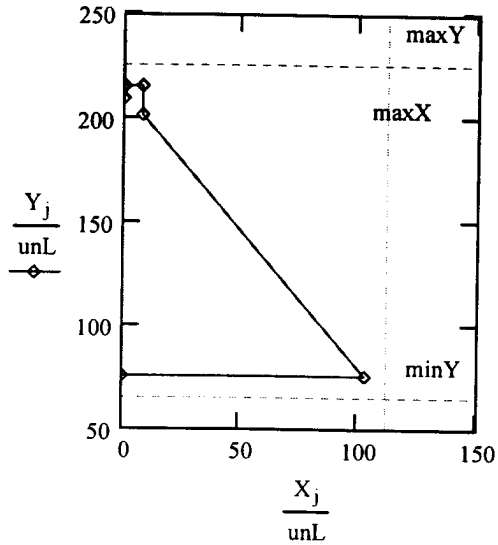
Ψ $\quad Structure_Width := 1$ <... width of structure

$maxY := \frac{max(Y)}{unL} + 10 \qquad minY := \frac{min(Y)}{unL} - 10 \qquad i := 1 .. length(X)$

$maxX := \frac{max(X)}{unL} + 10 \qquad minX := \frac{min(X)}{unL} - 10 \qquad j := 1 .. length(X) + 1$

$X_{length(X)+1} := X_1 \qquad Y_{length(Y)+1} := Y_1$

Graphical Representation of Structure defined by X & Y Coordinates



Densities of Water and Concrete, Water Level, Width of Structure, of Structure defined by perimeter coordinates

Ψ $\gamma w := \text{if}\left(\text{units} = 1, 9.81 \cdot \frac{kN}{m^3}, 62.4 \cdot \frac{lb}{ft^3}\right)$ <... water density

Ψ $\gamma c := \text{if}\left(\text{units} = 1, 23 \cdot \frac{kN}{m^3}, 150 \cdot \frac{lb}{ft^3}\right)$ <... concrete density

Ψ $US_Water_Level := 210.0$ <... upstream water level

Ψ $Tailwater_Level := 86$ <... tailwater level

Ψ $\phi := 52 \cdot deg$ <... angle of internal friction for foundation material

EHorizontal & Vertical Components of the Earth Quake Intensity and Coefficient of Hydrodynamic Pressure Distribution

Ψ $\lambda_{hor} := 0.13$ <... **horizontal** component of earth quake intensity = ratio of earth quake acceleration to accelaration due to gravity

Ψ $\lambda_{vert} := 0.0$ <... **vertical** component of earth quake intensity

Ψ $C_m := 0.74$ <... from fig 8-6, page 325 of "Design of Small Dams", for a structure with **vertical face**

Uplift, Ice load & Point of Application, Anchor Force & Point of Application, & Other Vertical and Horizontal Forces

Ψ Uplift := 33 <... percent of uplift pressure acting at the upstream point of the structure foundation

If imperial units selected, **Ice Load** will be in **lb/ft** of Structure. Otherwise, i.e., metric units, **Ice Load** will be in **kN/m**

Ψ Ice_Load := 0 <... ice load acting per unit width of the structure

Ψ Dist_WL_to_Ice_Load := 0.0 <... distance from water level to point of application of Ice load

If imperial units selected, **Anchor Force** will be in **lb.**Otherwise, i.e., metric units, Anchor Force will be in **kN**

Ψ Anchor_Force := 0 <... anchor force acting per unit width of the structure

Ψ Dist_to_Anc_Force := 0 <... distance from most upstream point of structure to point of application of anchor force

Additional Horizontal Forces Acting in the Downstream and Upstream Directions

Ψ US_Hor_Force := 2611 <... Horizontal Force acting in the Downstream Direction. For instance, this force can be used to input effect of soil pressure on the upstream side of Structure

Ψ EL_US_Hor_F := 89.0 <...Elevation at which the Upstream Horizontal Force is applied to the Structure

Ψ DS_Hor_Force := 0 <... Horizontal Force acting in the Upstream Direction. For instance, this force can be used to input effect of soil pressure on the downstream side of Structure

Ψ EL_DS_Hor_F := 0 <...Elevation at which the Downstream Horizontal Force is applied to the Structure

Additional Vertical Forces (Stabilizing Forces)

If imperial units selected, **Vertical Forces** will be in **lb.**Otherwise, i.e., metric units, **Vertical Forces** will be in **kN**

Ψ Vert_Force_1 := 0 <... Vertical Force acting on the Downward Direction. It is a stabilizing force

Ψ Dist_to_F1 := 0 <... distance from most upstream point of structure to point of application of vertical force

Ψ Vert_Force_2 := 0 <... Vertical Force acting on the Downward Direction. It is a stabilizing force

Ψ Dist_to_F2 := 0 <... distance from most upstream point of structure to point of application of vertical force

Computation Section Omitted

OOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOOO

FINAL RESULTS

initial point of inflection

PI = 0 m

initial point of inflection as % of the base

$$\frac{PI}{L} = 0\,\%$$

CALCULATED CRACK LENGTH

Cr = 0 m

% OF EFFECTIVE BASE
(portion not cracked)

EFF_BASE = 100 %

STRESSES AT FOUNDATION

fmin = 1739.16827 kPa

fmax = 841.35862 kPa

SAFETY FACTOR AGAINST SLIDING

FSS = 1.371

SAFETY FACTOR AGAINST OVERTURNING

FSO = 3.0933

Summary of Forces and Moments

1) Vertical Forces

$Wc = 163198.11\ kN$ <... weight of concrete in structure

$Fa = 0\ kN$ <... anchor Force

$V1 = 0\ kN$ <... Vertical Force 1 acting on the Downward Direction.

$V2 = 0\ kN$ <... Vertical Force 2 acting on the Downward Direction.

$Fec_v = 0\ kN$ <... Equivalent Vertical Inertia Force on Structure due to earth quake

$U = 30688.05\ kN$ <... uplift force acting upwards

$F_{ver_U} = 163198.11\ kN$ <... resultant of the vertical forceswithout uplift

$F_{ver} = 132510.06\ kN$ <... resultant of the vertical forceswith uplift

2) Horizontal Forces

$Fhu = 88074.18\ kN$ <... upstream hydrostatic force

$Fhd = 490.5\ kN$ <... downstream hydrostatic force

$Fi = 0\ kN$ <... Ice Force

$Fe = 12302.41\ kN$ <...hydrodynamic force

$Fec_h = 21215.75\ kN$ <... Equivalent Horizontal Inertia Force on Structure due to earth quake

$USHF = 2611\ kN$ <...horizontal force acting in the Downstream Direction

$DSHF = 0\ kN$ <...horizontal force acting in the Upstream Direction

$F_{hor} = 1.237 \times 10^5\ kN$ <... resultant of the horizontal forces

3) Stabilizing, Overturning, and Resultant Moments

$Ms = 11221073.01\ kN \cdot m$ <... stabilizing moment

$Mo_T = 3627560.08\ kN \cdot m$ <... overturning moment

$Mr = 7593512.94\ kN \cdot m$ <... resultant moment

UNAUTHORIZED USE OR DUPLICATION IS PROHIBITED
PROHIBIDA LA REPRODUCCION SIN AUTORIZACION DEL AUTOR

CENTRO DE RECURSOS TECNICOS
AUTORIDAD DEL CANAL DE PANAMA

FEASIBILITY DESIGN FOR THE UPPER CHAGRES WATER SUPPLY PROJECT

APPENDIX E
PART 1

POWER MARKET STUDY

Prepared by

MWH

In association with

TAMS
AN EARTH TECH COMPANY

FEASIBILITY DESIGN FOR THE UPPER CHAGRES WATER SUPPLY PROJECT

APPENDIX E, PART 1 – POWER MARKET STUDY

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1 INTRODUCTION

The Canal Capacity Projects Office of the Panama Canal Authority plans to construct the Upper Chagres Project to augment sources of water supply for meeting the growing municipal and industrial water uses of the Canal Zone, and increased lock operation.

The Upper Chagres Project will result in the formation of a reservoir to regulate water in the upper part of the Rio Chagres for delivery to Lake Gatun through Lake Madden. A 56 MW powerplant will be a part of the appurtenant works of the project,

A power market survey of Panama was conducted to determine the future power needs of the Panama national electric system. The results of this survey will be used in evaluation of the economic attractiveness of the Upper Chagres hydroelectric power plants.

A draft report, prepared in November, 2000, contained information received from the Electricity Department and taken from the following two reports:

(1) *Revision del Plan de Expansion Indicativo del Sistema de* Generation, ETESA, August 1998
(2) *Plan de Expansion del Sistema de Generacion 1999-2015,* ETESA, 1999

Due to a delay in the development studies, the Power Market Report was not finalized until September 2002. In the interim, four additional reports were made available:

(3) *Informe Indicativo de Demanda 2001-2010*, ETESA, November 2000
(4) *Informe de Indisponibilidad Unidades de Generacion, Noviembre 1999-Octubre 2000*, ETESA
(5) *Planiamiento Operativo del Sistema Integrado Nacional,* ETESA, July 2002
(6) *Plan de Expansion de Transmission*, ETESA, 2002

In addition, current information is available from the ETESA web site.

Some of the information from the four sources is conflicting, especially with respect to the generation companies and the installed capacities of the individual units. However to present a better picture of the situation, information was taken from all sources. It is recognized that some of the information presented herein is outdated or even incorrect.

This information is considered to be adequately representative to present the power market picture in Panama.

We also are aware of a newer expansion plan report, however, we have not been able to obtain a copy either through the APC or our own contacts.

2 ECONOMIC SETTING

The economy of the Panama has experienced continued growth over recent years. Annual Gross Domestic Product (GDP) has grown at an average annual rate of 6.7 percent during the period of 1989-1994, and the annual rate of growth of GDP was reduced to 3.3 percent for the 5-year period of 1994 through 1999. The GDP reached U. S. $ 9,130.3 million in 1999 at the 1995 price level.

Total population of Panama has slightly increased from 2.35 million in 1989 to 2.58 million in 1994 and 2.81 million in 1999. Average annual rates of growth in total population for the periods of 1989-1994 and 1994-1999 were at 1.9 percent and 1.7 percent, respectively.

The GDP values per capita, at the 1995 price level, were U.S. $ 2,383 for year 1989, $ 3,009 for year 1994, and $ 3,249 for year 1999. Average annual growth rate of the GDP per capita was at 4.8 percent for the period of 1989 through 1994, and the rate was reduced to 1.5 percent during the subsequent period of 1994 through 1999.

The annual GDP values, per capita GDP values, and annual growth rates of these values of Panama for the period of 1980 through 1999 are shown in Table 1.

The main changes in the structure of the Panama economy over the recent years occurred in the shares of Agriculture, Industry, Commerce, and Governmental Service sectors in the total GDP. The Agriculture Sector includes farming and fishery, and the Industry Sector consists of mining, manufacturing, electricity generation and supply, water supply, gas and construction. The Commerce Sector includes imports and exports, hotels and restaurants, transportation and communications, financial and banking services, and housing and rentals.

The shares of the Agriculture sector in the GDP of Panama shrank from 10.2% in 1989 to 8.1% in 1994 and 7.6% in 1999, and shares of the Governmental Services decreased from 15.2% in 1989 to 10.4% in 1994 and 10.1% in 1999. The shares of Industry and Commerce sectors increased. The shares of the Industry sector increased from 15.5% in 1989 to 18.5% in 1994, and remained unchanged at 18.5% in 1999, and shares of the Commerce sector increased from 50.2% in 1989 to 53.4% in 1994 and 53.9% in 1999.

Table 1 GDP and Per Capita GDP Values and Annual Growth Rates of Panama for Period of 1980-1999

(Values are in U.S. Dollars at the 1995 Price Level)

Year	GDP Values		Per Capita GDP Values	
	GDP in $ million	Growth Rate in Percent	GDP/Capita in Dollars	Growth Rate in Percent
1980	5,282.9	-	2,709	-
1981	5,769.2	9.2	2,897	6.9
1982	6,077.8	5.3	2,989	3.2
1983	5,804.8	-4.5	2,794	-6.5
1984	5,962.1	2.7	2,810	0.6
1985	6,256.8	4.9	2,887	2.7
1986	6,480.0	3.6	2,930	1.5
1987	6,362.8	-1.8	2,819	-3.8
1988	5,511.4	-13.4	2,393	-15.1
1989	5,597.5	1.6	2,383	-0.4
1990	6,050.9	8.1	2,524	5.9
1991	6,620.8	9.4	2,711	7.4
1992	7,163.8	8.2	2,879	6.2
1993	7,554.7	5.5	2,980	3.5
1994	7,770.0	2.9	3,009	1.0
1995	7,906.1	1.8	3,005	-0.1
1996	8,128.3	2.8	3,040	1.1
1997	8,492.2	4.5	3,124	3.0
1998	8,843.5	4.1	3,200	2.2
1999	9,130.3	3.2	3,249	1.5

3 THE EXISTING ELECTRIC SYSTEM IN PANAMA

Until 1998, electric energy was produced by the *Instituto de Recursos Hidraulicos y Electrificacion* (IRHE), and some small private industries generate electricity for their own uses. The IRHE was also responsible for the operation and maintenance of the transmission and distribution systems, and sales to electricity consumers in Panama. NIS). With the restructuring of electricity sector in 1998, the IRHE was abolished and the generation and distribution facilities were privatized. Transmission was assigned to a new government agency, the *Empresa de Transmision Electrica, S.A.* (ETESA), which was also responsible for load forecasts, planning of generation and transmission facilities to meet forecasted electrical needs of Panama, and operation of the National Dispatch Center (CND) of the Panama National Integrated System (PNIS).

3.1 System in 1998

With the abolition of IHRE, 10 generation companies and 3 distribution firms were formed to produce and sale electricity to consumers.

The generation companies of the PNIS as of early year 2000 included:

- EGE-Bayano: *Empresa de Generacion Electrica Bayano, S.A.*
- EGE-Fortuna: *Empresa de Generacion Electrica Fortuna, S.A.*
- EGE-Bahia Las Minas: *Empresa de Generacion Electrica Bahia Las Minas, S.A.*
- EGE-Chiriqui: *Empresa de Generacion Electrica Chiriqui, S.A.*
- COPESA: *Corporacion Panamena de Energia, S.A.*
- PanAm: IGC/ERI Pan Am Thermal Generating Ltd.
- Pana Energy
- Hidro Panama
- Petroelectrica de Panama, S.A.
- Petroterminales de Panama, S.A.

The three distribution companies were:

- EDE-Metro Oeste (EDEMET): *Empresa de Distribucion Electrica Metro Oeste, S.A.*

- EDE-Chiriqui (EDECHI): *Empresa de Distribucion Electrica Chiriqui, S.A.*
- EDE-Elektra Noreste (ELEKTRA): *Empresa de Distribucion Electrica Elektra Noreste, S.A.*

The newly formed distribution companies forecast electricity needs of their individual distribution systems, and submit these forecasts to ETESA.

It is the responsibility of ETESA to develop generation and transmission system expansion plans for the PNIS on the basis of the electricity forecasts by the distribution companies, and to operate and maintain the transmission system and dispatch center.

A map of Panama with locations of existing major generating and transmission facilities are shown in Exhibit 1.

3.1.1 The Generation System

As reported in ETESA's *Plan de Expansion del Sistema de Generacion, 1999* (1), the installed capacity of the generation companies was 998.8 MW. This capacity, based on anticipated additions and plant retirements, is now (November 2000) estimated to be 1,184.3 MW as shown in Table 2.

Table 2 Generation Company Power Facilities

Company and Power Plant	Number of Units and Unit Capacity, MW	Type of Power Plant	Type of Fuel	Installed Capacity, MW
EGE- Las Minas				
BLM #1- #4	1x20, 3x40	Steam	Bunker C	140.0
Catepillar	7	I.C.	Diesel	30.0
Monte Esperanze	1x 20	G.T.	Diesel	20.0
San Francisco	3	Steam	Bunker C	10.0
TG-CCBLM	4	I.C	Bunker C	34.8
Ciclo-Comb. BLM[1]		GT/Steam	M. Diesel Bunker C	160.0
Subtotal	1			394.8
EGE-Bayano				
Sub Estacion Panama	2x 20	G.T.	Diesel	40.0
Bayano	2x75	H	-	150.0
Subtotal				190.0

Company and Power Plant	Number of Units and Unit Capacity, MW	Type of Power Plant	Type of Fuel	Installed Capacity, MW
EGE-Chiriqui				
La Estrella	2x21	H	-	42.0
Los Valles	2x24	H	-	48.0
Subtotal				90.0
EGE-Fortuna				
Fortuna	3x100	H	-	300.0
Petroelectrica	12	I.C.	Diesel	55.0
Petroterminales	7	I.C.	Diesel	15.0
COPESA	1x42	I.C.	Diesel	42.0
Pan Am	6x16.0	I.C.	Bunker C	96.0
Hidro Panama				
Anton 1	1	H	-	1.5
Total				**1,184.3**

(1) Replaces John Brown 1 and 2 and includes 35 MW of new gas turbine generation and 60 MW of steam generation

I.C. = Internal Combustion Units, G.T. = Gas Turbines Units, H = Hydroelectric Units.

About 45 percent of the total installed capacity of the generation companies is from hydropower.

Two of the three distribution companies also own and operate a number of hydro and thermal power plants. Of the 49 MW in this category, about 35 MW are connected to the PNIS system and 14 MW are not. A tabulation of these plants are presented in Table 3.

Table 3 Distribution Company Power Facilities

Company and Power Plant	Number of Units and Unit Capacity, MW	Type of Power Plant	Type of Fuel	Installed Capacity MW
Connected to the PNIS				
EDE-Metro Oeste				
La Yeguada	2x3.0, 1x1.0	H	-	7.0
Chitre	1x2.0, 5x2.5	I.C.	Diesel	14.5
Capira	2x0.55, 1x1.0, 3x2.5	I.C.	Diesel	9.6
Macho Monte	1x0.77	H	-	0.77
Dolega	2x1.12, 2x0.4	H	-	3.04
Total connected to the PNIS				**34.9**

Company and Power Plant	Number of Units and Unit Capacity, MW	Type of Power Plant	Type of Fuel	Installed Capacity MW
Not Connected to the PNIS				
EDE-Elektra Noreste				
Taboga	2x0.365, 1x0.545	I.C.	Diesel	1.275
Chepillo	1x0.060, 1x0.075	I.C.	Diesel	0.135
Otoque	1x0.150, 1x0.125	I.C.	Diesel	0.275
San Miguel	1x0.090,1x0.160	I.C.	Diesel	0.250
Condadora	1x1.200,1x0.650, 1x0.850,1x.545, 1x0.912	I.C.	Diesel	4.157
Garachine	1x0.150,1x0.155,1x0.175	I.C.	Diesel	0.480
Jaque	1x0.160, 1x0.125	I.C.	Diesel	0.285
Yaviza	2x0.160, 1x0.250	I.C.	Diesel	0.570
La Palma	1x0.425,1x0.600,1x0.525	I.C.	Diesel	1.550
Tucuti	2x 0.035	I.C.	Diesel	0.070
Boca de Cupe	2x0.035	I.C.	Diesel	0.070
Sante Fe	1x0.160, 1x0.225, 1x0.250,1x0.600	I.C.	Diesel	1.235
Nargana	1x0.055, 1x0.100	I.C.	Diesel	0.155
Río Azucar	2x0.035	I.C.	Diesel	0.070
Subtotal				10.8
EDE-Metro Oeste				
Bocas del Toro	2x0.545, x1.000, 1x0.600	I.C.	Diesel	2.690
Chiriqui Grande	1x0.272,1x0.250,1x0.400	I.C.	Diesel	0.922
Subtotal				3.4
Total Not Connected to the PNIS				**14.2**

I.C. = Internal Combustion Units

The total energy production amounted to 4,191.6 million kWh in 1998 including energy produced at the plants owned by the distribution companies. Hydroelectric power plants produced 2,140.3 million kWh of energy, about 51.1 % of the system total energy production.

3.1.2 The Panama Canal Authority Power Plants

The Panama Canal Authority (ACP) owns and operates three power plants, the Gatun and Madden Hydroelectric Plants, and Miraflores Thermal Plant. The three plants have a total combined installed capacity of 175 MW. Total number of generating units, unit capacity, and fuel type for each of the three plants are shown in Table 4.

Table 4 Panama Canal Authority Power Plants

Power Plant	Number of Units and Unit Capacity, MW	Type of Power Plant	Type of Fuel	Installed Capacity, MW
Gatun	3x3.0, 3x5.0	H	-	24.0
Madden	3x12.0	H	-	36.0
Miraflores	2x10.0, 1x18.0 1x22.0, 1x37.0, 1x18.0	G.T. Steam	Diesel Bunker C	38.0 77.0
Total				**175.0**

The Gatun hydroelectric plant is located adjacent to the Gatun Spillway on the Atlantic side of the Panama Canal. Water surplus to canal operational requirements is used for power generation. The Madden hydroelectric plant is located at the downstream toe of the Madden Dam. The Madden Dam was constructed to form a reservoir for providing an adequate water supply to the Gatun Lake to maintain the minimum draft essential to passing ships through the Canal. The water released from the Madden reservoir to the Gatun Lake is used to generate power.

Historically, the power generated at the Gatun and Madden power plants was used for canal operations, supplied to U.S. government agencies operating in the Canal area, and sold in the spot market. Currently, generation is used to meet the electricity needs of the canal operation and any surplus can be sold into the Panama national electrical system. The Miraflores plant serves as backup for the hydroelectric plants in times of high water, and supplies electricity in times of low water, if needed.

3.1.3 Transmission Company and System

The *Empresa de Transmision Electrica* (ETESA) has the responsibility for the operation and maintenance of the PNIS transmission system and the National Dispatch Center, and the development of generation and transmission expansion plans for the PNIS.

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 (6).

For the six-month period of July-December 1998, ETESA's revenues, received from the generation and distribution companies for use of the transmission system, amounted to $17.0 million.

Transmission energy losses of the PNIS for the period of July-December 1998 were estimated at 72,1 GWh, or about 3.4 percent of total energy supply. This corresponds to a loss of $ 4.12 million with a unit cost of energy at $ 0.057/kWh. The transmission energy losses for year 1999 were reported at 150.8 GWh, or about 3.4 percent of the total energy production of 4,455 GWh, and for year 2002 at 186.8 GWh or about 3.7% of the total energy production of 4,999GWh.

3.2 System in Year 2002

After the restructuring, there were ten generation companies as described in Section 3.1. Currently, there are six companies generating a total of 1,060 MW that are providing the bulk of the electricity to Panama.

Two of the original ten companies, EGE Bayano and EGE Chiriqui were bought by the AES Corporation and merged into AES Panama. As reported in a 1999 plan of expansion (12), two additional generation companies, Petroterminales and Hidro Panama operated 15 MW and 1.5 MW respectively. It is not known whether these units were retired or just not considered as major producers for the 2002 operation plan (5).

In the 1999 expansion plan, it was also reported that the distribution companies operated a series of thermal plants. EDE Metro Oeste operated five plants totaling 35 MW that were connected to the Panama National Integrated System (PNIS) and 3.4 MW that were not connected. EDE Elektra Noreste operated 14 plants with a total capacity of 10.8 MW that were not connected to the grid.

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

The total installed capacity and distribution between thermal and hydro is presented in Table 5.

Table 5 Generation Facilities

Company	Hydro Capacity (MW)	Thermal Capacity (MW)	Total Capacity (MW)	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.

3.2.1 Energy Consumption

Three distribution companies were formed in 1998 to purchase energy from generation companies and to sell energy to consumers. The total energy consumption, number of consumers, and energy consumption by sector in year 1998 for each of three distribution companies are shown in Table 6.

Table 6 Energy Consumption and Customers in 1998

Company	Metro Oeste	Chiriqui	Elecktra Noreste	Total
Energy Consumption in MWh				
Residential	491.84	90.47	422.34	1,004.65
Commercial	809.39	91.03	441.64	1,342.06
Industrial	170.02	45.92	271.70	487.64
Governmental	257.87	37.86	181.52	477.25
Public Lighting	35.04	9.76	19.63	64.43
Own Uses	8.92	2.29	5.59	16.80
Total	1,773.08	277.33	1,342.42	3,392.83
% Total System	52%	8%	40%	100%
Number of Customers				
Total	216,283	68,301	167,445	452,029
% Total System	47.85%	15.11%	37%	100%

In 1999, the energy consumption and number of customers for each of the three distribution companies increased as shown in Table 7. The total number of customers for the three distribution companies increased by 5.3% during the 1998-1999 period, and the total energy consumption increased at the relatively low rate of 3.8 percent during the same period.

Table 7 Comparison of Energy Consumption and Number of Customers of the Three Distribution Companies in 1998 and 1999

Company	Metro Oeste	Chiriqui	Elecktra Noreste	Total
Energy Consumption in MWh				
Year 1998	1,773.08	277.33	1,342.42	3,392.83
% of Total System	52	8	40	100.0
Year 1999	1,784.99	287.64	1,448.74	3,521.37
% of Total System	51	8	41	100
Annual Growth Rate	0.7%	3.7%	7.9%	3.8%
Number of Consumers				
Year 1998	216,283	68,301	167,445	452,029
% of Total System	48	15	37	100
Year 1999	228,866	72,229	174,876	475,971
% of Total System	48	15	37	100
Annual Growth Rate	5.8%	5.8%	4.4%	5.3%

Total distribution system energy losses of the three distribution companies for the period of July-December 1998 were estimated at 379 million kWh, about 18% of purchased energy. These losses are shown by distribution company in Table 8.

Table 8 Distribution System Losses for July-December 1998

Company	Metro Oeste	Chiriqui	Elektra Noreste	Total
Energy Losses, MWh	113,768	9,218	255,978	378,964
Percent of Purchased Energy, %	11	5	27	18

Firm capacity contracts among the generation and distribution companies for year 1999 are shown in Table 9.

Table 9 Firm Capacity Contracts in 1999 in MW

Company	Metro Oeste	Chiriqui	Elektra Noreste	Total
Hydro Generation				
Fortuna	140	24	120	284
Bayano	51	-	31	82
EGE-Chiriqui	19	22	18	59
Total Hydro Generation	210	46	169	425
Thermal Generation				
Bahia Las Minas	156.5	-	98	254.5
IGC/ERI	30	-	-	30
COPESA	-	-	42	42
Total Thermal Generation	186.5	-	140	326.5
Total Hydro/Thermal	**396.5**	**46**	**309**	**751.5**

3.2.2 Electricity Tariff

Each of the three distribution companies has established a tariff structure including capacity and energy charges for various types of energy consumers. The tariff structure also includes clauses dealing with escalation of the capacity and energy charges on the basis of consumer price indices. The EDE-Metro Oeste and EDE-Chiriqui update their

tariff structures every six months, and the existing EDE-Elektra Noreste tariff structure will be valid until June 2003.

Each of the three distribution companies has individual contracts for capacity and energy purchases/sales with the generation companies. The duration of these contracts varies from two to five years.

The average unit energy sale price for the three distribution companies was $0.111/kWh in 1998 and $0.103/kWh in 1999. The average unit energy sale price for each consumer sector in 1998 is given in Table 10.

Table 10 Average Unit Energy Sales Price by Sector in 1998

($/kWh)

Sector	Residential	Commercial	Industrial	Government	System
Sale Prices	0.119	0.116	0.097	0.111	0.111

The unit energy sale prices in Panama have decreased slightly over the last decade. From 1990 through 1999, the price has decreased at a rate of 1.4% p.a. However, in 2002, the average sales price was estimated to be about $0.119/kWh.

4 LOAD AND ENERGY DEMANDS OF THE PANAMA ELECTRIC SYSTEM

Energy demand, peak load and the annual growth rates for the PNIS over the last 10 years are shown in Table 11. The average annual growth rate of the energy demand was at 5.5% for the period and the average annual growth rate for the peak load was 5.5%. The annual system load factor averaged about 67.4 percent over the period.

Table 11 Energy Demand, Peak Load, and Load Factor in the PNIS System

Year	Energy Demand, GWh	Annual Growth Rate, %	Peak Load, MW	Annual Growth Rate, %	Load Factor, %
1990	2,746.1	-	464.4	-	67.5
1991	2,896.6	5.48	488.5	5.19	67.7
1992	3,011.6	3.97	518.0	6.04	66.2
1993	3,199.1	6.23	541.2	4.48	67.5
1994	3,400.0	6.28	591.5	9.29	65.6
1995	3,619.4	6.45	619.2	4.68	66.7
1996	3,795.8	4.87	639.9	3.34	67.5
1997	4,254.4	12.08	706.6	10.42	68.7
1998	4,295.8	0.97	726.4	2.80	67.5
1999	4,456.8	4.76	754.5	3.87	67.4
2002[1]	4,998.5	3.90	857	4.33	67

[1] ETESA Web site

The total energy demands of the Panama Canal Authority for the period of 1992 through 1999 are shown in Table 12. The total energy demands include energy sales to the PNIS. The energy demand was decreased from 643.6 million kWh in year 1992 to 548.0 million kWh in 1998, and 450.0 million kWh in 1999. Fluctuations in energy demand for the period of 1992 through 1998 were partially dependent on the amount of energy sales to the PNIS. The decrease in energy demand for 1999 was due to the planned transfer of Panama Canal operation from U.S. to Panama. The peak load demand was reduced from 86 MW in 1992 to about 68 MW in year 1999.

Table 12 Historical Peak Load and Energy Demands of the ACP, 1992-2002

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Energy Demand GWh	624	599	635	570	522	548	450	444	457	405
Annual Rate of Change, %		-4.0	-6.0	-10.2	-8.4	-9.2	-17.9	-1.3	2.9	-11.4
Peak Load, MW	86	87	86	79	83	71	68	53	64	58
Annual Rate of Change, %		1.2	-1.2	-8.1	5.1	-14.5	-4.2	-22.1	20.8	-9.4

4.1 Load Demand Characteristics

There are minor variations among monthly peak loads and energy demands of the PNIS as monthly temperatures and rainfall in Panama remain relatively constant throughout the year. The monthly peak loads for 1999, expressed in term of percent of the annual peak load, are shown in Table 13. The monthly energy demands of the PNIS for year 1999 in term of percentage of total annual energy demand are also shown in Table 13.

Table 13 Monthly Peak Loads and Energy Demands of the PNIS in 1999 and 2000

Month	**Peak Load in Percent of Annual Peak Load**		**Energy Demands in Percent of Total Demand**	
	1999	**2000**	**1999**	**2000**
January	93.5	89.8	8.0	7.9
February	93.6	90.5	7.4	7.7
March	97.2	94.8	8.8	8.3
April	99.7	95.9	8.7	8.2
May	98.6	96.0	8.6	8.7
June	98.9	94.8	8.2	8.3
July	96.4	98.1	8.2	8.5
August	98.9	98.9	8.4	8.6
September	97.9	95.1	8.2	8.2
October	97.8	96.6	8.6	8.5
November	96.4	95.4	8.3	8.1
December	100.0	100.0	8.8	8.9
Total	-		**100.0**	**100.0**

Daily peak loads of the PNIS occur during the period of 11 A.M. through 3 P.M. on weekdays and Saturdays, and at 7 P.M. or 8 P.M. on Sundays. Hourly loads of typical weekdays and Sundays of the PNIS for the months of September 1999 and March 2000, expressed in terms of percent of the daily peaks, are given in Table 14.

Table 14 Hourly Loads of Typical Weekdays and Sundays

Date	Thurs. 9/16/99		Sun. 9/19/99		Mon. 3/20/00		Sun. 3/19/00	
Hour	Load, MW	Percent of Peak. %	Load, MW	Percent of Peak, %	Load, MW	Percent of Peak, %	Load, MW	Percent of Peak, %
1	413.4	57.9	413.4	77.7	408.2	55.5	435.4	79.7
2	396.8	55.6	389.7	73.2	383.9	52.2	407.4	74.6
3	388.2	54.3	376.6	70.8	380.9	51.8	390.4	71.5
4	382.0	53.5	368.4	69.2	373.1	50.7	380.2	69.6
5	385.0	53.9	354.6	66.6	378.4	51.4	376.9	69.0
6	415.6	58.2	353.7	66.5	412.7	56.1	372.9	68.3
7	435.3	60.9	340.5	64.0	431.8	58.7	358.6	65.7
8	519.9	72.8	357.2	67.1	505.3	68.7	352.2	64.5
9	627.5	87.8	378.7	71.2	628.8	85.4	365.1	66.9
10	676.3	94.7	403.5	75.8	693.6	94.2	398.6	73.0
11	702.0	98.3	420.7	79.1	723.7	98.3	425.7	78.0
12	710.8	99.5	433.3	81.4	729.7	99.1	428.4	78.4
13	699.5	97.9	432.2	81.2	714.8	97.1	440.0	80.6
14	714.3	100.0	433.5	81.5	731.5	99.4	444.0	81.3
15	713.3	99.9	437.4	82.2	736.0	100.0	445.9	81.7
16	704.3	98.6	436.1	82.0	718.4	97.6	440.2	80.6
17	669.3	93.7	434.1	81.6	673.8	91.5	446.3	81.7
18	612.7	85.8	440.3	82.7	599.8	81.5	440.4	80.6
19	640.7	89.7	493.5	92.7	607.9	82.6	493.9	90.4
20	630.7	88.3	531.9	100.0	638.3	86.7	546.1	100.0
21	607.1	85.0	532.1	100.0	622.2	84.5	538.8	98.7
22	574.9	80.5	505.1	94.9	570.7	77.5	522.3	95.6
23	519.2	72.7	474.1	89.1	502.4	68.3	479.8	87.9
24	467.5	65.4	429.7	80.8	447.5	60.8	435.7	79.8

5 FORECAST OF POWER DEMAND OF THE PANAMA ELECTRIC SYSTEM

Three demand forecasts are available for each of two economic assumptions, moderate growth and high growth. One forecast was developed in 1998 (reference 1), one in 1999 (reference 2) and the third in November 2000 (reference 3). The earlier estimates were developed using a multiple regression analysis to define the relationship between energy consumption and economic parameters for each consumer sector including residential, commercial, industrial, government, and public lighting. A regression equation was defined for each sector. The economic parameters included population, gross domestic product (GDP) per capita, unit energy sale price for each sector, and energy efficiency. The energy efficiency is the unit energy consumption rate for producing the GDP of the industry sector, and is computed by dividing the GDP by total energy consumption of the sector. GDP is a broad measure of the health of the Panamanian economy and is usually defined as the value of goods and services produced by labor and property in Panama. It is a measure of domestic production. The peak load demands were estimated on the basis of the forecasted energy demand and a system load factor at 67.9 %.

The more recent demand estimate was developed using a simplified relation of total energy sales as a function of gross national product (GNP). GNP is a measure of income since it reflects income from domestic production (GDP) plus net income from abroad. The coefficient of determination for the two samples (total energy and GNP) was highest using a polynomial function. The simplified approach was taken due to the difficulty in obtaining accurate economic information.

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 15.

Table 15 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		4,732
2002 (Actual)	857	4998		
2005	1,107	5,304	1,177	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 estimated in Table 16.

Table 16 Energy Forecast for Three Recent Estimates

Year	Medium Growth Scenario – GWh		
	1998 Estimate	1999 Estimate	2000 Estimate
2001	4,981	4,907	4,028
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.

6 UPPER CHAGRES' ROLE IN PNIS EXPANSION PLANS

The earliest commissioning date of the Upper Chagres power plants will probably be after 2010 especially if implementation is contingent upon the installation of a third set of locks. The peak loads in 2010 for the medium forecast will be about 1,600 MW. The ACP demand, which according to the ACP Electricity Department is not included, is another 60 MW.

The generation expansion plan of the PNIS for the period of 1999-2015 was developed and recommended by the EDESA in a 1999 study. Contribution from the ACP facilities was not included. The recommended generation expansion plan with private hydro development is shown in Table 17.

Table 17 Generation Expansion Plan 2000-2015

Operation Date	Type	Name of Plant	Capacity (MW)
1999 September	Hydro	Anton 1	1.5
November	Thermal	Combined Cycle	160
December	Thermal	Gas Turbine	96
2000	-	-	-
2001	-	-	-
2002 October	Hydro	Guasquitas	84
2003 April	Hydro	Canjilones	34.8
2004	Thermal	Gas turbine	50
2005	Thermal	Combined Cycle	100
2006	Hydro	Gualaca	27
2007	Hydro	Los Aniles	34
	Hydro	Chiriqui	56
2008	Hydro	Baru	150
2009	Thermal	Gas Turbine	50
2010	Thermal	Combined Cycle	150
2011	Thermal	Combined Cycle	100
2012	Thermal	Gas Turbine	50
	Hydro	Changuinola 5	120
2013	Thermal	Combined Cycle	250
2014	Thermal	Combined Cycle	100
2015	Thermal	Combined Cycle	100

In a personal communication with staff of the Electricity Department, it was indicated that the expansion plan is out of date and that they did not expect the new plants to come on line as indicated. However, the important part of the expansion plan is that hydro is expected to be a very important component of future development - the 1999 expansion plan suggests that new capacity will include about 386 MW of hydro capacity during the period of 2002 – 2008. The installed capacities, average annual energy production, and estimated construction costs of these hydroelectric projects and the Chagres Project are shown in Table 18.

Table 18 Pertinent Data of the Chagres and Candidate Expansion Plan Hydro Project for the Period 2002 through 2008

Project	Type of Plant	Installed Capacity, MW	Average Annual Energy, GWh	Estimated Construction Cost, $/kW
Chagres	Storage	56	254	805
Guasquitas	Storage	84	449	1618
Canjilones	Run of River	35	178	1816
Gualaca	Run of River	27	138	1656
Los Aniles	Run of River	34	172	1938
Chiriqui	Run of River	56	290	1635
Baru	Storage	150	800	1989

The cost of the 56-MW installation at Chagres was estimated at about $ 805 per kW of installed capacity. This would be lower than the estimated costs of the six candidate hydroelectric plants to be added to the PNIS for the period of 2002 – 2008.

6.1 Marginal Costs

The marginal costs for each calendar month of the PNIS for the period of 1999 – 2015 were estimated on the basis of the recommended generation expansion program and 1999 oil prices. These estimates indicated that the marginal costs will decrease over the period from $45/MWh in 1999 to about $42/MWh in 2015 and average about $43/MWh. This value could be used to represent the energy benefit of the Chagres Project hydropower. The actual marginal costs for the period from 1998-2002 were as follows:

Year	Marginal Cost ($/MWh)
1998	57
1999	45
2000	53
2001	52
2002	50

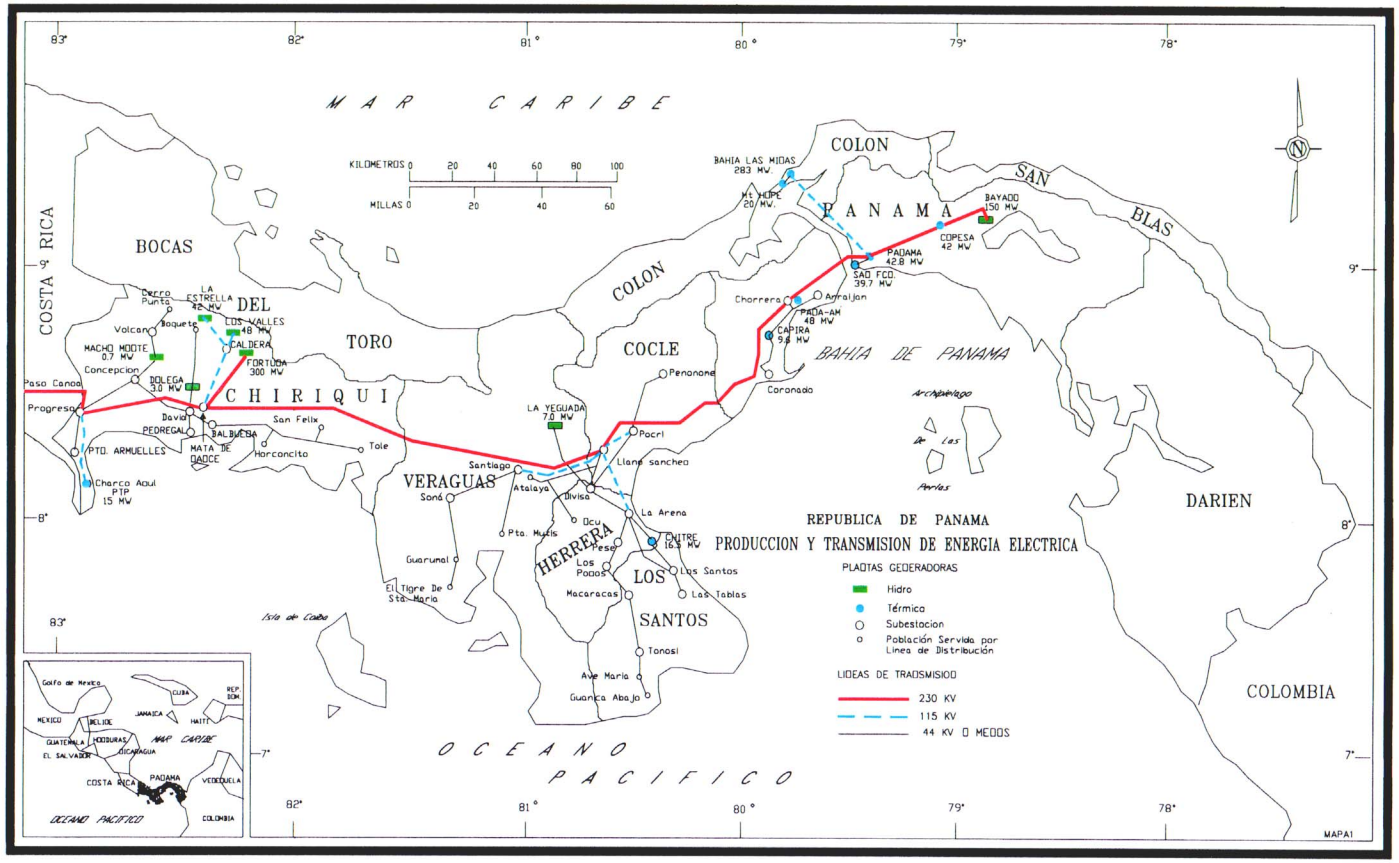
As the marginal costs are running higher than forecasted, the energy benefit may be understated.

7 CONCLUSIONS

As a result of this analysis, it can be concluded that:

- The existing system recognizes the importance of hydro to the extent that it provides about one-half of the available capacity.
- The current expansion plans for the period through 2015 include hydro as a major component.
- Demand for power is expected to grow at a rate of more than 4% per year.
- Based on the available information, the Chagres power and energy will be competitive in the national power system.
- Chagres capacity and energy will be easily absorbed into the system and will provide a very cost-effective addition – replacing any of the projects identified in the 1999 expansion plan

SISTEMA DE TRANSMISION ACTUAL
AÑO 1999



FEASIBILITY DESIGN FOR THE UPPER CHAGRES WATER SUPPLY PROJECT

APPENDIX E
PART 2

POTENTIAL FOR POWER DEVELOPMENT

Prepared by

MWH

In association with

TAMS
AN EARTH TECH COMPANY

FEASIBILITY DESIGN FOR THE UPPER CHAGRES WATER SUPPLY PROJECT

APPENDIX E – POWER AND ENERGY STUDIES
PART 2 – POTENTIAL FOR POWER DEVELOPMENT

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1 BACKGROUND AND SCOPE

The Panama Canal Authority (ACP) is evaluating several sources of additional water supply to meet future demand for the Canal operation and for municipal and industrial use in the Lake Gatun watershed. A Reconnaissance Study performed by the US Army Corps of Engineers, Mobil District, in December 1999 has identified the Upper Chagres dam and reservoir as a promising project to increase the guaranteed yield of the system of reservoirs supplying water to the Canal.

Based on the outcome of the Reconnaissance Study, the ACP has selected the Upper Chagres project to be evaluated at the feasibility level. As part of the Feasibility Study, the project hydroelectric potential identified in the Reconnaissance Study must be assessed. This report presents the analysis performed to evaluate this potential.

The present power and energy studies for the Upper Chagres Water Supply Project were performed by TAMS Consultants, Inc., an Earth Tech company, under the Sub-consultant Services Agreement No.15593 S-1 for MWH. A separate report covering the power market study was prepared by MWH, and is presented as Part 1 of this Appendix E – Power and Energy Studies. The report presents a power market survey of Panama and the future power needs of the Panama national electric system.

The hydroelectric potential of the Upper Chagres water supply project has been evaluated on the basis set forth in the Reconnaissance Study and further specified in the Scope of Work for the present Feasibility Study developed by the Autoridad del Canal de Panamá (ACP). The primary objective of the Upper Chagres project is to supply water to meet the growing demand of the Panama Canal for navigation, and of the municipal and industrial consumption in the Lake Gatun watershed. This objective will be achieved by storing and releasing regulated runoff water into the Lake Ahlajuela (Madden) located approximately 10 km downstream of the proposed dam. The Reconnaissance Study has stated that navigation benefits resulting from additional supply of water are significantly larger than hydropower benefits; as such the benefits of hydropower are incidental to the project and are not expected to govern its development.

The Reconnaissance Study has identified the hydropower potential of the project as a plant with an installed capacity of 34.5 MW.

The energy generated by the project was estimated at approximately 150 GWh per year. The power plant would be designed and configured to function as part of the national power grid. A 115-kV transmission line would be required to carry the energy to a connection with the grid near Panama City.

The conclusions of the power market studies indicate that the demand for power in the Panama National Integrated System (PNIS) is expected to grow at a rate of more than 5%

per year. It is also stated that the PNIS recognizes the importance of hydropower, as the current expansion plan for the period through 2015 includes six new hydroelectric power plants (not including Upper Chagres) totaling 386 MW at an average construction cost of $1,813 per kW of installed capacity. The report also recommends a value of $45 per MWh for the current marginal cost of energy for the period up to 2015.

2 SELECTED UPPER CHAGRES RESERVOIR

The Upper Chagres reservoir has been sized without consideration for hydroelectric power and is anticipated to increase the water yield the Panama Canal reservoir system to meet the system water demand up to Year 2017 at a reliability of 99.6%. This is based on the projection for unconstrained water demand for Navigation presented in the Reconnaissance Study and the M&I and tourism water demand presented in the report entitled "Long Term Forecast for M&I Demand" prepared by MWH, January 2001. The Panama Canal water supply system considered for this study consists of Lake Gatun operating between El. 23.93 (78.5 ft) and El. 26.75 (87.75 ft) and the Madden reservoir, operating between El. 57.91 (190 ft) and El. 76.81 (252 ft). It is assumed that the deepening of Lake Gatun will be completed and will allow draw down of the Lake three feet lower than it is currently allowed for normal operation with a minimum water level at El. 24.84 (81.5 ft). The reservoir operation studies conducted by the ACP with the HEC-5 simulation program have demonstrated that the demand of 50 lockage per day (120.5 m^3/s) can be met at the required reliability, with the Upper Chagres reservoir sized for an active storage of 450 MCM. The HEC-5 simulations considered releases from the Upper Chagres reservoir to supplement the storage of Madden and Gatun reservoirs. The discharge capacity of the reservoir outlet is equal to 31.6 m^3/sec for a water level at El. 155, and 43.0 m^3/sec for a water level at El. 210. Figure 1 below shows a plot of the reservoir levels against the monthly reservoir releases.

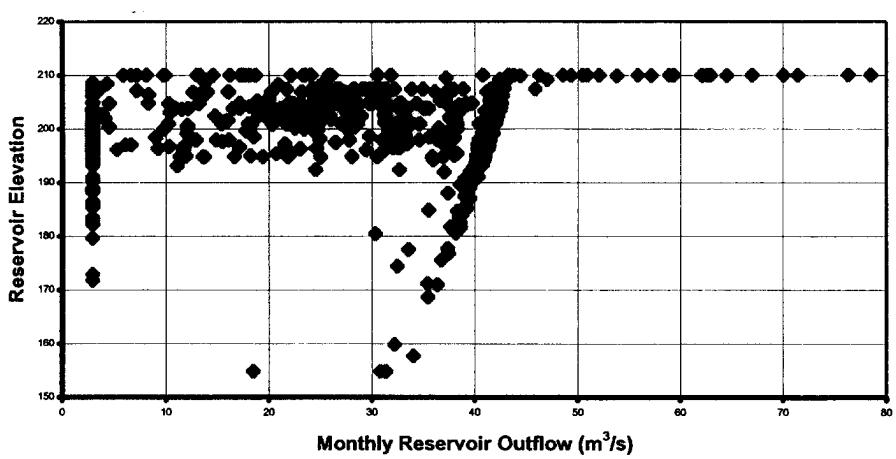


Figure 1 – Upper Chagres Reservoir Operation

The results of the Upper Chagres reservoir simulations under these conditions are shown in a tabular form in Attachment 2. The reservoir releases varied between 3 m^3/sec the imposed minimum release that occurs approximately 10% of the time and 95 m^3/sec. The average monthly discharge over the 52-year simulation is 29.6 m^3/sec.

Figure 2 below shows the Upper Chagres reservoir elevation frequency curve derived from the HEC-5 simulation. It indicates that the median reservoir level is approximately at El.201, and that 98% of the time the reservoir is above El. 177. This curve is used to select the best turbine operating range.

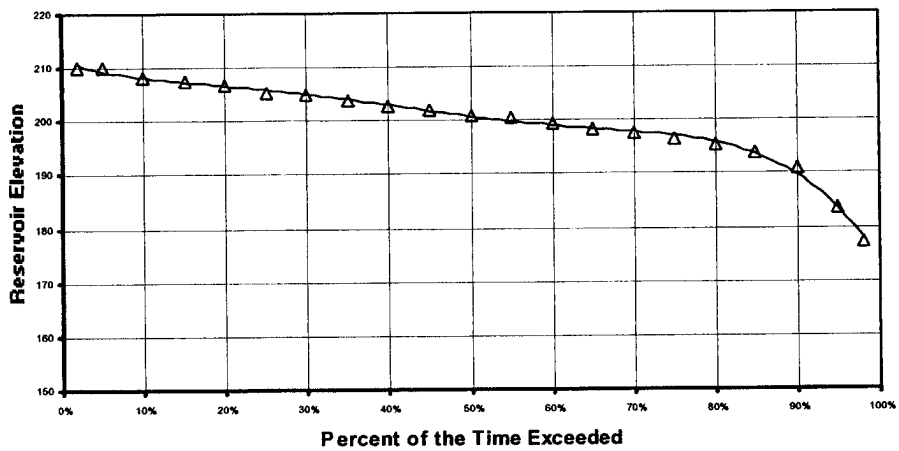


Figure 2 – Upper Chagres Reservoir Elevation Duration Curve

3 SCHEME SELECTION

3.1 Energy Production

The potential energy production of the Upper Chagres Hydroelectric scheme has been evaluated for two scenarios. The first one corresponds to the ACP's proposed operation of the reservoir with as sole objective to maximize the yield of the system of reservoir consisting of Gatun, Madden and Upper Chagres.

For that purpose a spreadsheet-type model was developed: the model uses the monthly output of the HEC-5 simulation performed by the ACP. The hydraulic capacity of the hydropower component was selected to operate with the reservoir levels ranging from El. 155 to El. 210. The project water released were those determined by the HEC-5 simulation. The tail-water rating curve established under the hydraulics studies was used for the purpose of calculating the gross head on the project.

The energy production was calculated for a range of installed capacity from 24 MW to 63 MW: the results are shown in Table 1 below. The input parameters of the computation are presented in Attachment 3.

Table 1 - Energy Production with Proposed Operation

Installed Capacity (MW)	Maximum Turbine Discharge (m^3/s)	Average Annual Energy (GWh)
24.0	26.5	173.6
32.0	35.3	215.6
40.0	44.1	243.1
49.0	54.1	250.6
56.0	61.8	253.3
63.0	69.5	255.4

The minimum reservoir release has been determined by the ACP to be 3.0 m^3/s. Under the proposed operation this is the average monthly discharge approximately 10% of the time. As a consequence the firm power plant capacity is limited to that discharge and it is estimated to be 8.7 MW.

The scenario represented by the type of operation described above will only occur when the navigation demand reaches the yield of the system of reservoir. Prior to that time the reservoir could be operated according to rules more favorable to hydropower production, without sacrificing the principal objectives of the reservoir. For that purpose an HEC-5 model was developed to estimate the potential energy production of the project that would be used to maximize energy and power returns. Using the same hydraulic

parameters the average annual energy and firm capacity of the project were estimated as shown in Table 2 below:

Table 2 - Energy Production to Maximize Hydropower Return

Installed Capacity (MW)	Maximum Turbine Discharge (m^3/s)	Firm Capacity (MW)	Average Annual Energy (GWh)
25.0	27.6	25.0	209.0
35.0	38.6	35.0	231.0
45.0	49.6	45.0	246.0
55.0	60.7	55.0	253.0
65.0	71.7	65.0	257.0
75.0	82.7	69.5	259.4

Under this scenario the firm capacity is significantly increased, as the operation objective is to generate a constant monthly energy. Storage provided by the Upper Chagres reservoir will increase the water supply yield for the purpose of Canal navigation over the current yield, but not as much as the ACP proposed operation. Therefore, this type of operation is representative of the initial years of the project. It will also be the likely mode of operation when the reservoir system yield is in excess of the water demand for navigation. For that reason it is recommended that the project be optimized on that basis, rather than the operation maximizing the water yield.

3.2 Power Scheme Selection

The ACP selected mode of operation for the reservoir includes long periods with an average monthly discharge of 3.0 m^3/s. Thus the project must include at least one unit capable of releasing that discharge under reasonably good operating conditions and efficiency. As the Upper Chagres reservoir releases into the Madden reservoir, it is anticipated that the hydropower releases will follow the load even at time of minimum release, and therefore the 3.0 m^3/s release will not be continuous, but will vary on an hourly basis. For the purpose of load following, it is anticipated that a turbine with a capacity of 6 to 8 MW, running at approximately 50% load will meet these requirements. All evaluated power plants have included a small unit. Additionally, to allow for continuous and flexible operation when the releases are larger, the larger size unit in the power plant should not exceed approximately twice the size of the smaller unit.

For the purpose of optimization a wide range of installed capacity was evaluated: including cost estimate, energy production and revenues. The following power plants were evaluated:

- One 16-MW and one 8-MW for a 24-MW power plant;
- One 16-MW and two 8-MW for a 32-MW power plant;

- Two 16-MW and one 8-MW for a 40-MW power plant;
- Three 14-MW and one 7-MW for a 49-MW power plant;
- Three 16-MW and one 8-MW for a 56-MW power plant; and,
- Three 18-MW and one 9-MW for a 63-MW power plant.

For each of these schemes quantities were estimated for the power intake, vertical shaft, steel lined tunnel, manifold, power plant and transmission system. The principal characteristics of each scheme are presented below in Table 3.

Table 3 - Scheme Optimization – Plant Characteristics

Proposed Scheme	Maximum Turbine Discharge (m^3/s)	Intake Gate Dimensions (m)	Shaft and Tunnel Diameter (m)	Powerhouse Dimensions (m)
1 x 16-MW & 1 x 8-MW	26.5	1.40 x 2.10	2.70	28 x 14
1 x 16-MW & 2 x 8-MW	35.3	1.70 x 2.60	3.20	35 x 14
2 x 16-MW & 1 x 8-MW	44.1	1.90 x 2.90	3.50	39 x 14
3 x 14-MW & 1 x 7-MW	54.1	2.10 x 3.20	3.90	47 x 14
3 x 16-MW & 1 x 8-MW	61.8	2.20 x 3.30	4.20	50 x 14
3 x 18-MW & 1 x 9-MW	69.5	2.30 x 3.50	4.50	53 x 14

Detailed cost estimates for all the schemes are presented in Attachment 4 and summarized below in Table 4.

Table 4 – Hydropower Component Cost Estimates ($, 000)

Proposed Scheme	Civil Works	Elect. & Mech. Equipment	Trans. System	Cont., Eng. & Adm.	Total Cost
1 x 16-MW & 1 x 8-MW	$9,389	$8,822	$3,998	$6,425	$28,634
1 x 16-MW & 2 x 8-MW	$10,368	$11,754	$4,098	$7,544	$33,764
2 x 16-MW & 1 x 8-MW	$11,408	$13,174	$4,319	$8,314	$37,215
3 x 14-MW & 1 x 7-MW	$12,300	$15,702	$4,679	$9,368	$42,049
3 x 16-MW & 1 x 8-MW	$13,227	$17,340	$4,720	$10,112	$45,399
3 x 18-MW & 1 x 9-MW	$14,593	$18,894	$4,807	$10,987	$49,281

The energy and power benefits for each of these schemes were estimated based on the current value of energy presented in the power market studies ($45 per MWh) and the value of firm capacity of $60 per kW-yr. The firm capacity was calculated on the basis of the projected monthly energy production: it the capacity that could be delivered 8 hours per day, every day of the month with the monthly energy exceeded 95% of the time.

The operation and maintenance cost of the hydropower scheme were estimated as follows:

- 1.0% of the cost of all civil works;
- 2.5% of the cost of all mechanical and electrical equipment;
- 1.5% of the cost of the transmission line.

For each of the scheme, the internal rate of return (IRR) and the marginal rate of return were calculated; the calculations are presented in Attachment 5. The results of this analysis are shown on Table 5 below.

Table 5 - Hydropower Component Rate of Return

Proposed Scheme	Total Cost ($,000)	Annual O&M Cost ($,000)	Annual Revenue ($, 000)	Internal Rate of Return	Marginal Rate of Return
1 x 16-MW & 1 x 8-MW	$28,611	$479	$10,615	28.4%	
1 x 16-MW & 2 x 8-MW	$33,739	$586	$12,045	27.4%	21.7%
2 x 16-MW & 1 x 8-MW	$37,188	$649	$13,155	27.2%	25.0%
3 x 14-MW & 1 x 7-MW	$42,018	$747	$14,190	26.1%	16.8%
3 x 16-MW & 1 x 8-MW	$45,365	$812	$14,768	25.2%	13.5%
3 x 18-MW & 1 x 9-MW	$49,245	$881	$15,345	24.3%	11.7%

All the considered schemes show an internal rate of return well above the ACP required level of 12% for development. The marginal rates of return calculated between the presented schemes are also generally above the 12% required except for the larger scheme of 63 MW. It indicates that for each of the schemes the return on the investment necessary to increase the plant to the next capacity is better than an alternative development. The marginal return for increasing the capacity from 49 MW to 56 MW is 13.5%, and provides a slight margin over the required 12%. On that basis the selected hydropower scheme will consist of three turbine/generator units rated at 16 MW each, and one turbine/generator rated at 8 MW. The selected number and size of units takes into consideration the required flexibility of operation under the anticipated range of heads and flows at the site.

The project firm capacity is significantly affected by the mode of operation selected, and therefore the return of the hydropower component will decrease as soon as the Chagres reservoir is to be used to its full capacity to meet the Canal water demand. It has been calculated however (see page AT5-13 to AT5-16 in Attachment5) that the IRR of the 56-MW power plant scheme would only be lowered to 24.3% if the water demand of the Canal reaches 50 lockage per day in 2017.

4 RECOMMENDED SCHEME

4.1 General

The proposed Upper Chagres Hydroelectric Scheme consists of a power intake, a vertical shaft and horizontal tunnel leading to the powerhouse located approximately 200 meters downstream of the dam axis on the right bank of the Rio Chagres. The power plant will house four units: one 8-MW and three 16-MW Francis turbines for a total installed capacity of 56 Megawatts. The 115-kV switchyard will be located about 200 meters from the powerhouse; the transmission line, 21.2 kilometer long, will intersect the existing 115-kV Panama-Colon line near the Madden dam.

4.2 Civil Works

4.2.1 Power Intake

The power intake is located in the middle of the right abutment of the dam, adjacent to the upstream face approximately 250 meters west of the spillway. The intake level was established for conditions anticipated after 100 years of sediment deposition. It consists of a reinforced concrete tower, 70 meters high with foundation at approximately El 145 and the access platform level with the crest of the dam. At the location of the intake, the existing ground level is between El. 165 and El. 170. This location was selected as it is anticipated that there is a layer approximately 20 to 25 meters deep of overburden and highly fractured rock. An approach channel approximately 50 meters long is required, and is to be excavated in the overburden with a 20 meter wide invert at El. 150. The tower will be built adjacent to the upstream face of the dam, with foundation 16 meters wide by 25 meters long. The waterways invert is located at El.150. The trashrack consists of two bays 6 meters wide by 8 meters high, separated by a central pier, and each upstream of a conduit 2.20 meters wide by 3.30 meters high. Each conduit contains a set of stoplog and gate, and a short length steel liner. The conduits join and transition into the 4.20-meter diameter vertical shaft. The vertical shaft extends in the tower all the way up to the crest of the dam.

4.2.2 Shaft, Tunnel and Manifold

At the base of the power intake, a vertical shaft 60 meters deep is to be excavated to El. 83 where it connects with the horizontal tunnel. The 4.20-meter diameter shaft is lined with reinforced concrete, and includes high pressure grouting. A 90° vertical bend transitions the shaft into the 4.20-meter diameter tunnel. The 200-meter long tunnel is steel lined and backfilled with concrete. The conduit diameter is reduced to 4.00 meters at the tunnel portal immediately upstream of the four-branch manifold. The manifold located in the back of the powerhouse consists of three 2.00-meter diameter branches and one 1.40-meter diameter. It is embedded in concrete and underneath the transformers. The manifold invert is at about El. 82.

4.2.3 Powerhouse

The powerhouse is a conventional 50-meter long by 15-meter wide reinforced concrete structure located on the right banks of the Rio Chagres, parallel to the direction of the river. It contains four unit bays and one service bay located at the southern end of the powerhouse nearest to the access. The foundation excavation, in sound rock, is down to El. 75 approximately 15 to 20 meters below existing ground surface at that location and is approximately 40 meters long. The three 16-MW units are located on the most upstream part of the powerhouse, nearest to the tunnel portal. The centerline of the units is located at El. 81.7 slightly below the minimum tailwater level. A 7-meter long shaft connects the generator to the turbine; the generator floor level is at El. 88. The powerhouse downstream deck and surrounding ground and access are at El. 94 to protect the area against flooding during the Probable Maximum Flood (a discharge released from the spillway of 6,300 m^3/s). Above that level, the superstructure is made of structural steel with metal cladding. The powerhouse houses the mechanical and electrical equipment in four bays and three levels below grade.

4.3 Mechanical and Electrical Equipment

4.3.1 Power Intake

The power tunnel intake will include a trash screen consisting of two bays, each with twelve 2.00 m by 2.00 m removable screen panels and associated supports and guides. At the top of the concrete intake structure a rail mounted trash rake will be provided. The trash rake will also serve to install and remove the trash screen panels.

The intake structure will contain the intake gates consisting of two 2.20 m by 3.30 m wheeled gates designed to close the power tunnel under full flow and reservoir pressure condition. The associated guides, hoists and controls will be provided. A set of stop log gates of construction similar to the intake gates but designed for operation under balanced head will be included.

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

4.3.2 Powerhouse

Main Inlet Valves

At the downstream end, the steel lined power tunnel will be connected to the proposed powerhouse by a four branch steel manifold. At the end of the three manifold branches, serving the 16-MW units, 2.00 m diameter spherical valves will be provided in the powerhouse. The fourth manifold branch, serving the 8-MW unit will have a spherical valve 1.40 m in diameter. Inlet valves will be provided with the required hydraulic power units and control devices, and the various tapings for filling and draining of the associated waterways.

Turbine/Generator Units

The turbines are of the vertical shaft Francis type with a steel spiral case. The general characteristics are described in table below.

Table 6 – Turbine-Generator Unit Characteristics

Description	16-MW Unit	8-MW Unit
Turbines		
Runner Diameter (m)	1.40	1.00
Design Net Head (m)	115.0	105.0
Designed Discharge (m^3/s)	16.70	9.10
Setting (m below min. TW)	0.30	1.20
Speed (rpm)	450	600
Generators (synchronous/direct coupled)		
Rated Output (kVA)	17,800	8,900
Terminal Voltage (kV)	13.8	13.8
Frequency (Hz)	60	60
Power Factor	0.90	0.90

Turbine/Generator Auxiliaries

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

Draft Tube Gates

Each 16-MW unit will have two welded steel sliding gates 2.20 m wide and 1.50 m high to allow for unit and tunnel dewatering. The 8-MW unit will have a single welded-steel sliding gate 3.30 m wide and 1.10 m high. The same 45-ton semi-gantry crane provided for the turbine/generator units will handle the draft tube gates.

Cranes

A 45-ton semi-gantry crane spanning the powerhouse and the draft tube deck, and running on rails located at El. 94 and El. 97 will be provided to handle the turbine and generator components, inlet valves and draft tube gates during erection and maintenance. The lower rail level, El. 94, is above the PMF water level.

Dewatering system

The dewatering system will consist of two dewatering pumps and two station drainage pumps in each of the two conveniently located station dewatering and sump pits, and associated piping and valves to enable dewatering of each turbine independently or to dewater the whole system including the power tunnel. To prevent powerhouse flooding pumps will be sized to cope with failure of largest penstock tapping in the powerhouse and upstream of main inlet valves.

Switchgear

The generating voltage will be 13.8 kV. Generators will have individual main power transformers directly connected to the generators. Generator breakers will be on the 115-kV side of the transformers and will be located in the switchyard. Station service power will be provided at 480/277 V through service power and station service transformers described below. Therefore, no HV or MV switchgear is anticipated in the powerhouse.

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

Transformers

Four main power transformers for the generating units will be provided. They will be located adjacent to the powerhouse and connected to the switchyard by overhead lines. The main power transformers will be three phase, oil filled step-up transformers 13.8 kV – 115 kV, 60 Hz with standard ratings of 20 MVA, Class OA (liquid-immersed air-cooled, self-cooled) and 10 MVA, Class OA for the 16-MW and 8-MW units respectively.

A service power transformer with standard rating of 5 MVA, Class OA located in the switchyard will be used to step down the voltage from 115 kV to 13.8 kV.

A station service transformer to serve all utilization level power requirements at the site will be located at the powerhouse. The transformer will be a three phase, oil filled step down transformer 13.8 kV - 480 V, and 60 Hz rated 2 MVA, Class OA. The station

service transformer will be fed from the service power transformer by an underground 15 kV cable.

Each unit will have a 100 kVA dry type transformer directly connected to the generator terminals stepping down the voltage from 13.8 kV to 480/277 V to feed the unit auxiliary MCC.

Station Auxiliaries

Other station auxiliaries will include a 350-kW stand-by diesel generator, station battery, lighting system, Heating, Ventilation and Air Conditioning, fire alarm and protection, communication, grounding and lightning protection. Medium and low voltage power cables, as well as control, instrumentation and communication wires and cables will be provided to serve various needs at the site.

4.3.3 Switchyard

The Switchyard will be located approximately at El. 140 on a leveled area about 200 m west of the powerhouse. The area required is approximately 90 meters by 80 meters. It will be a 115-kV switchyard of conventional open air design utilizing the 'breaker and a half' switching scheme. The switchyard will have four fully equipped bays serving the four generator units, a double circuit 115-kV transmission line and the service power transformer. All galvanized steel gantries and equipment supporting structures, as well as concrete foundations and cable trenches, will be provided. It will be fenced in and served by access and boundary roads. A suitably sized control building will also be provided to house the control, protection, metering and communication equipment.

4.3.4 Transmission System

The transmission system is depicted in the simplified one-line diagram included in this report. It includes the step-up main power transformers, one for each turbine/generator unit, connected by overhead lines to the 115-kV switchyard at the project site. From the switchyard a double circuit 115-kV transmission line will carry the station output to a location near the Madden dam where the existing 115kV Panama City–Colon transmission line will be turned-in. The existing line will be cut and the two resulting open ends will be connected to the proposed double circuit line from Upper Chagres project, in effect creating two new lines: Panama City – Upper Charges and Upper Chagres – Colon.

It is assumed that the existing transmission line can carry the total proposed Upper Chagres plant output of 56 MW either to Panama City or Colon. As described in Attachment 1, one of the four circuits would be sufficient to carry 35 MW. The assumed capacity of the existing line remains to be confirmed with ETESA. An alternative

approach would be to build a slightly longer single circuit line of required capacity from the Upper Chagres directly to the ETESA's Panama II substation.

The proposed double circuit line will cross the Chagres river near the project site in the southern direction and then follow the river and the southern shore of lake Alhajuela in the westerly direction to the area downstream of the Madden dam where it will intersect the existing 115-kV line. The total length of the proposed line is estimated at 21.2 km. The line route was overflown by helicopter and studied with the help of available geographic and topographic maps at various scales that depict the roads and main features of the land. About one third of the line route nearer to the project site is hilly and forested terrain while the two thirds nearer to the turn-in at the existing line are of more gentle topography suitable for relatively easy construction.

The transmission line will be designed and built for 115-kV operation utilizing steel towers with two circuits, each having three 500 kcmil 30/7 ACSR conductors. The shield wires and conductors will be supported by single shaft lattice steel towers with steel arms, each tower will be provided with four reinforced concrete caissons or spread footing and pier type foundations. The average height of the towers will be 30 meters for a normal span of 250 meters. A typical design for a double circuit tangent tower is shown in the drawings.

A suitable site on the left bank of the Chagres River where the existing 115 kV lines cross the river has been selected for the location of the turn-in. At this location one of the circuits on the existing double circuit line will be cut and the two new lines will be connected to the open ends of the existing line. Two or more specially designed single circuit angle towers will be required to accomplish the transition. Some adjustment and/or modification in the protection, and communication equipment at Panama City and Colon substations will be required to fully integrate the newly created Upper Chagres – Panama City and Upper Chagres – Colon transmission lines into the Panama National Grid.

5 PROJECT COST ESTIMATE

Detailed cost estimate of the hydropower component of the project are presented in Attachment 4 and are summarized below. The costs shown do not include the cost of access, general mobilization and other site preparation costs.

A 15% contingency factor has been used for the civil work component of the hydroelectric scheme. Contingencies on equipments and transmission line have been taken as 10%. An engineering and administration cost of 15% has been added to the overall construction cost.

The development cost of the hydropower component of the Upper Río Chagres Project, consisting of one power plant, located approximately 200 meters downhill of the toe of the dam equipped with three 16-MW units and one 8-MW unit would increase the overall cost of the project by an estimated amount of $45,365,000. This amount includes the costs of 21.2 km of 115-kV transmission line from the project site to the existing 115-kV transmission line joining Panama City to Colon.

Estimated Development Cost

Upper Río Chagres Power Plant		
Civil Works		
• Power Intake		$6,635,000
• Power Tunnel and Manifold		$3,817,000
• Powerhouse		$2,775,000
	Subtotal	**$13,227,000**
Electrical & Mechanical Equipment		
• Power Intake		$1,609,000
• Generating Equipment		$13,581,000
• Auxiliary Powerhouse Equipment		$369,000
• Auxiliary Electrical		$1,781,000
	Subtotal	**$17,340,000**
Transmission System		
• Switchyard		$2,583,000
• 115-kV Transmission Line		$2,137,000
	Subtotal	**$4,720,000**
Subtotal		**$35,287,000**
Contingencies		$4,190,000
Construction Cost of the Hydropower Component		$39,477,000
Engineering & Administration (15%)		$5,922,000
Total Estimated Development Cost		**$45,399,000**

6 ECONOMIC EVALUATION

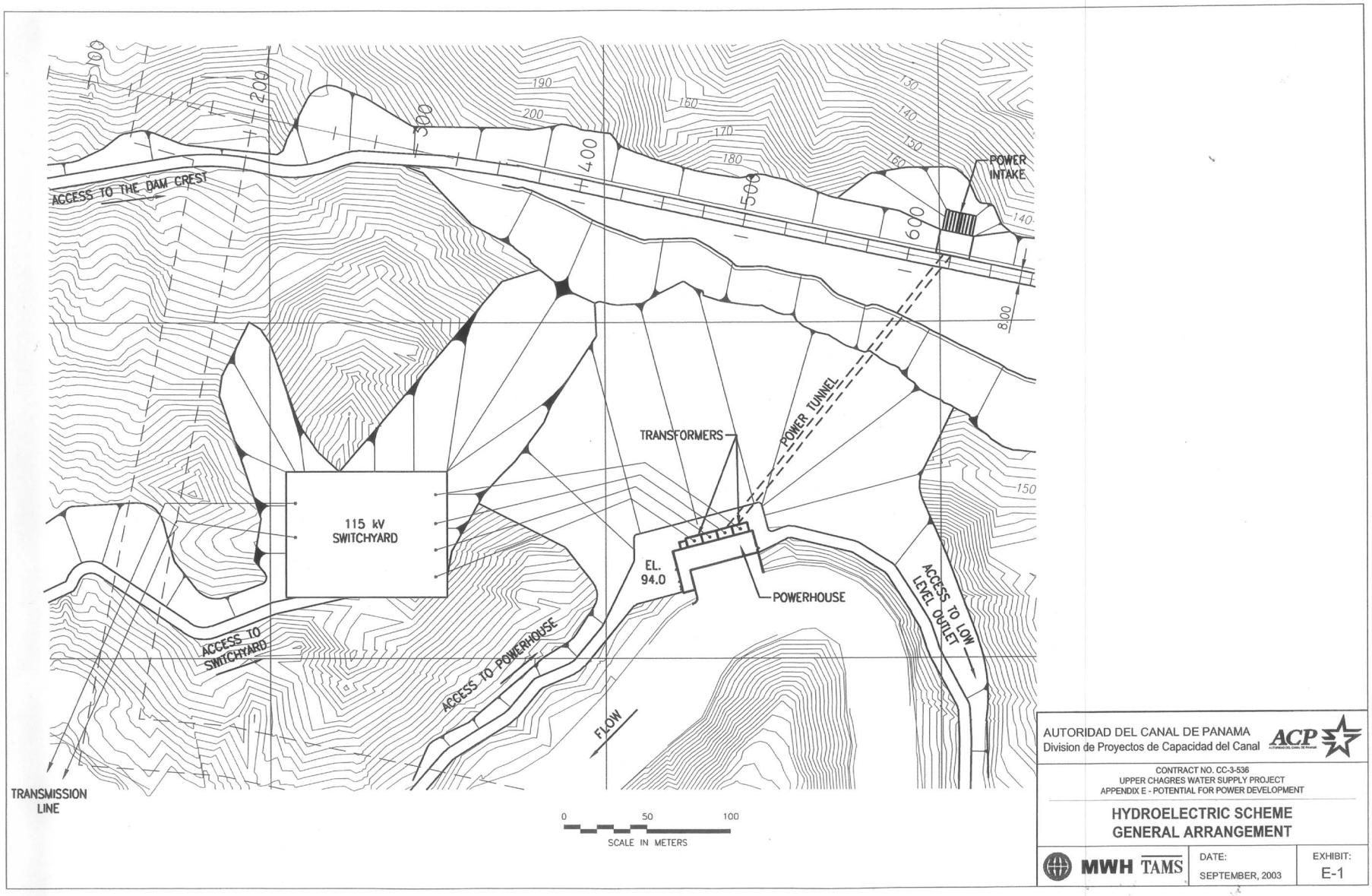
The economic analysis presented in the comparison of alternatives shows an internal rate of return of 25.2% for the recommended hydropower scheme, which is well above the requirement for development. The project as presented will generate an estimated annual revenue of $14,770,000 for the initial years of operation. The revenue consists of $11,410,000 for energy (at $45 per MWh) and $3,360,000 for firm capacity (at $60 per kW-year). While the revenues for energy will remain at that level for the life of the project, the firm capacity benefit will diminish when the Upper Chagres reservoir become fully dedicated to the Canal operation. The current water demand projection for navigation indicates that the Upper Chagres will be fully dedicated to the Canal by year 2017, i.e., when the demand reaches 50 lockage per day. Under this scenario the internal rate of return of the hydropower component would decrease to 24.3%, still a very high return, with estimated annual revenue of $11,930,000.

A sensitivity analysis of the rate of return to the costs of development and the value of energy is presented in Table 7 below.

Table 7 – Sensitivity Analysis

Variables	Internal Rate of Return
Base Case	25.2%
General Costs Increased by 20%	21.4%
General Costs Increased by 10%	23.1%
Value of Energy and Power Reduced by 20%	20.6%
Value of Energy and Power Reduced by 10%	22.9%
Value of Energy and Power Increased by 10%	27.4%
Value of Energy and Power Increased by 20%	29.6%
With reduced firm capacity in 2017	24.3%
General Costs Increased by 10%	22.1%
Civil Works Costs Increased by 20%	22.6%
Equipment Costs Increased by 20%	21.6%
Value of Energy and Power Reduced by 20%	19.5%
Value of Energy and Power Reduced by 10%	21.9%
Value of Energy and Power Increased by 10%	26.5%
Value of Energy and Power Increased by 20%	28.7%

EXHIBITS



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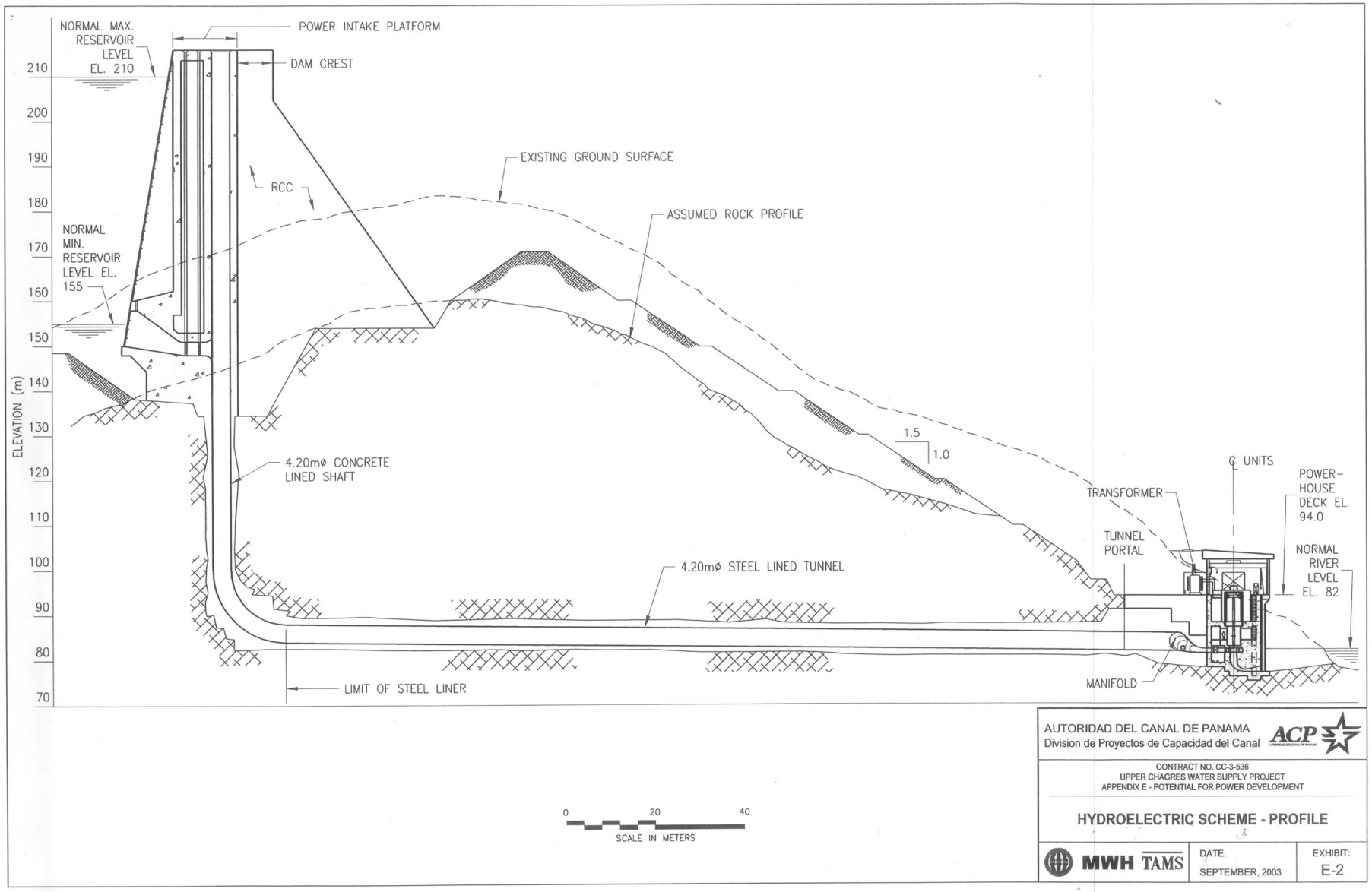

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX E - POTENTIAL FOR POWER DEVELOPMENT

HYDROELECTRIC SCHEME - PROFILE

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: E-2

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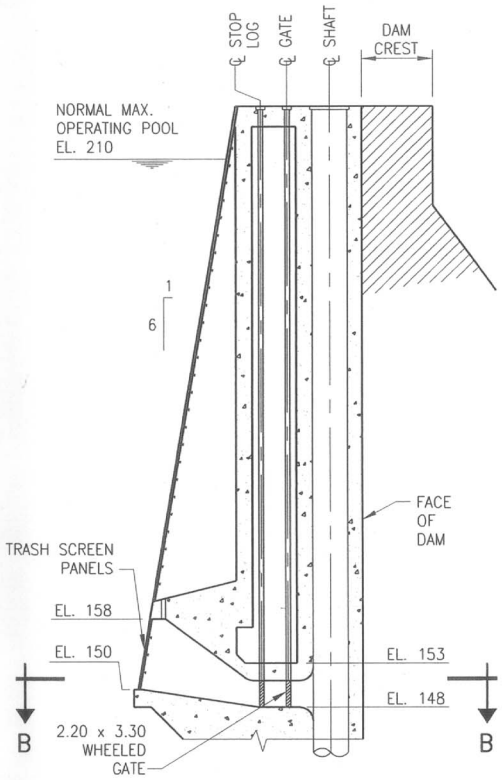

SECTION A–A

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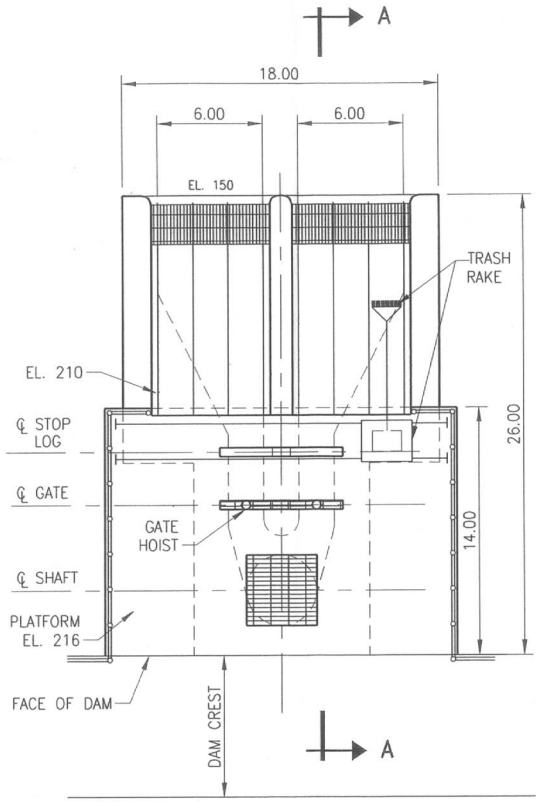
SCALE IN METERS



PLAN AT ELEV. 216

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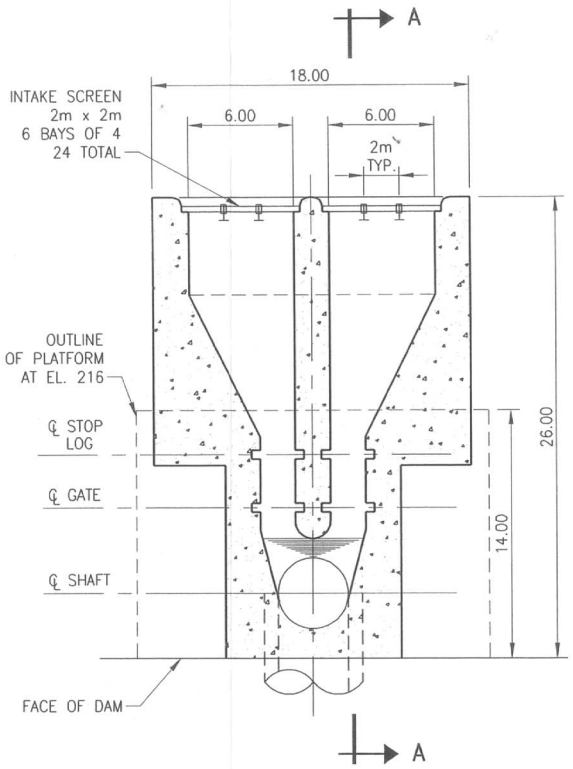

SECTIONAL PLAN B–B (AT ELEV. 150)

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SCALE IN METERS

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

CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX E - POTENTIAL FOR POWER DEVELOPMENT

POWER INTAKE - PLAN AND SECTION

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: E-3

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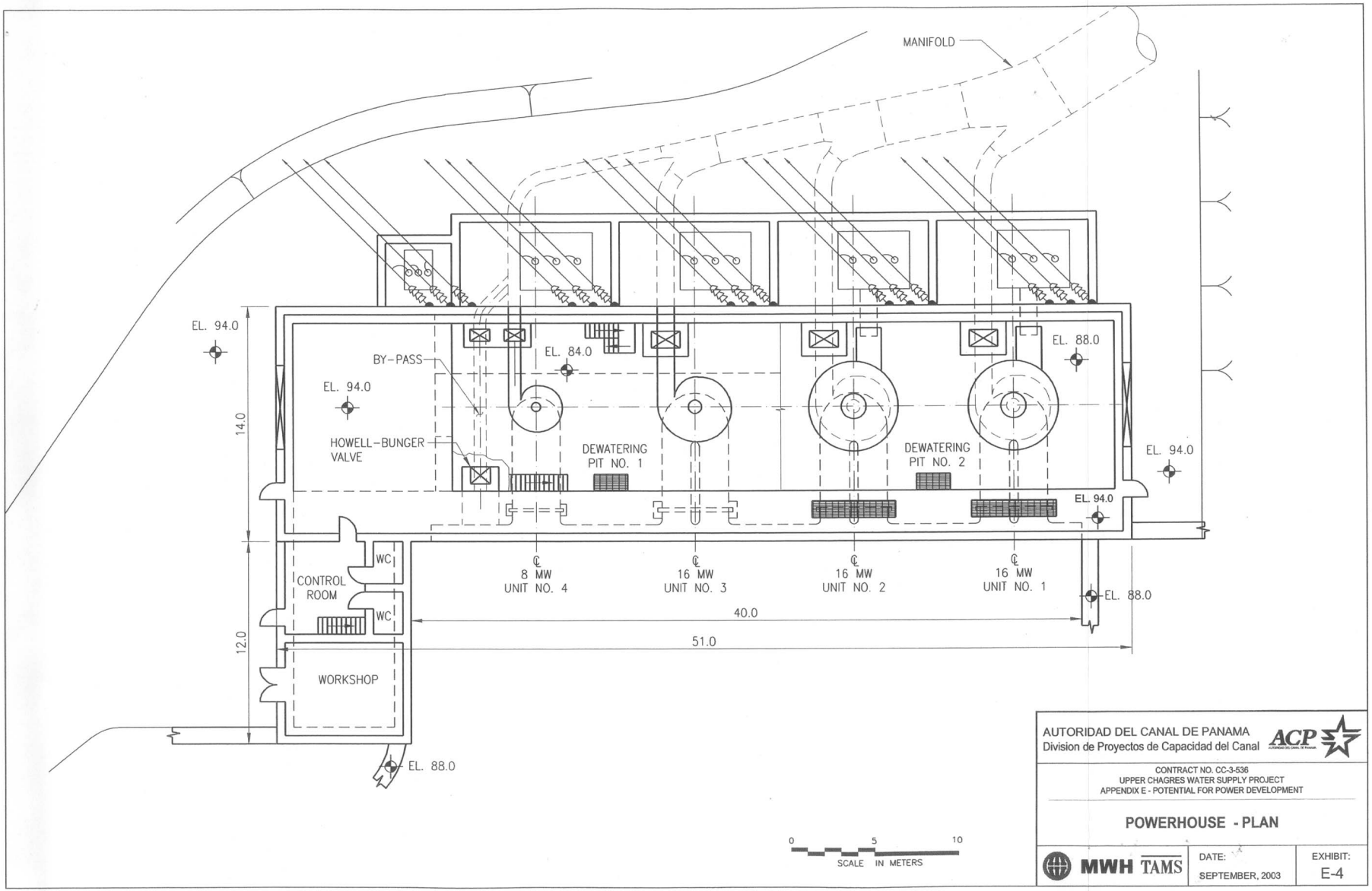

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX E - POTENTIAL FOR POWER DEVELOPMENT

POWERHOUSE - PLAN

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: E-4

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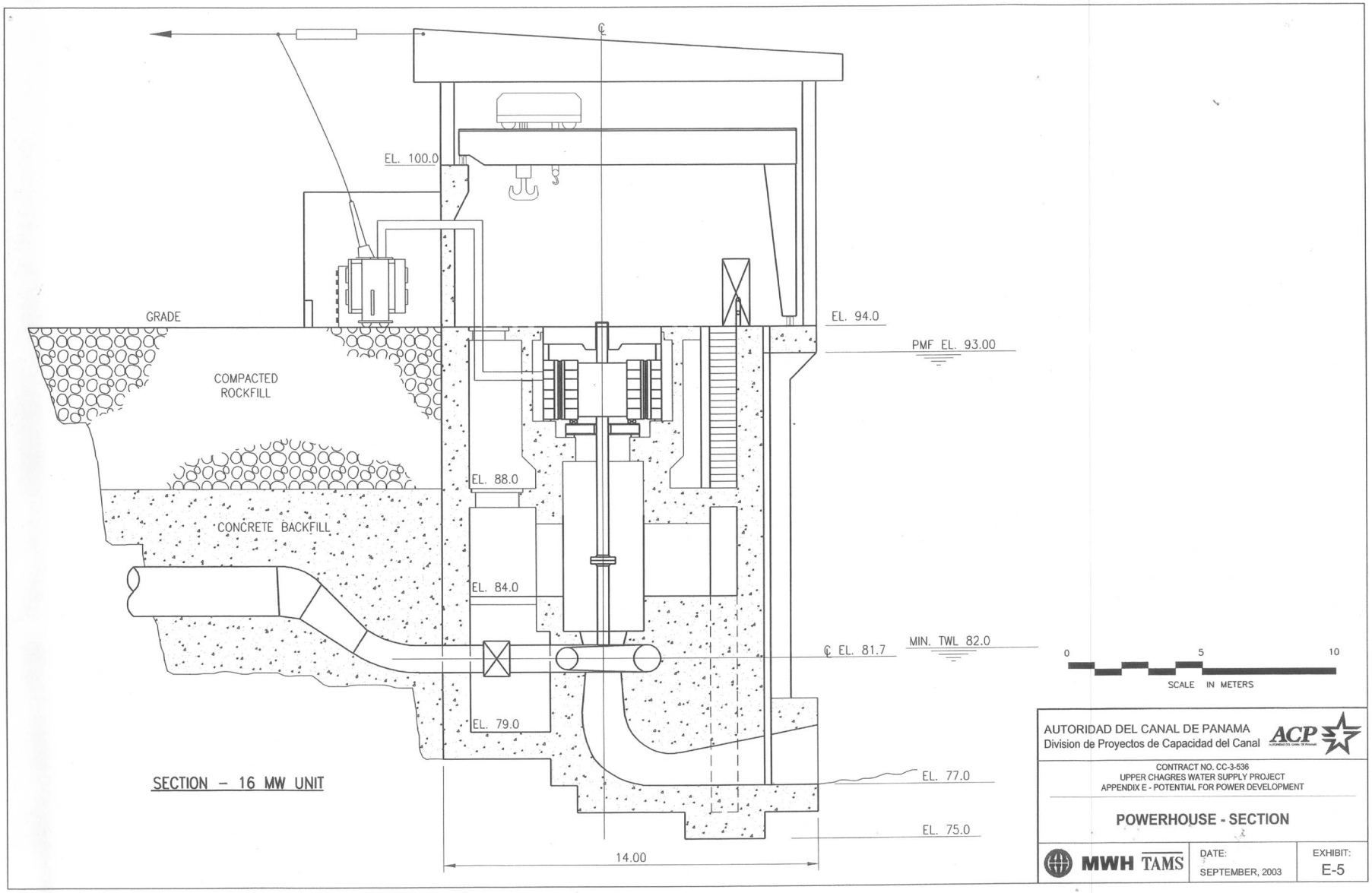

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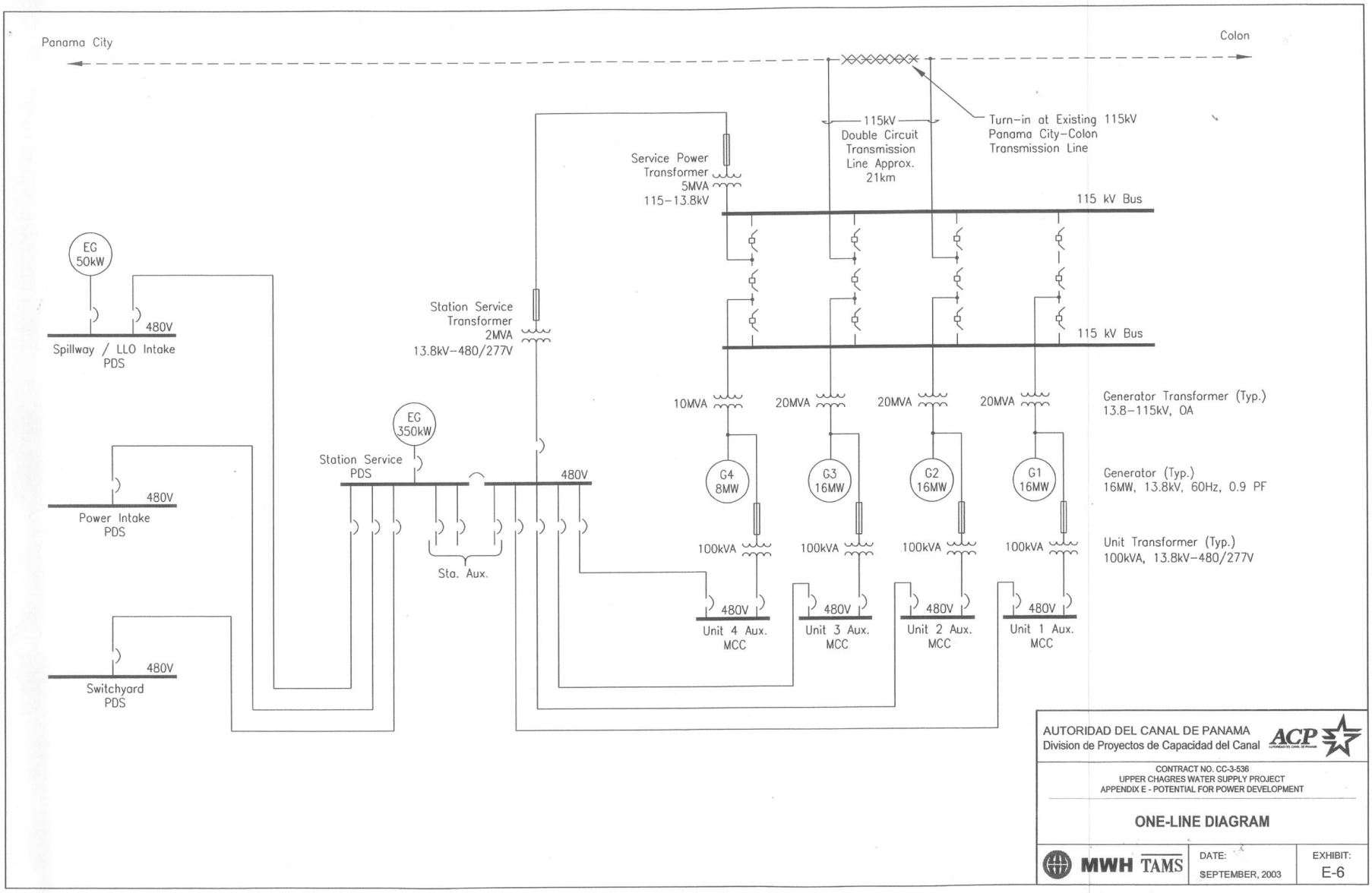

AUTORIDAD DEL CANAL DE PANAMA
Division de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX E - POTENTIAL FOR POWER DEVELOPMENT

ONE-LINE DIAGRAM

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: E-6

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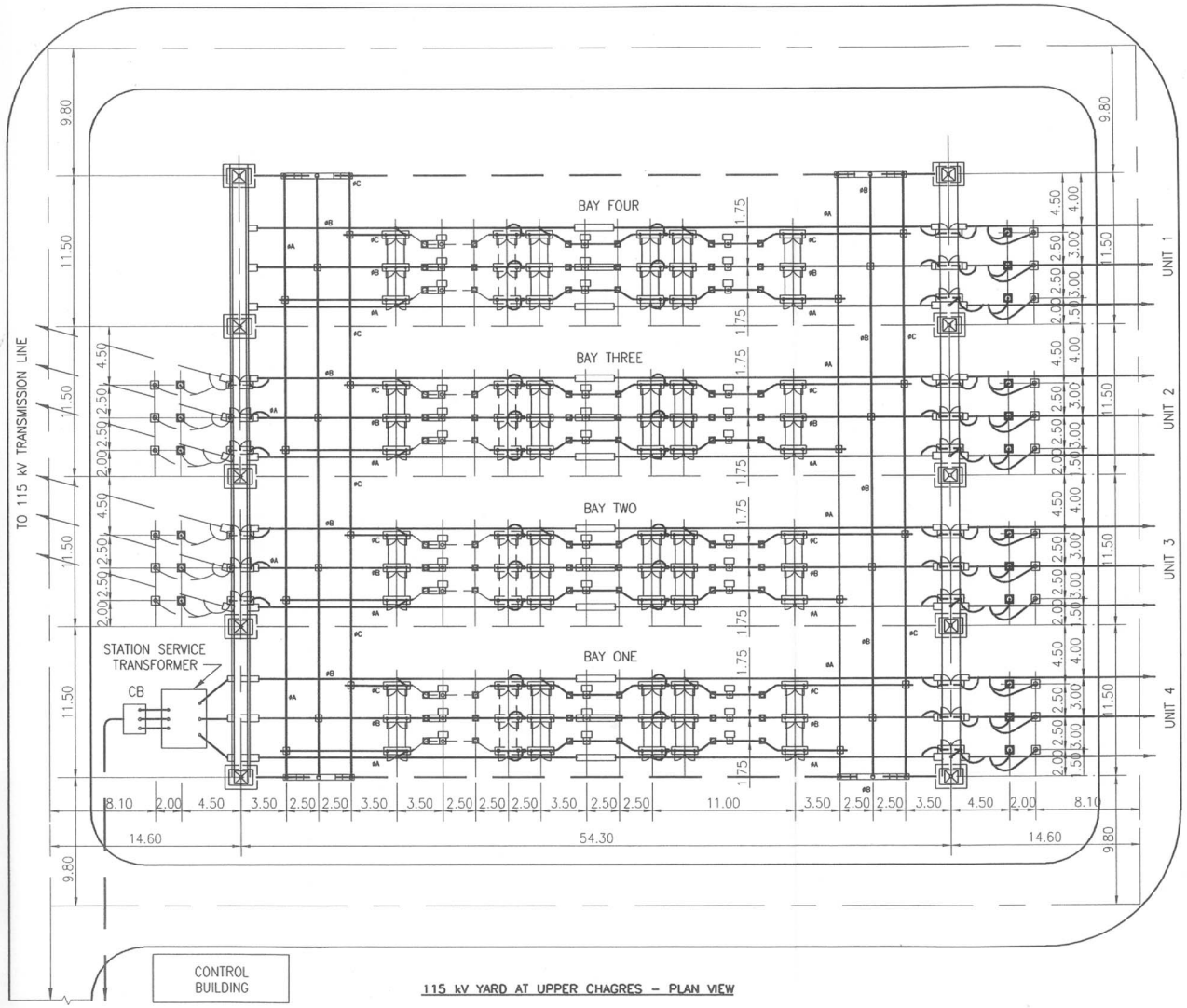

115 kV YARD AT UPPER CHAGRES – PLAN VIEW

5 0 5 10
SCALE IN METERS

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

CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX E - POTENTIAL FOR POWER DEVELOPMENT

115 kV SWITCHYARD - PLAN

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: E-7

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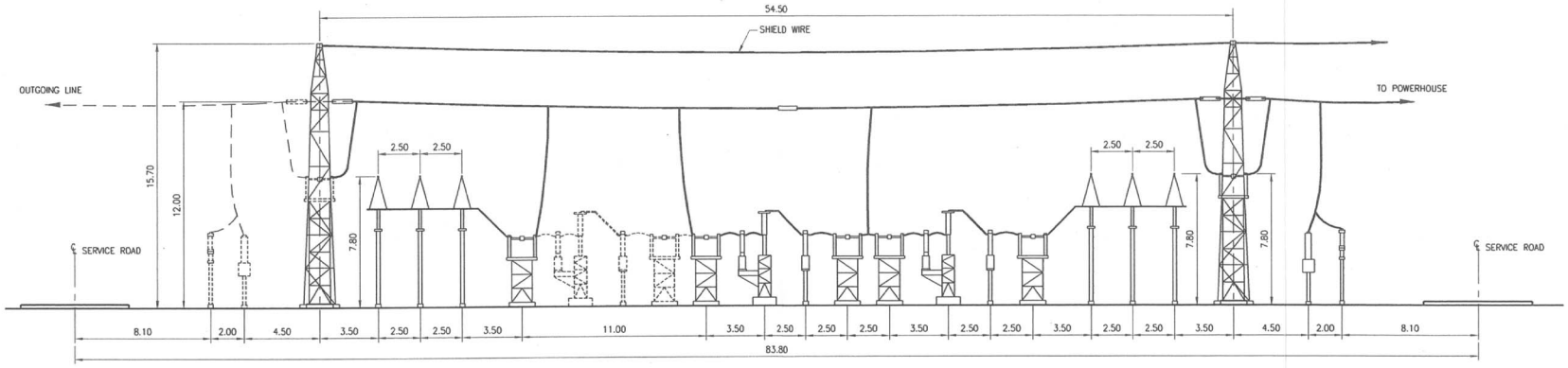

115 kV ELEVATION (BAY #2)

5 0 5 10

SCALE IN METERS

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

CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX E - POTENTIAL FOR POWER DEVELOPMENT

115 kV SWITCHYARD - ELEVATION

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: E-8

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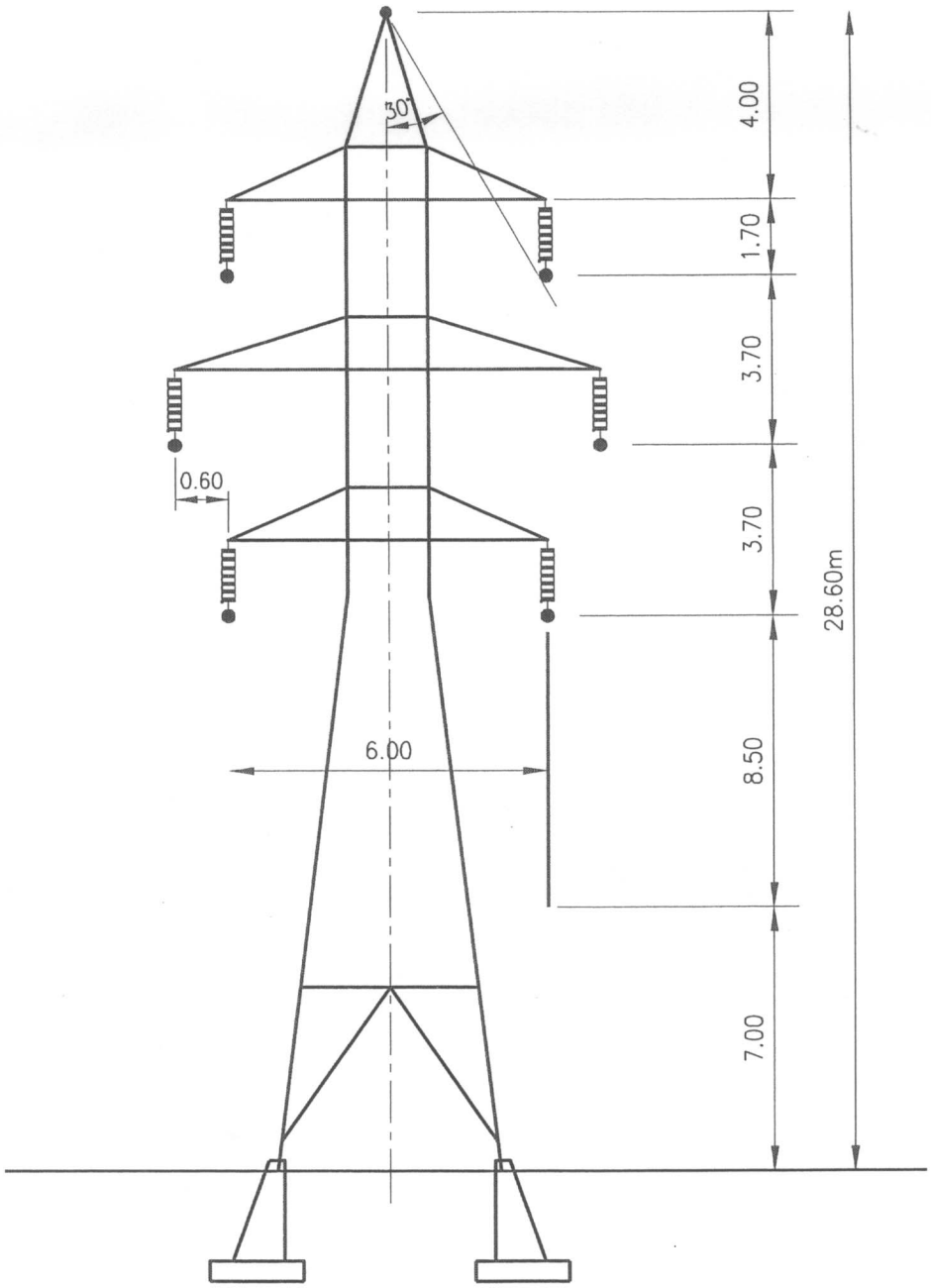


TYPICAL 115kV D/C TANGENT TOWER

NOT TO SCALE

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

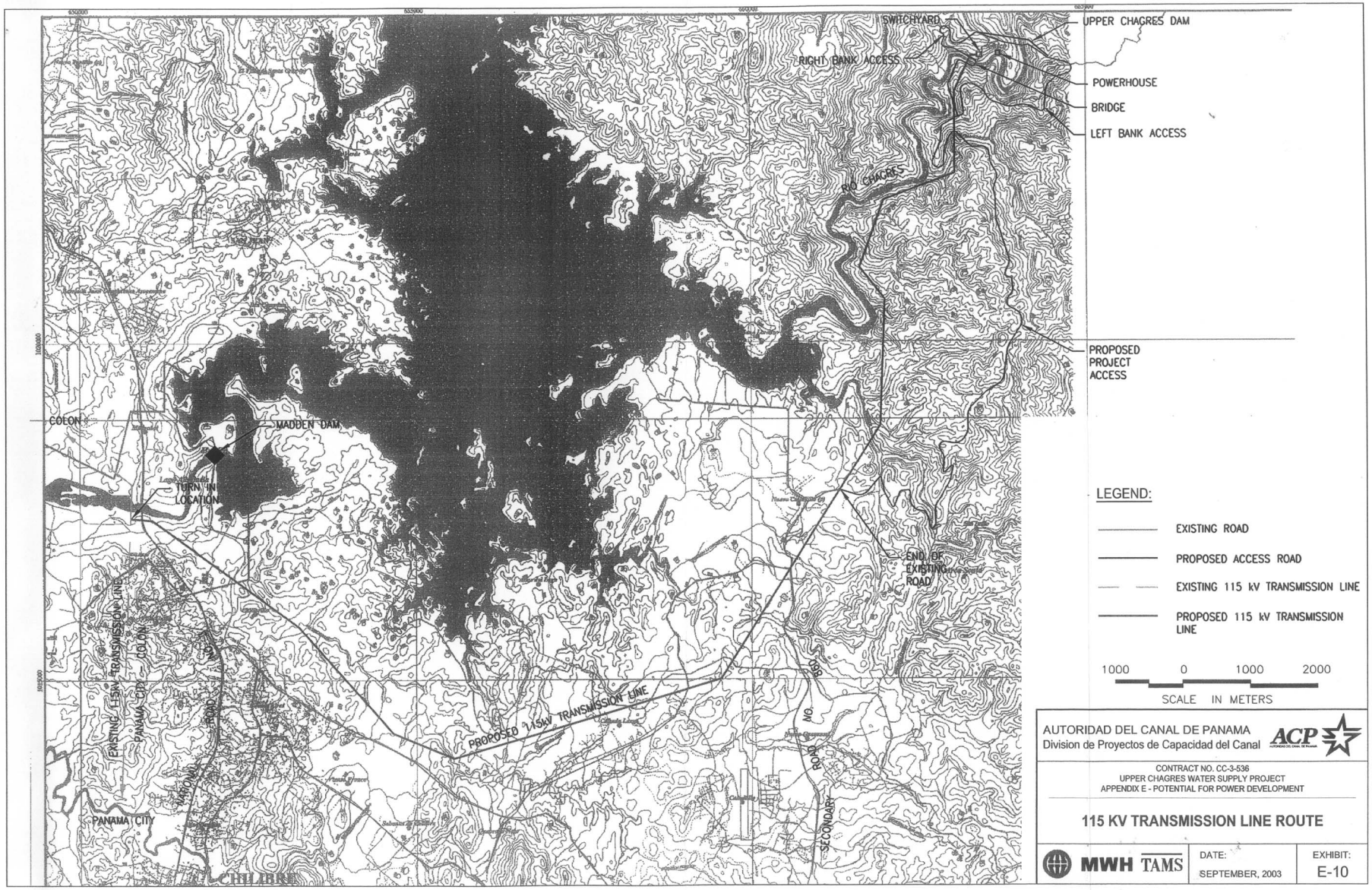
ACP

CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX E - POTENTIAL FOR POWER DEVELOPMENT

TRANSMISSION LINE
TYPICAL 115 KV TOWERS

MWH TAMS

DATE:	EXHIBIT:
SEPTEMBER, 2003	E-9



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

CONTRACT NO. CC-3-536
UPPER CHAGRES WATER SUPPLY PROJECT
APPENDIX E - POTENTIAL FOR POWER DEVELOPMENT

115 KV TRANSMISSION LINE ROUTE

MWH TAMS

DATE: SEPTEMBER, 2003

EXHIBIT: E-10

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ATTACHMENTS

ATTACHMENT 1

SITE RECONNAISSANCE REPORT

Site Reconnaissance Report

Site Trip From February 17 to February 21, 2002

The writer arrived to Panama City the night of Sunday February 17, 2002. Site visits and interviews were performed during the following week to gather information for the proposed feasibility study, as follows:

Monday, February 18

1) Met with Mr. Roderick E. Lee of the ACP Canal Capacity Projects office and Ing. Rodrigo Chanis assigned to act as liaison and ACP counterpart for the electrical work associated with the transmission feasibility study.

2) As told by Mr. Lee, the initial plan was to visit ACP's Gatun substation as the possible point of connection for the Rio Indio development and ACP's Madden and Miraflores substations as possible points of connections for the Upper Chagres river development. However, during the meeting with Ing. Enrique Tejera, ACP electrical system operation and maintenance, it was revealed that ACP's 44 kV system would not be capable of receiving 30 MW from Rio Indio neither 35 MW from Upper Chagres. Therefore the initial plan of visits was abandoned and the search for feasible points of connection with 115/230 kV capabilities concentrated in ETESA's La Chorrera substation for Rio Indio and Cocle del Norte projects and Panama II substation for the Upper Chagres project.

3) Visited ETESA's Ing. Jose M.Lopez and Ing. Delano E. James of operation and maintenance to obtain system information and review possibilities for interconnection at both 115 and 230 kV voltages. Copy of an up-to-date ETESA's electrical system map was provided to the writer. The discussion revealed the following:

   - La Chorrera substation has at present two empty bays at 230 kV and also two operating 230/115/13.8 kV step down transformers that feed a 13.8 kV distribution switchyard. However, the 115 kV yard has never been developed although land space has been provided for such purpose. ETESA does not have immediate plans to develop the 115 kV yard and is waiting for a private generator or the private distribution companies to generate the need for it. A connection for Rio Indio at 115 kV would entail to build the 115 kV yard as part of the project cost.

   - Regarding the connection of the Upper Chagres river project, ETESA's Panama II substation has capabilities and empty bays at 115 kV for that purpose. Another possibility for interconnection would be to intersect and open one of the four (4) 115 kV circuits running between Panama City and Colon and to extend its length with a double circuit line to the Upper Chagres substation to be provided with a breaker and a half scheme which is typical of the ETESA's substation arrangements.

4) ACP provided an array of topographic maps at the 1:25,000 scale for routing the transmission lines for the proposed project sites.

Tuesday, February 19

5) The morning was dedicated to make a visit to the Panama II substation together with ETESA's Ing. Jose M. Lopez. There are two (2) empty bays in the 115-kV switchyard one of which could be used for the interconnection to the Upper Chagres project. The crossing of the 115-kV line under the future second 230-kV transmission line from Llano Sanchez substation should be made underground, as ETESA does not allow aerial line crossings inside the substations.

6) A review of ETESA's system map revealed that besides Panama II there are no other 115-kV substations owned by ETESA in the area to connect the Upper Chagres project. However, there are two privately owned 115-kV substations connected to the ETESA system close to Madden, namely, Chilibre (owned by ELECTRA Distribution Company) and Cemento Panama. Chilibre is a tap of two 115-kV circuits and from system reliability is not considered adequate to hook the proposed 35-MW Upper Chagres generation. Cemento Panama substation, instead, is a promising point of interconnection since the ETESA 115-kV line is sectionalized.

7) Both Chilibre and Cemento Panama as well as Madden substations were visited during the same morning with the following results:

- Chilibre is not acceptable since it is a tap to the 115-kV system. Two ETESA line circuits are tapped, one serves a 13.8-kV step down transformer, and the other is used to extend a 115-kV single circuit line to another Cement plant. Additionally, it does not have space availability for expansion.

- Cemento Panama has a spare bay for connection of a 115-kV line circuit with the need of only minor additional switching equipment. This substation is located some 8 km north of the Chagres River and would require extending the length of the transmission line that much to a total of about 18 km.

- Madden substation was looked from the dam top and it is an exclusive 44-kV switchyard located immediately adjacent to the power plant with no room for expansion. Two aerial circuits connect this substation to ACP's 44-kV transmission system.

8) In the afternoon the ETESA's Substation Engineering Division was visited and the writer met Ing. Eduardo N. Brugiatti, Head of Substation Design. The alternative of opening one circuit of the 115-kV Panama-Colon transmission line to connect the Upper Chagres river project appeared acceptable to ETESA as long as the plant substation at Upper Chagres is built following their standards using a breaker and a half switching scheme.

Prints of typical substation plans, elevations and one lines with protection schemes at 115-kV and 230-kV were obtained.

Wednesday, February 20

9) The transmission line routes and site locations were flown over by helicopter together with ACP's personnel Ing. Roderick Lee and Rodrigo Chanis.

10) The writer provided the preliminary routes between La Chorrera substation and Rio Indio and Cocle del Norte sites. ACP furnished new tunnel coordinates for the Indio River tunnel and the writer corrected the route in the affected section.

11) The helicopter landed first at La Chorrera substation where ETESA's engineers Jose M. Lopez, O&M, Eduardo N. Brugiatti, Engineering, and Moses Cano, Planning, were awaiting the party. The substation yards were walked and ETESA showed two (2) 230-kV empty bays were the ACP line could be connected. The 115-kV yard was never developed but the space is available. If required to connect at 115-kV ACP should bare the cost for building the 115-kV yard where initially only one breaker would be installed for the ACP line; but the design should have provisions for ultimate breaker and a half scheme. The control room of the substation has ample space to locate the necessary panels for relays, metering and communications.

12) The party continued the flight over the proposed line route to the Rio Indio tunnel and plant sites. The terrain is of gentle topography with low hills showing marked signs of deforestation, traversed by dirt road accesses and few paved roads, where scattered buildings and little agricultural farming (pineapple, vineyards and fruit trees) and some large chicken houses are present. The area is accessible by land and of relatively easy line construction.

13) The foot of the tunnel is now at a new location facing the Pablon Island in the Gatun Lake, about 8 km east of the proposed Rio Indio dam.

14) After circling the location around the Pablon Island and the Rio Indio dam sites the party proceeded almost due west toward Cocle del Norte site. The flight deviated slightly to go over an intermediate site at the Cano Sucio River, which will not be developed for power.

15) As the helicopter moved west the topography became more hilly and the ground were covered by dense and thick where deforestation has been less active in this more remote and un-inhabited region. After circling the Rio Cocle del Norte site the helicopter turned due south toward the locality of Coclecito for refueling.

16) The party left Coclecito in a general northeast direction toward Rio Indio but passing first by the Toabre river site under study by another consultant. The flight headed toward the Rio Chagres crossing the Gatun Lake. ETESA's 115-kV transmission line circuits running from Panama City to Colon were intersected and a convenient space of land was

spotted adjacent to the crossing of the Chagres River at the southern bank where one of the line circuits could be cut in. The ACP double circuit transmission line would be running from this point in and out the plant site following the south margin of the Alahuela Lake in a general SW-NE direction for about 10 km.

17) The helicopter moved around the southern margin of Alahuela Lake where the transmission line route presents a gentle rolling type country with rounded hills, with short vegetation and practically no population, crossed by few scattered dirt roads. At one point some 2-3 km from the proposed site the line route enters a heavily wooded area of high hilly terrain in jurisdiction of the National Parks agency.

18) From the Upper Chagre site the party proceeded to fly south by Southwest to the Panama II substation that provides an option for connection of this power project to the national grid. The flown area is very hilly and steep at times, thickly wooded for most of the area and with no apparent roads, of difficult access. In the last part of the route near the Panama II substation, for about 5 km, the land becomes gentler, of lower elevations and occupied by scattered housing and roads. The Panama II substation was spotted and circled, after that the party returned and finally landed at the local airport.

Thursday, February 21

19) A number of documents were obtained from ETESA and ACP as well as pictures that were developed as follows:

- Typical Plan and Elevation drawings of the Panama II substation from ETESA
- Typical one-line diagrams w/protection schemes for 115-kV and 230-kV substation bays from ETESA.
- Typical 115-kV and 230-kV transmission line and substation costs from ETESA.
- ETESA's one-line electric interconnected system map.
- Physical location maps of the La Chorrera and Panama II substations and 115 kV and 230 kV transmission lines from ETESA.
- Typical 115 kV and 230 kV transmission line structure outlines from ACP
- Maps at 1:25,000 scale from ACP.
- ACP's one-line diagram for their 44 kV system.
- ACP's physical location map of their 44 kV lines and substations.

Photo 1 – Proposed Dam and Powerhouse Location

Photo 2 – Madden Dam and Powerhouse

Photo 3 – Madden Powerhouse and 44-kV Take-off Structures

Photo 4 – Río Chagres downstream of Madden Dam (background) – Proposed Location for 115-kV Transmission Line Cut-in (Tower Adjacent to Gravel Road)

ATTACHMENT 2

PROPOSED UPPER CHAGRES RESERVOIR OPERATION

PROPOSED UPPER CHAGRES RESERVOIR OPERATION
(As simulated by the ACP)

	Gatun Reservoir Elev. (m)	Madden Reservoir Elev. (m)	Upper Chagres Inflow (cms)	Upper Chagres Reservoir Elev. (m)	Upper Chagres Outflow (cms)	Upper Chagres Reservoir Spillage (cms)
Jan-48	26.52	76.07	16.6	207.38	80.8	44.7
Feb-48	26.04	74.06	9.0	205.25	18.9	0.0
Mar-48	25.78	68.40	6.3	202.38	19.0	0.0
Apr-48	25.00	69.92	6.1	193.99	40.8	0.0
May-48	25.21	62.78	14.2	196.17	5.3	0.0
Jun-48	24.80	67.55	23.7	191.96	40.1	0.0
Jul-48	25.54	66.14	40.0	196.29	23.0	0.0
Aug-48	25.75	67.67	31.5	193.90	40.3	0.0
Sep-48	25.85	69.49	26.6	199.73	3.0	0.0
Oct-48	26.09	71.50	38.9	203.81	19.4	0.0
Nov-48	26.61	75.96	45.8	205.49	37.2	0.0
Dec-48	26.75	76.61	29.5	210.01	7.3	0.0
Jan-49	26.33	75.90	15.0	204.02	42.5	4.1
Feb-49	26.12	70.69	9.4	204.76	4.6	0.0
Mar-49	25.28	72.30	6.9	196.70	41.3	0.7
Apr-49	25.07	65.15	7.2	197.57	3.0	0.0
May-49	25.23	61.25	23.5	193.09	40.3	0.0
Jun-49	25.46	68.76	39.1	192.81	39.8	0.0
Jul-49	25.82	69.42	51.0	197.28	33.4	0.0
Aug-49	25.90	68.28	48.3	200.17	36.5	0.0
Sep-49	25.91	70.41	38.3	201.51	31.3	0.0
Oct-49	26.18	71.93	45.0	204.30	31.3	0.0
Nov-49	26.64	75.29	61.3	208.08	42.3	3.7
Dec-49	26.75	76.81	53.6	210.01	43.8	6.1
Jan-50	26.41	75.90	20.6	207.38	32.2	0.0
Feb-50	26.30	72.50	17.1	204.76	30.0	0.0
Mar-50	25.87	71.02	10.8	197.66	41.4	0.9
Apr-50	25.73	64.70	20.0	200.01	9.8	0.0
May-50	25.45	70.45	40.5	199.70	41.2	0.0
Jun-50	25.82	69.34	30.2	198.85	33.2	0.0
Jul-50	26.01	72.15	53.9	201.66	41.2	0.3
Aug-50	26.36	72.79	45.9	202.48	41.6	1.3
Sep-50	25.91	74.61	32.9	204.04	24.8	0.0
Oct-50	26.18	71.93	26.2	206.81	12.6	0.0
Nov-50	26.64	75.29	50.8	208.41	42.6	4.4
Dec-50	26.75	76.81	60.1	210.01	52.0	14.4
Jan-51	26.52	75.90	19.7	207.38	31.4	0.0
Feb-51	26.30	75.08	43.3	207.37	42.5	4.3
Mar-51	26.03	72.22	23.3	204.18	37.5	0.0
Apr-51	25.82	69.46	19.4	201.12	33.7	0.0
May-51	25.82	68.09	25.8	197.30	41.0	0.0
Jun-51	25.82	65.96	30.5	196.85	31.9	0.0
Jul-51	25.82	66.14	33.2	195.43	38.3	0.0
Aug-51	25.82	67.67	24.9	197.92	14.9	0.0
Sep-51	25.91	69.49	28.7	200.96	15.4	0.0
Oct-51	26.18	71.93	24.8	203.81	10.9	0.0
Nov-51	26.61	74.69	28.9	206.86	13.6	0.0
Dec-51	26.75	76.81	28.3	208.26	20.9	0.0

PROPOSED UPPER CHAGRES RESERVOIR OPERATION
(As simulated by the ACP)

	Gatun Reservoir Elev. (m)	Madden Reservoir Elev. (m)	Upper Chagres Inflow (cms)	Upper Chagres Reservoir Elev. (m)	Upper Chagres Outflow (cms)	Upper Chagres Reservoir Spillage (cms)
Jan-52	26.43	75.90	18.4	207.38	21.7	0.0
Feb-52	26.26	71.76	12.4	204.76	24.9	0.0
Mar-52	25.44	73.16	9.0	197.25	41.4	0.8
Apr-52	25.37	66.34	10.6	198.99	3.0	0.0
May-52	25.58	63.05	24.2	194.61	40.6	0.0
Jun-52	25.58	68.52	23.9	190.72	39.0	0.0
Jul-52	25.82	66.14	31.5	197.08	6.7	0.0
Aug-52	25.82	67.67	38.2	197.92	34.6	0.0
Sep-52	25.91	69.49	35.0	200.96	21.7	0.0
Oct-52	26.46	71.93	49.4	203.81	35.5	0.0
Nov-52	26.61	74.53	31.5	206.86	16.0	0.0
Dec-52	26.75	76.81	53.3	208.99	42.6	4.6
Jan-53	26.52	75.90	41.5	208.57	42.8	5.1
Feb-53	26.30	74.06	27.1	205.48	42.5	4.1
Mar-53	25.95	71.02	14.0	202.38	27.9	0.0
Apr-53	25.80	66.27	12.5	200.01	23.4	0.0
May-53	25.58	72.14	37.7	199.01	41.1	0.0
Jun-53	25.82	69.11	27.6	200.15	22.5	0.0
Jul-53	25.82	68.60	32.6	198.07	40.4	0.0
Aug-53	25.82	67.67	31.5	199.81	24.3	0.0
Sep-53	25.91	69.49	28.1	200.96	22.3	0.0
Oct-53	26.18	71.93	33.6	203.81	19.7	0.0
Nov-53	26.61	75.29	39.6	206.86	24.2	0.0
Dec-53	26.75	76.81	34.3	210.01	18.7	0.0
Jan-54	26.37	75.90	18.3	207.38	29.8	0.0
Feb-54	26.18	72.61	13.7	204.76	26.7	0.0
Mar-54	25.35	74.65	12.4	198.10	41.5	1.0
Apr-54	25.19	69.19	12.8	200.31	3.0	0.0
May-54	25.59	67.42	21.7	195.31	40.8	0.0
Jun-54	25.82	65.65	34.7	196.07	31.2	0.0
Jul-54	26.29	66.14	34.7	195.11	38.0	0.0
Aug-54	26.20	72.27	39.0	197.92	27.8	0.0
Sep-54	26.25	73.26	38.2	203.65	11.5	0.0
Oct-54	26.18	74.71	25.0	205.96	13.5	0.0
Nov-54	26.64	75.36	64.3	209.89	44.4	6.4
Dec-54	26.75	76.81	63.2	210.01	62.1	24.7
Jan-55	26.65	76.81	64.9	209.95	64.5	27.1
Feb-55	26.27	76.42	18.4	207.38	31.0	0.0
Mar-55	26.03	71.83	12.7	205.64	20.0	0.0
Apr-55	25.78	67.36	10.2	201.15	31.3	0.0
May-55	25.82	66.14	15.3	194.68	40.8	0.0
Jun-55	25.82	65.53	17.5	194.80	16.6	0.0
Jul-55	25.82	66.14	28.3	194.80	28.0	0.0
Aug-55	26.15	67.67	48.7	197.92	36.4	0.0
Sep-55	25.91	71.13	31.4	200.96	18.0	0.0
Oct-55	26.18	71.93	28.5	204.70	10.3	0.0
Nov-55	26.64	75.29	77.1	209.97	50.9	12.7
Dec-55	26.75	76.81	44.0	210.01	43.3	6.0

PROPOSED UPPER CHAGRES RESERVOIR OPERATION
(As simulated by the ACP)

	Gatun Reservoir Elev. (m)	Madden Reservoir Elev. (m)	Upper Chagres Inflow (cms)	Upper Chagres Reservoir Elev. (m)	Upper Chagres Outflow (cms)	Upper Chagres Reservoir Spillage (cms)
Jan-56	26.52	76.81	62.5	209.95	62.1	24.8
Feb-56	26.30	74.07	21.7	207.38	33.9	0.0
Mar-56	26.03	71.09	19.2	203.13	38.5	0.0
Apr-56	25.82	67.36	19.8	200.20	33.4	0.0
May-56	25.82	66.77	43.4	200.56	41.3	0.4
Jun-56	25.82	65.53	37.3	199.61	41.2	0.2
Jul-56	26.16	66.14	63.9	204.33	41.5	1.3
Aug-56	25.82	71.56	34.1	202.60	41.8	2.1
Sep-56	26.00	70.23	35.7	203.42	31.3	0.0
Oct-56	26.46	72.69	44.6	204.47	39.2	0.0
Nov-56	26.64	76.10	86.4	210.00	58.9	20.6
Dec-56	26.75	76.81	41.5	210.01	40.8	3.5
Jan-57	26.35	75.90	17.5	207.38	29.1	0.0
Feb-57	26.17	71.88	11.6	204.76	24.6	0.0
Mar-57	25.37	73.20	8.2	197.04	41.4	0.8
Apr-57	25.11	65.67	6.9	197.83	3.0	0.0
May-57	25.22	60.12	13.1	190.70	40.1	0.0
Jun-57	24.88	64.01	12.7	182.50	38.6	0.0
Jul-57	24.98	57.94	11.9	185.34	3.0	0.0
Aug-57	25.02	63.83	13.9	176.77	37.5	0.0
Sep-57	25.05	65.86	18.2	182.24	3.0	0.0
Oct-57	26.01	66.93	30.6	191.03	3.0	0.0
Nov-57	26.54	72.62	49.0	200.18	12.1	0.0
Dec-57	26.75	75.70	33.0	202.49	21.5	0.0
Jan-58	26.37	75.90	32.9	208.65	3.0	0.0
Feb-58	26.28	74.06	14.8	204.76	34.4	0.0
Mar-58	26.03	70.31	10.7	202.38	21.2	0.0
Apr-58	25.82	67.36	7.3	194.32	40.9	0.0
May-58	25.82	66.14	17.6	192.41	24.5	0.0
Jun-58	25.81	65.53	21.3	194.80	11.4	0.0
Jul-58	25.82	63.79	22.1	194.80	21.8	0.0
Aug-58	25.82	67.67	25.2	190.93	39.8	0.0
Sep-58	25.91	69.49	27.0	196.91	3.0	0.0
Oct-58	26.18	71.73	27.7	202.62	3.0	0.0
Nov-58	26.37	74.85	33.3	208.43	4.4	0.0
Dec-58	26.75	75.24	27.3	208.72	25.3	0.0
Jan-59	26.22	75.90	12.7	202.36	42.2	3.3
Feb-59	25.97	70.77	8.6	203.29	3.0	0.0
Mar-59	25.17	72.17	6.7	194.96	41.0	0.0
Apr-59	25.06	64.83	9.7	196.49	3.0	0.0
May-59	25.12	60.42	17.9	190.63	40.0	0.0
Jun-59	24.75	66.50	17.5	183.92	38.7	0.0
Jul-59	25.05	60.55	16.4	188.26	3.0	0.0
Aug-59	24.94	66.79	18.4	181.61	38.3	0.0
Sep-59	25.72	63.43	32.1	190.65	3.0	0.0
Oct-59	26.11	67.81	33.2	196.17	11.7	0.0
Nov-59	26.56	72.70	55.0	206.33	8.4	0.0
Dec-59	26.75	76.81	89.5	210.01	71.4	33.5

PROPOSED UPPER CHAGRES RESERVOIR OPERATION
(As simulated by the ACP)

	Gatun Reservoir Elev. (m)	Madden Reservoir Elev. (m)	Upper Chagres Inflow (cms)	Upper Chagres Reservoir Elev. (m)	Upper Chagres Outflow (cms)	Upper Chagres Reservoir Spillage (cms)
Jan-60	26.52	76.21	54.0	209.89	53.8	16.4
Feb-60	26.22	74.06	12.3	206.77	27.3	0.0
Mar-60	26.00	71.02	8.9	202.38	28.9	0.0
Apr-60	25.82	67.94	21.5	200.01	32.5	0.0
May-60	25.82	66.14	27.4	196.43	40.8	0.0
Jun-60	25.92	65.53	29.7	194.80	35.9	0.0
Jul-60	25.82	67.97	30.8	194.80	30.5	0.0
Aug-60	25.82	67.67	29.1	199.16	12.0	0.0
Sep-60	25.91	69.49	30.2	200.96	21.8	0.0
Oct-60	26.18	71.93	34.4	203.81	20.4	0.0
Nov-60	26.61	75.29	35.6	206.86	20.2	0.0
Dec-60	26.75	76.81	94.1	210.04	78.5	40.6
Jan-61	26.45	75.90	18.4	207.38	30.2	0.0
Feb-61	26.27	71.76	10.1	204.76	23.1	0.0
Mar-61	25.49	73.24	8.2	197.05	41.4	0.8
Apr-61	25.41	66.57	11.9	199.15	3.0	0.0
May-61	25.48	61.90	18.5	193.31	40.5	0.0
Jun-61	25.64	69.23	43.1	194.80	36.9	0.0
Jul-61	25.82	66.14	26.8	197.67	15.5	0.0
Aug-61	25.82	67.67	33.5	197.92	32.1	0.0
Sep-61	25.91	69.49	31.5	200.96	18.3	0.0
Oct-61	26.18	71.93	37.8	203.81	23.9	0.0
Nov-61	26.61	75.29	45.1	206.86	29.7	0.0
Dec-61	26.75	76.81	28.5	210.01	13.0	0.0
Jan-62	26.38	75.90	17.6	207.38	29.3	0.0
Feb-62	26.18	71.98	11.2	204.76	24.2	0.0
Mar-62	25.39	73.55	9.0	197.25	41.4	0.8
Apr-62	25.24	66.52	9.5	198.72	3.0	0.0
May-62	25.67	62.69	27.6	195.25	40.6	0.0
Jun-62	25.49	67.64	20.2	190.25	39.8	0.0
Jul-62	25.82	66.14	33.0	196.36	9.3	0.0
Aug-62	25.82	67.67	44.2	197.92	37.8	0.0
Sep-62	25.91	69.49	38.1	200.96	24.8	0.0
Oct-62	26.18	71.93	36.4	203.81	22.5	0.0
Nov-62	26.61	75.29	40.7	206.86	25.3	0.0
Dec-62	26.75	76.81	31.8	210.01	16.2	0.0
Jan-63	26.52	75.90	37.9	208.78	42.9	5.4
Feb-63	26.30	74.06	19.4	204.76	39.7	1.3
Mar-63	25.86	71.02	12.9	202.38	23.3	0.0
Apr-63	25.80	67.36	27.3	200.01	38.3	0.0
May-63	25.82	66.14	39.0	199.33	41.1	0.0
Jun-63	25.82	65.53	41.3	199.30	41.1	0.0
Jul-63	25.82	66.14	47.8	200.74	41.2	0.2
Aug-63	26.10	67.67	45.8	201.59	41.4	0.8
Sep-63	25.91	72.27	49.4	203.10	41.6	1.5
Oct-63	26.18	71.93	37.7	205.36	26.6	0.0
Nov-63	26.64	75.29	43.9	206.86	36.1	0.0
Dec-63	26.75	75.90	25.4	210.01	9.8	0.0

PROPOSED UPPER CHAGRES RESERVOIR OPERATION
(As simulated by the ACP)

	Gatun Reservoir Elev. (m)	Madden Reservoir Elev. (m)	Upper Chagres Inflow (cms)	Upper Chagres Reservoir Elev. (m)	Upper Chagres Outflow (cms)	Upper Chagres Reservoir Spillage (cms)
Jan-64	26.25	75.90	15.4	204.16	42.5	4.2
Feb-64	26.03	70.23	12.1	204.76	8.3	0.0
Mar-64	25.21	71.50	9.9	197.51	41.4	0.9
Apr-64	25.16	63.82	16.9	200.36	4.6	0.0
May-64	25.04	67.82	27.0	196.70	40.9	0.0
Jun-64	25.82	67.49	45.5	197.84	40.7	0.0
Jul-64	26.23	66.74	28.0	196.56	32.6	0.0
Aug-64	25.82	71.37	26.4	198.53	18.5	0.0
Sep-64	25.91	69.91	31.7	203.08	10.4	0.0
Oct-64	26.18	71.93	27.9	204.28	21.9	0.0
Nov-64	26.61	75.29	39.2	206.86	26.2	0.0
Dec-64	26.75	75.60	22.2	210.01	6.7	0.0
Jan-65	26.40	75.90	18.2	204.73	42.5	4.3
Feb-65	26.23	70.88	14.1	204.76	13.2	0.0
Mar-65	25.40	72.15	11.9	198.00	41.4	1.0
Apr-65	25.19	64.15	10.7	199.74	3.0	0.0
May-65	24.84	67.43	23.7	195.20	40.7	0.0
Jun-65	25.05	64.53	33.2	196.06	29.5	0.0
Jul-65	25.23	60.01	23.3	191.61	40.0	0.0
Aug-65	25.12	64.79	30.7	189.10	39.3	0.0
Sep-65	25.65	64.68	40.3	189.56	38.6	0.0
Oct-65	26.05	70.17	50.8	197.20	21.5	0.0
Nov-65	26.64	75.74	50.1	204.19	18.2	0.0
Dec-65	26.75	76.81	51.4	210.01	23.3	0.0
Jan-66	26.52	75.90	25.9	207.38	37.7	0.0
Feb-66	26.11	74.06	16.8	204.76	29.7	0.0
Mar-66	25.84	68.84	12.6	202.38	23.1	0.0
Apr-66	25.23	72.07	34.7	200.87	41.5	1.1
May-66	25.76	71.10	41.0	200.74	41.3	0.6
Jun-66	25.82	69.76	32.7	199.53	37.8	0.0
Jul-66	25.82	68.49	34.0	198.40	38.0	0.0
Aug-66	25.85	67.67	30.4	199.80	24.7	0.0
Sep-66	25.91	69.80	38.1	200.96	32.4	0.0
Oct-66	26.18	71.93	42.4	203.97	27.8	0.0
Nov-66	26.64	76.50	79.0	209.96	49.3	10.9
Dec-66	26.75	76.81	77.1	210.04	76.3	39.0
Jan-67	26.52	75.90	33.9	207.38	45.8	8.1
Feb-67	26.19	74.06	19.9	204.76	32.8	0.0
Mar-67	25.92	68.99	13.4	202.38	23.9	0.0
Apr-67	25.32	71.90	31.3	200.18	41.4	0.9
May-67	25.47	70.55	43.0	200.45	41.2	0.3
Jun-67	25.82	70.50	49.5	202.03	41.4	0.9
Jul-67	25.91	71.07	44.9	202.65	41.6	1.5
Aug-67	25.82	71.20	33.9	201.79	37.7	0.0
Sep-67	25.94	71.19	35.3	203.12	28.4	0.0
Oct-67	26.18	72.82	30.5	204.86	22.0	0.0
Nov-67	26.61	75.29	36.2	207.25	24.1	0.0
Dec-67	26.75	76.81	37.1	210.01	23.5	0.0

PROPOSED UPPER CHAGRES RESERVOIR OPERATION
(As simulated by the ACP)

	Gatun Reservoir Elev. (m)	Madden Reservoir Elev. (m)	Upper Chagres Inflow (cms)	Upper Chagres Reservoir Elev. (m)	Upper Chagres Outflow (cms)	Upper Chagres Reservoir Spillage (cms)
Jan-68	26.30	75.90	14.9	207.38	26.5	0.0
Feb-68	26.21	71.99	12.6	204.76	25.2	0.0
Mar-68	25.49	73.81	13.8	198.48	41.5	1.1
Apr-68	25.30	67.59	16.3	201.33	3.0	0.0
May-68	25.58	64.53	36.9	200.32	41.3	0.6
Jun-68	25.66	70.14	32.6	198.19	41.0	0.0
Jul-68	25.82	67.61	37.0	198.47	35.6	0.0
Aug-68	25.82	67.67	36.1	199.32	32.5	0.0
Sep-68	25.91	69.49	36.2	200.96	28.6	0.0
Oct-68	26.27	71.93	33.9	203.81	20.1	0.0
Nov-68	26.61	75.68	31.4	206.86	16.1	0.0
Dec-68	26.75	76.81	25.5	210.01	10.0	0.0
Jan-69	26.38	75.90	16.5	207.38	28.3	0.0
Feb-69	26.20	71.92	13.0	204.76	26.0	0.0
Mar-69	25.39	73.57	11.2	197.83	41.4	1.0
Apr-69	25.23	67.25	17.5	201.08	3.0	0.0
May-69	25.55	64.24	31.3	198.65	41.2	0.1
Jun-69	25.27	67.89	19.8	193.39	40.4	0.0
Jul-69	25.73	63.28	29.6	196.57	17.1	0.0
Aug-69	25.77	68.79	36.5	197.92	31.0	0.0
Sep-69	25.91	69.49	32.2	201.56	16.0	0.0
Oct-69	26.18	71.93	23.3	203.81	12.2	0.0
Nov-69	26.61	74.86	29.3	206.86	14.0	0.0
Dec-69	26.75	76.81	74.7	210.01	59.3	21.5
Jan-70	26.75	76.81	67.4	209.98	67.0	29.6
Feb-70	26.30	76.81	11.5	207.38	24.3	0.0
Mar-70	26.03	72.74	19.8	206.07	25.3	0.0
Apr-70	25.82	72.33	42.1	205.90	42.3	3.6
May-70	25.82	73.22	48.6	207.11	42.4	3.8
Jun-70	25.82	71.61	28.5	204.23	42.2	3.4
Jul-70	25.82	71.32	31.8	202.05	41.8	2.0
Aug-70	26.04	71.89	37.4	201.83	38.2	0.0
Sep-70	26.00	72.27	35.8	203.47	27.4	0.0
Oct-70	26.23	73.42	39.7	205.40	30.3	0.0
Nov-70	26.64	75.68	41.1	207.51	30.4	0.0
Dec-70	26.75	76.81	74.8	210.02	62.6	24.9
Jan-71	26.52	75.90	43.6	209.18	47.0	9.6
Feb-71	26.30	74.06	16.8	204.76	39.2	0.8
Mar-71	26.03	71.02	15.4	202.38	25.9	0.0
Apr-71	25.64	67.36	16.7	200.01	27.6	0.0
May-71	25.82	66.14	23.7	195.48	40.8	0.0
Jun-71	25.82	65.87	37.8	194.80	40.2	0.0
Jul-71	25.82	66.87	46.5	196.32	40.3	0.0
Aug-71	25.82	67.67	38.7	198.56	29.8	0.0
Sep-71	25.91	69.51	33.3	200.96	22.5	0.0
Oct-71	26.18	71.93	31.1	203.82	17.2	0.0
Nov-71	26.61	75.29	39.3	206.86	24.1	0.0
Dec-71	26.75	76.02	21.6	210.01	6.0	0.0

PROPOSED UPPER CHAGRES RESERVOIR OPERATION
(As simulated by the ACP)

	Gatun Reservoir Elev. (m)	Madden Reservoir Elev. (m)	Upper Chagres Inflow (cms)	Upper Chagres Reservoir Elev. (m)	Upper Chagres Outflow (cms)	Upper Chagres Reservoir Spillage (cms)
Jan-72	26.52	76.81	57.4	209.95	57.2	19.8
Feb-72	26.27	74.06	14.6	207.38	26.9	0.0
Mar-72	26.03	69.67	10.3	202.38	33.2	0.0
Apr-72	25.82	67.36	25.8	198.91	41.3	0.6
May-72	25.82	66.14	17.6	192.87	40.4	0.0
Jun-72	25.82	65.53	21.7	194.80	13.7	0.0
Jul-72	25.52	66.14	14.1	194.80	13.6	0.0
Aug-72	25.59	61.34	25.3	197.92	12.9	0.0
Sep-72	25.91	69.47	19.7	192.67	40.3	0.0
Oct-72	26.18	71.93	31.7	200.07	3.0	0.0
Nov-72	26.34	73.38	34.0	206.33	3.0	0.0
Dec-72	26.57	75.78	19.9	204.54	27.8	0.0
Jan-73	25.87	75.63	11.9	206.27	3.0	0.0
Feb-73	25.66	70.26	8.4	207.14	3.0	0.0
Mar-73	24.84	71.77	5.6	199.19	41.8	2.0
Apr-73	24.66	63.75	5.1	199.54	3.0	0.0
May-73	24.79	58.61	16.3	193.12	40.5	0.0
Jun-73	24.82	65.11	28.4	190.24	39.6	0.0
Jul-73	25.46	60.77	28.3	196.67	3.0	0.0
Aug-73	25.61	67.57	32.3	196.49	32.7	0.0
Sep-73	25.91	68.48	28.3	202.26	3.0	0.0
Oct-73	26.18	71.93	36.1	201.04	41.5	1.1
Nov-73	26.64	75.29	60.4	206.86	31.6	0.0
Dec-73	26.75	76.81	46.0	210.01	30.6	0.0
Jan-74	26.46	75.90	27.2	207.38	38.9	1.1
Feb-74	26.25	72.11	13.2	204.76	26.2	0.0
Mar-74	25.44	73.86	9.7	197.41	41.4	0.9
Apr-74	25.23	67.35	7.5	198.36	3.0	0.0
May-74	25.28	57.94	13.0	200.69	3.0	0.0
Jun-74	25.17	64.06	16.9	194.76	40.7	0.0
Jul-74	25.73	61.80	21.9	190.07	39.7	0.0
Aug-74	25.79	67.35	31.3	187.98	37.4	0.0
Sep-74	25.83	69.23	31.4	195.50	3.0	0.0
Oct-74	26.18	72.55	42.8	196.90	37.2	0.0
Nov-74	26.61	74.95	39.7	204.94	3.0	0.0
Dec-74	26.75	76.81	26.8	204.99	25.9	0.0
Jan-75	26.09	75.90	12.1	206.75	3.0	0.0
Feb-75	25.87	71.48	7.5	204.76	17.2	0.0
Mar-75	25.08	73.11	5.1	196.28	41.3	0.6
Apr-75	24.82	65.81	5.6	196.75	3.0	0.0
May-75	25.02	61.73	30.3	194.04	40.3	0.0
Jun-75	24.85	67.71	28.9	191.23	39.8	0.0
Jul-75	25.40	66.25	44.8	196.43	24.6	0.0
Aug-75	25.82	67.65	52.1	199.27	40.8	0.0
Sep-75	25.91	69.49	34.7	200.91	27.0	0.0
Oct-75	26.46	71.93	46.6	203.81	32.6	0.0
Nov-75	26.64	76.50	58.1	206.99	42.2	3.2
Dec-75	26.75	76.81	58.0	210.01	43.3	5.4

PROPOSED UPPER CHAGRES RESERVOIR OPERATION
(As simulated by the ACP)

	Gatun Reservoir Elev. (m)	Madden Reservoir Elev. (m)	Upper Chagres Inflow (cms)	Upper Chagres Reservoir Elev. (m)	Upper Chagres Outflow (cms)	Upper Chagres Reservoir Spillage (cms)
Jan-76	26.52	75.90	25.8	207.38	37.5	0.0
Feb-76	26.08	74.06	14.0	204.76	26.4	0.0
Mar-76	25.77	68.99	11.2	202.38	21.7	0.0
Apr-76	25.12	71.30	12.7	195.66	41.0	0.0
May-76	25.22	65.52	19.9	198.39	9.0	0.0
Jun-76	25.51	61.98	18.5	192.80	40.3	0.0
Jul-76	24.96	65.48	12.9	184.79	39.0	0.0
Aug-76	25.09	57.94	15.0	188.68	3.0	0.0
Sep-76	25.29	64.40	22.3	183.46	38.5	0.0
Oct-76	25.74	69.72	39.8	184.82	35.5	0.0
Nov-76	26.01	71.93	42.7	195.85	3.0	0.0
Dec-76	26.63	71.62	17.9	199.61	3.0	0.0
Jan-77	25.89	73.14	15.8	194.21	36.0	0.0
Feb-77	25.68	66.71	11.0	195.93	3.0	0.0
Mar-77	24.83	68.01	8.2	186.99	39.6	0.0
Apr-77	24.60	57.94	8.2	188.46	3.0	0.0
May-77	24.18	61.55	14.7	180.59	38.2	0.0
Jun-77	24.25	57.94	17.1	174.43	32.5	0.0
Jul-77	23.93	62.74	22.6	168.66	35.5	0.0
Aug-77	24.92	57.94	28.8	179.67	3.0	0.0
Sep-77	25.11	64.85	26.7	175.51	36.8	0.0
Oct-77	25.77	69.52	56.4	193.16	3.0	0.0
Nov-77	26.35	71.99	45.3	203.01	3.0	0.0
Dec-77	26.75	75.83	33.1	201.13	41.6	1.3
Jan-78	26.09	75.19	13.8	203.28	3.0	0.0
Feb-78	25.96	69.45	11.7	204.80	3.0	0.0
Mar-78	25.15	71.77	8.4	197.18	41.4	0.8
Apr-78	25.46	66.32	26.6	200.56	12.1	0.0
May-78	25.73	65.80	28.2	197.26	41.0	0.0
Jun-78	25.82	71.10	39.8	197.00	40.6	0.0
Jul-78	25.82	69.22	46.7	199.35	37.4	0.0
Aug-78	25.82	70.10	48.9	201.02	41.2	0.3
Sep-78	25.91	69.49	32.4	202.47	25.0	0.0
Oct-78	26.18	71.93	34.7	203.81	27.9	0.0
Nov-78	26.61	75.29	42.7	206.86	27.4	0.0
Dec-78	26.26	75.75	23.6	210.01	8.1	0.0
Jan-79	26.09	72.03	12.1	203.48	42.4	4.0
Feb-79	25.46	73.02	8.9	196.55	41.2	0.3
Mar-79	25.21	65.15	6.9	197.39	3.0	0.0
Apr-79	24.83	67.89	17.8	191.65	40.1	0.0
May-79	25.26	61.10	17.1	193.14	11.1	0.0
Jun-79	25.34	67.26	23.7	188.87	39.5	0.0
Jul-79	25.73	65.82	27.3	195.36	3.0	0.0
Aug-79	25.82	66.95	36.7	196.50	32.1	0.0
Sep-79	25.91	69.49	31.7	198.13	24.9	0.0
Oct-79	26.18	71.69	28.5	203.79	3.0	0.0
Nov-79	26.56	75.29	42.8	206.86	27.2	0.0
Dec-79	26.58	76.81	41.1	210.01	25.8	0.0

PROPOSED UPPER CHAGRES RESERVOIR OPERATION
(As simulated by the ACP)

	Gatun Reservoir Elev. (m)	Madden Reservoir Elev. (m)	Upper Chagres Inflow (cms)	Upper Chagres Reservoir Elev. (m)	Upper Chagres Outflow (cms)	Upper Chagres Reservoir Spillage (cms)
Jan-80	26.52	75.90	30.9	207.38	42.6	4.9
Feb-80	26.25	74.06	18.5	204.76	31.2	0.0
Mar-80	26.03	68.07	10.1	202.38	20.6	0.0
Apr-80	25.52	67.36	10.7	195.17	41.0	0.0
May-80	25.73	64.51	22.4	192.41	32.7	0.0
Jun-80	25.73	68.03	29.3	194.80	19.4	0.0
Jul-80	25.82	66.14	17.9	196.68	10.3	0.0
Aug-80	25.82	67.67	21.3	197.92	16.1	0.0
Sep-80	25.78	69.49	23.6	200.96	10.2	0.0
Oct-80	26.17	71.93	30.4	203.81	16.5	0.0
Nov-80	26.57	75.29	43.6	206.86	28.3	0.0
Dec-80	26.67	76.81	39.6	210.01	24.0	0.0
Jan-81	26.52	74.44	23.3	207.38	35.0	0.0
Feb-81	26.23	74.06	17.7	202.60	42.1	3.0
Mar-81	26.03	69.74	14.4	202.38	14.8	0.0
Apr-81	25.82	72.42	100.7	210.00	62.9	24.2
May-81	26.03	71.49	46.4	209.92	46.2	8.9
Jun-81	26.30	72.35	37.2	208.67	42.9	5.3
Jul-81	26.37	73.13	40.0	208.02	42.7	4.8
Aug-81	26.36	73.76	38.9	207.16	42.6	4.4
Sep-81	25.91	74.63	27.9	205.28	36.7	0.0
Oct-81	26.18	72.47	33.2	206.83	25.4	0.0
Nov-81	26.64	75.29	40.8	207.33	38.0	0.0
Dec-81	26.75	76.81	61.7	210.01	48.5	10.8
Jan-82	26.52	75.90	32.1	207.61	42.8	5.1
Feb-82	26.19	74.06	14.6	204.76	28.7	0.0
Mar-82	25.98	68.06	9.2	202.38	19.6	0.0
Apr-82	25.41	69.45	12.3	195.55	41.0	0.0
May-82	25.55	64.34	22.1	195.44	22.1	0.0
Jun-82	25.34	68.43	19.3	190.19	39.8	0.0
Jul-82	25.71	63.80	32.7	197.00	6.2	0.0
Aug-82	25.48	68.22	31.2	194.51	40.4	0.0
Sep-82	25.82	67.31	29.5	200.90	3.0	0.0
Oct-82	26.18	73.35	45.9	201.78	41.4	0.9
Nov-82	26.17	74.10	32.0	207.44	3.7	0.0
Dec-82	26.13	69.99	20.4	204.71	32.7	0.0
Jan-83	25.42	71.61	15.3	198.80	41.5	1.2
Feb-83	25.19	66.93	8.5	191.95	37.0	0.0
Mar-83	24.31	68.86	6.2	181.57	38.6	0.0
Apr-83	24.11	60.85	5.4	182.19	3.0	0.0
May-83	24.02	62.17	36.6	181.76	37.7	0.0
Jun-83	24.07	62.36	22.2	177.53	33.6	0.0
Jul-83	24.07	57.94	19.6	183.47	3.0	0.0
Aug-83	23.93	62.81	21.7	177.70	37.4	0.0
Sep-83	24.90	57.94	27.7	186.03	3.0	0.0
Oct-83	25.16	67.61	34.3	184.62	38.3	0.0
Nov-83	25.86	67.75	40.0	195.02	3.0	0.0
Dec-83	26.26	75.40	76.6	203.38	41.0	0.0

PROPOSED UPPER CHAGRES RESERVOIR OPERATION
(As simulated by the ACP)

	Gatun Reservoir Elev. (m)	Madden Reservoir Elev. (m)	Upper Chagres Inflow (cms)	Upper Chagres Reservoir Elev. (m)	Upper Chagres Outflow (cms)	Upper Chagres Reservoir Spillage (cms)
Jan-84	26.33	69.80	25.6	207.99	3.0	0.0
Feb-84	25.74	71.64	15.5	202.58	42.2	3.2
Mar-84	25.53	66.76	8.9	194.66	40.9	0.0
Apr-84	24.82	67.98	6.3	185.19	39.3	0.0
May-84	25.08	58.96	18.7	190.20	3.0	0.0
Jun-84	25.13	65.72	30.3	187.38	39.0	0.0
Jul-84	25.62	61.49	39.1	194.93	11.9	0.0
Aug-84	25.82	69.70	67.9	201.53	40.8	0.0
Sep-84	25.91	69.49	48.4	202.85	41.6	1.4
Oct-84	26.18	71.93	55.1	205.55	42.0	2.6
Nov-84	26.61	75.29	55.8	208.21	42.4	4.0
Dec-84	26.22	76.81	35.1	210.01	26.1	0.0
Jan-85	26.15	72.76	19.2	207.38	30.8	0.0
Feb-85	25.50	74.03	12.9	201.69	42.0	2.8
Mar-85	25.27	66.96	12.9	203.62	3.0	0.0
Apr-85	24.44	69.00	9.4	196.26	41.2	0.2
May-85	24.59	64.39	19.6	194.75	25.0	0.0
Jun-85	25.03	63.41	34.2	193.21	40.0	0.0
Jul-85	25.46	60.35	26.2	189.56	39.5	0.0
Aug-85	25.42	66.19	21.2	183.74	38.6	0.0
Sep-85	25.90	69.49	37.9	193.79	3.0	0.0
Oct-85	26.09	71.91	30.6	200.73	3.0	0.0
Nov-85	26.52	69.99	29.9	206.15	3.0	0.0
Dec-85	26.75	76.38	52.0	208.03	42.5	4.2
Jan-86	26.20	75.90	17.7	208.70	13.8	0.0
Feb-86	26.02	72.11	11.8	204.76	31.5	0.0
Mar-86	25.19	73.51	12.1	198.07	41.4	1.0
Apr-86	25.19	68.76	22.0	201.92	4.2	0.0
May-86	25.22	67.19	49.4	203.40	41.7	1.7
Jun-86	25.60	65.71	30.6	201.07	41.6	1.4
Jul-86	25.73	65.64	25.3	197.15	41.0	0.0
Aug-86	25.53	70.25	22.0	192.34	40.2	0.0
Sep-86	25.86	69.49	36.6	200.59	3.0	0.0
Oct-86	26.46	71.93	57.7	203.92	41.6	1.4
Nov-86	26.61	76.50	40.2	206.86	25.3	0.0
Dec-86	26.22	76.81	30.3	210.01	14.6	0.0
Jan-87	26.05	72.46	13.3	207.38	24.9	0.0
Feb-87	25.38	73.98	12.6	201.62	42.0	2.7
Mar-87	25.10	66.91	8.2	202.55	3.0	0.0
Apr-87	25.22	64.95	28.5	199.74	41.4	0.8
May-87	25.72	66.81	55.9	202.77	41.4	0.9
Jun-87	25.82	65.71	36.1	201.57	41.6	1.4
Jul-87	25.82	66.14	36.4	200.45	41.4	0.7
Aug-87	25.82	67.67	44.2	200.97	41.3	0.5
Sep-87	25.91	69.49	51.5	202.92	41.5	1.3
Oct-87	26.33	71.93	39.8	203.81	35.1	0.0
Nov-87	26.61	75.93	60.7	207.48	42.2	3.4
Dec-87	26.61	76.81	29.8	210.01	17.2	0.0

PROPOSED UPPER CHAGRES RESERVOIR OPERATION
(As simulated by the ACP)

	Gatun Reservoir Elev. (m)	Madden Reservoir Elev. (m)	Upper Chagres Inflow (cms)	Upper Chagres Reservoir Elev. (m)	Upper Chagres Outflow (cms)	Upper Chagres Reservoir Spillage (cms)
Jan-88	26.40	72.63	13.7	207.38	25.3	0.0
Feb-88	25.65	74.30	14.5	201.77	42.0	2.8
Mar-88	25.39	67.73	9.1	202.68	4.0	0.0
Apr-88	24.59	69.45	7.0	194.57	40.9	0.0
May-88	24.69	64.61	24.5	195.44	20.7	0.0
Jun-88	24.98	60.95	22.3	190.96	39.9	0.0
Jul-88	24.92	70.25	43.8	191.98	39.6	0.0
Aug-88	25.68	70.45	57.3	200.70	22.8	0.0
Sep-88	25.94	69.51	40.8	202.58	31.2	0.0
Oct-88	26.46	72.18	50.8	204.40	41.8	2.2
Nov-88	26.61	76.50	44.5	207.00	31.3	0.0
Dec-88	26.75	76.81	32.4	210.01	17.5	0.0
Jan-89	26.34	75.90	20.6	207.38	32.2	0.0
Feb-89	26.18	72.50	19.9	204.76	32.9	0.0
Mar-89	25.36	74.02	12.1	198.02	41.4	1.0
Apr-89	25.13	67.46	8.6	199.23	3.0	0.0
May-89	25.09	63.30	17.2	193.07	40.5	0.0
Jun-89	24.64	68.26	31.9	191.05	39.7	0.0
Jul-89	25.06	65.37	34.5	196.86	11.8	0.0
Aug-89	25.73	66.79	37.9	196.10	40.5	0.0
Sep-89	25.72	70.23	32.3	197.47	26.5	0.0
Oct-89	26.18	71.93	58.5	204.20	28.5	0.0
Nov-89	26.61	75.29	67.4	209.21	42.4	3.9
Dec-89	26.75	76.81	36.2	210.01	31.9	0.0
Jan-90	26.52	75.90	29.7	207.38	41.6	3.8
Feb-90	26.14	74.06	17.6	204.76	30.7	0.0
Mar-90	25.90	69.31	14.0	202.38	24.7	0.0
Apr-90	25.16	70.75	22.4	198.05	41.2	0.3
May-90	25.38	67.15	74.6	205.31	41.5	1.2
Jun-90	25.56	63.84	21.0	201.00	41.8	2.0
Jul-90	25.59	68.66	19.1	195.50	40.8	0.0
Aug-90	25.82	67.67	34.1	199.65	17.8	0.0
Sep-90	26.05	69.49	44.7	200.96	38.3	0.0
Oct-90	26.46	73.13	57.4	204.21	41.7	1.6
Nov-90	26.61	76.50	58.6	207.46	42.3	3.5
Dec-90	26.75	76.81	63.1	210.01	50.5	12.7
Jan-91	26.29	75.90	19.6	207.38	31.4	0.0
Feb-91	26.04	71.92	12.7	204.76	25.7	0.0
Mar-91	25.30	73.87	15.4	198.92	41.5	1.3
Apr-91	25.09	67.20	11.8	200.79	3.0	0.0
May-91	25.46	65.54	31.4	198.38	41.1	0.0
Jun-91	25.73	63.01	21.9	193.64	40.4	0.0
Jul-91	25.55	67.78	22.9	189.03	39.5	0.0
Aug-91	25.73	65.01	23.1	194.38	3.0	0.0
Sep-91	25.91	71.59	33.4	192.64	40.0	0.0
Oct-91	26.18	71.93	33.4	200.38	3.0	0.0
Nov-91	26.61	75.29	57.4	206.86	25.3	0.0
Dec-91	26.40	76.81	33.6	210.01	18.2	0.0

PROPOSED UPPER CHAGRES RESERVOIR OPERATION
(As simulated by the ACP)

	Gatun Reservoir Elev. (m)	Madden Reservoir Elev. (m)	Upper Chagres Inflow (cms)	Upper Chagres Reservoir Elev. (m)	Upper Chagres Outflow (cms)	Upper Chagres Reservoir Spillage (cms)
Jan-92	26.25	72.82	16.4	207.38	28.2	0.0
Feb-92	25.51	74.14	10.9	201.15	42.0	2.6
Mar-92	25.25	67.12	8.8	202.27	3.0	0.0
Apr-92	25.20	62.19	14.0	195.91	41.0	0.0
May-92	25.21	69.76	46.6	197.41	40.5	0.0
Jun-92	25.82	69.24	45.2	198.44	40.8	0.0
Jul-92	25.82	68.10	34.9	197.82	37.0	0.0
Aug-92	25.82	69.35	49.8	200.05	41.0	0.0
Sep-92	26.04	69.49	41.1	201.96	31.4	0.0
Oct-92	26.18	72.94	33.4	203.81	24.3	0.0
Nov-92	26.55	75.29	48.8	207.27	31.5	0.0
Dec-92	26.67	74.23	31.1	210.01	17.7	0.0
Jan-93	26.14	76.71	25.3	206.25	42.7	4.7
Feb-93	25.97	71.80	12.2	207.09	7.3	0.0
Mar-93	25.23	73.77	17.0	201.72	42.0	2.7
Apr-93	25.20	70.50	26.8	202.13	24.3	0.0
May-93	25.36	68.91	36.3	200.96	41.5	1.0
Jun-93	25.82	69.18	47.8	202.20	41.5	1.1
Jul-93	25.82	68.85	36.1	200.99	41.5	1.1
Aug-93	25.82	67.67	25.9	200.39	28.3	0.0
Sep-93	26.04	69.49	37.7	200.96	34.6	0.0
Oct-93	26.18	73.06	58.2	204.37	41.7	1.7
Nov-93	26.61	75.29	40.8	207.32	26.0	0.0
Dec-93	26.66	76.81	26.5	210.01	13.3	0.0
Jan-94	26.52	72.86	12.9	207.38	24.4	0.0
Feb-94	25.86	74.06	8.6	200.88	42.0	2.5
Mar-94	25.65	67.39	7.3	201.62	3.0	0.0
Apr-94	24.93	69.16	6.4	193.20	40.7	0.0
May-94	25.22	65.19	25.5	195.00	18.2	0.0
Jun-94	25.73	65.51	36.7	194.07	40.1	0.0
Jul-94	25.73	65.00	37.9	202.38	3.5	0.0
Aug-94	25.72	71.43	33.0	200.53	41.5	1.0
Sep-94	25.91	69.49	34.4	203.12	21.4	0.0
Oct-94	26.18	71.93	37.1	203.81	33.4	0.0
Nov-94	26.61	75.29	65.3	208.42	42.3	3.6
Dec-94	26.17	76.72	30.3	210.01	22.2	0.0
Jan-95	26.22	73.76	15.4	204.16	42.5	4.2
Feb-95	25.49	74.60	8.3	199.50	31.7	0.0
Mar-95	25.22	68.15	4.8	199.81	3.0	0.0
Apr-95	25.04	63.69	6.1	191.08	40.3	0.0
May-95	24.91	67.82	19.2	184.80	38.9	0.0
Jun-95	25.61	64.14	36.4	194.26	3.0	0.0
Jul-95	25.82	71.22	43.6	195.08	40.2	0.0
Aug-95	25.82	68.57	41.3	201.33	15.7	0.0
Sep-95	25.91	69.49	28.7	201.81	26.0	0.0
Oct-95	26.15	71.93	31.0	203.81	21.2	0.0
Nov-95	26.61	75.10	38.5	206.86	23.2	0.0
Dec-95	26.75	76.81	50.0	209.45	37.2	0.0

PROPOSED UPPER CHAGRES RESERVOIR OPERATION
(As simulated by the ACP)

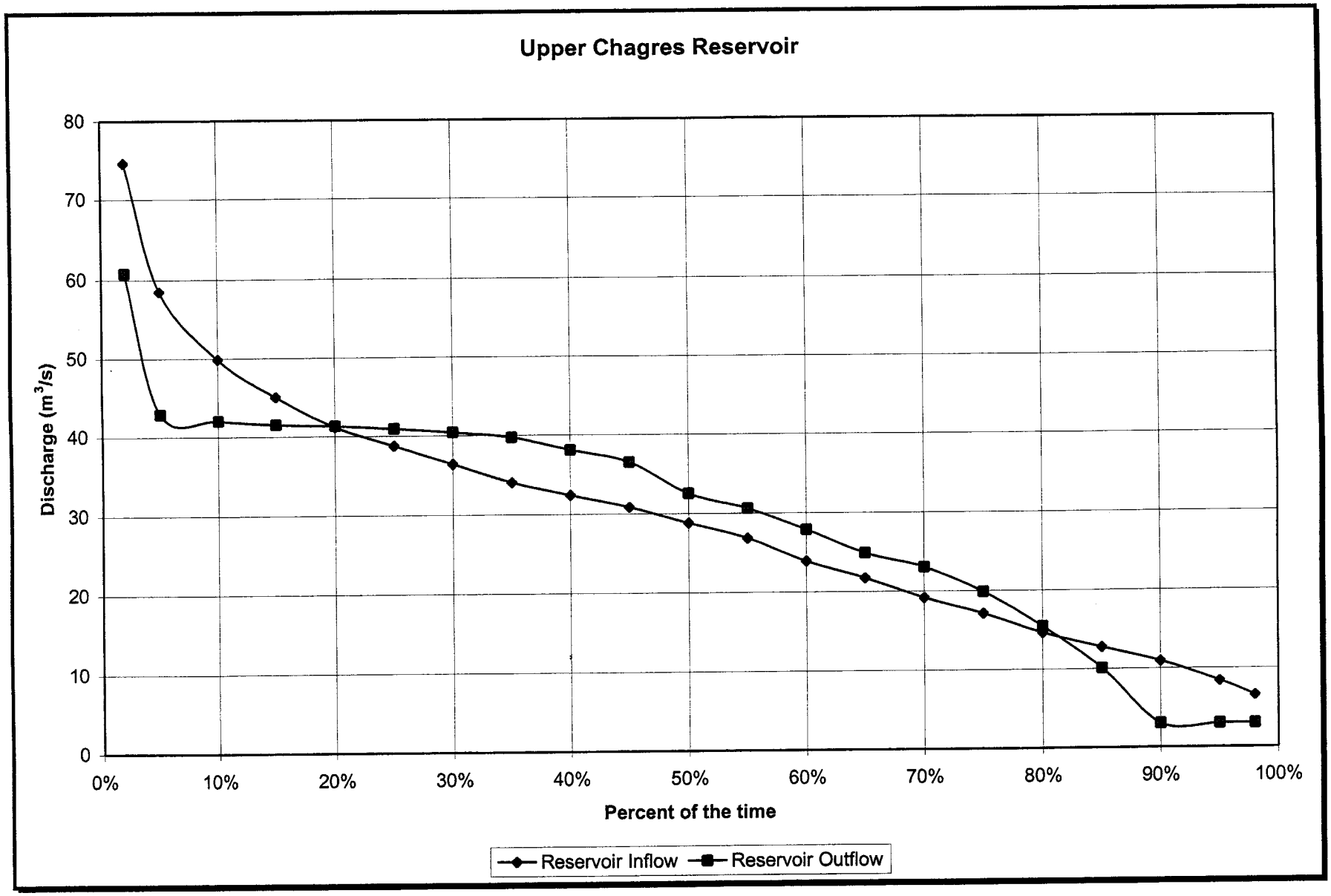
	Gatun Reservoir Elev. (m)	Madden Reservoir Elev. (m)	Upper Chagres Inflow (cms)	Upper Chagres Reservoir Elev. (m)	Upper Chagres Outflow (cms)	Upper Chagres Reservoir Spillage (cms)
Jan-96	26.75	76.81	73.2	209.97	70.0	32.6
Feb-96	26.30	76.81	30.5	207.39	42.8	5.0
Mar-96	26.03	73.28	22.6	206.07	28.0	0.0
Apr-96	25.82	69.83	19.3	202.19	37.6	0.0
May-96	25.82	69.23	47.5	203.30	41.7	1.7
Jun-96	25.82	69.23	42.5	203.38	41.8	2.1
Jul-96	25.82	68.00	45.3	204.02	41.9	2.3
Aug-96	25.88	67.67	49.9	205.58	42.1	2.9
Sep-96	25.91	70.14	33.7	203.80	42.0	2.8
Oct-96	26.18	71.93	42.1	204.48	38.5	0.0
Nov-96	26.64	75.29	83.2	210.00	55.8	17.6
Dec-96	26.75	76.81	94.7	210.12	93.6	56.4
Jan-97	26.39	75.90	29.0	207.38	41.5	3.8
Feb-97	26.21	72.31	16.8	204.76	30.1	0.0
Mar-97	25.40	73.68	9.1	197.33	41.4	0.8
Apr-97	25.16	66.93	7.8	198.41	3.0	0.0
May-97	25.22	63.95	31.4	195.91	40.6	0.0
Jun-97	25.40	60.28	26.8	192.50	40.1	0.0
Jul-97	24.98	64.50	16.2	185.52	39.1	0.0
Aug-97	24.99	57.94	13.5	188.91	3.0	0.0
Sep-97	24.79	63.29	18.4	182.43	38.4	0.0
Oct-97	24.77	67.14	24.6	180.48	30.3	0.0
Nov-97	25.33	60.73	21.9	186.46	3.0	0.0
Dec-97	24.67	63.23	21.6	180.94	38.0	0.0
Jan-98	23.93	64.92	12.2	170.94	36.4	0.0
Feb-98	23.93	57.94	8.4	172.89	3.0	0.0
Mar-98	23.93	57.94	5.0	157.70	34.0	0.0
Apr-98	23.93	57.94	14.3	154.84	18.5	0.0
May-98	23.93	57.94	39.6	159.80	32.2	0.0
Jun-98	24.20	57.94	24.0	154.84	31.4	0.0
Jul-98	24.24	65.15	31.0	154.84	30.9	0.0
Aug-98	25.18	60.55	33.9	171.79	3.0	0.0
Sep-98	25.34	67.64	34.2	171.18	35.4	0.0
Oct-98	26.08	65.80	33.5	183.05	3.0	0.0
Nov-98	26.25	68.38	38.5	193.42	3.0	0.0
Dec-98	26.75	74.94	54.8	197.14	40.3	0.0
Jan-99	26.27	75.28	30.8	203.46	3.0	0.0
Feb-99	26.14	70.06	24.0	207.37	3.0	0.0
Mar-99	25.47	72.19	14.8	201.53	42.0	2.7
Apr-99	25.38	68.25	17.5	200.88	20.3	0.0
May-99	25.69	66.32	25.7	197.02	41.0	0.0
Jun-99	25.82	65.99	36.2	195.87	40.5	0.0
Jul-99	25.82	66.14	45.3	197.03	40.5	0.0
Aug-99	25.98	67.67	53.8	200.25	40.9	0.0
Sep-99	25.91	71.12	44.2	200.96	40.4	0.0
Oct-99	26.18	71.93	40.5	204.69	22.4	0.0
Nov-99	26.64	75.29	52.1	206.86	41.2	2.4
Dec-99	26.75	76.81	126.8	210.20	110.5	72.7

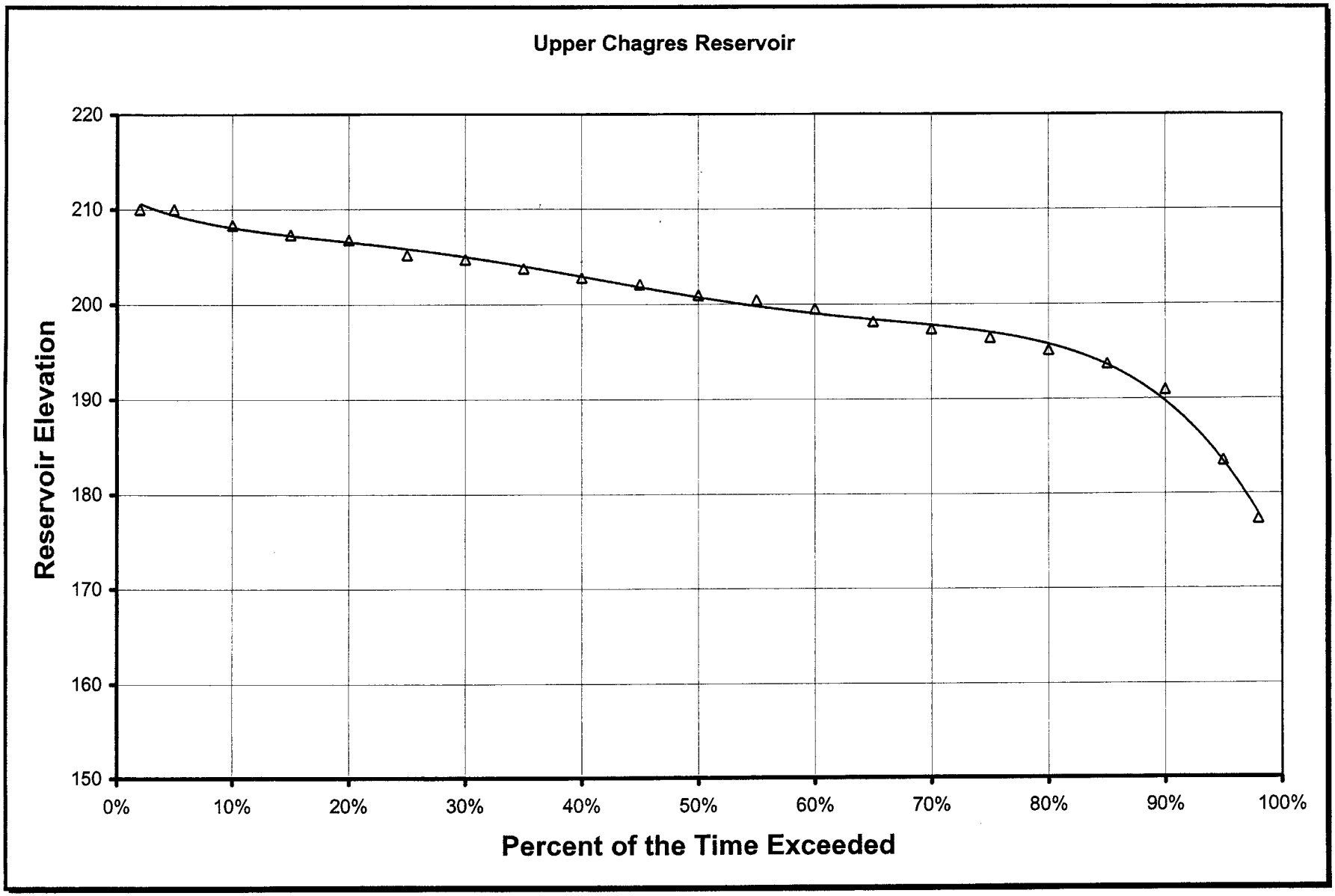
ATTACHMENT 3

ENERGY PRODUCTION ANALYSIS

Upper Chagres Project
Hydropower Development Potential

Monthly Flow Duration Curves				Monthly Reservoir Level Duration Curves					
Reservoir Inflow		Reservoir Outflow		Reservoir Elevation		Gross Head		Net Head	
Percent of the time	Exceeded Flow (cms)	Percent of the time	Exceeded Flow (cms)	Percent of the time	Exceeded Elev. (m)	Percent of the time	Exceeded Head (m)	Percent of the time	Exceeded Head (m)
2%	74.6	2%	60.8	2%	210.0	2%	127.8	2%	126.4
5%	58.5	5%	42.9	5%	210.0	5%	127.2	5%	125.4
10%	49.9	10%	42.0	10%	208.4	10%	127.0	10%	123.8
15%	45.0	15%	41.5	15%	207.4	15%	125.5	15%	123.1
20%	41.2	20%	41.3	20%	206.9	20%	124.6	20%	122.4
25%	38.8	25%	40.9	25%	205.3	25%	124.1	25%	121.5
30%	36.4	30%	40.4	30%	204.8	30%	123.1	30%	120.7
35%	34.0	35%	39.7	35%	203.8	35%	122.1	35%	119.8
40%	32.4	40%	38.1	40%	202.8	40%	121.0	40%	118.8
45%	30.9	45%	36.5	45%	202.1	45%	120.3	45%	117.9
50%	28.8	50%	32.5	50%	201.0	50%	119.5	50%	117.1
55%	26.8	55%	30.6	55%	200.4	55%	118.8	55%	116.3
60%	23.9	60%	27.9	60%	199.5	60%	118.0	60%	115.6
65%	21.7	65%	24.9	65%	198.2	65%	117.3	65%	114.9
70%	19.2	70%	23.1	70%	197.4	70%	116.1	70%	113.8
75%	17.1	75%	19.9	75%	196.5	75%	115.0	75%	112.7
80%	14.6	80%	15.4	80%	195.2	80%	113.8	80%	111.5
85%	12.7	85%	10.1	85%	193.7	85%	112.5	85%	110.2
90%	10.9	90%	3.0	90%	190.9	90%	110.2	90%	107.6
95%	8.4	95%	3.0	95%	183.5	95%	103.0	95%	101.3
98%	6.5	98%	3.0	98%	177.3	98%	97.0	98%	94.7


Upper Chagres Reservoir
Discharge (m³/s)
80
70
60
50
40
30
20
10
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of the time
Reservoir Inflow
Reservoir Outflow


Upper Chagres Reservoir
Reservoir Elevation
220
210
200
190
180
170
160
150
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent of the Time Exceeded

Upper Chagres Project
Hydropower Development Potential

UPPER CHAGRES HYDROELECTRIC SCHEME

Reservoir Operation between El.155 and El.210
(as per ACP Operation Rules)

Upper Chagres Power Plant	
Design head	**105.00 meters**
Maximum Operating Head	**131.25 meters**
Minimum Operating Head	**68.25 meters**
Discharge at Max Head	**51.16 cms**
Discharge at Min Head	**50.97 cms**
Head Loss at Max Head Discharge	**2.55 meters**
Head Loss at Min Head Discharge	**2.54 meters**
TW Elev at Max Head Discharge	**81.78**
TW Elev at Min Head Discharge	**81.78**
Res Elev at Max Head	**215.59**
Res Elev at Min Head	**152.57**
Installed Capacity (at Hd)	**24,000 kW**
Maximum Turbine Discharge (at Hd)	**26.5 cms**
Plant Efficiency	**86%**
Head Loss at Max Turb Discharge	**3.90 meters**
Average Annual Output	**173.6 GWh**
Firm Capacity (Exceeded 95% of the time 8 hr per day)	**8.67 MW**
Gatun Power Plant	
Average Annual Output	**61,045 MWh**
Madden Power Plant	
Average Annual Output	**193,020 MWh**

Upper Chagres Project
Hydropower Development Potential

UPPER CHAGRES HYDROELECTRIC SCHEME

Reservoir Operation between El.155 and El.210
(as per ACP Operation Rules)

Upper Chagres Power Plant	
Design head	**105.00 meters**
Maximum Operating Head	**131.25 meters**
Minimum Operating Head	**68.25 meters**
Discharge at Max Head	**51.16 cms**
Discharge at Min Head	**50.97 cms**
Head Loss at Max Head Discharge	**2.55 meters**
Head Loss at Min Head Discharge	**2.54 meters**
TW Elev at Max Head Discharge	**81.78**
TW Elev at Min Head Discharge	**81.78**
Res Elev at Max Head	**215.59**
Res Elev at Min Head	**152.57**
Installed Capacity (at Hd)	**32,000 kW**
Maximum Turbine Discharge (at Hd)	**35.3 cms**
Plant Efficiency	**86%**
Head Loss at Max Turb Discharge	**3.90 meters**
Average Annual Output	**215.6 GWh**
Firm Capacity (Exceeded 95% of the time 8 hr per day)	**8.67 MW**
Gatun Power Plant	
Average Annual Output	**61,045 MWh**
Madden Power Plant	
Average Annual Output	**193,020 MWh**

Upper Chagres Project
Hydropower Development Potential

UPPER CHAGRES HYDROELECTRIC SCHEME

Reservoir Operation between El.155 and El.210
(as per ACP Operation Rules)

Upper Chagres Power Plant	
Design head	**105.00 meters**
Maximum Operating Head	**131.25 meters**
Minimum Operating Head	**68.25 meters**
Discharge at Max Head	**51.16 cms**
Discharge at Min Head	**50.97 cms**
Head Loss at Max Head Discharge	**2.55 meters**
Head Loss at Min Head Discharge	**2.54 meters**
TW Elev at Max Head Discharge	**81.78**
TW Elev at Min Head Discharge	**81.78**
Res Elev at Max Head	**215.59**
Res Elev at Min Head	**152.57**
Installed Capacity (at Hd)	**40,000 kW**
Maximum Turbine Discharge (at Hd)	**44.1 cms**
Plant Efficiency	**86%**
Head Loss at Max Turb Discharge	**3.90 meters**
Average Annual Output	**243.1 GWh**
Firm Capacity (Exceeded 95% of the time 8 hr per day)	**8.67 MW**
Gatun Power Plant	
Average Annual Output	**61,045 MWh**
Madden Power Plant	
Average Annual Output	**193,020 MWh**

Upper Chagres Project
Hydropower Development Potential

UPPER CHAGRES HYDROELECTRIC SCHEME

Reservoir Operation between El.155 and El.210
(as per ACP Operation Rules)

Upper Chagres Power Plant	
Design head	**105.00 meters**
Maximum Operating Head	**131.25 meters**
Minimum Operating Head	**68.25 meters**
Discharge at Max Head	**44.77 cms**
Discharge at Min Head	**44.60 cms**
Head Loss at Max Head Discharge	**2.55 meters**
Head Loss at Min Head Discharge	**2.54 meters**
TW Elev at Max Head Discharge	**81.71**
TW Elev at Min Head Discharge	**81.71**
Res Elev at Max Head	**215.51**
Res Elev at Min Head	**152.49**
Installed Capacity (at Hd)	**49,000 kW**
Maximum Turbine Discharge (at Hd)	**54.1 cms**
Plant Efficiency	**86%**
Head Loss at Max Turb Discharge	**3.90 meters**
Average Annual Output	**250.6 GWh**
Firm Capacity (Exceeded 95% of the time 8 hr per day)	**8.67 MW**
Gatun Power Plant	
Average Annual Output	**61,045 MWh**
Madden Power Plant	
Average Annual Output	**193,020 MWh**

Upper Chagres Project
Hydropower Development Potential

UPPER CHAGRES HYDROELECTRIC SCHEME

Reservoir Operation between El.155 and El.210
(as per ACP Operation Rules)

Upper Chagres Power Plant	
Design head	**105.00 meters**
Maximum Operating Head	**131.25 meters**
Minimum Operating Head	**68.25 meters**
Discharge at Max Head	**51.16 cms**
Discharge at Min Head	**50.97 cms**
Head Loss at Max Head Discharge	**2.55 meters**
Head Loss at Min Head Discharge	**2.54 meters**
TW Elev at Max Head Discharge	**81.78**
TW Elev at Min Head Discharge	**81.78**
Res Elev at Max Head	**215.59**
Res Elev at Min Head	**152.57**
Installed Capacity (at Hd)	**56,000 kW**
Maximum Turbine Discharge (at Hd)	**61.8 cms**
Plant Efficiency	**86%**
Head Loss at Max Turb Discharge	**3.90 meters**
Average Annual Output	**253.3 GWh**
Firm Capacity (Exceeded 95% of the time 8 hr per day)	**8.67 MW**
Gatun Power Plant	
Average Annual Output	**61,045 MWh**
Madden Power Plant	
Average Annual Output	**193,020 MWh**

Upper Chagres Project
Hydropower Development Potential

UPPER CHAGRES HYDROELECTRIC SCHEME

Reservoir Operation between El.155 and El.210
(as per ACP Operation Rules)

Upper Chagres Power Plant	
Design head	**105.00 meters**
Maximum Operating Head	**131.25 meters**
Minimum Operating Head	**68.25 meters**
Discharge at Max Head	**57.56 cms**
Discharge at Min Head	**57.34 cms**
Head Loss at Max Head Discharge	**2.55 meters**
Head Loss at Min Head Discharge	**2.54 meters**
TW Elev at Max Head Discharge	**81.86**
TW Elev at Min Head Discharge	**81.85**
Res Elev at Max Head	**215.66**
Res Elev at Min Head	**152.64**
Installed Capacity (at Hd)	**63,000 kW**
Maximum Turbine Discharge (at Hd)	**69.5 cms**
Plant Efficiency	**86%**
Head Loss at Max Turb Discharge	**3.90 meters**
Average Annual Output	**255.4 GWh**
Firm Capacity (Exceeded 95% of the time 8 hr per day)	**8.67 MW**
Gatun Power Plant	
Average Annual Output	**61,045 MWh**
Madden Power Plant	
Average Annual Output	**193,020 MWh**

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 45 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-48	17,238	0	33,480	210.00	73.12	16.57	31.72	45,000	130.25	526,080	33,480	31	135,000
Feb-48	16,126	0	16,126	207.37	22.03	9.01	0.00	45,000	126.04	490,940	16,126	29	69,510
Mar-48	17,238	0	17,238	203.79	22.59	6.32	0.00	45,000	122.93	444,792	17,238	31	69,510
Apr-48	16,682	0	16,682	199.89	23.32	6.06	0.00	45,000	119.05	397,891	16,682	30	69,510
May-48	17,238	0	17,238	197.32	23.99	14.16	0.00	45,000	115.73	370,244	17,238	31	69,510
Jun-48	16,682	0	16,682	197.09	24.30	23.73	0.00	45,000	114.29	367,741	16,682	30	69,510
Jul-48	17,238	0	17,238	200.91	23.90	40.04	0.00	45,000	116.19	410,066	17,238	31	69,510
Aug-48	17,238	0	17,238	202.61	23.34	31.49	0.00	45,000	118.96	430,524	17,238	31	69,510
Sep-48	16,682	0	16,682	203.26	23.11	26.59	0.00	45,000	120.16	438,398	16,682	30	69,510
Oct-48	17,238	0	17,238	206.60	22.71	38.94	0.00	45,000	122.29	480,646	17,238	31	69,510
Nov-48	16,682	0	20,921	210.00	27.87	45.82	0.00	45,000	124.95	526,080	20,921	30	87,172
Dec-48	17,238	0	22,548	210.00	28.70	29.48	0.00	45,000	126.56	526,080	22,548	31	90,920
Jan-49	17,238	0	17,238	208.42	21.94	14.98	0.00	45,000	126.58	504,925	17,238	31	69,510
Feb-49	15,570	0	15,570	205.91	22.31	9.37	0.00	45,000	124.48	471,429	15,570	28	69,510
Mar-49	17,238	0	17,238	202.25	22.88	6.85	0.00	45,000	121.38	426,195	17,238	31	69,510
Apr-49	16,682	0	16,682	198.38	23.62	7.16	0.00	45,000	117.57	381,615	16,682	30	69,510
May-49	17,238	0	17,238	198.12	24.07	23.51	0.00	45,000	115.36	378,867	17,238	31	69,510
Jun-49	16,682	0	16,682	201.55	23.72	39.14	0.00	45,000	117.09	417,774	16,682	30	69,510
Jul-49	17,238	0	17,238	207.46	22.78	51.03	0.00	45,000	121.90	492,155	17,238	31	69,510
Aug-49	17,238	0	27,152	210.00	35.12	48.31	0.00	45,000	124.51	526,080	27,152	31	109,483
Sep-49	16,682	0	28,507	210.00	37.82	38.37	0.00	45,000	125.46	526,080	28,507	30	118,778
Oct-49	17,238	0	33,480	210.00	44.55	45.03	1.39	45,000	124.97	526,080	33,480	31	135,000
Nov-49	16,682	0	32,400	210.00	60.87	61.34	17.69	45,000	124.90	526,080	32,400	30	135,000
Dec-49	17,238	0	33,480	210.00	52.95	53.58	9.78	45,000	124.94	526,080	33,480	31	135,000
Jan-50	17,238	0	17,238	209.58	21.83	20.65	0.00	45,000	127.17	520,410	17,238	31	69,510
Feb-50	15,570	0	15,570	208.52	21.97	17.08	0.00	45,000	126.41	506,349	15,570	28	69,510
Mar-50	17,238	0	17,238	206.00	22.29	10.76	0.00	45,000	124.59	472,706	17,238	31	69,510
Apr-50	16,682	0	16,682	205.31	22.58	20.02	0.00	45,000	122.95	463,498	16,682	30	69,510
May-50	17,238	0	17,238	208.84	22.32	40.47	0.00	45,000	124.40	510,596	17,238	31	69,510
Jun-50	16,682	0	18,071	210.00	23.76	30.16	0.00	45,000	126.57	526,080	18,071	30	75,296
Jul-50	17,238	0	33,480	210.00	53.47	53.89	10.31	45,000	124.93	526,080	33,480	31	135,000
Aug-50	17,238	0	33,480	210.00	45.39	45.85	2.24	45,000	124.97	526,080	33,480	31	135,000
Sep-50	16,682	0	24,560	210.00	32.41	32.94	0.00	45,000	126.11	526,080	24,560	30	102,331
Oct-50	17,238	0	20,278	210.00	25.74	26.20	0.00	45,000	126.91	526,080	20,278	31	81,765
Nov-50	16,682	0	32,400	210.00	50.41	50.83	7.25	45,000	124.95	526,080	32,400	30	135,000
Dec-50	17,238	0	33,480	210.00	59.59	60.12	16.41	45,000	124.91	526,080	33,480	31	135,000
Jan-51	17,238	0	17,238	209.41	21.85	19.74	0.00	45,000	127.08	518,151	17,238	31	69,510
Feb-51	15,570	0	27,465	210.00	39.18	43.27	0.00	45,000	125.00	526,080	27,465	28	122,612
Mar-51	17,238	0	17,644	210.00	22.32	23.28	0.00	45,000	127.32	526,080	17,644	31	71,145
Apr-51	16,682	0	16,682	209.38	21.85	19.43	0.00	45,000	127.07	517,769	16,682	30	69,510
May-51	17,238	0	17,447	210.00	22.12	25.80	0.00	45,000	127.03	526,080	17,447	31	70,349
Jun-51	16,682	0	22,785	210.00	30.00	30.53	0.00	45,000	126.40	526,080	22,785	30	94,937
Jul-51	17,238	0	25,611	210.00	32.72	33.22	0.00	45,000	126.07	526,080	25,611	31	103,270
Aug-51	17,238	0	19,197	210.00	24.33	24.86	0.00	45,000	127.08	526,080	19,197	31	77,408
Sep-51	16,682	0	21,485	210.00	28.24	28.74	0.00	45,000	126.61	526,080	21,485	30	89,520
Oct-51	17,238	0	19,232	210.00	24.38	24.84	0.00	45,000	127.07	526,080	19,232	31	77,548
Nov-51	16,682	0	21,652	210.00	28.47	28.94	0.00	45,000	126.58	526,080	21,652	30	90,218
Dec-51	17,238	0	21,653	210.00	27.53	28.26	0.00	45,000	126.70	526,080	21,653	31	87,309

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 45 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-52	17,238	0	17,238	209.12	21.87	18.41	0.00	45,000	126.94	514,392	17,238	31	69,510
Feb-52	16,126	0	16,126	207.14	22.13	12.43	0.00	45,000	125.48	487,881	16,126	29	69,510
Mar-52	17,238	0	17,238	204.16	22.58	9.01	0.00	45,000	122.98	449,192	17,238	31	69,510
Apr-52	16,682	0	16,682	201.29	23.15	10.65	0.00	45,000	119.95	414,666	16,682	30	69,510
May-52	17,238	0	17,238	201.35	23.43	24.16	0.00	45,000	118.51	415,353	17,238	31	69,510
Jun-52	16,682	0	16,682	201.37	23.42	23.87	0.00	45,000	118.55	415,615	16,682	30	69,510
Jul-52	17,238	0	17,238	203.12	23.24	31.49	0.00	45,000	119.46	436,658	17,238	31	69,510
Aug-52	17,238	0	17,238	206.33	22.75	38.23	0.00	45,000	122.06	477,032	17,238	31	69,510
Sep-52	16,682	0	16,682	208.72	22.24	35.03	0.00	45,000	124.86	509,027	16,682	30	69,510
Oct-52	17,238	0	32,890	210.00	42.59	49.42	0.00	45,000	124.38	526,080	32,890	31	132,620
Nov-52	16,682	0	23,454	210.00	30.91	31.49	0.00	45,000	126.29	526,080	23,454	30	97,726
Dec-52	17,238	0	33,480	210.00	52.74	53.27	9.58	45,000	124.94	526,080	33,480	31	135,000
Jan-53	17,238	0	31,692	210.00	40.79	41.46	0.00	45,000	125.14	526,080	31,692	31	127,792
Feb-53	15,570	0	18,650	210.00	26.22	27.07	0.00	45,000	126.85	526,080	18,650	28	83,260
Mar-53	17,238	0	17,238	208.23	21.95	13.96	0.00	45,000	126.48	502,481	17,238	31	69,510
Apr-53	16,682	0	16,682	206.18	22.30	12.49	0.00	45,000	124.53	475,021	16,682	30	69,510
May-53	17,238	0	17,238	209.17	22.21	37.67	0.00	45,000	125.01	515,045	17,238	31	69,510
Jun-53	16,682	0	17,445	210.00	22.89	27.61	0.00	45,000	126.84	526,080	17,445	30	72,689
Jul-53	17,238	0	25,235	210.00	32.23	32.62	0.00	45,000	126.13	526,080	25,235	31	101,756
Aug-53	17,238	0	24,201	210.00	30.87	31.46	0.00	45,000	126.30	526,080	24,201	31	97,586
Sep-53	16,682	0	21,012	210.00	27.61	28.12	0.00	45,000	126.69	526,080	21,012	30	87,551
Oct-53	17,238	0	25,947	210.00	33.16	33.64	0.00	45,000	126.02	526,080	25,947	31	104,625
Nov-53	16,682	0	29,463	210.00	39.14	39.65	0.00	45,000	125.30	526,080	29,463	30	122,761
Dec-53	17,238	0	26,314	210.00	33.65	34.32	0.00	45,000	125.96	526,080	26,314	31	106,105
Jan-54	17,238	0	17,238	209.09	21.88	18.27	0.00	45,000	126.92	513,947	17,238	31	69,510
Feb-54	15,570	0	15,570	207.42	22.11	13.74	0.00	45,000	125.60	491,652	15,570	28	69,510
Mar-54	17,238	0	17,238	205.22	22.46	12.38	0.00	45,000	123.63	462,292	17,238	31	69,510
Apr-54	16,682	0	16,682	202.90	22.89	12.83	0.00	45,000	121.33	433,987	16,682	30	69,510
May-54	17,238	0	17,238	202.47	23.16	21.72	0.00	45,000	119.90	428,795	17,238	31	69,510
Jun-54	16,682	0	16,682	204.87	22.96	34.66	0.00	45,000	120.91	457,814	16,682	30	69,510
Jul-54	17,238	0	17,238	207.24	22.51	34.72	0.00	45,000	123.36	489,215	17,238	31	69,510
Aug-54	17,238	0	19,324	210.00	24.77	39.02	0.00	45,000	125.65	526,080	19,324	31	77,918
Sep-54	16,682	0	28,311	210.00	37.55	38.18	0.00	45,000	125.49	526,080	28,311	30	117,960
Oct-54	17,238	0	19,282	210.00	24.44	25.01	0.00	45,000	127.07	526,080	19,282	31	77,751
Nov-54	16,682	0	32,400	210.00	63.63	64.26	20.45	45,000	124.89	526,080	32,400	30	135,000
Dec-54	17,238	0	33,480	210.00	62.61	63.24	19.43	45,000	124.89	526,080	33,480	31	135,000
Jan-55	17,238	0	33,480	210.00	64.18	64.88	20.99	45,000	124.89	526,080	33,480	31	135,000
Feb-55	15,570	0	15,570	209.21	21.87	18.35	0.00	45,000	126.98	515,581	15,570	28	69,510
Mar-55	17,238	0	17,238	207.11	22.12	12.74	0.00	45,000	125.51	487,527	17,238	31	69,510
Apr-55	16,682	0	16,682	204.48	22.55	10.17	0.00	45,000	123.11	453,010	16,682	30	69,510
May-55	17,238	0	17,238	202.66	22.98	15.32	0.00	45,000	120.81	431,073	17,238	31	69,510
Jun-55	16,682	0	16,682	201.31	23.30	17.47	0.00	45,000	119.19	414,876	16,682	30	69,510
Jul-55	17,238	0	17,238	202.35	23.33	28.32	0.00	45,000	119.03	427,366	17,238	31	69,510
Aug-55	17,238	0	17,238	207.76	22.67	48.74	0.00	45,000	122.46	496,129	17,238	31	69,510
Sep-55	16,682	0	16,682	209.47	22.04	31.41	0.00	45,000	125.97	518,970	16,682	30	69,510
Oct-55	17,238	0	19,918	210.00	25.32	28.49	0.00	45,000	126.69	526,080	19,918	31	80,316
Nov-55	16,682	0	32,400	210.00	76.72	77.09	33.52	45,000	124.83	526,080	32,400	30	135,000
Dec-55	17,238	0	33,480	210.00	43.49	44.04	0.34	45,000	124.98	526,080	33,480	31	135,000

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 45 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-56	17,238	0	33,480	210.00	61.84	62.47	18.66	45,000	124.90	526,080	33,480	31	135,000
Feb-56	16,126	0	16,126	209.82	21.81	21.72	0.00	45,000	127.29	523,628	16,126	29	69,510
Mar-56	17,238	0	17,238	209.08	21.89	19.20	0.00	45,000	126.82	513,815	17,238	31	69,510
Apr-56	16,682	0	16,682	208.47	22.01	19.80	0.00	45,000	126.14	505,703	16,682	30	69,510
May-56	17,238	0	27,399	210.00	35.31	43.41	0.00	45,000	125.00	526,080	27,399	31	110,480
Jun-56	16,682	0	27,790	210.00	36.83	37.27	0.00	45,000	125.58	526,080	27,790	30	115,792
Jul-56	17,238	0	33,480	210.00	63.49	63.92	20.31	45,000	124.89	526,080	33,480	31	135,000
Aug-56	17,238	0	26,256	210.00	33.57	34.13	0.00	45,000	125.97	526,080	26,256	31	105,870
Sep-56	16,682	0	26,640	210.00	35.26	35.74	0.00	45,000	125.77	526,080	26,640	30	110,998
Oct-56	17,238	0	33,480	210.00	44.16	44.63	1.01	45,000	124.97	526,080	33,480	31	135,000
Nov-56	16,682	0	32,400	210.00	85.97	86.38	42.76	45,000	124.79	526,080	32,400	30	135,000
Dec-56	17,238	0	31,725	210.00	40.83	41.49	0.00	45,000	125.14	526,080	31,725	31	127,922
Jan-57	17,238	0	17,238	208.95	21.89	17.50	0.00	45,000	126.85	512,033	17,238	31	69,510
Feb-57	15,570	0	15,570	206.88	22.17	11.55	0.00	45,000	125.25	484,434	15,570	28	69,510
Mar-57	17,238	0	17,238	203.68	22.64	8.18	0.00	45,000	122.63	443,463	17,238	31	69,510
Apr-57	16,682	0	16,682	199.95	23.33	6.91	0.00	45,000	119.02	398,567	16,682	30	69,510
May-57	17,238	0	17,238	197.11	24.01	13.14	0.00	45,000	115.65	368,028	17,238	31	69,510
Jun-57	16,682	0	16,682	194.06	24.64	12.74	0.00	45,000	112.67	336,058	16,682	30	69,510
Jul-57	17,238	0	17,238	190.27	25.45	11.89	0.00	45,000	109.11	298,710	17,238	31	69,510
Aug-57	17,238	0	17,238	186.28	26.41	13.91	0.00	45,000	105.12	264,309	17,238	31	69,510
Sep-57	16,682	0	16,682	183.23	27.35	18.18	0.00	42,521	101.54	239,825	16,682	30	69,510
Oct-57	17,238	0	17,238	184.19	27.66	30.64	0.00	40,607	100.39	247,228	17,238	31	69,510
Nov-57	16,682	0	16,682	190.86	26.59	48.99	0.00	41,186	104.44	304,512	16,682	30	69,510
Dec-57	17,238	0	17,238	192.77	25.53	33.05	0.00	45,000	108.75	323,351	17,238	31	69,510
Jan-58	17,238	0	17,238	194.76	25.07	32.88	0.00	45,000	110.76	342,897	17,238	31	69,510
Feb-58	15,570	0	15,570	192.05	25.15	14.78	0.00	45,000	110.39	316,261	15,570	28	69,510
Mar-58	17,238	0	17,238	187.39	26.01	10.70	0.00	45,000	106.76	273,789	17,238	31	69,510
Apr-58	16,682	0	16,682	180.65	27.53	7.31	0.00	43,261	100.85	220,048	16,682	30	69,510
May-58	17,238	0	17,238	176.08	29.26	17.62	0.00	39,062	94.89	188,005	17,238	31	69,510
Jun-58	16,682	0	16,682	172.01	30.70	21.27	0.00	36,132	90.45	162,917	16,682	30	69,510
Jul-58	17,238	0	17,238	167.12	32.38	22.12	0.00	33,776	85.74	134,991	17,238	31	69,510
Aug-58	17,238	0	17,238	162.16	34.40	25.23	0.00	30,881	80.72	110,057	17,238	31	69,510
Sep-58	16,682	0	16,682	156.19	37.12	27.05	0.00	28,115	74.81	83,599	16,682	30	69,510
Oct-58	17,238	4,047	13,192	155.00	29.49	27.73	0.00	24,957	72.06	78,480	13,192	31	53,192
Nov-58	16,682	2,517	14,165	155.00	33.20	33.33	0.00	24,320	71.02	78,480	14,165	30	59,021
Dec-58	17,238	5,161	12,078	155.00	27.12	27.27	0.00	24,320	71.75	78,480	12,078	31	48,700
Jan-59	17,238	11,566	5,673	155.00	12.51	12.72	0.00	24,320	73.05	78,480	5,673	31	22,875
Feb-59	15,570	12,137	3,433	155.00	8.35	8.58	0.00	24,320	73.30	78,480	3,433	28	15,325
Mar-59	17,238	14,291	2,947	155.00	6.47	6.68	0.00	24,320	73.41	78,480	2,947	31	11,884
Apr-59	16,682	12,504	4,179	155.00	9.50	9.74	0.00	24,320	73.23	78,480	4,179	30	17,411
May-59	17,238	9,246	7,993	155.00	17.70	17.87	0.00	24,320	72.74	78,480	7,993	31	32,229
Jun-59	16,682	9,092	7,590	155.00	17.36	17.47	0.00	24,320	72.76	78,480	7,590	30	31,625
Jul-59	17,238	9,877	7,361	155.00	16.28	16.43	0.00	24,320	72.82	78,480	7,361	31	29,683
Aug-59	17,238	8,981	8,257	155.00	18.29	18.44	0.00	24,320	72.70	78,480	8,257	31	33,295
Sep-59	16,682	3,011	13,671	155.00	31.98	32.11	0.00	24,320	71.16	78,480	13,671	30	56,964
Oct-59	17,238	2,626	14,613	155.00	33.14	33.25	0.00	24,320	71.02	78,480	14,613	31	58,922
Nov-59	16,682	0	16,682	165.50	36.49	54.97	0.00	24,320	76.10	126,019	16,682	30	69,510
Dec-59	17,238	0	17,238	188.92	29.15	89.52	0.00	29,885	95.25	286,824	17,238	31	69,510

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 45 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-60	17,238	0	17,238	196.58	25.27	53.98	0.00	44,280	109.86	362,291	17,238	31	69,510
Feb-60	16,126	0	16,126	193.39	24.77	12.29	0.00	45,000	112.08	329,407	16,126	29	69,510
Mar-60	17,238	0	17,238	188.45	25.72	8.95	0.00	45,000	107.94	282,865	17,238	31	69,510
Apr-60	16,682	0	16,682	186.76	26.59	21.47	0.00	43,971	104.41	268,415	16,682	30	69,510
May-60	17,238	0	17,238	186.87	26.80	27.44	0.00	42,841	103.60	269,405	17,238	31	69,510
Jun-60	16,682	0	16,682	187.71	26.68	29.68	0.00	42,919	104.09	276,487	16,682	30	69,510
Jul-60	17,238	0	17,238	189.02	26.40	30.84	0.00	43,472	105.19	287,658	17,238	31	69,510
Aug-60	17,238	0	17,238	189.87	26.12	29.14	0.00	44,345	106.31	294,931	17,238	31	69,510
Sep-60	16,682	0	16,682	190.95	25.87	30.22	0.00	44,913	107.31	305,399	16,682	30	69,510
Oct-60	17,238	0	17,238	193.28	25.46	34.35	0.00	45,000	109.06	328,337	17,238	31	69,510
Nov-60	16,682	0	16,682	195.93	24.87	35.60	0.00	45,000	111.66	355,307	16,682	30	69,510
Dec-60	17,238	0	22,226	210.00	29.87	94.11	0.00	45,000	119.87	526,080	22,226	31	89,620
Jan-61	17,238	0	17,238	209.14	21.87	18.38	0.00	45,000	126.95	514,656	17,238	31	69,510
Feb-61	15,570	0	15,570	206.80	22.16	10.14	0.00	45,000	125.32	483,415	15,570	28	69,510
Mar-61	17,238	0	17,238	203.60	22.66	8.16	0.00	45,000	122.55	442,443	17,238	31	69,510
Apr-61	16,682	0	16,682	201.03	23.23	11.92	0.00	45,000	119.53	411,470	16,682	30	69,510
May-61	17,238	0	17,238	199.75	23.62	18.46	0.00	45,000	117.57	396,342	17,238	31	69,510
Jun-61	16,682	0	16,682	203.96	23.32	43.13	0.00	45,000	119.07	446,795	16,682	30	69,510
Jul-61	17,238	0	17,238	204.77	22.83	26.85	0.00	45,000	121.63	456,603	17,238	31	69,510
Aug-61	17,238	0	17,238	206.90	22.55	33.50	0.00	45,000	123.14	484,712	17,238	31	69,510
Sep-61	16,682	0	16,682	208.65	22.19	31.55	0.00	45,000	125.11	507,992	16,682	30	69,510
Oct-61	17,238	0	23,870	210.00	30.60	37.78	0.00	45,000	125.65	526,080	23,870	31	96,252
Nov-61	16,682	0	32,400	210.00	44.62	45.06	1.47	45,000	124.97	526,080	32,400	30	135,000
Dec-61	17,238	0	21,975	210.00	27.95	28.46	0.00	45,000	126.65	526,080	21,975	31	88,610
Jan-62	17,238	0	17,238	208.99	21.89	17.62	0.00	45,000	126.87	512,563	17,238	31	69,510
Feb-62	15,570	0	15,570	206.85	22.17	11.24	0.00	45,000	125.26	483,969	15,570	28	69,510
Mar-62	17,238	0	17,238	203.82	22.63	9.03	0.00	45,000	122.68	445,165	17,238	31	69,510
Apr-62	16,682	0	16,682	200.71	23.24	9.49	0.00	45,000	119.48	407,665	16,682	30	69,510
May-62	17,238	0	17,238	201.55	23.47	27.64	0.00	45,000	118.32	417,777	17,238	31	69,510
Jun-62	16,682	0	16,682	200.78	23.46	20.22	0.00	45,000	118.35	408,411	16,682	30	69,510
Jul-62	17,238	0	17,238	202.86	23.33	33.05	0.00	45,000	119.02	433,586	17,238	31	69,510
Aug-62	17,238	0	17,238	207.31	22.67	44.18	0.00	45,000	122.47	490,150	17,238	31	69,510
Sep-62	16,682	0	18,025	210.00	23.85	38.15	0.00	45,000	125.79	526,080	18,025	30	75,104
Oct-62	17,238	0	28,038	210.00	35.93	36.39	0.00	45,000	125.69	526,080	28,038	31	113,055
Nov-62	16,682	0	30,220	210.00	40.18	40.67	0.00	45,000	125.19	526,080	30,220	30	125,918
Dec-62	17,238	0	24,413	210.00	31.14	31.78	0.00	45,000	126.26	526,080	24,413	31	98,439
Jan-63	17,238	0	28,893	210.00	37.07	37.86	0.00	45,000	125.55	526,080	28,893	31	116,505
Feb-63	15,570	0	15,570	209.41	21.85	19.37	0.00	45,000	127.08	518,184	15,570	28	69,510
Mar-63	17,238	0	17,238	207.39	22.08	12.86	0.00	45,000	125.75	491,206	17,238	31	69,510
Apr-63	16,682	0	16,682	208.24	22.19	27.33	0.00	45,000	125.15	502,534	16,682	30	69,510
May-63	17,238	0	23,087	210.00	29.62	39.02	0.00	45,000	125.56	526,080	23,087	31	93,094
Jun-63	16,682	0	30,695	210.00	40.83	41.29	0.00	45,000	125.14	526,080	30,695	30	127,897
Jul-63	17,238	0	33,480	210.00	47.33	47.78	4.18	45,000	124.96	526,080	33,480	31	135,000
Aug-63	17,238	0	33,480	210.00	45.34	45.77	2.19	45,000	124.97	526,080	33,480	31	135,000
Sep-63	16,682	0	32,400	210.00	48.98	49.39	5.83	45,000	124.95	526,080	32,400	30	135,000
Oct-63	17,238	0	29,022	210.00	37.24	37.69	0.00	45,000	125.53	526,080	29,022	31	117,025
Nov-63	16,682	0	32,400	210.00	43.45	43.90	0.30	45,000	124.98	526,080	32,400	30	135,000
Dec-63	17,238	0	19,491	210.00	24.71	25.37	0.00	45,000	127.03	526,080	19,491	31	78,593

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 45 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-64	17,238	0	17,238	208.55	21.93	15.43	0.00	45,000	126.64	506,747	17,238	31	69,510
Feb-64	16,126	0	16,126	206.51	22.24	12.09	0.00	45,000	124.86	479,447	16,126	29	69,510
Mar-64	17,238	0	17,238	203.67	22.68	9.91	0.00	45,000	122.43	443,309	17,238	31	69,510
Apr-64	16,682	0	16,682	202.18	23.11	16.94	0.00	45,000	120.15	425,365	16,682	30	69,510
May-64	17,238	0	17,238	202.91	23.18	26.96	0.00	45,000	119.76	434,142	17,238	31	69,510
Jun-64	16,682	0	16,682	207.48	22.65	45.54	0.00	45,000	122.58	492,414	16,682	30	69,510
Jul-64	17,238	0	17,238	208.56	22.15	28.01	0.00	45,000	125.36	506,851	17,238	31	69,510
Aug-64	17,238	0	17,238	209.37	21.98	26.42	0.00	45,000	126.33	517,718	17,238	31	69,510
Sep-64	16,682	0	21,293	210.00	28.06	31.69	0.00	45,000	126.32	526,080	21,293	30	88,722
Oct-64	17,238	0	21,675	210.00	27.56	27.92	0.00	45,000	126.69	526,080	21,675	31	87,400
Nov-64	16,682	0	29,220	210.00	38.80	39.19	0.00	45,000	125.34	526,080	29,220	30	121,751
Dec-64	17,238	0	17,238	209.96	21.80	22.23	0.00	45,000	127.36	525,543	17,238	31	69,510
Jan-65	17,238	0	17,238	209.08	21.88	18.15	0.00	45,000	126.89	513,782	17,238	31	69,510
Feb-65	15,570	0	15,570	207.48	22.10	14.10	0.00	45,000	125.63	492,483	15,570	28	69,510
Mar-65	17,238	0	17,238	205.20	22.46	11.87	0.00	45,000	123.65	462,022	17,238	31	69,510
Apr-65	16,682	0	16,682	202.40	22.94	10.68	0.00	45,000	121.06	428,029	16,682	30	69,510
May-65	17,238	0	17,238	202.40	23.21	23.73	0.00	45,000	119.62	427,981	17,238	31	69,510
Jun-65	16,682	0	16,682	204.51	23.01	33.16	0.00	45,000	120.69	453,449	16,682	30	69,510
Jul-65	17,238	0	17,238	204.51	22.80	23.28	0.00	45,000	121.77	453,392	17,238	31	69,510
Aug-65	17,238	0	17,238	206.10	22.65	30.73	0.00	45,000	122.61	474,032	17,238	31	69,510
Sep-65	16,682	0	16,682	209.55	22.18	40.33	0.00	45,000	125.16	520,056	16,682	30	69,510
Oct-65	17,238	0	33,480	210.00	48.21	50.83	4.97	45,000	124.72	526,080	33,480	31	135,000
Nov-65	16,682	0	32,400	210.00	49.82	50.10	6.66	45,000	124.95	526,080	32,400	30	135,000
Dec-65	17,238	0	33,480	210.00	50.89	51.40	7.73	45,000	124.94	526,080	33,480	31	135,000
Jan-66	17,238	0	19,893	210.00	25.24	25.88	0.00	45,000	126.97	526,080	19,893	31	80,214
Feb-66	15,570	0	15,570	208.91	21.89	16.82	0.00	45,000	126.83	511,594	15,570	28	69,510
Mar-66	17,238	0	17,238	206.82	22.18	12.60	0.00	45,000	125.21	483,643	17,238	31	69,510
Apr-66	16,682	0	16,682	209.12	22.16	34.69	0.00	45,000	125.31	514,285	16,682	30	69,510
May-66	17,238	0	28,162	210.00	36.23	41.01	0.00	45,000	125.21	526,080	28,162	31	113,557
Jun-66	16,682	0	24,431	210.00	32.24	32.74	0.00	45,000	126.13	526,080	24,431	30	101,796
Jul-66	17,238	0	26,262	210.00	33.58	33.98	0.00	45,000	125.97	526,080	26,262	31	105,897
Aug-66	17,238	0	23,554	210.00	30.02	30.42	0.00	45,000	126.40	526,080	23,554	31	94,977
Sep-66	16,682	0	28,508	210.00	37.82	38.15	0.00	45,000	125.46	526,080	28,508	30	118,783
Oct-66	17,238	0	32,608	210.00	42.00	42.37	0.00	45,000	125.06	526,080	32,608	31	131,485
Nov-66	16,682	0	32,400	210.00	78.64	79.04	35.44	45,000	124.83	526,080	32,400	30	135,000
Dec-66	17,238	0	33,480	210.00	76.70	77.14	33.50	45,000	124.83	526,080	33,480	31	135,000
Jan-67	17,238	0	25,942	210.00	33.16	33.93	0.00	45,000	126.02	526,080	25,942	31	104,607
Feb-67	15,570	0	15,570	209.48	21.84	19.88	0.00	45,000	127.12	519,164	15,570	28	69,510
Mar-67	17,238	0	17,238	207.57	22.06	13.40	0.00	45,000	125.88	493,675	17,238	31	69,510
Apr-67	16,682	0	16,682	209.21	22.08	31.27	0.00	45,000	125.74	515,519	16,682	30	69,510
May-67	17,238	0	29,852	210.00	38.47	43.05	0.00	45,000	124.99	526,080	29,852	31	120,373
Jun-67	16,682	0	32,400	210.00	49.09	49.50	5.93	45,000	124.95	526,080	32,400	30	135,000
Jul-67	17,238	0	33,480	210.00	44.53	44.86	1.37	45,000	124.97	526,080	33,480	31	135,000
Aug-67	17,238	0	26,243	210.00	33.56	33.93	0.00	45,000	125.97	526,080	26,243	31	105,820
Sep-67	16,682	0	26,362	210.00	34.88	35.32	0.00	45,000	125.81	526,080	26,362	30	109,842
Oct-67	17,238	0	23,690	210.00	30.19	30.50	0.00	45,000	126.38	526,080	23,690	31	95,526
Nov-67	16,682	0	27,044	210.00	35.81	36.16	0.00	45,000	125.70	526,080	27,044	30	112,683
Dec-67	17,238	0	28,500	210.00	36.54	37.10	0.00	45,000	125.61	526,080	28,500	31	114,918

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 45 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-68	17,238	0	17,238	208.43	21.94	14.87	0.00	45,000	126.58	505,056	17,238	31	69,510
Feb-68	16,126	0	16,126	206.48	22.25	12.57	0.00	45,000	124.78	479,040	16,126	29	69,510
Mar-68	17,238	0	17,238	204.50	22.61	13.79	0.00	45,000	122.80	453,359	17,238	31	69,510
Apr-68	16,682	0	16,682	202.89	22.96	16.26	0.00	45,000	120.94	433,950	16,682	30	69,510
May-68	17,238	0	17,238	205.85	22.82	36.90	0.00	45,000	121.68	470,639	17,238	31	69,510
Jun-68	16,682	0	16,682	207.76	22.37	32.60	0.00	45,000	124.12	496,122	16,682	30	69,510
Jul-68	17,238	0	19,886	210.00	25.46	37.04	0.00	45,000	125.82	526,080	19,886	31	80,185
Aug-68	17,238	0	27,835	210.00	35.66	36.05	0.00	45,000	125.72	526,080	27,835	31	112,239
Sep-68	16,682	0	27,113	210.00	35.90	36.25	0.00	45,000	125.69	526,080	27,113	30	112,973
Oct-68	17,238	0	26,231	210.00	33.54	33.90	0.00	45,000	125.98	526,080	26,231	31	105,770
Nov-68	16,682	0	23,516	210.00	31.00	31.35	0.00	45,000	126.28	526,080	23,516	30	97,983
Dec-68	17,238	0	19,620	210.00	24.88	25.49	0.00	45,000	127.01	526,080	19,620	31	79,113
Jan-69	17,238	0	17,238	208.79	21.90	16.54	0.00	45,000	126.77	509,920	17,238	31	69,510
Feb-69	15,570	0	15,570	206.97	22.17	13.00	0.00	45,000	125.22	485,690	15,570	28	69,510
Mar-69	17,238	0	17,238	204.49	22.57	11.21	0.00	45,000	123.05	453,205	17,238	31	69,510
Apr-69	16,682	0	16,682	203.18	22.93	17.53	0.00	45,000	121.08	437,396	16,682	30	69,510
May-69	17,238	0	17,238	204.94	22.89	31.27	0.00	45,000	121.31	458,591	17,238	31	69,510
Jun-69	16,682	0	16,682	204.23	22.79	19.82	0.00	45,000	121.85	450,025	16,682	30	69,510
Jul-69	17,238	0	17,238	205.62	22.72	29.62	0.00	45,000	122.23	467,671	17,238	31	69,510
Aug-69	17,238	0	17,238	208.41	22.33	36.50	0.00	45,000	124.34	504,808	17,238	31	69,510
Sep-69	16,682	0	17,931	210.00	23.62	32.17	0.00	45,000	126.37	526,080	17,931	30	74,711
Oct-69	17,238	0	17,988	210.00	22.77	23.25	0.00	45,000	127.27	526,080	17,988	31	72,534
Nov-69	16,682	0	21,997	210.00	28.94	29.28	0.00	45,000	126.53	526,080	21,997	30	91,652
Dec-69	17,238	0	33,480	210.00	74.26	74.71	31.06	45,000	124.84	526,080	33,480	31	135,000
Jan-70	17,238	0	33,480	210.00	66.83	67.43	23.64	45,000	124.88	526,080	33,480	31	135,000
Feb-70	15,570	0	15,570	207.96	21.98	11.47	0.00	45,000	126.34	498,795	15,570	28	69,510
Mar-70	17,238	0	17,238	207.32	22.22	19.77	0.00	45,000	124.97	490,259	17,238	31	69,510
Apr-70	16,682	0	20,775	210.00	27.59	42.11	0.00	45,000	125.35	526,080	20,775	30	86,563
May-70	17,238	0	33,480	210.00	48.10	48.60	4.95	45,000	124.96	526,080	33,480	31	135,000
Jun-70	16,682	0	21,357	210.00	28.07	28.46	0.00	45,000	126.63	526,080	21,357	30	88,986
Jul-70	17,238	0	24,600	210.00	31.39	31.80	0.00	45,000	126.23	526,080	24,600	31	99,195
Aug-70	17,238	0	28,870	210.00	37.04	37.38	0.00	45,000	125.56	526,080	28,870	31	116,411
Sep-70	16,682	0	26,761	210.00	35.42	35.82	0.00	45,000	125.75	526,080	26,761	30	111,504
Oct-70	17,238	0	30,637	210.00	39.39	39.73	0.00	45,000	125.27	526,080	30,637	31	123,535
Nov-70	16,682	0	30,616	210.00	40.72	41.06	0.00	45,000	125.15	526,080	30,616	30	127,566
Dec-70	17,238	0	33,480	210.00	74.51	74.82	31.31	45,000	124.84	526,080	33,480	31	135,000
Jan-71	17,238	0	33,361	210.00	42.99	43.58	0.00	45,000	124.99	526,080	33,361	31	134,521
Feb-71	15,570	0	15,570	208.92	21.89	16.79	0.00	45,000	126.83	511,634	15,570	28	69,510
Mar-71	17,238	0	17,238	207.40	22.12	15.38	0.00	45,000	125.50	491,393	17,238	31	69,510
Apr-71	16,682	0	16,682	206.13	22.38	16.74	0.00	45,000	124.08	474,448	16,682	30	69,510
May-71	17,238	0	17,238	206.29	22.48	23.70	0.00	45,000	123.51	476,492	17,238	31	69,510
Jun-71	16,682	0	16,682	209.25	22.20	37.81	0.00	45,000	125.10	516,024	16,682	30	69,510
Jul-71	17,238	0	32,753	210.00	42.32	46.47	0.00	45,000	124.66	526,080	32,753	31	132,068
Aug-71	17,238	0	29,844	210.00	38.34	38.71	0.00	45,000	125.40	526,080	29,844	31	120,340
Sep-71	16,682	0	24,899	210.00	32.88	33.28	0.00	45,000	126.05	526,080	24,899	30	103,746
Oct-71	17,238	0	24,050	210.00	30.67	31.10	0.00	45,000	126.32	526,080	24,050	31	96,976
Nov-71	16,682	0	29,345	210.00	38.97	39.31	0.00	45,000	125.32	526,080	29,345	30	122,270
Dec-71	17,238	0	17,238	209.81	21.81	21.61	0.00	45,000	127.29	523,578	17,238	31	69,510

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 45 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-72	17,238	0	33,480	210.00	55.94	57.43	12.74	45,000	124.83	526,080	33,480	31	135,000
Feb-72	16,126	0	16,126	208.48	21.93	14.64	0.00	45,000	126.61	505,790	16,126	29	69,510
Mar-72	17,238	0	17,238	205.89	22.30	10.31	0.00	45,000	124.51	471,268	17,238	31	69,510
Apr-72	16,682	0	16,682	206.42	22.49	25.83	0.00	45,000	123.46	478,346	16,682	30	69,510
May-72	17,238	0	17,238	205.32	22.54	17.59	0.00	45,000	123.17	463,657	17,238	31	69,510
Jun-72	16,682	0	16,682	205.06	22.67	21.75	0.00	45,000	122.47	460,160	16,682	30	69,510
Jul-72	17,238	0	17,238	202.98	22.90	14.10	0.00	45,000	121.28	434,953	17,238	31	69,510
Aug-72	17,238	0	17,238	203.39	23.06	25.35	0.00	45,000	120.42	439,901	17,238	31	69,510
Sep-72	16,682	0	16,682	202.58	23.10	19.68	0.00	45,000	120.21	430,203	16,682	30	69,510
Oct-72	17,238	0	17,238	204.46	22.99	31.75	0.00	45,000	120.76	452,822	17,238	31	69,510
Nov-72	16,682	0	16,682	206.65	22.60	34.04	0.00	45,000	122.87	481,421	16,682	30	69,510
Dec-72	17,238	0	17,238	206.02	22.46	19.88	0.00	45,000	123.64	472,883	17,238	31	69,510
Jan-73	17,238	0	17,238	203.56	22.74	11.92	0.00	45,000	122.12	442,022	17,238	31	69,510
Feb-73	15,570	0	15,570	200.41	23.30	8.35	0.00	45,000	119.19	403,997	15,570	28	69,510
Mar-73	17,238	0	17,238	195.68	24.11	5.64	0.00	45,000	115.17	352,577	17,238	31	69,510
Apr-73	16,682	0	16,682	190.27	25.25	5.10	0.00	45,000	109.97	298,663	16,682	30	69,510
May-73	17,238	0	17,238	187.02	26.32	16.26	0.00	45,000	105.50	270,626	17,238	31	69,510
Jun-73	16,682	0	16,682	187.48	26.69	28.40	0.00	43,014	104.05	274,560	16,682	30	69,510
Jul-73	17,238	0	17,238	187.86	26.58	28.29	0.00	43,322	104.48	277,782	17,238	31	69,510
Aug-73	17,238	0	17,238	189.67	26.29	32.34	0.00	43,573	105.61	293,256	17,238	31	69,510
Sep-73	16,682	0	16,682	190.25	25.98	28.29	0.00	44,782	106.87	298,548	16,682	30	69,510
Oct-73	17,238	0	17,238	193.04	25.57	36.14	0.00	45,000	108.58	325,969	17,238	31	69,510
Nov-73	16,682	0	16,682	201.66	24.22	60.43	0.00	45,000	114.63	419,083	16,682	30	69,510
Dec-73	17,238	0	17,238	206.53	22.87	46.05	0.00	45,000	121.44	479,821	17,238	31	69,510
Jan-74	17,238	0	17,238	207.36	22.34	27.19	0.00	45,000	124.27	490,885	17,238	31	69,510
Feb-74	15,570	0	15,570	205.55	22.44	13.20	0.00	45,000	123.76	466,638	15,570	28	69,510
Mar-74	17,238	0	17,238	202.48	22.89	9.69	0.00	45,000	121.29	428,921	17,238	31	69,510
Apr-74	16,682	0	16,682	198.71	23.56	7.48	0.00	45,000	117.84	385,223	16,682	30	69,510
May-74	17,238	0	17,238	195.80	24.28	13.00	0.00	45,000	114.34	353,869	17,238	31	69,510
Jun-74	16,682	0	16,682	193.70	24.84	16.85	0.00	45,000	111.80	332,451	16,682	30	69,510
Jul-74	17,238	0	17,238	192.74	25.20	21.92	0.00	45,000	110.20	323,061	17,238	31	69,510
Aug-74	17,238	0	17,238	194.34	25.12	31.29	0.00	45,000	110.53	338,797	17,238	31	69,510
Sep-74	16,682	0	16,682	195.93	24.75	31.38	0.00	45,000	112.19	355,332	16,682	30	69,510
Oct-74	17,238	0	17,238	200.48	24.07	42.79	0.00	45,000	115.35	404,865	17,238	31	69,510
Nov-74	16,682	0	16,682	203.97	23.25	39.73	0.00	45,000	119.44	446,952	16,682	30	69,510
Dec-74	17,238	0	17,238	204.71	22.83	26.76	0.00	45,000	121.60	455,859	17,238	31	69,510
Jan-75	17,238	0	17,238	202.13	23.01	12.12	0.00	45,000	120.66	424,724	17,238	31	69,510
Feb-75	15,570	0	15,570	198.60	23.61	7.50	0.00	45,000	117.61	383,982	15,570	28	69,510
Mar-75	17,238	0	17,238	193.46	24.54	5.13	0.00	45,000	113.15	330,168	17,238	31	69,510
Apr-75	16,682	0	16,682	187.66	25.80	5.58	0.00	45,000	107.62	276,092	16,682	30	69,510
May-75	17,238	0	17,238	188.76	26.44	30.33	0.00	43,441	105.04	285,500	17,238	31	69,510
Jun-75	16,682	0	16,682	189.51	26.20	28.86	0.00	44,176	105.99	291,876	16,682	30	69,510
Jul-75	17,238	0	17,238	194.79	25.44	44.80	0.00	44,675	109.13	343,215	17,238	31	69,510
Aug-75	17,238	0	17,238	201.51	24.07	52.08	0.00	45,000	115.36	417,290	17,238	31	69,510
Sep-75	16,682	0	16,682	203.92	23.15	34.75	0.00	45,000	119.94	446,309	16,682	30	69,510
Oct-75	17,238	0	17,238	208.83	22.44	46.64	0.00	45,000	123.73	510,404	17,238	31	69,510
Nov-75	16,682	0	32,400	210.00	51.72	58.06	8.35	45,000	124.34	526,080	32,400	30	135,000
Dec-75	17,238	0	33,480	210.00	57.55	58.03	14.38	45,000	124.92	526,080	33,480	31	135,000

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 45 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-76	17,238	0	19,773	210.00	25.08	25.80	0.00	45,000	126.99	526,080	19,773	31	79,730
Feb-76	16,126	0	16,126	208.33	21.94	13.99	0.00	45,000	126.53	503,782	16,126	29	69,510
Mar-76	17,238	0	17,238	205.93	22.31	11.24	0.00	45,000	124.45	471,708	17,238	31	69,510
Apr-76	16,682	0	16,682	203.72	22.73	12.74	0.00	45,000	122.14	443,885	16,682	30	69,510
May-76	17,238	0	17,238	202.92	23.03	19.88	0.00	45,000	120.56	434,254	17,238	31	69,510
Jun-76	16,682	0	16,682	201.82	23.22	18.46	0.00	45,000	119.58	420,998	16,682	30	69,510
Jul-76	17,238	0	17,238	199.26	23.58	12.86	0.00	45,000	117.75	391,084	17,238	31	69,510
Aug-76	17,238	0	17,238	196.90	24.11	14.98	0.00	45,000	115.19	365,782	17,238	31	69,510
Sep-76	16,682	0	16,682	196.35	24.42	22.34	0.00	45,000	113.70	359,815	16,682	30	69,510
Oct-76	17,238	0	17,238	200.19	24.06	39.85	0.00	45,000	115.39	401,359	17,238	31	69,510
Nov-76	16,682	0	16,682	204.29	23.25	42.68	0.00	45,000	119.45	450,805	16,682	30	69,510
Dec-76	17,238	0	17,238	203.05	22.96	17.93	0.00	45,000	120.92	435,876	17,238	31	69,510
Jan-77	17,238	0	17,238	201.24	23.26	15.80	0.00	45,000	119.36	414,056	17,238	31	69,510
Feb-77	15,570	0	15,570	198.36	23.73	10.96	0.00	45,000	117.03	381,478	15,570	28	69,510
Mar-77	17,238	0	17,238	194.06	24.50	8.18	0.00	45,000	113.31	336,078	17,238	31	69,510
Apr-77	16,682	0	16,682	189.21	25.56	8.21	0.00	45,000	108.62	289,320	16,682	30	69,510
May-77	17,238	0	17,238	185.34	26.68	14.70	0.00	44,475	104.07	256,312	17,238	31	69,510
Jun-77	16,682	0	16,682	181.72	27.71	17.11	0.00	41,896	100.22	228,246	16,682	30	69,510
Jul-77	17,238	0	17,238	179.46	28.57	22.57	0.00	39,703	97.19	211,320	17,238	31	69,510
Aug-77	17,238	0	17,238	179.34	28.95	28.83	0.00	38,322	95.93	210,457	17,238	31	69,510
Sep-77	16,682	0	16,682	178.34	29.12	26.71	0.00	38,241	95.34	203,588	16,682	30	69,510
Oct-77	17,238	0	17,238	188.07	27.73	56.36	0.00	37,595	100.13	279,610	17,238	31	69,510
Nov-77	16,682	0	16,682	193.38	25.77	45.26	0.00	43,716	107.77	329,381	16,682	30	69,510
Dec-77	17,238	0	17,238	195.46	24.91	33.11	0.00	45,000	111.45	350,248	17,238	31	69,510
Jan-78	17,238	0	17,238	192.31	25.04	13.85	0.00	45,000	110.90	318,788	17,238	31	69,510
Feb-78	15,570	0	15,570	188.49	25.85	11.67	0.00	45,000	107.40	283,158	15,570	28	69,510
Mar-78	17,238	0	17,238	182.17	27.17	8.44	0.00	43,993	102.21	231,723	17,238	31	69,510
Apr-78	16,682	0	16,682	181.51	28.20	26.62	0.00	39,974	98.46	226,634	16,682	30	69,510
May-78	17,238	0	17,238	181.37	28.32	28.21	0.00	39,577	98.04	225,557	17,238	31	69,510
Jun-78	16,682	0	16,682	185.35	27.75	39.85	0.00	39,493	100.05	256,381	16,682	30	69,510
Jul-78	17,238	0	17,238	191.45	26.36	46.73	0.00	41,901	105.35	310,296	17,238	31	69,510
Aug-78	17,238	0	17,238	197.66	24.86	48.88	0.00	45,000	111.69	373,857	17,238	31	69,510
Sep-78	16,682	0	16,682	199.62	23.99	32.43	0.00	45,000	115.76	394,939	16,682	30	69,510
Oct-78	17,238	0	17,238	202.06	23.52	34.66	0.00	45,000	118.04	423,906	17,238	31	69,510
Nov-78	16,682	0	16,682	206.13	22.87	42.68	0.00	45,000	121.41	474,359	16,682	30	69,510
Dec-78	17,238	0	17,238	206.25	22.49	23.56	0.00	45,000	123.49	475,999	17,238	31	69,510
Jan-79	17,238	0	17,238	203.89	22.68	12.12	0.00	45,000	122.40	446,003	17,238	31	69,510
Feb-79	15,570	0	15,570	200.88	23.22	8.89	0.00	45,000	119.60	409,702	15,570	28	69,510
Mar-79	17,238	0	17,238	196.56	23.96	6.85	0.00	45,000	115.90	362,032	17,238	31	69,510
Apr-79	16,682	0	16,682	194.77	24.63	17.78	0.00	45,000	112.72	343,067	16,682	30	69,510
May-79	17,238	0	17,238	192.52	25.10	17.11	0.00	45,000	110.64	320,897	17,238	31	69,510
Jun-79	16,682	0	16,682	192.00	25.43	23.70	0.00	45,000	109.21	315,746	16,682	30	69,510
Jul-79	17,238	0	17,238	192.44	25.44	27.30	0.00	45,000	109.17	320,033	17,238	31	69,510
Aug-79	17,238	0	17,238	195.50	25.02	36.73	0.00	45,000	110.99	350,688	17,238	31	69,510
Sep-79	16,682	0	16,682	197.17	24.49	31.75	0.00	45,000	113.39	368,578	16,682	30	69,510
Oct-79	17,238	0	17,238	198.15	24.20	28.55	0.00	45,000	114.76	379,216	17,238	31	69,510
Nov-79	16,682	0	16,682	202.36	23.63	42.82	0.00	45,000	117.52	427,503	16,682	30	69,510
Dec-79	17,238	0	17,238	206.22	22.83	41.09	0.00	45,000	121.61	475,575	17,238	31	69,510

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 45 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-80	17,238	0	17,238	207.79	22.33	30.87	0.00	45,000	124.33	496,629	17,238	31	69,510
Feb-80	16,126	0	16,126	206.98	22.26	18.52	0.00	45,000	124.71	485,739	16,126	29	69,510
Mar-80	17,238	0	17,238	204.23	22.59	10.05	0.00	45,000	122.93	450,037	17,238	31	69,510
Apr-80	16,682	0	16,682	201.41	23.13	10.70	0.00	45,000	120.05	416,084	16,682	30	69,510
May-80	17,238	0	17,238	201.08	23.45	22.37	0.00	45,000	118.43	412,086	17,238	31	69,510
Jun-80	16,682	0	16,682	202.26	23.36	29.28	0.00	45,000	118.87	426,353	16,682	30	69,510
Jul-80	17,238	0	17,238	200.97	23.37	17.93	0.00	45,000	118.81	410,697	17,238	31	69,510
Aug-80	17,238	0	17,238	200.37	23.56	21.27	0.00	45,000	117.84	403,545	17,238	31	69,510
Sep-80	16,682	0	16,682	200.27	23.63	23.56	0.00	45,000	117.49	402,337	16,682	30	69,510
Oct-80	17,238	0	17,238	201.73	23.50	30.39	0.00	45,000	118.18	419,932	17,238	31	69,510
Nov-80	16,682	0	16,682	205.99	22.92	43.64	0.00	45,000	121.17	472,587	16,682	30	69,510
Dec-80	17,238	0	17,238	209.36	22.21	39.59	0.00	45,000	125.01	517,541	17,238	31	69,510
Jan-81	17,238	0	17,238	209.49	21.90	23.28	0.00	45,000	126.80	519,260	17,238	31	69,510
Feb-81	15,570	0	15,570	208.57	21.97	17.67	0.00	45,000	126.39	507,029	15,570	28	69,510
Mar-81	17,238	0	17,238	206.86	22.20	14.36	0.00	45,000	125.05	484,206	17,238	31	69,510
Apr-81	16,682	0	32,400	210.00	84.03	100.68	40.26	45,000	123.20	526,080	32,400	30	135,000
May-81	17,238	0	33,480	210.00	45.89	46.36	2.74	45,000	124.97	526,080	33,480	31	135,000
Jun-81	16,682	0	27,745	210.00	36.77	37.21	0.00	45,000	125.59	526,080	27,745	30	115,603
Jul-81	17,238	0	30,782	210.00	39.59	39.99	0.00	45,000	125.25	526,080	30,782	31	124,122
Aug-81	17,238	0	29,961	210.00	38.49	38.91	0.00	45,000	125.38	526,080	29,961	31	120,810
Sep-81	16,682	0	20,891	210.00	27.44	27.90	0.00	45,000	126.71	526,080	20,891	30	87,047
Oct-81	17,238	0	25,622	210.00	32.74	33.16	0.00	45,000	126.07	526,080	25,622	31	103,315
Nov-81	16,682	0	30,380	210.00	40.40	40.78	0.00	45,000	125.17	526,080	30,380	30	126,584
Dec-81	17,238	0	33,480	210.00	61.22	61.71	18.04	45,000	124.90	526,080	33,480	31	135,000
Jan-82	17,238	0	24,637	210.00	31.44	32.09	0.00	45,000	126.23	526,080	24,637	31	99,344
Feb-82	15,570	0	15,570	208.50	21.93	14.56	0.00	45,000	126.62	506,043	15,570	28	69,510
Mar-82	17,238	0	17,238	205.69	22.32	9.18	0.00	45,000	124.41	468,481	17,238	31	69,510
Apr-82	16,682	0	16,682	203.34	22.79	12.26	0.00	45,000	121.81	439,331	16,682	30	69,510
May-82	17,238	0	17,238	203.03	23.06	22.06	0.00	45,000	120.42	435,566	17,238	31	69,510
Jun-82	16,682	0	16,682	202.10	23.18	19.26	0.00	45,000	119.78	424,366	16,682	30	69,510
Jul-82	17,238	0	17,238	204.15	23.07	32.74	0.00	45,000	120.36	449,120	17,238	31	69,510
Aug-82	17,238	0	17,238	205.84	22.70	31.18	0.00	45,000	122.31	470,577	17,238	31	69,510
Sep-82	16,682	0	16,682	207.14	22.43	29.51	0.00	45,000	123.80	487,885	16,682	30	69,510
Oct-82	17,238	0	24,256	210.00	31.30	45.91	0.00	45,000	124.81	526,080	24,256	31	97,807
Nov-82	16,682	0	23,845	210.00	31.44	31.97	0.00	45,000	126.23	526,080	23,845	30	99,353
Dec-82	17,238	0	17,238	209.56	21.84	20.39	0.00	45,000	127.16	520,209	17,238	31	69,510
Jan-83	17,238	0	17,238	208.04	22.01	15.26	0.00	45,000	126.16	499,972	17,238	31	69,510
Feb-83	15,570	0	15,570	205.38	22.39	8.50	0.00	45,000	124.03	464,415	15,570	28	69,510
Mar-83	17,238	0	17,238	201.51	23.00	6.20	0.00	45,000	120.70	417,227	17,238	31	69,510
Apr-83	16,682	0	16,682	197.07	23.83	5.44	0.00	45,000	116.52	367,577	16,682	30	69,510
May-83	17,238	0	17,238	200.10	24.00	36.65	0.00	45,000	115.71	400,279	17,238	31	69,510
Jun-83	16,682	0	16,682	199.66	23.72	22.20	0.00	45,000	117.04	395,450	16,682	30	69,510
Jul-83	17,238	0	17,238	198.50	23.89	19.63	0.00	45,000	116.22	382,937	17,238	31	69,510
Aug-83	17,238	0	17,238	197.80	24.09	21.66	0.00	45,000	115.26	375,422	17,238	31	69,510
Sep-83	16,682	0	16,682	198.60	24.08	27.70	0.00	45,000	115.31	383,993	16,682	30	69,510
Oct-83	17,238	0	17,238	201.04	23.73	34.32	0.00	45,000	117.03	411,536	17,238	31	69,510
Nov-83	16,682	0	16,682	204.59	23.13	39.99	0.00	45,000	120.04	454,370	16,682	30	69,510
Dec-83	17,238	0	33,480	210.00	49.35	76.61	5.22	45,000	122.20	526,080	33,480	31	135,000

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 45 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-84	17,238	0	19,546	210.00	24.79	25.60	0.00	45,000	127.03	526,080	19,546	31	78,815
Feb-84	16,126	0	16,126	208.64	21.92	15.46	0.00	45,000	126.69	507,900	16,126	29	69,510
Mar-84	17,238	0	17,238	205.77	22.30	8.95	0.00	45,000	124.53	469,645	17,238	31	69,510
Apr-84	16,682	0	16,682	202.11	22.90	6.32	0.00	45,000	121.24	424,537	16,682	30	69,510
May-84	17,238	0	17,238	200.96	23.39	18.66	0.00	45,000	118.73	410,594	17,238	31	69,510
Jun-84	16,682	0	16,682	202.38	23.36	30.33	0.00	45,000	118.86	427,741	16,682	30	69,510
Jul-84	17,238	0	17,238	205.81	22.87	39.11	0.00	45,000	121.39	470,128	17,238	31	69,510
Aug-84	17,238	0	33,480	210.00	46.64	67.91	2.73	45,000	122.82	526,080	33,480	31	135,000
Sep-84	16,682	0	32,400	210.00	47.99	48.43	4.83	45,000	124.96	526,080	32,400	30	135,000
Oct-84	17,238	0	33,480	210.00	54.73	55.14	11.56	45,000	124.93	526,080	33,480	31	135,000
Nov-84	16,682	0	32,400	210.00	55.46	55.85	12.29	45,000	124.92	526,080	32,400	30	135,000
Dec-84	17,238	0	27,018	210.00	34.58	35.15	0.00	45,000	125.85	526,080	27,018	31	108,942
Jan-85	17,238	0	17,238	209.29	21.86	19.17	0.00	45,000	127.02	516,553	17,238	31	69,510
Feb-85	15,570	0	15,570	207.47	22.09	12.89	0.00	45,000	125.73	492,287	15,570	28	69,510
Mar-85	17,238	0	17,238	205.39	22.44	12.94	0.00	45,000	123.73	464,473	17,238	31	69,510
Apr-85	16,682	0	16,682	202.33	22.92	9.40	0.00	45,000	121.13	427,163	16,682	30	69,510
May-85	17,238	0	17,238	201.40	23.32	19.57	0.00	45,000	119.07	415,945	17,238	31	69,510
Jun-85	16,682	0	16,682	203.70	23.18	34.18	0.00	45,000	119.77	443,608	16,682	30	69,510
Jul-85	17,238	0	17,238	204.34	22.90	26.20	0.00	45,000	121.27	451,341	17,238	31	69,510
Aug-85	17,238	0	17,238	203.90	22.88	21.21	0.00	45,000	121.37	446,025	17,238	31	69,510
Sep-85	16,682	0	16,682	206.90	22.62	37.86	0.00	45,000	122.73	484,644	16,682	30	69,510
Oct-85	17,238	0	17,238	208.51	22.21	30.61	0.00	45,000	125.04	506,220	17,238	31	69,510
Nov-85	16,682	0	16,682	209.97	21.93	29.88	0.00	45,000	126.61	525,741	16,682	30	69,510
Dec-85	17,238	0	33,480	210.00	51.27	51.97	8.10	45,000	124.93	526,080	33,480	31	135,000
Jan-86	17,238	0	17,238	209.01	21.88	17.73	0.00	45,000	126.88	512,859	17,238	31	69,510
Feb-86	15,570	0	15,570	206.95	22.16	11.78	0.00	45,000	125.32	485,411	15,570	28	69,510
Mar-86	17,238	0	17,238	204.68	22.55	12.15	0.00	45,000	123.13	455,478	17,238	31	69,510
Apr-86	16,682	0	16,682	204.34	22.80	21.98	0.00	45,000	121.77	451,371	16,682	30	69,510
May-86	17,238	0	17,238	209.68	22.33	49.36	0.00	45,000	124.36	521,767	17,238	31	69,510
Jun-86	16,682	0	21,625	210.00	28.47	30.64	0.00	45,000	126.42	526,080	21,625	30	90,106
Jul-86	17,238	0	19,611	210.00	24.87	25.35	0.00	45,000	127.02	526,080	19,611	31	79,076
Aug-86	17,238	0	17,238	209.95	21.80	22.03	0.00	45,000	127.36	525,463	17,238	31	69,510
Sep-86	16,682	0	27,140	210.00	35.95	36.65	0.00	45,000	125.66	526,080	27,140	30	113,084
Oct-86	17,238	0	33,480	210.00	57.34	57.66	14.17	45,000	124.92	526,080	33,480	31	135,000
Nov-86	16,682	0	29,825	210.00	39.64	40.16	0.00	45,000	125.24	526,080	29,825	30	124,272
Dec-86	17,238	0	23,145	210.00	29.48	30.27	0.00	45,000	126.46	526,080	23,145	31	93,327
Jan-87	17,238	0	17,238	208.08	21.97	13.34	0.00	45,000	126.41	500,507	17,238	31	69,510
Feb-87	15,570	0	15,570	206.16	22.31	12.60	0.00	45,000	124.45	474,859	15,570	28	69,510
Mar-87	17,238	0	17,238	202.86	22.79	8.21	0.00	45,000	121.84	433,545	17,238	31	69,510
Apr-87	16,682	0	16,682	203.89	23.02	28.52	0.00	45,000	120.61	445,949	16,682	30	69,510
May-87	17,238	0	19,702	210.00	25.61	55.93	0.00	45,000	123.93	526,080	19,702	31	79,443
Jun-87	16,682	0	26,907	210.00	35.62	36.05	0.00	45,000	125.73	526,080	26,907	30	112,114
Jul-87	17,238	0	28,054	210.00	35.95	36.45	0.00	45,000	125.69	526,080	28,054	31	113,123
Aug-87	17,238	0	33,480	210.00	43.70	44.24	0.55	45,000	124.97	526,080	33,480	31	135,000
Sep-87	16,682	0	32,400	210.00	51.04	51.51	7.88	45,000	124.94	526,080	32,400	30	135,000
Oct-87	17,238	0	30,558	210.00	39.29	39.76	0.00	45,000	125.29	526,080	30,558	31	123,218
Nov-87	16,682	0	32,400	210.00	60.20	60.66	17.03	45,000	124.90	526,080	32,400	30	135,000
Dec-87	17,238	0	22,916	210.00	29.18	29.79	0.00	45,000	126.50	526,080	22,916	31	92,401

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 45 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-88	17,238	0	17,238	208.17	21.96	13.71	0.00	45,000	126.45	501,648	17,238	31	69,510
Feb-88	16,126	0	16,126	206.53	22.27	14.50	0.00	45,000	124.68	479,788	16,126	29	69,510
Mar-88	17,238	0	17,238	203.48	22.69	9.15	0.00	45,000	122.36	440,966	17,238	31	69,510
Apr-88	16,682	0	16,682	199.75	23.37	6.97	0.00	45,000	118.82	396,395	16,682	30	69,510
May-88	17,238	0	17,238	199.82	23.75	24.50	0.00	45,000	116.94	397,130	17,238	31	69,510
Jun-88	16,682	0	16,682	199.40	23.78	22.34	0.00	45,000	116.76	392,595	16,682	30	69,510
Jul-88	17,238	0	17,238	203.92	23.35	43.78	0.00	45,000	118.89	446,356	17,238	31	69,510
Aug-88	17,238	0	20,857	210.00	27.15	57.29	0.00	45,000	123.76	526,080	20,857	31	84,103
Sep-88	16,682	0	30,368	210.00	40.38	40.84	0.00	45,000	125.17	526,080	30,368	30	126,535
Oct-88	17,238	0	33,480	210.00	50.42	50.81	7.26	45,000	124.95	526,080	33,480	31	135,000
Nov-88	16,682	0	32,400	210.00	43.96	44.46	0.81	45,000	124.97	526,080	32,400	30	135,000
Dec-88	17,238	0	24,863	210.00	31.74	32.40	0.00	45,000	126.19	526,080	24,863	31	100,253
Jan-89	17,238	0	17,238	209.58	21.83	20.62	0.00	45,000	127.17	520,439	17,238	31	69,510
Feb-89	15,570	0	15,570	209.06	21.92	19.94	0.00	45,000	126.69	513,497	15,570	28	69,510
Mar-89	17,238	0	17,238	206.85	22.16	12.12	0.00	45,000	125.29	483,969	17,238	31	69,510
Apr-89	16,682	0	16,682	203.83	22.63	8.64	0.00	45,000	122.68	445,187	16,682	30	69,510
May-89	17,238	0	17,238	202.41	23.07	17.19	0.00	45,000	120.35	428,088	17,238	31	69,510
Jun-89	16,682	0	16,682	204.24	23.03	31.92	0.00	45,000	120.56	450,215	16,682	30	69,510
Jul-89	17,238	0	17,238	206.63	22.62	34.47	0.00	45,000	122.76	481,044	17,238	31	69,510
Aug-89	17,238	0	17,238	209.71	22.12	37.86	0.00	45,000	125.51	522,224	17,238	31	69,510
Sep-89	16,682	0	23,013	210.00	30.35	32.28	0.00	45,000	126.21	526,080	23,013	30	95,887
Oct-89	17,238	0	33,480	210.00	58.10	58.54	14.93	45,000	124.91	526,080	33,480	31	135,000
Nov-89	16,682	0	32,400	210.00	66.97	67.43	23.79	45,000	124.88	526,080	32,400	30	135,000
Dec-89	17,238	0	27,809	210.00	35.63	36.19	0.00	45,000	125.72	526,080	27,809	31	112,133
Jan-90	17,238	0	22,882	210.00	29.13	29.74	0.00	45,000	126.50	526,080	22,882	31	92,264
Feb-90	15,570	0	15,570	209.09	21.88	17.59	0.00	45,000	126.92	513,915	15,570	28	69,510
Mar-90	17,238	0	17,238	207.34	22.11	14.05	0.00	45,000	125.56	490,514	17,238	31	69,510
Apr-90	16,682	0	16,682	207.22	22.28	22.37	0.00	45,000	124.61	489,010	16,682	30	69,510
May-90	17,238	0	33,480	210.00	60.26	74.57	16.59	45,000	123.48	526,080	33,480	31	135,000
Jun-90	16,682	0	16,682	209.76	21.82	21.01	0.00	45,000	127.26	522,870	16,682	30	69,510
Jul-90	17,238	0	17,238	209.12	21.90	19.14	0.00	45,000	126.81	514,312	17,238	31	69,510
Aug-90	17,238	0	22,912	210.00	29.28	34.10	0.00	45,000	126.05	526,080	22,912	31	92,386
Sep-90	16,682	0	32,400	210.00	44.31	44.75	1.15	45,000	124.97	526,080	32,400	30	135,000
Oct-90	17,238	0	33,480	210.00	57.02	57.43	13.85	45,000	124.92	526,080	33,480	31	135,000
Nov-90	16,682	0	32,400	210.00	58.17	58.62	15.00	45,000	124.91	526,080	32,400	30	135,000
Dec-90	17,238	0	33,480	210.00	62.54	63.10	19.36	45,000	124.89	526,080	33,480	31	135,000
Jan-91	17,238	0	17,238	209.42	21.85	19.60	0.00	45,000	127.09	518,279	17,238	31	69,510
Feb-91	15,570	0	15,570	207.57	22.06	12.66	0.00	45,000	125.85	493,695	15,570	28	69,510
Mar-91	17,238	0	17,238	206.04	22.37	15.43	0.00	45,000	124.12	473,257	17,238	31	69,510
Apr-91	16,682	0	16,682	203.65	22.73	11.75	0.00	45,000	122.18	443,092	16,682	30	69,510
May-91	17,238	0	17,238	205.44	22.79	31.44	0.00	45,000	121.84	465,230	17,238	31	69,510
Jun-91	16,682	0	16,682	205.22	22.65	21.92	0.00	45,000	122.62	462,315	16,682	30	69,510
Jul-91	17,238	0	17,238	205.20	22.67	22.85	0.00	45,000	122.49	461,961	17,238	31	69,510
Aug-91	17,238	0	17,238	205.19	22.67	23.05	0.00	45,000	122.47	461,841	17,238	31	69,510
Sep-91	16,682	0	16,682	207.22	22.48	33.36	0.00	45,000	123.51	488,975	16,682	30	69,510
Oct-91	17,238	0	17,238	209.40	22.10	33.42	0.00	45,000	125.66	518,091	17,238	31	69,510
Nov-91	16,682	0	32,400	210.00	53.92	57.40	10.65	45,000	124.62	526,080	32,400	30	135,000
Dec-91	17,238	0	25,892	210.00	33.09	33.62	0.00	45,000	126.03	526,080	25,892	31	104,405

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 45 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-92	17,238	0	17,238	208.77	21.91	16.37	0.00	45,000	126.76	509,686	17,238	31	69,510
Feb-92	16,126	0	16,126	206.54	22.22	10.93	0.00	45,000	124.99	479,829	16,126	29	69,510
Mar-92	17,238	0	17,238	203.49	22.69	8.75	0.00	45,000	122.36	441,162	17,238	31	69,510
Apr-92	16,682	0	16,682	201.43	23.20	14.05	0.00	45,000	119.68	416,286	16,682	30	69,510
May-92	17,238	0	17,238	206.47	22.89	46.64	0.00	45,000	121.28	478,944	17,238	31	69,510
Jun-92	16,682	0	20,006	210.00	26.63	45.23	0.00	45,000	125.04	526,080	20,006	30	83,357
Jul-92	17,238	0	27,000	210.00	34.56	34.92	0.00	45,000	125.85	526,080	27,000	31	108,869
Aug-92	17,238	0	33,480	210.00	49.51	49.84	6.36	45,000	124.95	526,080	33,480	31	135,000
Sep-92	16,682	0	30,636	210.00	40.75	41.12	0.00	45,000	125.15	526,080	30,636	30	127,650
Oct-92	17,238	0	25,801	210.00	32.97	33.39	0.00	45,000	126.04	526,080	25,801	31	104,037
Nov-92	16,682	0	32,400	210.00	48.41	48.82	5.25	45,000	124.95	526,080	32,400	30	135,000
Dec-92	17,238	0	24,050	210.00	30.67	31.12	0.00	45,000	126.32	526,080	24,050	31	96,976
Jan-93	17,238	0	19,596	210.00	24.85	25.32	0.00	45,000	127.02	526,080	19,596	31	79,016
Feb-93	15,570	0	15,570	208.13	21.96	12.21	0.00	45,000	126.43	501,114	15,570	28	69,510
Mar-93	17,238	0	17,238	206.97	22.23	17.02	0.00	45,000	124.88	485,690	17,238	31	69,510
Apr-93	16,682	0	16,682	207.76	22.27	26.82	0.00	45,000	124.70	496,192	16,682	30	69,510
May-93	17,238	0	19,310	210.00	24.70	36.33	0.00	45,000	125.92	526,080	19,310	31	77,865
Jun-93	16,682	0	32,400	210.00	47.46	47.83	4.31	45,000	124.96	526,080	32,400	30	135,000
Jul-93	17,238	0	27,838	210.00	35.67	36.11	0.00	45,000	125.72	526,080	27,838	31	112,250
Aug-93	17,238	0	20,053	210.00	25.44	25.86	0.00	45,000	126.95	526,080	20,053	31	80,860
Sep-93	16,682	0	28,148	210.00	37.33	37.69	0.00	45,000	125.52	526,080	28,148	30	117,284
Oct-93	17,238	0	33,480	210.00	57.80	58.20	14.63	45,000	124.91	526,080	33,480	31	135,000
Nov-93	16,682	0	30,414	210.00	40.44	40.78	0.00	45,000	125.17	526,080	30,414	30	126,723
Dec-93	17,238	0	20,525	210.00	26.06	26.51	0.00	45,000	126.87	526,080	20,525	31	82,762
Jan-94	17,238	0	17,238	207.99	21.97	12.86	0.00	45,000	126.36	499,305	17,238	31	69,510
Feb-94	15,570	0	15,570	205.34	22.40	8.64	0.00	45,000	123.98	463,852	15,570	28	69,510
Mar-94	17,238	0	17,238	201.71	22.99	7.31	0.00	45,000	120.78	419,618	17,238	31	69,510
Apr-94	16,682	0	16,682	197.56	23.76	6.40	0.00	45,000	116.88	372,810	16,682	30	69,510
May-94	17,238	0	17,238	197.79	24.19	25.46	0.00	45,000	114.77	375,286	17,238	31	69,510
Jun-94	16,682	0	16,682	200.73	23.85	36.73	0.00	45,000	116.44	407,915	16,682	30	69,510
Jul-94	17,238	0	17,238	203.92	23.23	37.95	0.00	45,000	119.54	446,273	17,238	31	69,510
Aug-94	17,238	0	17,238	206.02	22.71	32.99	0.00	45,000	122.29	472,881	17,238	31	69,510
Sep-94	16,682	0	16,682	208.29	22.31	34.41	0.00	45,000	124.47	503,216	16,682	30	69,510
Oct-94	17,238	0	21,951	210.00	28.11	37.07	0.00	45,000	125.77	526,080	21,951	31	88,511
Nov-94	16,682	0	32,400	210.00	64.89	65.28	21.71	45,000	124.88	526,080	32,400	30	135,000
Dec-94	17,238	0	23,306	210.00	29.69	30.30	0.00	45,000	126.44	526,080	23,306	31	93,975
Jan-95	17,238	0	17,238	208.56	21.92	15.43	0.00	45,000	126.65	506,855	17,238	31	69,510
Feb-95	15,570	0	15,570	205.89	22.29	8.33	0.00	45,000	124.55	471,227	15,570	28	69,510
Mar-95	17,238	0	17,238	201.81	22.92	4.79	0.00	45,000	121.15	420,908	17,238	31	69,510
Apr-95	16,682	0	16,682	197.65	23.73	6.06	0.00	45,000	116.99	373,794	16,682	30	69,510
May-95	17,238	0	17,238	196.31	24.34	19.17	0.00	45,000	114.06	359,351	17,238	31	69,510
Jun-95	16,682	0	16,682	199.18	24.18	36.39	0.00	45,000	114.84	390,240	16,682	30	69,510
Jul-95	17,238	0	17,238	203.69	23.40	43.61	0.00	45,000	118.67	443,495	17,238	31	69,510
Aug-95	17,238	0	17,238	207.49	22.59	41.32	0.00	45,000	122.94	492,578	17,238	31	69,510
Sep-95	16,682	0	16,682	208.69	22.14	28.72	0.00	45,000	125.44	508,635	16,682	30	69,510
Oct-95	17,238	0	18,912	210.00	24.09	30.98	0.00	45,000	126.46	526,080	18,912	31	76,259
Nov-95	16,682	0	28,708	210.00	38.10	38.49	0.00	45,000	125.43	526,080	28,708	30	119,617
Dec-95	17,238	0	33,480	210.00	49.52	50.01	6.36	45,000	124.95	526,080	33,480	31	135,000

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 45 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-96	17,238	0	33,480	210.00	72.51	73.21	29.32	45,000	124.85	526,080	33,480	31	135,000
Feb-96	16,126	0	21,800	210.00	29.69	30.53	0.00	45,000	126.44	526,080	21,800	29	93,967
Mar-96	17,238	0	17,238	209.98	21.80	22.63	0.00	45,000	127.37	525,810	17,238	31	69,510
Apr-96	16,682	0	16,682	209.32	21.86	19.26	0.00	45,000	127.03	516,989	16,682	30	69,510
May-96	17,238	0	33,480	210.00	43.50	47.46	0.23	45,000	124.63	526,080	33,480	31	135,000
Jun-96	16,682	0	31,638	210.00	42.11	42.54	0.00	45,000	125.05	526,080	31,638	30	131,826
Jul-96	17,238	0	33,480	210.00	44.87	45.26	1.72	45,000	124.97	526,080	33,480	31	135,000
Aug-96	17,238	0	33,480	210.00	49.44	49.87	6.28	45,000	124.95	526,080	33,480	31	135,000
Sep-96	16,682	0	25,177	210.00	33.26	33.67	0.00	45,000	126.01	526,080	25,177	30	104,903
Oct-96	17,238	0	32,416	210.00	41.75	42.14	0.00	45,000	125.08	526,080	32,416	31	130,711
Nov-96	16,682	0	32,400	210.00	82.85	83.18	39.64	45,000	124.81	526,080	32,400	30	135,000
Dec-96	17,238	0	33,480	210.00	94.29	94.67	49.96	45,000	121.64	526,080	33,480	31	135,000
Jan-97	17,238	0	22,376	210.00	28.47	28.97	0.00	45,000	126.58	526,080	22,376	31	90,224
Feb-97	15,570	0	15,570	208.98	21.89	16.79	0.00	45,000	126.86	512,452	15,570	28	69,510
Mar-97	17,238	0	17,238	206.21	22.23	9.09	0.00	45,000	124.93	475,544	17,238	31	69,510
Apr-97	16,682	0	16,682	203.00	22.77	7.76	0.00	45,000	121.94	435,199	16,682	30	69,510
May-97	17,238	0	17,238	204.78	22.92	31.35	0.00	45,000	121.14	456,737	17,238	31	69,510
Jun-97	16,682	0	16,682	205.54	22.68	26.85	0.00	45,000	122.45	466,562	16,682	30	69,510
Jul-97	17,238	0	17,238	204.05	22.74	16.20	0.00	45,000	122.10	447,938	17,238	31	69,510
Aug-97	17,238	0	17,238	201.84	23.11	13.51	0.00	45,000	120.17	421,200	17,238	31	69,510
Sep-97	16,682	0	16,682	200.68	23.44	18.38	0.00	45,000	118.45	407,288	16,682	30	69,510
Oct-97	17,238	0	17,238	200.85	23.54	24.61	0.00	45,000	117.94	409,320	17,238	31	69,510
Nov-97	16,682	0	16,682	200.43	23.57	21.86	0.00	45,000	117.81	404,208	16,682	30	69,510
Dec-97	17,238	0	17,238	199.86	23.67	21.58	0.00	45,000	117.31	397,546	17,238	31	69,510
Jan-98	17,238	0	17,238	196.80	24.05	12.18	0.00	45,000	115.44	364,621	17,238	31	69,510
Feb-98	15,570	0	15,570	192.83	24.81	8.35	0.00	45,000	111.92	323,873	15,570	28	69,510
Mar-98	17,238	0	17,238	186.52	26.01	4.98	0.00	45,000	106.77	266,407	17,238	31	69,510
Apr-98	16,682	0	16,682	182.16	27.46	14.30	0.00	42,685	101.13	231,638	16,682	30	69,510
May-98	17,238	0	17,238	186.14	27.52	39.56	0.00	39,968	100.91	263,181	17,238	31	69,510
Jun-98	16,682	0	16,682	185.13	27.12	24.02	0.00	42,432	102.38	254,557	16,682	30	69,510
Jul-98	17,238	0	17,238	186.27	27.10	30.95	0.00	41,759	102.45	264,276	17,238	31	69,510
Aug-98	17,238	0	17,238	188.49	26.65	33.93	0.00	42,518	104.18	283,166	17,238	31	69,510
Sep-98	16,682	0	16,682	190.74	26.06	34.15	0.00	43,994	106.54	303,328	16,682	30	69,510
Oct-98	17,238	0	17,238	192.82	25.54	33.47	0.00	45,000	108.71	323,811	17,238	31	69,510
Nov-98	16,682	0	16,682	196.23	24.88	38.52	0.00	45,000	111.59	358,477	16,682	30	69,510
Dec-98	17,238	0	17,238	203.50	23.69	54.83	0.00	45,000	117.22	441,237	17,238	31	69,510
Jan-99	17,238	0	17,238	205.15	22.84	30.76	0.00	45,000	121.59	461,384	17,238	31	69,510
Feb-99	15,570	0	15,570	205.31	22.66	24.02	0.00	45,000	122.51	463,448	15,570	28	69,510
Mar-99	17,238	0	17,238	203.44	22.82	14.84	0.00	45,000	121.65	440,580	17,238	31	69,510
Apr-99	16,682	0	16,682	202.15	23.13	17.53	0.00	45,000	120.02	424,988	16,682	30	69,510
May-99	17,238	0	17,238	202.62	23.22	25.66	0.00	45,000	119.60	430,605	17,238	31	69,510
Jun-99	16,682	0	16,682	205.38	22.90	36.22	0.00	45,000	121.27	464,366	16,682	30	69,510
Jul-99	17,238	0	17,238	209.93	22.22	45.26	0.00	45,000	124.99	525,133	17,238	31	69,510
Aug-99	17,238	0	33,480	210.00	53.08	53.81	9.90	45,000	124.90	526,080	33,480	31	135,000
Sep-99	16,682	0	32,400	210.00	43.83	44.24	0.68	45,000	124.97	526,080	32,400	30	135,000
Oct-99	17,238	0	31,143	210.00	40.07	40.47	0.00	45,000	125.20	526,080	31,143	31	125,578
Nov-99	16,682	0	32,400	210.00	51.76	52.11	8.60	45,000	124.94	526,080	32,400	30	135,000
Dec-99	17,238	0	33,480	210.00	126.49	126.79	82.01	45,000	121.24	526,080	33,480	31	135,000

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 55 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-48	17,238	0	40,920	210.00	73.12	16.57	22.27	55,000	129.62	526,080	40,920	31	165,000
Feb-48	16,126	0	16,126	207.37	22.03	9.01	0.00	55,000	126.04	490,940	16,126	29	69,510
Mar-48	17,238	0	17,238	203.79	22.59	6.32	0.00	55,000	122.93	444,792	17,238	31	69,510
Apr-48	16,682	0	16,682	199.89	23.32	6.06	0.00	55,000	119.05	397,891	16,682	30	69,510
May-48	17,238	0	17,238	197.32	23.99	14.16	0.00	55,000	115.73	370,244	17,238	31	69,510
Jun-48	16,682	0	16,682	197.09	24.30	23.73	0.00	55,000	114.29	367,741	16,682	30	69,510
Jul-48	17,238	0	17,238	200.91	23.90	40.04	0.00	55,000	116.19	410,066	17,238	31	69,510
Aug-48	17,238	0	17,238	202.61	23.34	31.49	0.00	55,000	118.96	430,524	17,238	31	69,510
Sep-48	16,682	0	16,682	203.26	23.11	26.59	0.00	55,000	120.16	438,398	16,682	30	69,510
Oct-48	17,238	0	17,238	206.60	22.71	38.94	0.00	55,000	122.29	480,646	17,238	31	69,510
Nov-48	16,682	0	20,921	210.00	27.87	45.82	0.00	55,000	124.95	526,080	20,921	30	87,172
Dec-48	17,238	0	22,548	210.00	28.70	29.48	0.00	55,000	126.56	526,080	22,548	31	90,920
Jan-49	17,238	0	17,238	208.42	21.94	14.98	0.00	55,000	126.58	504,925	17,238	31	69,510
Feb-49	15,570	0	15,570	205.91	22.31	9.37	0.00	55,000	124.48	471,429	15,570	28	69,510
Mar-49	17,238	0	17,238	202.25	22.88	6.85	0.00	55,000	121.38	426,195	17,238	31	69,510
Apr-49	16,682	0	16,682	198.38	23.62	7.16	0.00	55,000	117.57	381,615	16,682	30	69,510
May-49	17,238	0	17,238	198.12	24.07	23.51	0.00	55,000	115.36	378,867	17,238	31	69,510
Jun-49	16,682	0	16,682	201.55	23.72	39.14	0.00	55,000	117.09	417,774	16,682	30	69,510
Jul-49	17,238	0	17,238	207.46	22.78	51.03	0.00	55,000	121.90	492,155	17,238	31	69,510
Aug-49	17,238	0	27,152	210.00	35.12	48.31	0.00	55,000	124.51	526,080	27,152	31	109,483
Sep-49	16,682	0	28,507	210.00	37.82	38.37	0.00	55,000	125.46	526,080	28,507	30	118,778
Oct-49	17,238	0	34,536	210.00	44.55	45.03	0.00	55,000	124.88	526,080	34,536	31	139,258
Nov-49	16,682	0	39,600	210.00	60.87	61.34	7.82	55,000	124.24	526,080	39,600	30	165,000
Dec-49	17,238	0	40,855	210.00	52.95	53.58	0.00	55,000	124.28	526,080	40,855	31	164,736
Jan-50	17,238	0	17,238	209.58	21.83	20.65	0.00	55,000	127.17	520,410	17,238	31	69,510
Feb-50	15,570	0	15,570	208.52	21.97	17.08	0.00	55,000	126.41	506,349	15,570	28	69,510
Mar-50	17,238	0	17,238	206.00	22.29	10.76	0.00	55,000	124.59	472,706	17,238	31	69,510
Apr-50	16,682	0	16,682	205.31	22.58	20.02	0.00	55,000	122.95	463,498	16,682	30	69,510
May-50	17,238	0	17,238	208.84	22.32	40.47	0.00	55,000	124.40	510,596	17,238	31	69,510
Jun-50	16,682	0	18,071	210.00	23.76	30.16	0.00	55,000	126.57	526,080	18,071	30	75,296
Jul-50	17,238	0	40,920	210.00	53.47	53.89	0.44	55,000	124.27	526,080	40,920	31	165,000
Aug-50	17,238	0	35,175	210.00	45.39	45.85	0.00	55,000	124.82	526,080	35,175	31	141,834
Sep-50	16,682	0	24,560	210.00	32.41	32.94	0.00	55,000	126.11	526,080	24,560	30	102,331
Oct-50	17,238	0	20,278	210.00	25.74	26.20	0.00	55,000	126.91	526,080	20,278	31	81,765
Nov-50	16,682	0	37,694	210.00	50.41	50.83	0.00	55,000	124.46	526,080	37,694	30	157,058
Dec-50	17,238	0	40,920	210.00	59.59	60.12	6.54	55,000	124.25	526,080	40,920	31	165,000
Jan-51	17,238	0	17,238	209.41	21.85	19.74	0.00	55,000	127.08	518,151	17,238	31	69,510
Feb-51	15,570	0	27,465	210.00	39.18	43.27	0.00	55,000	125.00	526,080	27,465	28	122,612
Mar-51	17,238	0	17,644	210.00	22.32	23.28	0.00	55,000	127.32	526,080	17,644	31	71,145
Apr-51	16,682	0	16,682	209.38	21.85	19.43	0.00	55,000	127.07	517,769	16,682	30	69,510
May-51	17,238	0	17,447	210.00	22.12	25.80	0.00	55,000	127.03	526,080	17,447	31	70,349
Jun-51	16,682	0	22,785	210.00	30.00	30.53	0.00	55,000	126.40	526,080	22,785	30	94,937
Jul-51	17,238	0	25,611	210.00	32.72	33.22	0.00	55,000	126.07	526,080	25,611	31	103,270
Aug-51	17,238	0	19,197	210.00	24.33	24.86	0.00	55,000	127.08	526,080	19,197	31	77,408
Sep-51	16,682	0	21,485	210.00	28.24	28.74	0.00	55,000	126.61	526,080	21,485	30	89,520
Oct-51	17,238	0	19,232	210.00	24.38	24.84	0.00	55,000	127.07	526,080	19,232	31	77,548
Nov-51	16,682	0	21,652	210.00	28.47	28.94	0.00	55,000	126.58	526,080	21,652	30	90,218
Dec-51	17,238	0	21,653	210.00	27.53	28.26	0.00	55,000	126.70	526,080	21,653	31	87,309

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 55 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-52	17,238	0	17,238	209.12	21.87	18.41	0.00	55,000	126.94	514,392	17,238	31	69,510
Feb-52	16,126	0	16,126	207.14	22.13	12.43	0.00	55,000	125.48	487,881	16,126	29	69,510
Mar-52	17,238	0	17,238	204.16	22.58	9.01	0.00	55,000	122.98	449,192	17,238	31	69,510
Apr-52	16,682	0	16,682	201.29	23.15	10.65	0.00	55,000	119.95	414,666	16,682	30	69,510
May-52	17,238	0	17,238	201.35	23.43	24.16	0.00	55,000	118.51	415,353	17,238	31	69,510
Jun-52	16,682	0	16,682	201.37	23.42	23.87	0.00	55,000	118.55	415,615	16,682	30	69,510
Jul-52	17,238	0	17,238	203.12	23.24	31.49	0.00	55,000	119.46	436,658	17,238	31	69,510
Aug-52	17,238	0	17,238	206.33	22.75	38.23	0.00	55,000	122.06	477,032	17,238	31	69,510
Sep-52	16,682	0	16,682	208.72	22.24	35.03	0.00	55,000	124.86	509,027	16,682	30	69,510
Oct-52	17,238	0	32,890	210.00	42.59	49.42	0.00	55,000	124.38	526,080	32,890	31	132,620
Nov-52	16,682	0	23,454	210.00	30.91	31.49	0.00	55,000	126.29	526,080	23,454	30	97,726
Dec-52	17,238	0	40,700	210.00	52.74	53.27	0.00	55,000	124.30	526,080	40,700	31	164,111
Jan-53	17,238	0	31,692	210.00	40.79	41.46	0.00	55,000	125.14	526,080	31,692	31	127,792
Feb-53	15,570	0	18,650	210.00	26.22	27.07	0.00	55,000	126.85	526,080	18,650	28	83,260
Mar-53	17,238	0	17,238	208.23	21.95	13.96	0.00	55,000	126.48	502,481	17,238	31	69,510
Apr-53	16,682	0	16,682	206.18	22.30	12.49	0.00	55,000	124.53	475,021	16,682	30	69,510
May-53	17,238	0	17,238	209.17	22.21	37.67	0.00	55,000	125.01	515,045	17,238	31	69,510
Jun-53	16,682	0	17,445	210.00	22.89	27.61	0.00	55,000	126.84	526,080	17,445	30	72,689
Jul-53	17,238	0	25,235	210.00	32.23	32.62	0.00	55,000	126.13	526,080	25,235	31	101,756
Aug-53	17,238	0	24,201	210.00	30.87	31.46	0.00	55,000	126.30	526,080	24,201	31	97,586
Sep-53	16,682	0	21,012	210.00	27.61	28.12	0.00	55,000	126.69	526,080	21,012	30	87,551
Oct-53	17,238	0	25,947	210.00	33.16	33.64	0.00	55,000	126.02	526,080	25,947	31	104,625
Nov-53	16,682	0	29,463	210.00	39.14	39.65	0.00	55,000	125.30	526,080	29,463	30	122,761
Dec-53	17,238	0	26,314	210.00	33.65	34.32	0.00	55,000	125.96	526,080	26,314	31	106,105
Jan-54	17,238	0	17,238	209.09	21.88	18.27	0.00	55,000	126.92	513,947	17,238	31	69,510
Feb-54	15,570	0	15,570	207.42	22.11	13.74	0.00	55,000	125.60	491,652	15,570	28	69,510
Mar-54	17,238	0	17,238	205.22	22.46	12.38	0.00	55,000	123.63	462,292	17,238	31	69,510
Apr-54	16,682	0	16,682	202.90	22.89	12.83	0.00	55,000	121.33	433,987	16,682	30	69,510
May-54	17,238	0	17,238	202.47	23.16	21.72	0.00	55,000	119.90	428,795	17,238	31	69,510
Jun-54	16,682	0	16,682	204.87	22.96	34.66	0.00	55,000	120.91	457,814	16,682	30	69,510
Jul-54	17,238	0	17,238	207.24	22.51	34.72	0.00	55,000	123.36	489,215	17,238	31	69,510
Aug-54	17,238	0	19,324	210.00	24.77	39.02	0.00	55,000	125.65	526,080	19,324	31	77,918
Sep-54	16,682	0	28,311	210.00	37.55	38.18	0.00	55,000	125.49	526,080	28,311	30	117,960
Oct-54	17,238	0	19,282	210.00	24.44	25.01	0.00	55,000	127.07	526,080	19,282	31	77,751
Nov-54	16,682	0	39,600	210.00	63.63	64.26	10.57	55,000	124.23	526,080	39,600	30	165,000
Dec-54	17,238	0	40,920	210.00	62.61	63.24	9.56	55,000	124.24	526,080	40,920	31	165,000
Jan-55	17,238	0	40,920	210.00	64.18	64.88	11.12	55,000	124.23	526,080	40,920	31	165,000
Feb-55	15,570	0	15,570	209.21	21.87	18.35	0.00	55,000	126.98	515,581	15,570	28	69,510
Mar-55	17,238	0	17,238	207.11	22.12	12.74	0.00	55,000	125.51	487,527	17,238	31	69,510
Apr-55	16,682	0	16,682	204.48	22.55	10.17	0.00	55,000	123.11	453,010	16,682	30	69,510
May-55	17,238	0	17,238	202.66	22.98	15.32	0.00	55,000	120.81	431,073	17,238	31	69,510
Jun-55	16,682	0	16,682	201.31	23.30	17.47	0.00	55,000	119.19	414,876	16,682	30	69,510
Jul-55	17,238	0	17,238	202.35	23.33	28.32	0.00	55,000	119.03	427,366	17,238	31	69,510
Aug-55	17,238	0	17,238	207.76	22.67	48.74	0.00	55,000	122.46	496,129	17,238	31	69,510
Sep-55	16,682	0	16,682	209.47	22.04	31.41	0.00	55,000	125.97	518,970	16,682	30	69,510
Oct-55	17,238	0	19,918	210.00	25.32	28.49	0.00	55,000	126.69	526,080	19,918	31	80,316
Nov-55	16,682	0	39,600	210.00	76.72	77.09	23.64	55,000	124.18	526,080	39,600	30	165,000
Dec-55	17,238	0	33,734	210.00	43.49	44.04	0.00	55,000	124.95	526,080	33,734	31	136,025

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 55 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-56	17,238	0	40,920	210.00	61.84	62.47	8.79	55,000	124.24	526,080	40,920	31	165,000
Feb-56	16,126	0	16,126	209.82	21.81	21.72	0.00	55,000	127.29	523,628	16,126	29	69,510
Mar-56	17,238	0	17,238	209.08	21.89	19.20	0.00	55,000	126.82	513,815	17,238	31	69,510
Apr-56	16,682	0	16,682	208.47	22.01	19.80	0.00	55,000	126.14	505,703	16,682	30	69,510
May-56	17,238	0	27,399	210.00	35.31	43.41	0.00	55,000	125.00	526,080	27,399	31	110,480
Jun-56	16,682	0	27,790	210.00	36.83	37.27	0.00	55,000	125.58	526,080	27,790	30	115,792
Jul-56	17,238	0	40,920	210.00	63.49	63.92	10.43	55,000	124.23	526,080	40,920	31	165,000
Aug-56	17,238	0	26,256	210.00	33.57	34.13	0.00	55,000	125.97	526,080	26,256	31	105,870
Sep-56	16,682	0	26,640	210.00	35.26	35.74	0.00	55,000	125.77	526,080	26,640	30	110,998
Oct-56	17,238	0	34,245	210.00	44.16	44.63	0.00	55,000	124.91	526,080	34,245	31	138,086
Nov-56	16,682	0	39,600	210.00	85.97	86.38	32.87	55,000	124.14	526,080	39,600	30	165,000
Dec-56	17,238	0	31,725	210.00	40.83	41.49	0.00	55,000	125.14	526,080	31,725	31	127,922
Jan-57	17,238	0	17,238	208.95	21.89	17.50	0.00	55,000	126.85	512,033	17,238	31	69,510
Feb-57	15,570	0	15,570	206.88	22.17	11.55	0.00	55,000	125.25	484,434	15,570	28	69,510
Mar-57	17,238	0	17,238	203.68	22.64	8.18	0.00	55,000	122.63	443,463	17,238	31	69,510
Apr-57	16,682	0	16,682	199.95	23.33	6.91	0.00	55,000	119.02	398,567	16,682	30	69,510
May-57	17,238	0	17,238	197.11	24.01	13.14	0.00	55,000	115.65	368,028	17,238	31	69,510
Jun-57	16,682	0	16,682	194.06	24.64	12.74	0.00	55,000	112.67	336,058	16,682	30	69,510
Jul-57	17,238	0	17,238	190.27	25.45	11.89	0.00	55,000	109.11	298,710	17,238	31	69,510
Aug-57	17,238	0	17,238	186.28	26.41	13.91	0.00	55,000	105.12	264,309	17,238	31	69,510
Sep-57	16,682	0	16,682	183.23	27.35	18.18	0.00	51,968	101.54	239,825	16,682	30	69,510
Oct-57	17,238	0	17,238	184.19	27.66	30.64	0.00	49,629	100.39	247,228	17,238	31	69,510
Nov-57	16,682	0	16,682	190.86	26.59	48.99	0.00	50,336	104.44	304,512	16,682	30	69,510
Dec-57	17,238	0	17,238	192.77	25.53	33.05	0.00	55,000	108.75	323,351	17,238	31	69,510
Jan-58	17,238	0	17,238	194.76	25.07	32.88	0.00	55,000	110.76	342,897	17,238	31	69,510
Feb-58	15,570	0	15,570	192.05	25.15	14.78	0.00	55,000	110.39	316,261	15,570	28	69,510
Mar-58	17,238	0	17,238	187.39	26.01	10.70	0.00	55,000	106.76	273,789	17,238	31	69,510
Apr-58	16,682	0	16,682	180.65	27.53	7.31	0.00	52,874	100.85	220,048	16,682	30	69,510
May-58	17,238	0	17,238	176.08	29.26	17.62	0.00	47,739	94.89	188,005	17,238	31	69,510
Jun-58	16,682	0	16,682	172.01	30.70	21.27	0.00	44,161	90.45	162,917	16,682	30	69,510
Jul-58	17,238	0	17,238	167.12	32.38	22.12	0.00	41,283	85.74	134,991	17,238	31	69,510
Aug-58	17,238	0	17,238	162.16	34.40	25.23	0.00	37,748	80.72	110,057	17,238	31	69,510
Sep-58	16,682	0	16,682	156.19	37.12	27.05	0.00	34,371	74.81	83,599	16,682	30	69,510
Oct-58	17,238	4,047	13,192	155.00	29.49	27.73	0.00	30,502	72.06	78,480	13,192	31	53,192
Nov-58	16,682	2,517	14,165	155.00	33.20	33.33	0.00	29,720	71.02	78,480	14,165	30	59,021
Dec-58	17,238	5,161	12,078	155.00	27.12	27.27	0.00	29,720	71.75	78,480	12,078	31	48,700
Jan-59	17,238	11,566	5,673	155.00	12.51	12.72	0.00	29,720	73.05	78,480	5,673	31	22,875
Feb-59	15,570	12,137	3,433	155.00	8.35	8.58	0.00	29,720	73.30	78,480	3,433	28	15,325
Mar-59	17,238	14,291	2,947	155.00	6.47	6.68	0.00	29,720	73.41	78,480	2,947	31	11,884
Apr-59	16,682	12,504	4,179	155.00	9.50	9.74	0.00	29,720	73.23	78,480	4,179	30	17,411
May-59	17,238	9,246	7,993	155.00	17.70	17.87	0.00	29,720	72.74	78,480	7,993	31	32,229
Jun-59	16,682	9,092	7,590	155.00	17.36	17.47	0.00	29,720	72.76	78,480	7,590	30	31,625
Jul-59	17,238	9,877	7,361	155.00	16.28	16.43	0.00	29,720	72.82	78,480	7,361	31	29,683
Aug-59	17,238	8,981	8,257	155.00	18.29	18.44	0.00	29,720	72.70	78,480	8,257	31	33,295
Sep-59	16,682	3,011	13,671	155.00	31.98	32.11	0.00	29,720	71.16	78,480	13,671	30	56,964
Oct-59	17,238	2,626	14,613	155.00	33.14	33.25	0.00	29,720	71.02	78,480	14,613	31	58,922
Nov-59	16,682	0	16,682	165.50	36.49	54.97	0.00	29,720	76.10	126,019	16,682	30	69,510
Dec-59	17,238	0	17,238	188.92	29.15	89.52	0.00	36,533	95.25	286,824	17,238	31	69,510

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 55 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-60	17,238	0	17,238	196.58	25.27	53.98	0.00	54,119	109.86	362,291	17,238	31	69,510
Feb-60	16,126	0	16,126	193.39	24.77	12.29	0.00	55,000	112.08	329,407	16,126	29	69,510
Mar-60	17,238	0	17,238	188.45	25.72	8.95	0.00	55,000	107.94	282,865	17,238	31	69,510
Apr-60	16,682	0	16,682	186.76	26.59	21.47	0.00	53,741	104.41	268,415	16,682	30	69,510
May-60	17,238	0	17,238	186.87	26.80	27.44	0.00	52,361	103.60	269,405	17,238	31	69,510
Jun-60	16,682	0	16,682	187.71	26.68	29.68	0.00	52,455	104.09	276,487	16,682	30	69,510
Jul-60	17,238	0	17,238	189.02	26.40	30.84	0.00	53,132	105.19	287,658	17,238	31	69,510
Aug-60	17,238	0	17,238	189.87	26.12	29.14	0.00	54,199	106.31	294,931	17,238	31	69,510
Sep-60	16,682	0	16,682	190.95	25.87	30.22	0.00	54,894	107.31	305,399	16,682	30	69,510
Oct-60	17,238	0	17,238	193.28	25.46	34.35	0.00	55,000	109.06	328,337	17,238	31	69,510
Nov-60	16,682	0	16,682	195.93	24.87	35.60	0.00	55,000	111.66	355,307	16,682	30	69,510
Dec-60	17,238	0	22,226	210.00	29.87	94.11	0.00	55,000	119.87	526,080	22,226	31	89,620
Jan-61	17,238	0	17,238	209.14	21.87	18.38	0.00	55,000	126.95	514,656	17,238	31	69,510
Feb-61	15,570	0	15,570	206.80	22.16	10.14	0.00	55,000	125.32	483,415	15,570	28	69,510
Mar-61	17,238	0	17,238	203.60	22.66	8.16	0.00	55,000	122.55	442,443	17,238	31	69,510
Apr-61	16,682	0	16,682	201.03	23.23	11.92	0.00	55,000	119.53	411,470	16,682	30	69,510
May-61	17,238	0	17,238	199.75	23.62	18.46	0.00	55,000	117.57	396,342	17,238	31	69,510
Jun-61	16,682	0	16,682	203.96	23.32	43.13	0.00	55,000	119.07	446,795	16,682	30	69,510
Jul-61	17,238	0	17,238	204.77	22.83	26.85	0.00	55,000	121.63	456,603	17,238	31	69,510
Aug-61	17,238	0	17,238	206.90	22.55	33.50	0.00	55,000	123.14	484,712	17,238	31	69,510
Sep-61	16,682	0	16,682	208.65	22.19	31.55	0.00	55,000	125.11	507,992	16,682	30	69,510
Oct-61	17,238	0	23,870	210.00	30.60	37.78	0.00	55,000	125.65	526,080	23,870	31	96,252
Nov-61	16,682	0	33,479	210.00	44.62	45.06	0.00	55,000	124.87	526,080	33,479	30	139,495
Dec-61	17,238	0	21,975	210.00	27.95	28.46	0.00	55,000	126.65	526,080	21,975	31	88,610
Jan-62	17,238	0	17,238	208.99	21.89	17.62	0.00	55,000	126.87	512,563	17,238	31	69,510
Feb-62	15,570	0	15,570	206.85	22.17	11.24	0.00	55,000	125.26	483,969	15,570	28	69,510
Mar-62	17,238	0	17,238	203.82	22.63	9.03	0.00	55,000	122.68	445,165	17,238	31	69,510
Apr-62	16,682	0	16,682	200.71	23.24	9.49	0.00	55,000	119.48	407,665	16,682	30	69,510
May-62	17,238	0	17,238	201.55	23.47	27.64	0.00	55,000	118.32	417,777	17,238	31	69,510
Jun-62	16,682	0	16,682	200.78	23.46	20.22	0.00	55,000	118.35	408,411	16,682	30	69,510
Jul-62	17,238	0	17,238	202.86	23.33	33.05	0.00	55,000	119.02	433,586	17,238	31	69,510
Aug-62	17,238	0	17,238	207.31	22.67	44.18	0.00	55,000	122.47	490,150	17,238	31	69,510
Sep-62	16,682	0	18,025	210.00	23.85	38.15	0.00	55,000	125.79	526,080	18,025	30	75,104
Oct-62	17,238	0	28,038	210.00	35.93	36.39	0.00	55,000	125.69	526,080	28,038	31	113,055
Nov-62	16,682	0	30,220	210.00	40.18	40.67	0.00	55,000	125.19	526,080	30,220	30	125,918
Dec-62	17,238	0	24,413	210.00	31.14	31.78	0.00	55,000	126.26	526,080	24,413	31	98,439
Jan-63	17,238	0	28,893	210.00	37.07	37.86	0.00	55,000	125.55	526,080	28,893	31	116,505
Feb-63	15,570	0	15,570	209.41	21.85	19.37	0.00	55,000	127.08	518,184	15,570	28	69,510
Mar-63	17,238	0	17,238	207.39	22.08	12.86	0.00	55,000	125.75	491,206	17,238	31	69,510
Apr-63	16,682	0	16,682	208.24	22.19	27.33	0.00	55,000	125.15	502,534	16,682	30	69,510
May-63	17,238	0	23,087	210.00	29.62	39.02	0.00	55,000	125.56	526,080	23,087	31	93,094
Jun-63	16,682	0	30,695	210.00	40.83	41.29	0.00	55,000	125.14	526,080	30,695	30	127,897
Jul-63	17,238	0	36,639	210.00	47.33	47.78	0.00	55,000	124.68	526,080	36,639	31	147,739
Aug-63	17,238	0	35,138	210.00	45.34	45.77	0.00	55,000	124.82	526,080	35,138	31	141,687
Sep-63	16,682	0	36,659	210.00	48.98	49.39	0.00	55,000	124.56	526,080	36,659	30	152,746
Oct-63	17,238	0	29,022	210.00	37.24	37.69	0.00	55,000	125.53	526,080	29,022	31	117,025
Nov-63	16,682	0	32,619	210.00	43.45	43.90	0.00	55,000	124.96	526,080	32,619	30	135,911
Dec-63	17,238	0	19,491	210.00	24.71	25.37	0.00	55,000	127.03	526,080	19,491	31	78,593

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 55 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-64	17,238	0	17,238	208.55	21.93	15.43	0.00	55,000	126.64	506,747	17,238	31	69,510
Feb-64	16,126	0	16,126	206.51	22.24	12.09	0.00	55,000	124.86	479,447	16,126	29	69,510
Mar-64	17,238	0	17,238	203.67	22.68	9.91	0.00	55,000	122.43	443,309	17,238	31	69,510
Apr-64	16,682	0	16,682	202.18	23.11	16.94	0.00	55,000	120.15	425,365	16,682	30	69,510
May-64	17,238	0	17,238	202.91	23.18	26.96	0.00	55,000	119.76	434,142	17,238	31	69,510
Jun-64	16,682	0	16,682	207.48	22.65	45.54	0.00	55,000	122.58	492,414	16,682	30	69,510
Jul-64	17,238	0	17,238	208.56	22.15	28.01	0.00	55,000	125.36	506,851	17,238	31	69,510
Aug-64	17,238	0	17,238	209.37	21.98	26.42	0.00	55,000	126.33	517,718	17,238	31	69,510
Sep-64	16,682	0	21,293	210.00	28.06	31.69	0.00	55,000	126.32	526,080	21,293	30	88,722
Oct-64	17,238	0	21,675	210.00	27.56	27.92	0.00	55,000	126.69	526,080	21,675	31	87,400
Nov-64	16,682	0	29,220	210.00	38.80	39.19	0.00	55,000	125.34	526,080	29,220	30	121,751
Dec-64	17,238	0	17,238	209.96	21.80	22.23	0.00	55,000	127.36	525,543	17,238	31	69,510
Jan-65	17,238	0	17,238	209.08	21.88	18.15	0.00	55,000	126.89	513,782	17,238	31	69,510
Feb-65	15,570	0	15,570	207.48	22.10	14.10	0.00	55,000	125.63	492,483	15,570	28	69,510
Mar-65	17,238	0	17,238	205.20	22.46	11.87	0.00	55,000	123.65	462,022	17,238	31	69,510
Apr-65	16,682	0	16,682	202.40	22.94	10.68	0.00	55,000	121.06	428,029	16,682	30	69,510
May-65	17,238	0	17,238	202.40	23.21	23.73	0.00	55,000	119.62	427,981	17,238	31	69,510
Jun-65	16,682	0	16,682	204.51	23.01	33.16	0.00	55,000	120.69	453,449	16,682	30	69,510
Jul-65	17,238	0	17,238	204.51	22.80	23.28	0.00	55,000	121.77	453,392	17,238	31	69,510
Aug-65	17,238	0	17,238	206.10	22.65	30.73	0.00	55,000	122.61	474,032	17,238	31	69,510
Sep-65	16,682	0	16,682	209.55	22.18	40.33	0.00	55,000	125.16	520,056	16,682	30	69,510
Oct-65	17,238	0	37,232	210.00	48.21	50.83	0.00	55,000	124.39	526,080	37,232	31	150,128
Nov-65	16,682	0	37,268	210.00	49.82	50.10	0.00	55,000	124.50	526,080	37,268	30	155,282
Dec-65	17,238	0	39,310	210.00	50.89	51.40	0.00	55,000	124.43	526,080	39,310	31	158,508
Jan-66	17,238	0	19,893	210.00	25.24	25.88	0.00	55,000	126.97	526,080	19,893	31	80,214
Feb-66	15,570	0	15,570	208.91	21.89	16.82	0.00	55,000	126.83	511,594	15,570	28	69,510
Mar-66	17,238	0	17,238	206.82	22.18	12.60	0.00	55,000	125.21	483,643	17,238	31	69,510
Apr-66	16,682	0	16,682	209.12	22.16	34.69	0.00	55,000	125.31	514,285	16,682	30	69,510
May-66	17,238	0	28,162	210.00	36.23	41.01	0.00	55,000	125.21	526,080	28,162	31	113,557
Jun-66	16,682	0	24,431	210.00	32.24	32.74	0.00	55,000	126.13	526,080	24,431	30	101,796
Jul-66	17,238	0	26,262	210.00	33.58	33.98	0.00	55,000	125.97	526,080	26,262	31	105,897
Aug-66	17,238	0	23,554	210.00	30.02	30.42	0.00	55,000	126.40	526,080	23,554	31	94,977
Sep-66	16,682	0	28,508	210.00	37.82	38.15	0.00	55,000	125.46	526,080	28,508	30	118,783
Oct-66	17,238	0	32,608	210.00	42.00	42.37	0.00	55,000	125.06	526,080	32,608	31	131,485
Nov-66	16,682	0	39,600	210.00	78.64	79.04	25.56	55,000	124.17	526,080	39,600	30	165,000
Dec-66	17,238	0	40,920	210.00	76.70	77.14	23.62	55,000	124.18	526,080	40,920	31	165,000
Jan-67	17,238	0	25,942	210.00	33.16	33.93	0.00	55,000	126.02	526,080	25,942	31	104,607
Feb-67	15,570	0	15,570	209.48	21.84	19.88	0.00	55,000	127.12	519,164	15,570	28	69,510
Mar-67	17,238	0	17,238	207.57	22.06	13.40	0.00	55,000	125.88	493,675	17,238	31	69,510
Apr-67	16,682	0	16,682	209.21	22.08	31.27	0.00	55,000	125.74	515,519	16,682	30	69,510
May-67	17,238	0	29,852	210.00	38.47	43.05	0.00	55,000	124.99	526,080	29,852	31	120,373
Jun-67	16,682	0	36,739	210.00	49.09	49.50	0.00	55,000	124.56	526,080	36,739	30	153,078
Jul-67	17,238	0	34,520	210.00	44.53	44.86	0.00	55,000	124.88	526,080	34,520	31	139,194
Aug-67	17,238	0	26,243	210.00	33.56	33.93	0.00	55,000	125.97	526,080	26,243	31	105,820
Sep-67	16,682	0	26,362	210.00	34.88	35.32	0.00	55,000	125.81	526,080	26,362	30	109,842
Oct-67	17,238	0	23,690	210.00	30.19	30.50	0.00	55,000	126.38	526,080	23,690	31	95,526
Nov-67	16,682	0	27,044	210.00	35.81	36.16	0.00	55,000	125.70	526,080	27,044	30	112,683
Dec-67	17,238	0	28,500	210.00	36.54	37.10	0.00	55,000	125.61	526,080	28,500	31	114,918

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 55 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-68	17,238	0	17,238	208.43	21.94	14.87	0.00	55,000	126.58	505,056	17,238	31	69,510
Feb-68	16,126	0	16,126	206.48	22.25	12.57	0.00	55,000	124.78	479,040	16,126	29	69,510
Mar-68	17,238	0	17,238	204.50	22.61	13.79	0.00	55,000	122.80	453,359	17,238	31	69,510
Apr-68	16,682	0	16,682	202.89	22.96	16.26	0.00	55,000	120.94	433,950	16,682	30	69,510
May-68	17,238	0	17,238	205.85	22.82	36.90	0.00	55,000	121.68	470,639	17,238	31	69,510
Jun-68	16,682	0	16,682	207.76	22.37	32.60	0.00	55,000	124.12	496,122	16,682	30	69,510
Jul-68	17,238	0	19,886	210.00	25.46	37.04	0.00	55,000	125.82	526,080	19,886	31	80,185
Aug-68	17,238	0	27,835	210.00	35.66	36.05	0.00	55,000	125.72	526,080	27,835	31	112,239
Sep-68	16,682	0	27,113	210.00	35.90	36.25	0.00	55,000	125.69	526,080	27,113	30	112,973
Oct-68	17,238	0	26,231	210.00	33.54	33.90	0.00	55,000	125.98	526,080	26,231	31	105,770
Nov-68	16,682	0	23,516	210.00	31.00	31.35	0.00	55,000	126.28	526,080	23,516	30	97,983
Dec-68	17,238	0	19,620	210.00	24.88	25.49	0.00	55,000	127.01	526,080	19,620	31	79,113
Jan-69	17,238	0	17,238	208.79	21.90	16.54	0.00	55,000	126.77	509,920	17,238	31	69,510
Feb-69	15,570	0	15,570	206.97	22.17	13.00	0.00	55,000	125.22	485,690	15,570	28	69,510
Mar-69	17,238	0	17,238	204.49	22.57	11.21	0.00	55,000	123.05	453,205	17,238	31	69,510
Apr-69	16,682	0	16,682	203.18	22.93	17.53	0.00	55,000	121.08	437,396	16,682	30	69,510
May-69	17,238	0	17,238	204.94	22.89	31.27	0.00	55,000	121.31	458,591	17,238	31	69,510
Jun-69	16,682	0	16,682	204.23	22.79	19.82	0.00	55,000	121.85	450,025	16,682	30	69,510
Jul-69	17,238	0	17,238	205.62	22.72	29.62	0.00	55,000	122.23	467,671	17,238	31	69,510
Aug-69	17,238	0	17,238	208.41	22.33	36.50	0.00	55,000	124.34	504,808	17,238	31	69,510
Sep-69	16,682	0	17,931	210.00	23.62	32.17	0.00	55,000	126.37	526,080	17,931	30	74,711
Oct-69	17,238	0	17,988	210.00	22.77	23.25	0.00	55,000	127.27	526,080	17,988	31	72,534
Nov-69	16,682	0	21,997	210.00	28.94	29.28	0.00	55,000	126.53	526,080	21,997	30	91,652
Dec-69	17,238	0	40,920	210.00	74.26	74.71	21.18	55,000	124.19	526,080	40,920	31	165,000
Jan-70	17,238	0	40,920	210.00	66.83	67.43	13.77	55,000	124.22	526,080	40,920	31	165,000
Feb-70	15,570	0	15,570	207.96	21.98	11.47	0.00	55,000	126.34	498,795	15,570	28	69,510
Mar-70	17,238	0	17,238	207.32	22.22	19.77	0.00	55,000	124.97	490,259	17,238	31	69,510
Apr-70	16,682	0	20,775	210.00	27.59	42.11	0.00	55,000	125.35	526,080	20,775	30	86,563
May-70	17,238	0	37,218	210.00	48.10	48.60	0.00	55,000	124.63	526,080	37,218	31	150,072
Jun-70	16,682	0	21,357	210.00	28.07	28.46	0.00	55,000	126.63	526,080	21,357	30	88,986
Jul-70	17,238	0	24,600	210.00	31.39	31.80	0.00	55,000	126.23	526,080	24,600	31	99,195
Aug-70	17,238	0	28,870	210.00	37.04	37.38	0.00	55,000	125.56	526,080	28,870	31	116,411
Sep-70	16,682	0	26,761	210.00	35.42	35.82	0.00	55,000	125.75	526,080	26,761	30	111,504
Oct-70	17,238	0	30,637	210.00	39.39	39.73	0.00	55,000	125.27	526,080	30,637	31	123,535
Nov-70	16,682	0	30,616	210.00	40.72	41.06	0.00	55,000	125.15	526,080	30,616	30	127,566
Dec-70	17,238	0	40,920	210.00	74.51	74.82	21.43	55,000	124.18	526,080	40,920	31	165,000
Jan-71	17,238	0	33,361	210.00	42.99	43.58	0.00	55,000	124.99	526,080	33,361	31	134,521
Feb-71	15,570	0	15,570	208.92	21.89	16.79	0.00	55,000	126.83	511,634	15,570	28	69,510
Mar-71	17,238	0	17,238	207.40	22.12	15.38	0.00	55,000	125.50	491,393	17,238	31	69,510
Apr-71	16,682	0	16,682	206.13	22.38	16.74	0.00	55,000	124.08	474,448	16,682	30	69,510
May-71	17,238	0	17,238	206.29	22.48	23.70	0.00	55,000	123.51	476,492	17,238	31	69,510
Jun-71	16,682	0	16,682	209.25	22.20	37.81	0.00	55,000	125.10	516,024	16,682	30	69,510
Jul-71	17,238	0	32,753	210.00	42.32	46.47	0.00	55,000	124.66	526,080	32,753	31	132,068
Aug-71	17,238	0	29,844	210.00	38.34	38.71	0.00	55,000	125.40	526,080	29,844	31	120,340
Sep-71	16,682	0	24,899	210.00	32.88	33.28	0.00	55,000	126.05	526,080	24,899	30	103,746
Oct-71	17,238	0	24,050	210.00	30.67	31.10	0.00	55,000	126.32	526,080	24,050	31	96,976
Nov-71	16,682	0	29,345	210.00	38.97	39.31	0.00	55,000	125.32	526,080	29,345	30	122,270
Dec-71	17,238	0	17,238	209.81	21.81	21.61	0.00	55,000	127.29	523,578	17,238	31	69,510

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 55 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-72	17,238	0	40,920	210.00	55.94	57.43	2.86	55,000	124.17	526,080	40,920	31	165,000
Feb-72	16,126	0	16,126	208.48	21.93	14.64	0.00	55,000	126.61	505,790	16,126	29	69,510
Mar-72	17,238	0	17,238	205.89	22.30	10.31	0.00	55,000	124.51	471,268	17,238	31	69,510
Apr-72	16,682	0	16,682	206.42	22.49	25.83	0.00	55,000	123.46	478,346	16,682	30	69,510
May-72	17,238	0	17,238	205.32	22.54	17.59	0.00	55,000	123.17	463,657	17,238	31	69,510
Jun-72	16,682	0	16,682	205.06	22.67	21.75	0.00	55,000	122.47	460,160	16,682	30	69,510
Jul-72	17,238	0	17,238	202.98	22.90	14.10	0.00	55,000	121.28	434,953	17,238	31	69,510
Aug-72	17,238	0	17,238	203.39	23.06	25.35	0.00	55,000	120.42	439,901	17,238	31	69,510
Sep-72	16,682	0	16,682	202.58	23.10	19.68	0.00	55,000	120.21	430,203	16,682	30	69,510
Oct-72	17,238	0	17,238	204.46	22.99	31.75	0.00	55,000	120.76	452,822	17,238	31	69,510
Nov-72	16,682	0	16,682	206.65	22.60	34.04	0.00	55,000	122.87	481,421	16,682	30	69,510
Dec-72	17,238	0	17,238	206.02	22.46	19.88	0.00	55,000	123.64	472,883	17,238	31	69,510
Jan-73	17,238	0	17,238	203.56	22.74	11.92	0.00	55,000	122.12	442,022	17,238	31	69,510
Feb-73	15,570	0	15,570	200.41	23.30	8.35	0.00	55,000	119.19	403,997	15,570	28	69,510
Mar-73	17,238	0	17,238	195.68	24.11	5.64	0.00	55,000	115.17	352,577	17,238	31	69,510
Apr-73	16,682	0	16,682	190.27	25.25	5.10	0.00	55,000	109.97	298,663	16,682	30	69,510
May-73	17,238	0	17,238	187.02	26.32	16.26	0.00	55,000	105.50	270,626	17,238	31	69,510
Jun-73	16,682	0	16,682	187.48	26.69	28.40	0.00	52,572	104.05	274,560	16,682	30	69,510
Jul-73	17,238	0	17,238	187.86	26.58	28.29	0.00	52,948	104.48	277,782	17,238	31	69,510
Aug-73	17,238	0	17,238	189.67	26.29	32.34	0.00	53,256	105.61	293,256	17,238	31	69,510
Sep-73	16,682	0	16,682	190.25	25.98	28.29	0.00	54,734	106.87	298,548	16,682	30	69,510
Oct-73	17,238	0	17,238	193.04	25.57	36.14	0.00	55,000	108.58	325,969	17,238	31	69,510
Nov-73	16,682	0	16,682	201.66	24.22	60.43	0.00	55,000	114.63	419,083	16,682	30	69,510
Dec-73	17,238	0	17,238	206.53	22.87	46.05	0.00	55,000	121.44	479,821	17,238	31	69,510
Jan-74	17,238	0	17,238	207.36	22.34	27.19	0.00	55,000	124.27	490,885	17,238	31	69,510
Feb-74	15,570	0	15,570	205.55	22.44	13.20	0.00	55,000	123.76	466,638	15,570	28	69,510
Mar-74	17,238	0	17,238	202.48	22.89	9.69	0.00	55,000	121.29	428,921	17,238	31	69,510
Apr-74	16,682	0	16,682	198.71	23.56	7.48	0.00	55,000	117.84	385,223	16,682	30	69,510
May-74	17,238	0	17,238	195.80	24.28	13.00	0.00	55,000	114.34	353,869	17,238	31	69,510
Jun-74	16,682	0	16,682	193.70	24.84	16.85	0.00	55,000	111.80	332,451	16,682	30	69,510
Jul-74	17,238	0	17,238	192.74	25.20	21.92	0.00	55,000	110.20	323,061	17,238	31	69,510
Aug-74	17,238	0	17,238	194.34	25.12	31.29	0.00	55,000	110.53	338,797	17,238	31	69,510
Sep-74	16,682	0	16,682	195.93	24.75	31.38	0.00	55,000	112.19	355,332	16,682	30	69,510
Oct-74	17,238	0	17,238	200.48	24.07	42.79	0.00	55,000	115.35	404,865	17,238	31	69,510
Nov-74	16,682	0	16,682	203.97	23.25	39.73	0.00	55,000	119.44	446,952	16,682	30	69,510
Dec-74	17,238	0	17,238	204.71	22.83	26.76	0.00	55,000	121.60	455,859	17,238	31	69,510
Jan-75	17,238	0	17,238	202.13	23.01	12.12	0.00	55,000	120.66	424,724	17,238	31	69,510
Feb-75	15,570	0	15,570	198.60	23.61	7.50	0.00	55,000	117.61	383,982	15,570	28	69,510
Mar-75	17,238	0	17,238	193.46	24.54	5.13	0.00	55,000	113.15	330,168	17,238	31	69,510
Apr-75	16,682	0	16,682	187.66	25.80	5.58	0.00	55,000	107.62	276,092	16,682	30	69,510
May-75	17,238	0	17,238	188.76	26.44	30.33	0.00	53,094	105.04	285,500	17,238	31	69,510
Jun-75	16,682	0	16,682	189.51	26.20	28.86	0.00	53,993	105.99	291,876	16,682	30	69,510
Jul-75	17,238	0	17,238	194.79	25.44	44.80	0.00	54,602	109.13	343,215	17,238	31	69,510
Aug-75	17,238	0	17,238	201.51	24.07	52.08	0.00	55,000	115.36	417,290	17,238	31	69,510
Sep-75	16,682	0	16,682	203.92	23.15	34.75	0.00	55,000	119.94	446,309	16,682	30	69,510
Oct-75	17,238	0	17,238	208.83	22.44	46.64	0.00	55,000	123.73	510,404	17,238	31	69,510
Nov-75	16,682	0	38,464	210.00	51.72	58.06	0.00	55,000	123.78	526,080	38,464	30	160,268
Dec-75	17,238	0	40,920	210.00	57.55	58.03	4.51	55,000	124.26	526,080	40,920	31	165,000

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 55 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-76	17,238	0	19,773	210.00	25.08	25.80	0.00	55,000	126.99	526,080	19,773	31	79,730
Feb-76	16,126	0	16,126	208.33	21.94	13.99	0.00	55,000	126.53	503,782	16,126	29	69,510
Mar-76	17,238	0	17,238	205.93	22.31	11.24	0.00	55,000	124.45	471,708	17,238	31	69,510
Apr-76	16,682	0	16,682	203.72	22.73	12.74	0.00	55,000	122.14	443,885	16,682	30	69,510
May-76	17,238	0	17,238	202.92	23.03	19.88	0.00	55,000	120.56	434,254	17,238	31	69,510
Jun-76	16,682	0	16,682	201.82	23.22	18.46	0.00	55,000	119.58	420,998	16,682	30	69,510
Jul-76	17,238	0	17,238	199.26	23.58	12.86	0.00	55,000	117.75	391,084	17,238	31	69,510
Aug-76	17,238	0	17,238	196.90	24.11	14.98	0.00	55,000	115.19	365,782	17,238	31	69,510
Sep-76	16,682	0	16,682	196.35	24.42	22.34	0.00	55,000	113.70	359,815	16,682	30	69,510
Oct-76	17,238	0	17,238	200.19	24.06	39.85	0.00	55,000	115.39	401,359	17,238	31	69,510
Nov-76	16,682	0	16,682	204.29	23.25	42.68	0.00	55,000	119.45	450,805	16,682	30	69,510
Dec-76	17,238	0	17,238	203.05	22.96	17.93	0.00	55,000	120.92	435,876	17,238	31	69,510
Jan-77	17,238	0	17,238	201.24	23.26	15.80	0.00	55,000	119.36	414,056	17,238	31	69,510
Feb-77	15,570	0	15,570	198.36	23.73	10.96	0.00	55,000	117.03	381,478	15,570	28	69,510
Mar-77	17,238	0	17,238	194.06	24.50	8.18	0.00	55,000	113.31	336,078	17,238	31	69,510
Apr-77	16,682	0	16,682	189.21	25.56	8.21	0.00	55,000	108.62	289,320	16,682	30	69,510
May-77	17,238	0	17,238	185.34	26.68	14.70	0.00	54,358	104.07	256,312	17,238	31	69,510
Jun-77	16,682	0	16,682	181.72	27.71	17.11	0.00	51,204	100.22	228,246	16,682	30	69,510
Jul-77	17,238	0	17,238	179.46	28.57	22.57	0.00	48,523	97.19	211,320	17,238	31	69,510
Aug-77	17,238	0	17,238	179.34	28.95	28.83	0.00	46,834	95.93	210,457	17,238	31	69,510
Sep-77	16,682	0	16,682	178.34	29.12	26.71	0.00	46,736	95.34	203,588	16,682	30	69,510
Oct-77	17,238	0	17,238	188.07	27.73	56.36	0.00	45,948	100.13	279,610	17,238	31	69,510
Nov-77	16,682	0	16,682	193.38	25.77	45.26	0.00	53,430	107.77	329,381	16,682	30	69,510
Dec-77	17,238	0	17,238	195.46	24.91	33.11	0.00	55,000	111.45	350,248	17,238	31	69,510
Jan-78	17,238	0	17,238	192.31	25.04	13.85	0.00	55,000	110.90	318,788	17,238	31	69,510
Feb-78	15,570	0	15,570	188.49	25.85	11.67	0.00	55,000	107.40	283,158	15,570	28	69,510
Mar-78	17,238	0	17,238	182.17	27.17	8.44	0.00	53,769	102.21	231,723	17,238	31	69,510
Apr-78	16,682	0	16,682	181.51	28.20	26.62	0.00	48,855	98.46	226,634	16,682	30	69,510
May-78	17,238	0	17,238	181.37	28.32	28.21	0.00	48,369	98.04	225,557	17,238	31	69,510
Jun-78	16,682	0	16,682	185.35	27.75	39.85	0.00	48,266	100.05	256,381	16,682	30	69,510
Jul-78	17,238	0	17,238	191.45	26.36	46.73	0.00	51,211	105.35	310,296	17,238	31	69,510
Aug-78	17,238	0	17,238	197.66	24.86	48.88	0.00	55,000	111.69	373,857	17,238	31	69,510
Sep-78	16,682	0	16,682	199.62	23.99	32.43	0.00	55,000	115.76	394,939	16,682	30	69,510
Oct-78	17,238	0	17,238	202.06	23.52	34.66	0.00	55,000	118.04	423,906	17,238	31	69,510
Nov-78	16,682	0	16,682	206.13	22.87	42.68	0.00	55,000	121.41	474,359	16,682	30	69,510
Dec-78	17,238	0	17,238	206.25	22.49	23.56	0.00	55,000	123.49	475,999	17,238	31	69,510
Jan-79	17,238	0	17,238	203.89	22.68	12.12	0.00	55,000	122.40	446,003	17,238	31	69,510
Feb-79	15,570	0	15,570	200.88	23.22	8.89	0.00	55,000	119.60	409,702	15,570	28	69,510
Mar-79	17,238	0	17,238	196.56	23.96	6.85	0.00	55,000	115.90	362,032	17,238	31	69,510
Apr-79	16,682	0	16,682	194.77	24.63	17.78	0.00	55,000	112.72	343,067	16,682	30	69,510
May-79	17,238	0	17,238	192.52	25.10	17.11	0.00	55,000	110.64	320,897	17,238	31	69,510
Jun-79	16,682	0	16,682	192.00	25.43	23.70	0.00	55,000	109.21	315,746	16,682	30	69,510
Jul-79	17,238	0	17,238	192.44	25.44	27.30	0.00	55,000	109.17	320,033	17,238	31	69,510
Aug-79	17,238	0	17,238	195.50	25.02	36.73	0.00	55,000	110.99	350,688	17,238	31	69,510
Sep-79	16,682	0	16,682	197.17	24.49	31.75	0.00	55,000	113.39	368,578	16,682	30	69,510
Oct-79	17,238	0	17,238	198.15	24.20	28.55	0.00	55,000	114.76	379,216	17,238	31	69,510
Nov-79	16,682	0	16,682	202.36	23.63	42.82	0.00	55,000	117.52	427,503	16,682	30	69,510
Dec-79	17,238	0	17,238	206.22	22.83	41.09	0.00	55,000	121.61	475,575	17,238	31	69,510

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 55 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-80	17,238	0	17,238	207.79	22.33	30.87	0.00	55,000	124.33	496,629	17,238	31	69,510
Feb-80	16,126	0	16,126	206.98	22.26	18.52	0.00	55,000	124.71	485,739	16,126	29	69,510
Mar-80	17,238	0	17,238	204.23	22.59	10.05	0.00	55,000	122.93	450,037	17,238	31	69,510
Apr-80	16,682	0	16,682	201.41	23.13	10.70	0.00	55,000	120.05	416,084	16,682	30	69,510
May-80	17,238	0	17,238	201.08	23.45	22.37	0.00	55,000	118.43	412,086	17,238	31	69,510
Jun-80	16,682	0	16,682	202.26	23.36	29.28	0.00	55,000	118.87	426,353	16,682	30	69,510
Jul-80	17,238	0	17,238	200.97	23.37	17.93	0.00	55,000	118.81	410,697	17,238	31	69,510
Aug-80	17,238	0	17,238	200.37	23.56	21.27	0.00	55,000	117.84	403,545	17,238	31	69,510
Sep-80	16,682	0	16,682	200.27	23.63	23.56	0.00	55,000	117.49	402,337	16,682	30	69,510
Oct-80	17,238	0	17,238	201.73	23.50	30.39	0.00	55,000	118.18	419,932	17,238	31	69,510
Nov-80	16,682	0	16,682	205.99	22.92	43.64	0.00	55,000	121.17	472,587	16,682	30	69,510
Dec-80	17,238	0	17,238	209.36	22.21	39.59	0.00	55,000	125.01	517,541	17,238	31	69,510
Jan-81	17,238	0	17,238	209.49	21.90	23.28	0.00	55,000	126.80	519,260	17,238	31	69,510
Feb-81	15,570	0	15,570	208.57	21.97	17.67	0.00	55,000	126.39	507,029	15,570	28	69,510
Mar-81	17,238	0	17,238	206.86	22.20	14.36	0.00	55,000	125.05	484,206	17,238	31	69,510
Apr-81	16,682	0	39,600	210.00	84.03	100.68	30.24	55,000	122.53	526,080	39,600	30	165,000
May-81	17,238	0	35,551	210.00	45.89	46.36	0.00	55,000	124.78	526,080	35,551	31	143,350
Jun-81	16,682	0	27,745	210.00	36.77	37.21	0.00	55,000	125.59	526,080	27,745	30	115,603
Jul-81	17,238	0	30,782	210.00	39.59	39.99	0.00	55,000	125.25	526,080	30,782	31	124,122
Aug-81	17,238	0	29,961	210.00	38.49	38.91	0.00	55,000	125.38	526,080	29,961	31	120,810
Sep-81	16,682	0	20,891	210.00	27.44	27.90	0.00	55,000	126.71	526,080	20,891	30	87,047
Oct-81	17,238	0	25,622	210.00	32.74	33.16	0.00	55,000	126.07	526,080	25,622	31	103,315
Nov-81	16,682	0	30,380	210.00	40.40	40.78	0.00	55,000	125.17	526,080	30,380	30	126,584
Dec-81	17,238	0	40,920	210.00	61.22	61.71	8.17	55,000	124.24	526,080	40,920	31	165,000
Jan-82	17,238	0	24,637	210.00	31.44	32.09	0.00	55,000	126.23	526,080	24,637	31	99,344
Feb-82	15,570	0	15,570	208.50	21.93	14.56	0.00	55,000	126.62	506,043	15,570	28	69,510
Mar-82	17,238	0	17,238	205.69	22.32	9.18	0.00	55,000	124.41	468,481	17,238	31	69,510
Apr-82	16,682	0	16,682	203.34	22.79	12.26	0.00	55,000	121.81	439,331	16,682	30	69,510
May-82	17,238	0	17,238	203.03	23.06	22.06	0.00	55,000	120.42	435,566	17,238	31	69,510
Jun-82	16,682	0	16,682	202.10	23.18	19.26	0.00	55,000	119.78	424,366	16,682	30	69,510
Jul-82	17,238	0	17,238	204.15	23.07	32.74	0.00	55,000	120.36	449,120	17,238	31	69,510
Aug-82	17,238	0	17,238	205.84	22.70	31.18	0.00	55,000	122.31	470,577	17,238	31	69,510
Sep-82	16,682	0	16,682	207.14	22.43	29.51	0.00	55,000	123.80	487,885	16,682	30	69,510
Oct-82	17,238	0	24,256	210.00	31.30	45.91	0.00	55,000	124.81	526,080	24,256	31	97,807
Nov-82	16,682	0	23,845	210.00	31.44	31.97	0.00	55,000	126.23	526,080	23,845	30	99,353
Dec-82	17,238	0	17,238	209.56	21.84	20.39	0.00	55,000	127.16	520,209	17,238	31	69,510
Jan-83	17,238	0	17,238	208.04	22.01	15.26	0.00	55,000	126.16	499,972	17,238	31	69,510
Feb-83	15,570	0	15,570	205.38	22.39	8.50	0.00	55,000	124.03	464,415	15,570	28	69,510
Mar-83	17,238	0	17,238	201.51	23.00	6.20	0.00	55,000	120.70	417,227	17,238	31	69,510
Apr-83	16,682	0	16,682	197.07	23.83	5.44	0.00	55,000	116.52	367,577	16,682	30	69,510
May-83	17,238	0	17,238	200.10	24.00	36.65	0.00	55,000	115.71	400,279	17,238	31	69,510
Jun-83	16,682	0	16,682	199.66	23.72	22.20	0.00	55,000	117.04	395,450	16,682	30	69,510
Jul-83	17,238	0	17,238	198.50	23.89	19.63	0.00	55,000	116.22	382,937	17,238	31	69,510
Aug-83	17,238	0	17,238	197.80	24.09	21.66	0.00	55,000	115.26	375,422	17,238	31	69,510
Sep-83	16,682	0	16,682	198.60	24.08	27.70	0.00	55,000	115.31	383,993	16,682	30	69,510
Oct-83	17,238	0	17,238	201.04	23.73	34.32	0.00	55,000	117.03	411,536	17,238	31	69,510
Nov-83	16,682	0	16,682	204.59	23.13	39.99	0.00	55,000	120.04	454,370	16,682	30	69,510
Dec-83	17,238	0	37,333	210.00	49.35	76.61	0.00	55,000	121.85	526,080	37,333	31	150,537

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 55 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-84	17,238	0	19,546	210.00	24.79	25.60	0.00	55,000	127.03	526,080	19,546	31	78,815
Feb-84	16,126	0	16,126	208.64	21.92	15.46	0.00	55,000	126.69	507,900	16,126	29	69,510
Mar-84	17,238	0	17,238	205.77	22.30	8.95	0.00	55,000	124.53	469,645	17,238	31	69,510
Apr-84	16,682	0	16,682	202.11	22.90	6.32	0.00	55,000	121.24	424,537	16,682	30	69,510
May-84	17,238	0	17,238	200.96	23.39	18.66	0.00	55,000	118.73	410,594	17,238	31	69,510
Jun-84	16,682	0	16,682	202.38	23.36	30.33	0.00	55,000	118.86	427,741	16,682	30	69,510
Jul-84	17,238	0	17,238	205.81	22.87	39.11	0.00	55,000	121.39	470,128	17,238	31	69,510
Aug-84	17,238	0	35,512	210.00	46.64	67.91	0.00	55,000	122.63	526,080	35,512	31	143,193
Sep-84	16,682	0	35,936	210.00	47.99	48.43	0.00	55,000	124.63	526,080	35,936	30	149,734
Oct-84	17,238	0	40,920	210.00	54.73	55.14	1.69	55,000	124.27	526,080	40,920	31	165,000
Nov-84	16,682	0	39,600	210.00	55.46	55.85	2.42	55,000	124.27	526,080	39,600	30	165,000
Dec-84	17,238	0	27,018	210.00	34.58	35.15	0.00	55,000	125.85	526,080	27,018	31	108,942
Jan-85	17,238	0	17,238	209.29	21.86	19.17	0.00	55,000	127.02	516,553	17,238	31	69,510
Feb-85	15,570	0	15,570	207.47	22.09	12.89	0.00	55,000	125.73	492,287	15,570	28	69,510
Mar-85	17,238	0	17,238	205.39	22.44	12.94	0.00	55,000	123.73	464,473	17,238	31	69,510
Apr-85	16,682	0	16,682	202.33	22.92	9.40	0.00	55,000	121.13	427,163	16,682	30	69,510
May-85	17,238	0	17,238	201.40	23.32	19.57	0.00	55,000	119.07	415,945	17,238	31	69,510
Jun-85	16,682	0	16,682	203.70	23.18	34.18	0.00	55,000	119.77	443,608	16,682	30	69,510
Jul-85	17,238	0	17,238	204.34	22.90	26.20	0.00	55,000	121.27	451,341	17,238	31	69,510
Aug-85	17,238	0	17,238	203.90	22.88	21.21	0.00	55,000	121.37	446,025	17,238	31	69,510
Sep-85	16,682	0	16,682	206.90	22.62	37.86	0.00	55,000	122.73	484,644	16,682	30	69,510
Oct-85	17,238	0	17,238	208.51	22.21	30.61	0.00	55,000	125.04	506,220	17,238	31	69,510
Nov-85	16,682	0	16,682	209.97	21.93	29.88	0.00	55,000	126.61	525,741	16,682	30	69,510
Dec-85	17,238	0	39,594	210.00	51.27	51.97	0.00	55,000	124.39	526,080	39,594	31	159,652
Jan-86	17,238	0	17,238	209.01	21.88	17.73	0.00	55,000	126.88	512,859	17,238	31	69,510
Feb-86	15,570	0	15,570	206.95	22.16	11.78	0.00	55,000	125.32	485,411	15,570	28	69,510
Mar-86	17,238	0	17,238	204.68	22.55	12.15	0.00	55,000	123.13	455,478	17,238	31	69,510
Apr-86	16,682	0	16,682	204.34	22.80	21.98	0.00	55,000	121.77	451,371	16,682	30	69,510
May-86	17,238	0	17,238	209.68	22.33	49.36	0.00	55,000	124.36	521,767	17,238	31	69,510
Jun-86	16,682	0	21,625	210.00	28.47	30.64	0.00	55,000	126.42	526,080	21,625	30	90,106
Jul-86	17,238	0	19,611	210.00	24.87	25.35	0.00	55,000	127.02	526,080	19,611	31	79,076
Aug-86	17,238	0	17,238	209.95	21.80	22.03	0.00	55,000	127.36	525,463	17,238	31	69,510
Sep-86	16,682	0	27,140	210.00	35.95	36.65	0.00	55,000	125.66	526,080	27,140	30	113,084
Oct-86	17,238	0	40,920	210.00	57.34	57.66	4.30	55,000	124.26	526,080	40,920	31	165,000
Nov-86	16,682	0	29,825	210.00	39.64	40.16	0.00	55,000	125.24	526,080	29,825	30	124,272
Dec-86	17,238	0	23,145	210.00	29.48	30.27	0.00	55,000	126.46	526,080	23,145	31	93,327
Jan-87	17,238	0	17,238	208.08	21.97	13.34	0.00	55,000	126.41	500,507	17,238	31	69,510
Feb-87	15,570	0	15,570	206.16	22.31	12.60	0.00	55,000	124.45	474,859	15,570	28	69,510
Mar-87	17,238	0	17,238	202.86	22.79	8.21	0.00	55,000	121.84	433,545	17,238	31	69,510
Apr-87	16,682	0	16,682	203.89	23.02	28.52	0.00	55,000	120.61	445,949	16,682	30	69,510
May-87	17,238	0	19,702	210.00	25.61	55.93	0.00	55,000	123.93	526,080	19,702	31	79,443
Jun-87	16,682	0	26,907	210.00	35.62	36.05	0.00	55,000	125.73	526,080	26,907	30	112,114
Jul-87	17,238	0	28,054	210.00	35.95	36.45	0.00	55,000	125.69	526,080	28,054	31	113,123
Aug-87	17,238	0	33,895	210.00	43.70	44.24	0.00	55,000	124.94	526,080	33,895	31	136,674
Sep-87	16,682	0	38,155	210.00	51.04	51.51	0.00	55,000	124.42	526,080	38,155	30	158,978
Oct-87	17,238	0	30,558	210.00	39.29	39.76	0.00	55,000	125.29	526,080	30,558	31	123,218
Nov-87	16,682	0	39,600	210.00	60.20	60.66	7.15	55,000	124.25	526,080	39,600	30	165,000
Dec-87	17,238	0	22,916	210.00	29.18	29.79	0.00	55,000	126.50	526,080	22,916	31	92,401

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 55 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-88	17,238	0	17,238	208.17	21.96	13.71	0.00	55,000	126.45	501,648	17,238	31	69,510
Feb-88	16,126	0	16,126	206.53	22.27	14.50	0.00	55,000	124.68	479,788	16,126	29	69,510
Mar-88	17,238	0	17,238	203.48	22.69	9.15	0.00	55,000	122.36	440,966	17,238	31	69,510
Apr-88	16,682	0	16,682	199.75	23.37	6.97	0.00	55,000	118.82	396,395	16,682	30	69,510
May-88	17,238	0	17,238	199.82	23.75	24.50	0.00	55,000	116.94	397,130	17,238	31	69,510
Jun-88	16,682	0	16,682	199.40	23.78	22.34	0.00	55,000	116.76	392,595	16,682	30	69,510
Jul-88	17,238	0	17,238	203.92	23.35	43.78	0.00	55,000	118.89	446,356	17,238	31	69,510
Aug-88	17,238	0	20,857	210.00	27.15	57.29	0.00	55,000	123.76	526,080	20,857	31	84,103
Sep-88	16,682	0	30,368	210.00	40.38	40.84	0.00	55,000	125.17	526,080	30,368	30	126,535
Oct-88	17,238	0	38,962	210.00	50.42	50.81	0.00	55,000	124.46	526,080	38,962	31	157,106
Nov-88	16,682	0	32,995	210.00	43.96	44.46	0.00	55,000	124.92	526,080	32,995	30	137,480
Dec-88	17,238	0	24,863	210.00	31.74	32.40	0.00	55,000	126.19	526,080	24,863	31	100,253
Jan-89	17,238	0	17,238	209.58	21.83	20.62	0.00	55,000	127.17	520,439	17,238	31	69,510
Feb-89	15,570	0	15,570	209.06	21.92	19.94	0.00	55,000	126.69	513,497	15,570	28	69,510
Mar-89	17,238	0	17,238	206.85	22.16	12.12	0.00	55,000	125.29	483,969	17,238	31	69,510
Apr-89	16,682	0	16,682	203.83	22.63	8.64	0.00	55,000	122.68	445,187	16,682	30	69,510
May-89	17,238	0	17,238	202.41	23.07	17.19	0.00	55,000	120.35	428,088	17,238	31	69,510
Jun-89	16,682	0	16,682	204.24	23.03	31.92	0.00	55,000	120.56	450,215	16,682	30	69,510
Jul-89	17,238	0	17,238	206.63	22.62	34.47	0.00	55,000	122.76	481,044	17,238	31	69,510
Aug-89	17,238	0	17,238	209.71	22.12	37.86	0.00	55,000	125.51	522,224	17,238	31	69,510
Sep-89	16,682	0	23,013	210.00	30.35	32.28	0.00	55,000	126.21	526,080	23,013	30	95,887
Oct-89	17,238	0	40,920	210.00	58.10	58.54	5.06	55,000	124.25	526,080	40,920	31	165,000
Nov-89	16,682	0	39,600	210.00	66.97	67.43	13.91	55,000	124.22	526,080	39,600	30	165,000
Dec-89	17,238	0	27,809	210.00	35.63	36.19	0.00	55,000	125.72	526,080	27,809	31	112,133
Jan-90	17,238	0	22,882	210.00	29.13	29.74	0.00	55,000	126.50	526,080	22,882	31	92,264
Feb-90	15,570	0	15,570	209.09	21.88	17.59	0.00	55,000	126.92	513,915	15,570	28	69,510
Mar-90	17,238	0	17,238	207.34	22.11	14.05	0.00	55,000	125.56	490,514	17,238	31	69,510
Apr-90	16,682	0	16,682	207.22	22.28	22.37	0.00	55,000	124.61	489,010	16,682	30	69,510
May-90	17,238	0	40,920	210.00	60.26	74.57	6.60	55,000	122.82	526,080	40,920	31	165,000
Jun-90	16,682	0	16,682	209.76	21.82	21.01	0.00	55,000	127.26	522,870	16,682	30	69,510
Jul-90	17,238	0	17,238	209.12	21.90	19.14	0.00	55,000	126.81	514,312	17,238	31	69,510
Aug-90	17,238	0	22,912	210.00	29.28	34.10	0.00	55,000	126.05	526,080	22,912	31	92,386
Sep-90	16,682	0	33,245	210.00	44.31	44.75	0.00	55,000	124.90	526,080	33,245	30	138,522
Oct-90	17,238	0	40,920	210.00	57.02	57.43	3.97	55,000	124.26	526,080	40,920	31	165,000
Nov-90	16,682	0	39,600	210.00	58.17	58.62	5.12	55,000	124.25	526,080	39,600	30	165,000
Dec-90	17,238	0	40,920	210.00	62.54	63.10	9.49	55,000	124.24	526,080	40,920	31	165,000
Jan-91	17,238	0	17,238	209.42	21.85	19.60	0.00	55,000	127.09	518,279	17,238	31	69,510
Feb-91	15,570	0	15,570	207.57	22.06	12.66	0.00	55,000	125.85	493,695	15,570	28	69,510
Mar-91	17,238	0	17,238	206.04	22.37	15.43	0.00	55,000	124.12	473,257	17,238	31	69,510
Apr-91	16,682	0	16,682	203.65	22.73	11.75	0.00	55,000	122.18	443,092	16,682	30	69,510
May-91	17,238	0	17,238	205.44	22.79	31.44	0.00	55,000	121.84	465,230	17,238	31	69,510
Jun-91	16,682	0	16,682	205.22	22.65	21.92	0.00	55,000	122.62	462,315	16,682	30	69,510
Jul-91	17,238	0	17,238	205.20	22.67	22.85	0.00	55,000	122.49	461,961	17,238	31	69,510
Aug-91	17,238	0	17,238	205.19	22.67	23.05	0.00	55,000	122.47	461,841	17,238	31	69,510
Sep-91	16,682	0	16,682	207.22	22.48	33.36	0.00	55,000	123.51	488,975	16,682	30	69,510
Oct-91	17,238	0	17,238	209.40	22.10	33.42	0.00	55,000	125.66	518,091	17,238	31	69,510
Nov-91	16,682	0	39,600	210.00	53.92	57.40	0.75	55,000	123.96	526,080	39,600	30	165,000
Dec-91	17,238	0	25,892	210.00	33.09	33.62	0.00	55,000	126.03	526,080	25,892	31	104,405

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 55 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-92	17,238	0	17,238	208.77	21.91	16.37	0.00	55,000	126.76	509,686	17,238	31	69,510
Feb-92	16,126	0	16,126	206.54	22.22	10.93	0.00	55,000	124.99	479,829	16,126	29	69,510
Mar-92	17,238	0	17,238	203.49	22.69	8.75	0.00	55,000	122.36	441,162	17,238	31	69,510
Apr-92	16,682	0	16,682	201.43	23.20	14.05	0.00	55,000	119.68	416,286	16,682	30	69,510
May-92	17,238	0	17,238	206.47	22.89	46.64	0.00	55,000	121.28	478,944	17,238	31	69,510
Jun-92	16,682	0	20,006	210.00	26.63	45.23	0.00	55,000	125.04	526,080	20,006	30	83,357
Jul-92	17,238	0	27,000	210.00	34.56	34.92	0.00	55,000	125.85	526,080	27,000	31	108,869
Aug-92	17,238	0	38,280	210.00	49.51	49.84	0.00	55,000	124.53	526,080	38,280	31	154,353
Sep-92	16,682	0	30,636	210.00	40.75	41.12	0.00	55,000	125.15	526,080	30,636	30	127,650
Oct-92	17,238	0	25,801	210.00	32.97	33.39	0.00	55,000	126.04	526,080	25,801	31	104,037
Nov-92	16,682	0	36,239	210.00	48.41	48.82	0.00	55,000	124.60	526,080	36,239	30	150,997
Dec-92	17,238	0	24,050	210.00	30.67	31.12	0.00	55,000	126.32	526,080	24,050	31	96,976
Jan-93	17,238	0	19,596	210.00	24.85	25.32	0.00	55,000	127.02	526,080	19,596	31	79,016
Feb-93	15,570	0	15,570	208.13	21.96	12.21	0.00	55,000	126.43	501,114	15,570	28	69,510
Mar-93	17,238	0	17,238	206.97	22.23	17.02	0.00	55,000	124.88	485,690	17,238	31	69,510
Apr-93	16,682	0	16,682	207.76	22.27	26.82	0.00	55,000	124.70	496,192	16,682	30	69,510
May-93	17,238	0	19,310	210.00	24.70	36.33	0.00	55,000	125.92	526,080	19,310	31	77,865
Jun-93	16,682	0	35,551	210.00	47.46	47.83	0.00	55,000	124.67	526,080	35,551	30	148,130
Jul-93	17,238	0	27,838	210.00	35.67	36.11	0.00	55,000	125.72	526,080	27,838	31	112,250
Aug-93	17,238	0	20,053	210.00	25.44	25.86	0.00	55,000	126.95	526,080	20,053	31	80,860
Sep-93	16,682	0	28,148	210.00	37.33	37.69	0.00	55,000	125.52	526,080	28,148	30	117,284
Oct-93	17,238	0	40,920	210.00	57.80	58.20	4.76	55,000	124.26	526,080	40,920	31	165,000
Nov-93	16,682	0	30,414	210.00	40.44	40.78	0.00	55,000	125.17	526,080	30,414	30	126,723
Dec-93	17,238	0	20,525	210.00	26.06	26.51	0.00	55,000	126.87	526,080	20,525	31	82,762
Jan-94	17,238	0	17,238	207.99	21.97	12.86	0.00	55,000	126.36	499,305	17,238	31	69,510
Feb-94	15,570	0	15,570	205.34	22.40	8.64	0.00	55,000	123.98	463,852	15,570	28	69,510
Mar-94	17,238	0	17,238	201.71	22.99	7.31	0.00	55,000	120.78	419,618	17,238	31	69,510
Apr-94	16,682	0	16,682	197.56	23.76	6.40	0.00	55,000	116.88	372,810	16,682	30	69,510
May-94	17,238	0	17,238	197.79	24.19	25.46	0.00	55,000	114.77	375,286	17,238	31	69,510
Jun-94	16,682	0	16,682	200.73	23.85	36.73	0.00	55,000	116.44	407,915	16,682	30	69,510
Jul-94	17,238	0	17,238	203.92	23.23	37.95	0.00	55,000	119.54	446,273	17,238	31	69,510
Aug-94	17,238	0	17,238	206.02	22.71	32.99	0.00	55,000	122.29	472,881	17,238	31	69,510
Sep-94	16,682	0	16,682	208.29	22.31	34.41	0.00	55,000	124.47	503,216	16,682	30	69,510
Oct-94	17,238	0	21,951	210.00	28.11	37.07	0.00	55,000	125.77	526,080	21,951	31	88,511
Nov-94	16,682	0	39,600	210.00	64.89	65.28	11.83	55,000	124.23	526,080	39,600	30	165,000
Dec-94	17,238	0	23,306	210.00	29.69	30.30	0.00	55,000	126.44	526,080	23,306	31	93,975
Jan-95	17,238	0	17,238	208.56	21.92	15.43	0.00	55,000	126.65	506,855	17,238	31	69,510
Feb-95	15,570	0	15,570	205.89	22.29	8.33	0.00	55,000	124.55	471,227	15,570	28	69,510
Mar-95	17,238	0	17,238	201.81	22.92	4.79	0.00	55,000	121.15	420,908	17,238	31	69,510
Apr-95	16,682	0	16,682	197.65	23.73	6.06	0.00	55,000	116.99	373,794	16,682	30	69,510
May-95	17,238	0	17,238	196.31	24.34	19.17	0.00	55,000	114.06	359,351	17,238	31	69,510
Jun-95	16,682	0	16,682	199.18	24.18	36.39	0.00	55,000	114.84	390,240	16,682	30	69,510
Jul-95	17,238	0	17,238	203.69	23.40	43.61	0.00	55,000	118.67	443,495	17,238	31	69,510
Aug-95	17,238	0	17,238	207.49	22.59	41.32	0.00	55,000	122.94	492,578	17,238	31	69,510
Sep-95	16,682	0	16,682	208.69	22.14	28.72	0.00	55,000	125.44	508,635	16,682	30	69,510
Oct-95	17,238	0	18,912	210.00	24.09	30.98	0.00	55,000	126.46	526,080	18,912	31	76,259
Nov-95	16,682	0	28,708	210.00	38.10	38.49	0.00	55,000	125.43	526,080	28,708	30	119,617
Dec-95	17,238	0	38,282	210.00	49.52	50.01	0.00	55,000	124.53	526,080	38,282	31	154,363

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 55 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-96	17,238	0	40,920	210.00	72.51	73.21	19.44	55,000	124.19	526,080	40,920	31	165,000
Feb-96	16,126	0	21,800	210.00	29.69	30.53	0.00	55,000	126.44	526,080	21,800	29	93,967
Mar-96	17,238	0	17,238	209.98	21.80	22.63	0.00	55,000	127.37	525,810	17,238	31	69,510
Apr-96	16,682	0	16,682	209.32	21.86	19.26	0.00	55,000	127.03	516,989	16,682	30	69,510
May-96	17,238	0	33,651	210.00	43.50	47.46	0.00	55,000	124.61	526,080	33,651	31	135,688
Jun-96	16,682	0	31,638	210.00	42.11	42.54	0.00	55,000	125.05	526,080	31,638	30	131,826
Jul-96	17,238	0	34,780	210.00	44.87	45.26	0.00	55,000	124.86	526,080	34,780	31	140,243
Aug-96	17,238	0	38,224	210.00	49.44	49.87	0.00	55,000	124.53	526,080	38,224	31	154,130
Sep-96	16,682	0	25,177	210.00	33.26	33.67	0.00	55,000	126.01	526,080	25,177	30	104,903
Oct-96	17,238	0	32,416	210.00	41.75	42.14	0.00	55,000	125.08	526,080	32,416	31	130,711
Nov-96	16,682	0	39,600	210.00	82.85	83.18	29.76	55,000	124.15	526,080	39,600	30	165,000
Dec-96	17,238	0	40,920	210.00	94.29	94.67	40.11	55,000	121.64	526,080	40,920	31	165,000
Jan-97	17,238	0	22,376	210.00	28.47	28.97	0.00	55,000	126.58	526,080	22,376	31	90,224
Feb-97	15,570	0	15,570	208.98	21.89	16.79	0.00	55,000	126.86	512,452	15,570	28	69,510
Mar-97	17,238	0	17,238	206.21	22.23	9.09	0.00	55,000	124.93	475,544	17,238	31	69,510
Apr-97	16,682	0	16,682	203.00	22.77	7.76	0.00	55,000	121.94	435,199	16,682	30	69,510
May-97	17,238	0	17,238	204.78	22.92	31.35	0.00	55,000	121.14	456,737	17,238	31	69,510
Jun-97	16,682	0	16,682	205.54	22.68	26.85	0.00	55,000	122.45	466,562	16,682	30	69,510
Jul-97	17,238	0	17,238	204.05	22.74	16.20	0.00	55,000	122.10	447,938	17,238	31	69,510
Aug-97	17,238	0	17,238	201.84	23.11	13.51	0.00	55,000	120.17	421,200	17,238	31	69,510
Sep-97	16,682	0	16,682	200.68	23.44	18.38	0.00	55,000	118.45	407,288	16,682	30	69,510
Oct-97	17,238	0	17,238	200.85	23.54	24.61	0.00	55,000	117.94	409,320	17,238	31	69,510
Nov-97	16,682	0	16,682	200.43	23.57	21.86	0.00	55,000	117.81	404,208	16,682	30	69,510
Dec-97	17,238	0	17,238	199.86	23.67	21.58	0.00	55,000	117.31	397,546	17,238	31	69,510
Jan-98	17,238	0	17,238	196.80	24.05	12.18	0.00	55,000	115.44	364,621	17,238	31	69,510
Feb-98	15,570	0	15,570	192.83	24.81	8.35	0.00	55,000	111.92	323,873	15,570	28	69,510
Mar-98	17,238	0	17,238	186.52	26.01	4.98	0.00	55,000	106.77	266,407	17,238	31	69,510
Apr-98	16,682	0	16,682	182.16	27.46	14.30	0.00	52,169	101.13	231,638	16,682	30	69,510
May-98	17,238	0	17,238	186.14	27.52	39.56	0.00	48,847	100.91	263,181	17,238	31	69,510
Jun-98	16,682	0	16,682	185.13	27.12	24.02	0.00	51,861	102.38	254,557	16,682	30	69,510
Jul-98	17,238	0	17,238	186.27	27.10	30.95	0.00	51,037	102.45	264,276	17,238	31	69,510
Aug-98	17,238	0	17,238	188.49	26.65	33.93	0.00	51,965	104.18	283,166	17,238	31	69,510
Sep-98	16,682	0	16,682	190.74	26.06	34.15	0.00	53,770	106.54	303,328	16,682	30	69,510
Oct-98	17,238	0	17,238	192.82	25.54	33.47	0.00	55,000	108.71	323,811	17,238	31	69,510
Nov-98	16,682	0	16,682	196.23	24.88	38.52	0.00	55,000	111.59	358,477	16,682	30	69,510
Dec-98	17,238	0	17,238	203.50	23.69	54.83	0.00	55,000	117.22	441,237	17,238	31	69,510
Jan-99	17,238	0	17,238	205.15	22.84	30.76	0.00	55,000	121.59	461,384	17,238	31	69,510
Feb-99	15,570	0	15,570	205.31	22.66	24.02	0.00	55,000	122.51	463,448	15,570	28	69,510
Mar-99	17,238	0	17,238	203.44	22.82	14.84	0.00	55,000	121.65	440,580	17,238	31	69,510
Apr-99	16,682	0	16,682	202.15	23.13	17.53	0.00	55,000	120.02	424,988	16,682	30	69,510
May-99	17,238	0	17,238	202.62	23.22	25.66	0.00	55,000	119.60	430,605	17,238	31	69,510
Jun-99	16,682	0	16,682	205.38	22.90	36.22	0.00	55,000	121.27	464,366	16,682	30	69,510
Jul-99	17,238	0	17,238	209.93	22.22	45.26	0.00	55,000	124.99	525,133	17,238	31	69,510
Aug-99	17,238	0	40,920	210.00	53.08	53.81	0.02	55,000	124.24	526,080	40,920	31	165,000
Sep-99	16,682	0	32,899	210.00	43.83	44.24	0.00	55,000	124.93	526,080	32,899	30	137,078
Oct-99	17,238	0	31,143	210.00	40.07	40.47	0.00	55,000	125.20	526,080	31,143	31	125,578
Nov-99	16,682	0	38,675	210.00	51.76	52.11	0.00	55,000	124.37	526,080	38,675	30	161,147
Dec-99	17,238	0	40,920	210.00	126.49	126.79	72.12	55,000	121.24	526,080	40,920	31	165,000

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 65 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-48	17,238	0	48,360	210.00	73.12	16.57	12.73	65,000	128.98	526,080	48,360	31	195,000
Feb-48	16,126	0	16,126	207.37	22.03	9.01	0.00	65,000	126.04	490,940	16,126	29	69,510
Mar-48	17,238	0	17,238	203.79	22.59	6.32	0.00	65,000	122.93	444,792	17,238	31	69,510
Apr-48	16,682	0	16,682	199.89	23.32	6.06	0.00	65,000	119.05	397,891	16,682	30	69,510
May-48	17,238	0	17,238	197.32	23.99	14.16	0.00	65,000	115.73	370,244	17,238	31	69,510
Jun-48	16,682	0	16,682	197.09	24.30	23.73	0.00	65,000	114.29	367,741	16,682	30	69,510
Jul-48	17,238	0	17,238	200.91	23.90	40.04	0.00	65,000	116.19	410,066	17,238	31	69,510
Aug-48	17,238	0	17,238	202.61	23.34	31.49	0.00	65,000	118.96	430,524	17,238	31	69,510
Sep-48	16,682	0	16,682	203.26	23.11	26.59	0.00	65,000	120.16	438,398	16,682	30	69,510
Oct-48	17,238	0	17,238	206.60	22.71	38.94	0.00	65,000	122.29	480,646	17,238	31	69,510
Nov-48	16,682	0	20,921	210.00	27.87	45.82	0.00	65,000	124.95	526,080	20,921	30	87,172
Dec-48	17,238	0	22,548	210.00	28.70	29.48	0.00	65,000	126.56	526,080	22,548	31	90,920
Jan-49	17,238	0	17,238	208.42	21.94	14.98	0.00	65,000	126.58	504,925	17,238	31	69,510
Feb-49	15,570	0	15,570	205.91	22.31	9.37	0.00	65,000	124.48	471,429	15,570	28	69,510
Mar-49	17,238	0	17,238	202.25	22.88	6.85	0.00	65,000	121.38	426,195	17,238	31	69,510
Apr-49	16,682	0	16,682	198.38	23.62	7.16	0.00	65,000	117.57	381,615	16,682	30	69,510
May-49	17,238	0	17,238	198.12	24.07	23.51	0.00	65,000	115.36	378,867	17,238	31	69,510
Jun-49	16,682	0	16,682	201.55	23.72	39.14	0.00	65,000	117.09	417,774	16,682	30	69,510
Jul-49	17,238	0	17,238	207.46	22.78	51.03	0.00	65,000	121.90	492,155	17,238	31	69,510
Aug-49	17,238	0	27,152	210.00	35.12	48.31	0.00	65,000	124.51	526,080	27,152	31	109,483
Sep-49	16,682	0	28,507	210.00	37.82	38.37	0.00	65,000	125.46	526,080	28,507	30	118,778
Oct-49	17,238	0	34,536	210.00	44.55	45.03	0.00	65,000	124.88	526,080	34,536	31	139,258
Nov-49	16,682	0	45,246	210.00	60.87	61.34	0.00	65,000	123.72	526,080	45,246	30	188,524
Dec-49	17,238	0	40,855	210.00	52.95	53.58	0.00	65,000	124.28	526,080	40,855	31	164,736
Jan-50	17,238	0	17,238	209.58	21.83	20.65	0.00	65,000	127.17	520,410	17,238	31	69,510
Feb-50	15,570	0	15,570	208.52	21.97	17.08	0.00	65,000	126.41	506,349	15,570	28	69,510
Mar-50	17,238	0	17,238	206.00	22.29	10.76	0.00	65,000	124.59	472,706	17,238	31	69,510
Apr-50	16,682	0	16,682	205.31	22.58	20.02	0.00	65,000	122.95	463,498	16,682	30	69,510
May-50	17,238	0	17,238	208.84	22.32	40.47	0.00	65,000	124.40	510,596	17,238	31	69,510
Jun-50	16,682	0	18,071	210.00	23.76	30.16	0.00	65,000	126.57	526,080	18,071	30	75,296
Jul-50	17,238	0	41,246	210.00	53.47	53.89	0.00	65,000	124.25	526,080	41,246	31	166,315
Aug-50	17,238	0	35,175	210.00	45.39	45.85	0.00	65,000	124.82	526,080	35,175	31	141,834
Sep-50	16,682	0	24,560	210.00	32.41	32.94	0.00	65,000	126.11	526,080	24,560	30	102,331
Oct-50	17,238	0	20,278	210.00	25.74	26.20	0.00	65,000	126.91	526,080	20,278	31	81,765
Nov-50	16,682	0	37,694	210.00	50.41	50.83	0.00	65,000	124.46	526,080	37,694	30	157,058
Dec-50	17,238	0	45,804	210.00	59.59	60.12	0.00	65,000	123.81	526,080	45,804	31	184,692
Jan-51	17,238	0	17,238	209.41	21.85	19.74	0.00	65,000	127.08	518,151	17,238	31	69,510
Feb-51	15,570	0	27,465	210.00	39.18	43.27	0.00	65,000	125.00	526,080	27,465	28	122,612
Mar-51	17,238	0	17,644	210.00	22.32	23.28	0.00	65,000	127.32	526,080	17,644	31	71,145
Apr-51	16,682	0	16,682	209.38	21.85	19.43	0.00	65,000	127.07	517,769	16,682	30	69,510
May-51	17,238	0	17,447	210.00	22.12	25.80	0.00	65,000	127.03	526,080	17,447	31	70,349
Jun-51	16,682	0	22,785	210.00	30.00	30.53	0.00	65,000	126.40	526,080	22,785	30	94,937
Jul-51	17,238	0	25,611	210.00	32.72	33.22	0.00	65,000	126.07	526,080	25,611	31	103,270
Aug-51	17,238	0	19,197	210.00	24.33	24.86	0.00	65,000	127.08	526,080	19,197	31	77,408
Sep-51	16,682	0	21,485	210.00	28.24	28.74	0.00	65,000	126.61	526,080	21,485	30	89,520
Oct-51	17,238	0	19,232	210.00	24.38	24.84	0.00	65,000	127.07	526,080	19,232	31	77,548
Nov-51	16,682	0	21,652	210.00	28.47	28.94	0.00	65,000	126.58	526,080	21,652	30	90,218
Dec-51	17,238	0	21,653	210.00	27.53	28.26	0.00	65,000	126.70	526,080	21,653	31	87,309

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 65 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-52	17,238	0	17,238	209.12	21.87	18.41	0.00	65,000	126.94	514,392	17,238	31	69,510
Feb-52	16,126	0	16,126	207.14	22.13	12.43	0.00	65,000	125.48	487,881	16,126	29	69,510
Mar-52	17,238	0	17,238	204.16	22.58	9.01	0.00	65,000	122.98	449,192	17,238	31	69,510
Apr-52	16,682	0	16,682	201.29	23.15	10.65	0.00	65,000	119.95	414,666	16,682	30	69,510
May-52	17,238	0	17,238	201.35	23.43	24.16	0.00	65,000	118.51	415,353	17,238	31	69,510
Jun-52	16,682	0	16,682	201.37	23.42	23.87	0.00	65,000	118.55	415,615	16,682	30	69,510
Jul-52	17,238	0	17,238	203.12	23.24	31.49	0.00	65,000	119.46	436,658	17,238	31	69,510
Aug-52	17,238	0	17,238	206.33	22.75	38.23	0.00	65,000	122.06	477,032	17,238	31	69,510
Sep-52	16,682	0	16,682	208.72	22.24	35.03	0.00	65,000	124.86	509,027	16,682	30	69,510
Oct-52	17,238	0	32,890	210.00	42.59	49.42	0.00	65,000	124.38	526,080	32,890	31	132,620
Nov-52	16,682	0	23,454	210.00	30.91	31.49	0.00	65,000	126.29	526,080	23,454	30	97,726
Dec-52	17,238	0	40,700	210.00	52.74	53.27	0.00	65,000	124.30	526,080	40,700	31	164,111
Jan-53	17,238	0	31,692	210.00	40.79	41.46	0.00	65,000	125.14	526,080	31,692	31	127,792
Feb-53	15,570	0	18,650	210.00	26.22	27.07	0.00	65,000	126.85	526,080	18,650	28	83,260
Mar-53	17,238	0	17,238	208.23	21.95	13.96	0.00	65,000	126.48	502,481	17,238	31	69,510
Apr-53	16,682	0	16,682	206.18	22.30	12.49	0.00	65,000	124.53	475,021	16,682	30	69,510
May-53	17,238	0	17,238	209.17	22.21	37.67	0.00	65,000	125.01	515,045	17,238	31	69,510
Jun-53	16,682	0	17,445	210.00	22.89	27.61	0.00	65,000	126.84	526,080	17,445	30	72,689
Jul-53	17,238	0	25,235	210.00	32.23	32.62	0.00	65,000	126.13	526,080	25,235	31	101,756
Aug-53	17,238	0	24,201	210.00	30.87	31.46	0.00	65,000	126.30	526,080	24,201	31	97,586
Sep-53	16,682	0	21,012	210.00	27.61	28.12	0.00	65,000	126.69	526,080	21,012	30	87,551
Oct-53	17,238	0	25,947	210.00	33.16	33.64	0.00	65,000	126.02	526,080	25,947	31	104,625
Nov-53	16,682	0	29,463	210.00	39.14	39.65	0.00	65,000	125.30	526,080	29,463	30	122,761
Dec-53	17,238	0	26,314	210.00	33.65	34.32	0.00	65,000	125.96	526,080	26,314	31	106,105
Jan-54	17,238	0	17,238	209.09	21.88	18.27	0.00	65,000	126.92	513,947	17,238	31	69,510
Feb-54	15,570	0	15,570	207.42	22.11	13.74	0.00	65,000	125.60	491,652	15,570	28	69,510
Mar-54	17,238	0	17,238	205.22	22.46	12.38	0.00	65,000	123.63	462,292	17,238	31	69,510
Apr-54	16,682	0	16,682	202.90	22.89	12.83	0.00	65,000	121.33	433,987	16,682	30	69,510
May-54	17,238	0	17,238	202.47	23.16	21.72	0.00	65,000	119.90	428,795	17,238	31	69,510
Jun-54	16,682	0	16,682	204.87	22.96	34.66	0.00	65,000	120.91	457,814	16,682	30	69,510
Jul-54	17,238	0	17,238	207.24	22.51	34.72	0.00	65,000	123.36	489,215	17,238	31	69,510
Aug-54	17,238	0	19,324	210.00	24.77	39.02	0.00	65,000	125.65	526,080	19,324	31	77,918
Sep-54	16,682	0	28,311	210.00	37.55	38.18	0.00	65,000	125.49	526,080	28,311	30	117,960
Oct-54	17,238	0	19,282	210.00	24.44	25.01	0.00	65,000	127.07	526,080	19,282	31	77,751
Nov-54	16,682	0	46,800	210.00	63.63	64.26	0.59	65,000	123.57	526,080	46,800	30	195,000
Dec-54	17,238	0	48,044	210.00	62.61	63.24	0.00	65,000	123.60	526,080	48,044	31	193,728
Jan-55	17,238	0	48,360	210.00	64.18	64.88	1.13	65,000	123.56	526,080	48,360	31	195,000
Feb-55	15,570	0	15,570	209.21	21.87	18.35	0.00	65,000	126.98	515,581	15,570	28	69,510
Mar-55	17,238	0	17,238	207.11	22.12	12.74	0.00	65,000	125.51	487,527	17,238	31	69,510
Apr-55	16,682	0	16,682	204.48	22.55	10.17	0.00	65,000	123.11	453,010	16,682	30	69,510
May-55	17,238	0	17,238	202.66	22.98	15.32	0.00	65,000	120.81	431,073	17,238	31	69,510
Jun-55	16,682	0	16,682	201.31	23.30	17.47	0.00	65,000	119.19	414,876	16,682	30	69,510
Jul-55	17,238	0	17,238	202.35	23.33	28.32	0.00	65,000	119.03	427,366	17,238	31	69,510
Aug-55	17,238	0	17,238	207.76	22.67	48.74	0.00	65,000	122.46	496,129	17,238	31	69,510
Sep-55	16,682	0	16,682	209.47	22.04	31.41	0.00	65,000	125.97	518,970	16,682	30	69,510
Oct-55	17,238	0	19,918	210.00	25.32	28.49	0.00	65,000	126.69	526,080	19,918	31	80,316
Nov-55	16,682	0	46,800	210.00	76.72	77.09	13.65	65,000	123.51	526,080	46,800	30	195,000
Dec-55	17,238	0	33,734	210.00	43.49	44.04	0.00	65,000	124.95	526,080	33,734	31	136,025

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 65 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-56	17,238	0	47,472	210.00	61.84	62.47	0.00	65,000	123.65	526,080	47,472	31	191,420
Feb-56	16,126	0	16,126	209.82	21.81	21.72	0.00	65,000	127.29	523,628	16,126	29	69,510
Mar-56	17,238	0	17,238	209.08	21.89	19.20	0.00	65,000	126.82	513,815	17,238	31	69,510
Apr-56	16,682	0	16,682	208.47	22.01	19.80	0.00	65,000	126.14	505,703	16,682	30	69,510
May-56	17,238	0	27,399	210.00	35.31	43.41	0.00	65,000	125.00	526,080	27,399	31	110,480
Jun-56	16,682	0	27,790	210.00	36.83	37.27	0.00	65,000	125.58	526,080	27,790	30	115,792
Jul-56	17,238	0	48,360	210.00	63.49	63.92	0.45	65,000	123.57	526,080	48,360	31	195,000
Aug-56	17,238	0	26,256	210.00	33.57	34.13	0.00	65,000	125.97	526,080	26,256	31	105,870
Sep-56	16,682	0	26,640	210.00	35.26	35.74	0.00	65,000	125.77	526,080	26,640	30	110,998
Oct-56	17,238	0	34,245	210.00	44.16	44.63	0.00	65,000	124.91	526,080	34,245	31	138,086
Nov-56	16,682	0	46,800	210.00	85.97	86.38	22.88	65,000	123.47	526,080	46,800	30	195,000
Dec-56	17,238	0	31,725	210.00	40.83	41.49	0.00	65,000	125.14	526,080	31,725	31	127,922
Jan-57	17,238	0	17,238	208.95	21.89	17.50	0.00	65,000	126.85	512,033	17,238	31	69,510
Feb-57	15,570	0	15,570	206.88	22.17	11.55	0.00	65,000	125.25	484,434	15,570	28	69,510
Mar-57	17,238	0	17,238	203.68	22.64	8.18	0.00	65,000	122.63	443,463	17,238	31	69,510
Apr-57	16,682	0	16,682	199.95	23.33	6.91	0.00	65,000	119.02	398,567	16,682	30	69,510
May-57	17,238	0	17,238	197.11	24.01	13.14	0.00	65,000	115.65	368,028	17,238	31	69,510
Jun-57	16,682	0	16,682	194.06	24.64	12.74	0.00	65,000	112.67	336,058	16,682	30	69,510
Jul-57	17,238	0	17,238	190.27	25.45	11.89	0.00	65,000	109.11	298,710	17,238	31	69,510
Aug-57	17,238	0	17,238	186.28	26.41	13.91	0.00	65,000	105.12	264,309	17,238	31	69,510
Sep-57	16,682	0	16,682	183.23	27.35	18.18	0.00	61,416	101.54	239,825	16,682	30	69,510
Oct-57	17,238	0	17,238	184.19	27.66	30.64	0.00	58,651	100.39	247,228	17,238	31	69,510
Nov-57	16,682	0	16,682	190.86	26.59	48.99	0.00	59,487	104.44	304,512	16,682	30	69,510
Dec-57	17,238	0	17,238	192.77	25.53	33.05	0.00	65,000	108.75	323,351	17,238	31	69,510
Jan-58	17,238	0	17,238	194.76	25.07	32.88	0.00	65,000	110.76	342,897	17,238	31	69,510
Feb-58	15,570	0	15,570	192.05	25.15	14.78	0.00	65,000	110.39	316,261	15,570	28	69,510
Mar-58	17,238	0	17,238	187.39	26.01	10.70	0.00	65,000	106.76	273,789	17,238	31	69,510
Apr-58	16,682	0	16,682	180.65	27.53	7.31	0.00	62,487	100.85	220,048	16,682	30	69,510
May-58	17,238	0	17,238	176.08	29.26	17.62	0.00	56,417	94.89	188,005	17,238	31	69,510
Jun-58	16,682	0	16,682	172.01	30.70	21.27	0.00	52,189	90.45	162,917	16,682	30	69,510
Jul-58	17,238	0	17,238	167.12	32.38	22.12	0.00	48,790	85.74	134,991	17,238	31	69,510
Aug-58	17,238	0	17,238	162.16	34.40	25.23	0.00	44,612	80.72	110,057	17,238	31	69,510
Sep-58	16,682	0	16,682	156.19	37.12	27.05	0.00	40,619	74.81	83,599	16,682	30	69,510
Oct-58	17,238	4,047	13,192	155.00	29.49	27.73	0.00	36,053	72.06	78,480	13,192	31	53,192
Nov-58	16,682	2,517	14,165	155.00	33.20	33.33	0.00	35,130	71.02	78,480	14,165	30	59,021
Dec-58	17,238	5,161	12,078	155.00	27.12	27.27	0.00	35,130	71.75	78,480	12,078	31	48,700
Jan-59	17,238	11,566	5,673	155.00	12.51	12.72	0.00	35,130	73.05	78,480	5,673	31	22,875
Feb-59	15,570	12,137	3,433	155.00	8.35	8.58	0.00	35,130	73.30	78,480	3,433	28	15,325
Mar-59	17,238	14,291	2,947	155.00	6.47	6.68	0.00	35,130	73.41	78,480	2,947	31	11,884
Apr-59	16,682	12,504	4,179	155.00	9.50	9.74	0.00	35,130	73.23	78,480	4,179	30	17,411
May-59	17,238	9,246	7,993	155.00	17.70	17.87	0.00	35,130	72.74	78,480	7,993	31	32,229
Jun-59	16,682	9,092	7,590	155.00	17.36	17.47	0.00	35,130	72.76	78,480	7,590	30	31,625
Jul-59	17,238	9,877	7,361	155.00	16.28	16.43	0.00	35,130	72.82	78,480	7,361	31	29,683
Aug-59	17,238	8,981	8,257	155.00	18.29	18.44	0.00	35,130	72.70	78,480	8,257	31	33,295
Sep-59	16,682	3,011	13,671	155.00	31.98	32.11	0.00	35,130	71.16	78,480	13,671	30	56,964
Oct-59	17,238	2,626	14,613	155.00	33.14	33.25	0.00	35,130	71.02	78,480	14,613	31	58,922
Nov-59	16,682	0	16,682	165.50	36.49	54.97	0.00	35,130	76.10	126,019	16,682	30	69,510
Dec-59	17,238	0	17,238	188.92	29.15	89.52	0.00	43,175	95.25	286,824	17,238	31	69,510

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 65 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-60	17,238	0	17,238	196.58	25.27	53.98	0.00	63,959	109.86	362,291	17,238	31	69,510
Feb-60	16,126	0	16,126	193.39	24.77	12.29	0.00	65,000	112.08	329,407	16,126	29	69,510
Mar-60	17,238	0	17,238	188.45	25.72	8.95	0.00	65,000	107.94	282,865	17,238	31	69,510
Apr-60	16,682	0	16,682	186.76	26.59	21.47	0.00	63,512	104.41	268,415	16,682	30	69,510
May-60	17,238	0	17,238	186.87	26.80	27.44	0.00	61,880	103.60	269,405	17,238	31	69,510
Jun-60	16,682	0	16,682	187.71	26.68	29.68	0.00	61,992	104.09	276,487	16,682	30	69,510
Jul-60	17,238	0	17,238	189.02	26.40	30.84	0.00	62,792	105.19	287,658	17,238	31	69,510
Aug-60	17,238	0	17,238	189.87	26.12	29.14	0.00	64,053	106.31	294,931	17,238	31	69,510
Sep-60	16,682	0	16,682	190.95	25.87	30.22	0.00	64,875	107.31	305,399	16,682	30	69,510
Oct-60	17,238	0	17,238	193.28	25.46	34.35	0.00	65,000	109.06	328,337	17,238	31	69,510
Nov-60	16,682	0	16,682	195.93	24.87	35.60	0.00	65,000	111.66	355,307	16,682	30	69,510
Dec-60	17,238	0	22,226	210.00	29.87	94.11	0.00	65,000	119.87	526,080	22,226	31	89,620
Jan-61	17,238	0	17,238	209.14	21.87	18.38	0.00	65,000	126.95	514,656	17,238	31	69,510
Feb-61	15,570	0	15,570	206.80	22.16	10.14	0.00	65,000	125.32	483,415	15,570	28	69,510
Mar-61	17,238	0	17,238	203.60	22.66	8.16	0.00	65,000	122.55	442,443	17,238	31	69,510
Apr-61	16,682	0	16,682	201.03	23.23	11.92	0.00	65,000	119.53	411,470	16,682	30	69,510
May-61	17,238	0	17,238	199.75	23.62	18.46	0.00	65,000	117.57	396,342	17,238	31	69,510
Jun-61	16,682	0	16,682	203.96	23.32	43.13	0.00	65,000	119.07	446,795	16,682	30	69,510
Jul-61	17,238	0	17,238	204.77	22.83	26.85	0.00	65,000	121.63	456,603	17,238	31	69,510
Aug-61	17,238	0	17,238	206.90	22.55	33.50	0.00	65,000	123.14	484,712	17,238	31	69,510
Sep-61	16,682	0	16,682	208.65	22.19	31.55	0.00	65,000	125.11	507,992	16,682	30	69,510
Oct-61	17,238	0	23,870	210.00	30.60	37.78	0.00	65,000	125.65	526,080	23,870	31	96,252
Nov-61	16,682	0	33,479	210.00	44.62	45.06	0.00	65,000	124.87	526,080	33,479	30	139,495
Dec-61	17,238	0	21,975	210.00	27.95	28.46	0.00	65,000	126.65	526,080	21,975	31	88,610
Jan-62	17,238	0	17,238	208.99	21.89	17.62	0.00	65,000	126.87	512,563	17,238	31	69,510
Feb-62	15,570	0	15,570	206.85	22.17	11.24	0.00	65,000	125.26	483,969	15,570	28	69,510
Mar-62	17,238	0	17,238	203.82	22.63	9.03	0.00	65,000	122.68	445,165	17,238	31	69,510
Apr-62	16,682	0	16,682	200.71	23.24	9.49	0.00	65,000	119.48	407,665	16,682	30	69,510
May-62	17,238	0	17,238	201.55	23.47	27.64	0.00	65,000	118.32	417,777	17,238	31	69,510
Jun-62	16,682	0	16,682	200.78	23.46	20.22	0.00	65,000	118.35	408,411	16,682	30	69,510
Jul-62	17,238	0	17,238	202.86	23.33	33.05	0.00	65,000	119.02	433,586	17,238	31	69,510
Aug-62	17,238	0	17,238	207.31	22.67	44.18	0.00	65,000	122.47	490,150	17,238	31	69,510
Sep-62	16,682	0	18,025	210.00	23.85	38.15	0.00	65,000	125.79	526,080	18,025	30	75,104
Oct-62	17,238	0	28,038	210.00	35.93	36.39	0.00	65,000	125.69	526,080	28,038	31	113,055
Nov-62	16,682	0	30,220	210.00	40.18	40.67	0.00	65,000	125.19	526,080	30,220	30	125,918
Dec-62	17,238	0	24,413	210.00	31.14	31.78	0.00	65,000	126.26	526,080	24,413	31	98,439
Jan-63	17,238	0	28,893	210.00	37.07	37.86	0.00	65,000	125.55	526,080	28,893	31	116,505
Feb-63	15,570	0	15,570	209.41	21.85	19.37	0.00	65,000	127.08	518,184	15,570	28	69,510
Mar-63	17,238	0	17,238	207.39	22.08	12.86	0.00	65,000	125.75	491,206	17,238	31	69,510
Apr-63	16,682	0	16,682	208.24	22.19	27.33	0.00	65,000	125.15	502,534	16,682	30	69,510
May-63	17,238	0	23,087	210.00	29.62	39.02	0.00	65,000	125.56	526,080	23,087	31	93,094
Jun-63	16,682	0	30,695	210.00	40.83	41.29	0.00	65,000	125.14	526,080	30,695	30	127,897
Jul-63	17,238	0	36,639	210.00	47.33	47.78	0.00	65,000	124.68	526,080	36,639	31	147,739
Aug-63	17,238	0	35,138	210.00	45.34	45.77	0.00	65,000	124.82	526,080	35,138	31	141,687
Sep-63	16,682	0	36,659	210.00	48.98	49.39	0.00	65,000	124.56	526,080	36,659	30	152,746
Oct-63	17,238	0	29,022	210.00	37.24	37.69	0.00	65,000	125.53	526,080	29,022	31	117,025
Nov-63	16,682	0	32,619	210.00	43.45	43.90	0.00	65,000	124.96	526,080	32,619	30	135,911
Dec-63	17,238	0	19,491	210.00	24.71	25.37	0.00	65,000	127.03	526,080	19,491	31	78,593

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 65 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-64	17,238	0	17,238	208.55	21.93	15.43	0.00	65,000	126.64	506,747	17,238	31	69,510
Feb-64	16,126	0	16,126	206.51	22.24	12.09	0.00	65,000	124.86	479,447	16,126	29	69,510
Mar-64	17,238	0	17,238	203.67	22.68	9.91	0.00	65,000	122.43	443,309	17,238	31	69,510
Apr-64	16,682	0	16,682	202.18	23.11	16.94	0.00	65,000	120.15	425,365	16,682	30	69,510
May-64	17,238	0	17,238	202.91	23.18	26.96	0.00	65,000	119.76	434,142	17,238	31	69,510
Jun-64	16,682	0	16,682	207.48	22.65	45.54	0.00	65,000	122.58	492,414	16,682	30	69,510
Jul-64	17,238	0	17,238	208.56	22.15	28.01	0.00	65,000	125.36	506,851	17,238	31	69,510
Aug-64	17,238	0	17,238	209.37	21.98	26.42	0.00	65,000	126.33	517,718	17,238	31	69,510
Sep-64	16,682	0	21,293	210.00	28.06	31.69	0.00	65,000	126.32	526,080	21,293	30	88,722
Oct-64	17,238	0	21,675	210.00	27.56	27.92	0.00	65,000	126.69	526,080	21,675	31	87,400
Nov-64	16,682	0	29,220	210.00	38.80	39.19	0.00	65,000	125.34	526,080	29,220	30	121,751
Dec-64	17,238	0	17,238	209.96	21.80	22.23	0.00	65,000	127.36	525,543	17,238	31	69,510
Jan-65	17,238	0	17,238	209.08	21.88	18.15	0.00	65,000	126.89	513,782	17,238	31	69,510
Feb-65	15,570	0	15,570	207.48	22.10	14.10	0.00	65,000	125.63	492,483	15,570	28	69,510
Mar-65	17,238	0	17,238	205.20	22.46	11.87	0.00	65,000	123.65	462,022	17,238	31	69,510
Apr-65	16,682	0	16,682	202.40	22.94	10.68	0.00	65,000	121.06	428,029	16,682	30	69,510
May-65	17,238	0	17,238	202.40	23.21	23.73	0.00	65,000	119.62	427,981	17,238	31	69,510
Jun-65	16,682	0	16,682	204.51	23.01	33.16	0.00	65,000	120.69	453,449	16,682	30	69,510
Jul-65	17,238	0	17,238	204.51	22.80	23.28	0.00	65,000	121.77	453,392	17,238	31	69,510
Aug-65	17,238	0	17,238	206.10	22.65	30.73	0.00	65,000	122.61	474,032	17,238	31	69,510
Sep-65	16,682	0	16,682	209.55	22.18	40.33	0.00	65,000	125.16	520,056	16,682	30	69,510
Oct-65	17,238	0	37,232	210.00	48.21	50.83	0.00	65,000	124.39	526,080	37,232	31	150,128
Nov-65	16,682	0	37,268	210.00	49.82	50.10	0.00	65,000	124.50	526,080	37,268	30	155,282
Dec-65	17,238	0	39,310	210.00	50.89	51.40	0.00	65,000	124.43	526,080	39,310	31	158,508
Jan-66	17,238	0	19,893	210.00	25.24	25.88	0.00	65,000	126.97	526,080	19,893	31	80,214
Feb-66	15,570	0	15,570	208.91	21.89	16.82	0.00	65,000	126.83	511,594	15,570	28	69,510
Mar-66	17,238	0	17,238	206.82	22.18	12.60	0.00	65,000	125.21	483,643	17,238	31	69,510
Apr-66	16,682	0	16,682	209.12	22.16	34.69	0.00	65,000	125.31	514,285	16,682	30	69,510
May-66	17,238	0	28,162	210.00	36.23	41.01	0.00	65,000	125.21	526,080	28,162	31	113,557
Jun-66	16,682	0	24,431	210.00	32.24	32.74	0.00	65,000	126.13	526,080	24,431	30	101,796
Jul-66	17,238	0	26,262	210.00	33.58	33.98	0.00	65,000	125.97	526,080	26,262	31	105,897
Aug-66	17,238	0	23,554	210.00	30.02	30.42	0.00	65,000	126.40	526,080	23,554	31	94,977
Sep-66	16,682	0	28,508	210.00	37.82	38.15	0.00	65,000	125.46	526,080	28,508	30	118,783
Oct-66	17,238	0	32,608	210.00	42.00	42.37	0.00	65,000	125.06	526,080	32,608	31	131,485
Nov-66	16,682	0	46,800	210.00	78.64	79.04	15.57	65,000	123.50	526,080	46,800	30	195,000
Dec-66	17,238	0	48,360	210.00	76.70	77.14	13.63	65,000	123.51	526,080	48,360	31	195,000
Jan-67	17,238	0	25,942	210.00	33.16	33.93	0.00	65,000	126.02	526,080	25,942	31	104,607
Feb-67	15,570	0	15,570	209.48	21.84	19.88	0.00	65,000	127.12	519,164	15,570	28	69,510
Mar-67	17,238	0	17,238	207.57	22.06	13.40	0.00	65,000	125.88	493,675	17,238	31	69,510
Apr-67	16,682	0	16,682	209.21	22.08	31.27	0.00	65,000	125.74	515,519	16,682	30	69,510
May-67	17,238	0	29,852	210.00	38.47	43.05	0.00	65,000	124.99	526,080	29,852	31	120,373
Jun-67	16,682	0	36,739	210.00	49.09	49.50	0.00	65,000	124.56	526,080	36,739	30	153,078
Jul-67	17,238	0	34,520	210.00	44.53	44.86	0.00	65,000	124.88	526,080	34,520	31	139,194
Aug-67	17,238	0	26,243	210.00	33.56	33.93	0.00	65,000	125.97	526,080	26,243	31	105,820
Sep-67	16,682	0	26,362	210.00	34.88	35.32	0.00	65,000	125.81	526,080	26,362	30	109,842
Oct-67	17,238	0	23,690	210.00	30.19	30.50	0.00	65,000	126.38	526,080	23,690	31	95,526
Nov-67	16,682	0	27,044	210.00	35.81	36.16	0.00	65,000	125.70	526,080	27,044	30	112,683
Dec-67	17,238	0	28,500	210.00	36.54	37.10	0.00	65,000	125.61	526,080	28,500	31	114,918

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 65 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-68	17,238	0	17,238	208.43	21.94	14.87	0.00	65,000	126.58	505,056	17,238	31	69,510
Feb-68	16,126	0	16,126	206.48	22.25	12.57	0.00	65,000	124.78	479,040	16,126	29	69,510
Mar-68	17,238	0	17,238	204.50	22.61	13.79	0.00	65,000	122.80	453,359	17,238	31	69,510
Apr-68	16,682	0	16,682	202.89	22.96	16.26	0.00	65,000	120.94	433,950	16,682	30	69,510
May-68	17,238	0	17,238	205.85	22.82	36.90	0.00	65,000	121.68	470,639	17,238	31	69,510
Jun-68	16,682	0	16,682	207.76	22.37	32.60	0.00	65,000	124.12	496,122	16,682	30	69,510
Jul-68	17,238	0	19,886	210.00	25.46	37.04	0.00	65,000	125.82	526,080	19,886	31	80,185
Aug-68	17,238	0	27,835	210.00	35.66	36.05	0.00	65,000	125.72	526,080	27,835	31	112,239
Sep-68	16,682	0	27,113	210.00	35.90	36.25	0.00	65,000	125.69	526,080	27,113	30	112,973
Oct-68	17,238	0	26,231	210.00	33.54	33.90	0.00	65,000	125.98	526,080	26,231	31	105,770
Nov-68	16,682	0	23,516	210.00	31.00	31.35	0.00	65,000	126.28	526,080	23,516	30	97,983
Dec-68	17,238	0	19,620	210.00	24.88	25.49	0.00	65,000	127.01	526,080	19,620	31	79,113
Jan-69	17,238	0	17,238	208.79	21.90	16.54	0.00	65,000	126.77	509,920	17,238	31	69,510
Feb-69	15,570	0	15,570	206.97	22.17	13.00	0.00	65,000	125.22	485,690	15,570	28	69,510
Mar-69	17,238	0	17,238	204.49	22.57	11.21	0.00	65,000	123.05	453,205	17,238	31	69,510
Apr-69	16,682	0	16,682	203.18	22.93	17.53	0.00	65,000	121.08	437,396	16,682	30	69,510
May-69	17,238	0	17,238	204.94	22.89	31.27	0.00	65,000	121.31	458,591	17,238	31	69,510
Jun-69	16,682	0	16,682	204.23	22.79	19.82	0.00	65,000	121.85	450,025	16,682	30	69,510
Jul-69	17,238	0	17,238	205.62	22.72	29.62	0.00	65,000	122.23	467,671	17,238	31	69,510
Aug-69	17,238	0	17,238	208.41	22.33	36.50	0.00	65,000	124.34	504,808	17,238	31	69,510
Sep-69	16,682	0	17,931	210.00	23.62	32.17	0.00	65,000	126.37	526,080	17,931	30	74,711
Oct-69	17,238	0	17,988	210.00	22.77	23.25	0.00	65,000	127.27	526,080	17,988	31	72,534
Nov-69	16,682	0	21,997	210.00	28.94	29.28	0.00	65,000	126.53	526,080	21,997	30	91,652
Dec-69	17,238	0	48,360	210.00	74.26	74.71	11.19	65,000	123.52	526,080	48,360	31	195,000
Jan-70	17,238	0	48,360	210.00	66.83	67.43	3.78	65,000	123.55	526,080	48,360	31	195,000
Feb-70	15,570	0	15,570	207.96	21.98	11.47	0.00	65,000	126.34	498,795	15,570	28	69,510
Mar-70	17,238	0	17,238	207.32	22.22	19.77	0.00	65,000	124.97	490,259	17,238	31	69,510
Apr-70	16,682	0	20,775	210.00	27.59	42.11	0.00	65,000	125.35	526,080	20,775	30	86,563
May-70	17,238	0	37,218	210.00	48.10	48.60	0.00	65,000	124.63	526,080	37,218	31	150,072
Jun-70	16,682	0	21,357	210.00	28.07	28.46	0.00	65,000	126.63	526,080	21,357	30	88,986
Jul-70	17,238	0	24,600	210.00	31.39	31.80	0.00	65,000	126.23	526,080	24,600	31	99,195
Aug-70	17,238	0	28,870	210.00	37.04	37.38	0.00	65,000	125.56	526,080	28,870	31	116,411
Sep-70	16,682	0	26,761	210.00	35.42	35.82	0.00	65,000	125.75	526,080	26,761	30	111,504
Oct-70	17,238	0	30,637	210.00	39.39	39.73	0.00	65,000	125.27	526,080	30,637	31	123,535
Nov-70	16,682	0	30,616	210.00	40.72	41.06	0.00	65,000	125.15	526,080	30,616	30	127,566
Dec-70	17,238	0	48,360	210.00	74.51	74.82	11.44	65,000	123.52	526,080	48,360	31	195,000
Jan-71	17,238	0	33,361	210.00	42.99	43.58	0.00	65,000	124.99	526,080	33,361	31	134,521
Feb-71	15,570	0	15,570	208.92	21.89	16.79	0.00	65,000	126.83	511,634	15,570	28	69,510
Mar-71	17,238	0	17,238	207.40	22.12	15.38	0.00	65,000	125.50	491,393	17,238	31	69,510
Apr-71	16,682	0	16,682	206.13	22.38	16.74	0.00	65,000	124.08	474,448	16,682	30	69,510
May-71	17,238	0	17,238	206.29	22.48	23.70	0.00	65,000	123.51	476,492	17,238	31	69,510
Jun-71	16,682	0	16,682	209.25	22.20	37.81	0.00	65,000	125.10	516,024	16,682	30	69,510
Jul-71	17,238	0	32,753	210.00	42.32	46.47	0.00	65,000	124.66	526,080	32,753	31	132,068
Aug-71	17,238	0	29,844	210.00	38.34	38.71	0.00	65,000	125.40	526,080	29,844	31	120,340
Sep-71	16,682	0	24,899	210.00	32.88	33.28	0.00	65,000	126.05	526,080	24,899	30	103,746
Oct-71	17,238	0	24,050	210.00	30.67	31.10	0.00	65,000	126.32	526,080	24,050	31	96,976
Nov-71	16,682	0	29,345	210.00	38.97	39.31	0.00	65,000	125.32	526,080	29,345	30	122,270
Dec-71	17,238	0	17,238	209.81	21.81	21.61	0.00	65,000	127.29	523,578	17,238	31	69,510

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 65 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-72	17,238	0	43,059	210.00	55.94	57.43	0.00	65,000	123.98	526,080	43,059	31	173,626
Feb-72	16,126	0	16,126	208.48	21.93	14.64	0.00	65,000	126.61	505,790	16,126	29	69,510
Mar-72	17,238	0	17,238	205.89	22.30	10.31	0.00	65,000	124.51	471,268	17,238	31	69,510
Apr-72	16,682	0	16,682	206.42	22.49	25.83	0.00	65,000	123.46	478,346	16,682	30	69,510
May-72	17,238	0	17,238	205.32	22.54	17.59	0.00	65,000	123.17	463,657	17,238	31	69,510
Jun-72	16,682	0	16,682	205.06	22.67	21.75	0.00	65,000	122.47	460,160	16,682	30	69,510
Jul-72	17,238	0	17,238	202.98	22.90	14.10	0.00	65,000	121.28	434,953	17,238	31	69,510
Aug-72	17,238	0	17,238	203.39	23.06	25.35	0.00	65,000	120.42	439,901	17,238	31	69,510
Sep-72	16,682	0	16,682	202.58	23.10	19.68	0.00	65,000	120.21	430,203	16,682	30	69,510
Oct-72	17,238	0	17,238	204.46	22.99	31.75	0.00	65,000	120.76	452,822	17,238	31	69,510
Nov-72	16,682	0	16,682	206.65	22.60	34.04	0.00	65,000	122.87	481,421	16,682	30	69,510
Dec-72	17,238	0	17,238	206.02	22.46	19.88	0.00	65,000	123.64	472,883	17,238	31	69,510
Jan-73	17,238	0	17,238	203.56	22.74	11.92	0.00	65,000	122.12	442,022	17,238	31	69,510
Feb-73	15,570	0	15,570	200.41	23.30	8.35	0.00	65,000	119.19	403,997	15,570	28	69,510
Mar-73	17,238	0	17,238	195.68	24.11	5.64	0.00	65,000	115.17	352,577	17,238	31	69,510
Apr-73	16,682	0	16,682	190.27	25.25	5.10	0.00	65,000	109.97	298,663	16,682	30	69,510
May-73	17,238	0	17,238	187.02	26.32	16.26	0.00	65,000	105.50	270,626	17,238	31	69,510
Jun-73	16,682	0	16,682	187.48	26.69	28.40	0.00	62,129	104.05	274,560	16,682	30	69,510
Jul-73	17,238	0	17,238	187.86	26.58	28.29	0.00	62,574	104.48	277,782	17,238	31	69,510
Aug-73	17,238	0	17,238	189.67	26.29	32.34	0.00	62,938	105.61	293,256	17,238	31	69,510
Sep-73	16,682	0	16,682	190.25	25.98	28.29	0.00	64,686	106.87	298,548	16,682	30	69,510
Oct-73	17,238	0	17,238	193.04	25.57	36.14	0.00	65,000	108.58	325,969	17,238	31	69,510
Nov-73	16,682	0	16,682	201.66	24.22	60.43	0.00	65,000	114.63	419,083	16,682	30	69,510
Dec-73	17,238	0	17,238	206.53	22.87	46.05	0.00	65,000	121.44	479,821	17,238	31	69,510
Jan-74	17,238	0	17,238	207.36	22.34	27.19	0.00	65,000	124.27	490,885	17,238	31	69,510
Feb-74	15,570	0	15,570	205.55	22.44	13.20	0.00	65,000	123.76	466,638	15,570	28	69,510
Mar-74	17,238	0	17,238	202.48	22.89	9.69	0.00	65,000	121.29	428,921	17,238	31	69,510
Apr-74	16,682	0	16,682	198.71	23.56	7.48	0.00	65,000	117.84	385,223	16,682	30	69,510
May-74	17,238	0	17,238	195.80	24.28	13.00	0.00	65,000	114.34	353,869	17,238	31	69,510
Jun-74	16,682	0	16,682	193.70	24.84	16.85	0.00	65,000	111.80	332,451	16,682	30	69,510
Jul-74	17,238	0	17,238	192.74	25.20	21.92	0.00	65,000	110.20	323,061	17,238	31	69,510
Aug-74	17,238	0	17,238	194.34	25.12	31.29	0.00	65,000	110.53	338,797	17,238	31	69,510
Sep-74	16,682	0	16,682	195.93	24.75	31.38	0.00	65,000	112.19	355,332	16,682	30	69,510
Oct-74	17,238	0	17,238	200.48	24.07	42.79	0.00	65,000	115.35	404,865	17,238	31	69,510
Nov-74	16,682	0	16,682	203.97	23.25	39.73	0.00	65,000	119.44	446,952	16,682	30	69,510
Dec-74	17,238	0	17,238	204.71	22.83	26.76	0.00	65,000	121.60	455,859	17,238	31	69,510
Jan-75	17,238	0	17,238	202.13	23.01	12.12	0.00	65,000	120.66	424,724	17,238	31	69,510
Feb-75	15,570	0	15,570	198.60	23.61	7.50	0.00	65,000	117.61	383,982	15,570	28	69,510
Mar-75	17,238	0	17,238	193.46	24.54	5.13	0.00	65,000	113.15	330,168	17,238	31	69,510
Apr-75	16,682	0	16,682	187.66	25.80	5.58	0.00	65,000	107.62	276,092	16,682	30	69,510
May-75	17,238	0	17,238	188.76	26.44	30.33	0.00	62,747	105.04	285,500	17,238	31	69,510
Jun-75	16,682	0	16,682	189.51	26.20	28.86	0.00	63,810	105.99	291,876	16,682	30	69,510
Jul-75	17,238	0	17,238	194.79	25.44	44.80	0.00	64,530	109.13	343,215	17,238	31	69,510
Aug-75	17,238	0	17,238	201.51	24.07	52.08	0.00	65,000	115.36	417,290	17,238	31	69,510
Sep-75	16,682	0	16,682	203.92	23.15	34.75	0.00	65,000	119.94	446,309	16,682	30	69,510
Oct-75	17,238	0	17,238	208.83	22.44	46.64	0.00	65,000	123.73	510,404	17,238	31	69,510
Nov-75	16,682	0	38,464	210.00	51.72	58.06	0.00	65,000	123.78	526,080	38,464	30	160,268
Dec-75	17,238	0	44,290	210.00	57.55	58.03	0.00	65,000	123.96	526,080	44,290	31	178,589

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 65 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-76	17,238	0	19,773	210.00	25.08	25.80	0.00	65,000	126.99	526,080	19,773	31	79,730
Feb-76	16,126	0	16,126	208.33	21.94	13.99	0.00	65,000	126.53	503,782	16,126	29	69,510
Mar-76	17,238	0	17,238	205.93	22.31	11.24	0.00	65,000	124.45	471,708	17,238	31	69,510
Apr-76	16,682	0	16,682	203.72	22.73	12.74	0.00	65,000	122.14	443,885	16,682	30	69,510
May-76	17,238	0	17,238	202.92	23.03	19.88	0.00	65,000	120.56	434,254	17,238	31	69,510
Jun-76	16,682	0	16,682	201.82	23.22	18.46	0.00	65,000	119.58	420,998	16,682	30	69,510
Jul-76	17,238	0	17,238	199.26	23.58	12.86	0.00	65,000	117.75	391,084	17,238	31	69,510
Aug-76	17,238	0	17,238	196.90	24.11	14.98	0.00	65,000	115.19	365,782	17,238	31	69,510
Sep-76	16,682	0	16,682	196.35	24.42	22.34	0.00	65,000	113.70	359,815	16,682	30	69,510
Oct-76	17,238	0	17,238	200.19	24.06	39.85	0.00	65,000	115.39	401,359	17,238	31	69,510
Nov-76	16,682	0	16,682	204.29	23.25	42.68	0.00	65,000	119.45	450,805	16,682	30	69,510
Dec-76	17,238	0	17,238	203.05	22.96	17.93	0.00	65,000	120.92	435,876	17,238	31	69,510
Jan-77	17,238	0	17,238	201.24	23.26	15.80	0.00	65,000	119.36	414,056	17,238	31	69,510
Feb-77	15,570	0	15,570	198.36	23.73	10.96	0.00	65,000	117.03	381,478	15,570	28	69,510
Mar-77	17,238	0	17,238	194.06	24.50	8.18	0.00	65,000	113.31	336,078	17,238	31	69,510
Apr-77	16,682	0	16,682	189.21	25.56	8.21	0.00	65,000	108.62	289,320	16,682	30	69,510
May-77	17,238	0	17,238	185.34	26.68	14.70	0.00	64,241	104.07	256,312	17,238	31	69,510
Jun-77	16,682	0	16,682	181.72	27.71	17.11	0.00	60,513	100.22	228,246	16,682	30	69,510
Jul-77	17,238	0	17,238	179.46	28.57	22.57	0.00	57,343	97.19	211,320	17,238	31	69,510
Aug-77	17,238	0	17,238	179.34	28.95	28.83	0.00	55,347	95.93	210,457	17,238	31	69,510
Sep-77	16,682	0	16,682	178.34	29.12	26.71	0.00	55,230	95.34	203,588	16,682	30	69,510
Oct-77	17,238	0	17,238	188.07	27.73	56.36	0.00	54,300	100.13	279,610	17,238	31	69,510
Nov-77	16,682	0	16,682	193.38	25.77	45.26	0.00	63,144	107.77	329,381	16,682	30	69,510
Dec-77	17,238	0	17,238	195.46	24.91	33.11	0.00	65,000	111.45	350,248	17,238	31	69,510
Jan-78	17,238	0	17,238	192.31	25.04	13.85	0.00	65,000	110.90	318,788	17,238	31	69,510
Feb-78	15,570	0	15,570	188.49	25.85	11.67	0.00	65,000	107.40	283,158	15,570	28	69,510
Mar-78	17,238	0	17,238	182.17	27.17	8.44	0.00	63,545	102.21	231,723	17,238	31	69,510
Apr-78	16,682	0	16,682	181.51	28.20	26.62	0.00	57,735	98.46	226,634	16,682	30	69,510
May-78	17,238	0	17,238	181.37	28.32	28.21	0.00	57,161	98.04	225,557	17,238	31	69,510
Jun-78	16,682	0	16,682	185.35	27.75	39.85	0.00	57,039	100.05	256,381	16,682	30	69,510
Jul-78	17,238	0	17,238	191.45	26.36	46.73	0.00	60,521	105.35	310,296	17,238	31	69,510
Aug-78	17,238	0	17,238	197.66	24.86	48.88	0.00	65,000	111.69	373,857	17,238	31	69,510
Sep-78	16,682	0	16,682	199.62	23.99	32.43	0.00	65,000	115.76	394,939	16,682	30	69,510
Oct-78	17,238	0	17,238	202.06	23.52	34.66	0.00	65,000	118.04	423,906	17,238	31	69,510
Nov-78	16,682	0	16,682	206.13	22.87	42.68	0.00	65,000	121.41	474,359	16,682	30	69,510
Dec-78	17,238	0	17,238	206.25	22.49	23.56	0.00	65,000	123.49	475,999	17,238	31	69,510
Jan-79	17,238	0	17,238	203.89	22.68	12.12	0.00	65,000	122.40	446,003	17,238	31	69,510
Feb-79	15,570	0	15,570	200.88	23.22	8.89	0.00	65,000	119.60	409,702	15,570	28	69,510
Mar-79	17,238	0	17,238	196.56	23.96	6.85	0.00	65,000	115.90	362,032	17,238	31	69,510
Apr-79	16,682	0	16,682	194.77	24.63	17.78	0.00	65,000	112.72	343,067	16,682	30	69,510
May-79	17,238	0	17,238	192.52	25.10	17.11	0.00	65,000	110.64	320,897	17,238	31	69,510
Jun-79	16,682	0	16,682	192.00	25.43	23.70	0.00	65,000	109.21	315,746	16,682	30	69,510
Jul-79	17,238	0	17,238	192.44	25.44	27.30	0.00	65,000	109.17	320,033	17,238	31	69,510
Aug-79	17,238	0	17,238	195.50	25.02	36.73	0.00	65,000	110.99	350,688	17,238	31	69,510
Sep-79	16,682	0	16,682	197.17	24.49	31.75	0.00	65,000	113.39	368,578	16,682	30	69,510
Oct-79	17,238	0	17,238	198.15	24.20	28.55	0.00	65,000	114.76	379,216	17,238	31	69,510
Nov-79	16,682	0	16,682	202.36	23.63	42.82	0.00	65,000	117.52	427,503	16,682	30	69,510
Dec-79	17,238	0	17,238	206.22	22.83	41.09	0.00	65,000	121.61	475,575	17,238	31	69,510

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 65 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-80	17,238	0	17,238	207.79	22.33	30.87	0.00	65,000	124.33	496,629	17,238	31	69,510
Feb-80	16,126	0	16,126	206.98	22.26	18.52	0.00	65,000	124.71	485,739	16,126	29	69,510
Mar-80	17,238	0	17,238	204.23	22.59	10.05	0.00	65,000	122.93	450,037	17,238	31	69,510
Apr-80	16,682	0	16,682	201.41	23.13	10.70	0.00	65,000	120.05	416,084	16,682	30	69,510
May-80	17,238	0	17,238	201.08	23.45	22.37	0.00	65,000	118.43	412,086	17,238	31	69,510
Jun-80	16,682	0	16,682	202.26	23.36	29.28	0.00	65,000	118.87	426,353	16,682	30	69,510
Jul-80	17,238	0	17,238	200.97	23.37	17.93	0.00	65,000	118.81	410,697	17,238	31	69,510
Aug-80	17,238	0	17,238	200.37	23.56	21.27	0.00	65,000	117.84	403,545	17,238	31	69,510
Sep-80	16,682	0	16,682	200.27	23.63	23.56	0.00	65,000	117.49	402,337	16,682	30	69,510
Oct-80	17,238	0	17,238	201.73	23.50	30.39	0.00	65,000	118.18	419,932	17,238	31	69,510
Nov-80	16,682	0	16,682	205.99	22.92	43.64	0.00	65,000	121.17	472,587	16,682	30	69,510
Dec-80	17,238	0	17,238	209.36	22.21	39.59	0.00	65,000	125.01	517,541	17,238	31	69,510
Jan-81	17,238	0	17,238	209.49	21.90	23.28	0.00	65,000	126.80	519,260	17,238	31	69,510
Feb-81	15,570	0	15,570	208.57	21.97	17.67	0.00	65,000	126.39	507,029	15,570	28	69,510
Mar-81	17,238	0	17,238	206.86	22.20	14.36	0.00	65,000	125.05	484,206	17,238	31	69,510
Apr-81	16,682	0	46,800	210.00	84.03	100.68	20.11	65,000	121.85	526,080	46,800	30	195,000
May-81	17,238	0	35,551	210.00	45.89	46.36	0.00	65,000	124.78	526,080	35,551	31	143,350
Jun-81	16,682	0	27,745	210.00	36.77	37.21	0.00	65,000	125.59	526,080	27,745	30	115,603
Jul-81	17,238	0	30,782	210.00	39.59	39.99	0.00	65,000	125.25	526,080	30,782	31	124,122
Aug-81	17,238	0	29,961	210.00	38.49	38.91	0.00	65,000	125.38	526,080	29,961	31	120,810
Sep-81	16,682	0	20,891	210.00	27.44	27.90	0.00	65,000	126.71	526,080	20,891	30	87,047
Oct-81	17,238	0	25,622	210.00	32.74	33.16	0.00	65,000	126.07	526,080	25,622	31	103,315
Nov-81	16,682	0	30,380	210.00	40.40	40.78	0.00	65,000	125.17	526,080	30,380	30	126,584
Dec-81	17,238	0	47,015	210.00	61.22	61.71	0.00	65,000	123.70	526,080	47,015	31	189,575
Jan-82	17,238	0	24,637	210.00	31.44	32.09	0.00	65,000	126.23	526,080	24,637	31	99,344
Feb-82	15,570	0	15,570	208.50	21.93	14.56	0.00	65,000	126.62	506,043	15,570	28	69,510
Mar-82	17,238	0	17,238	205.69	22.32	9.18	0.00	65,000	124.41	468,481	17,238	31	69,510
Apr-82	16,682	0	16,682	203.34	22.79	12.26	0.00	65,000	121.81	439,331	16,682	30	69,510
May-82	17,238	0	17,238	203.03	23.06	22.06	0.00	65,000	120.42	435,566	17,238	31	69,510
Jun-82	16,682	0	16,682	202.10	23.18	19.26	0.00	65,000	119.78	424,366	16,682	30	69,510
Jul-82	17,238	0	17,238	204.15	23.07	32.74	0.00	65,000	120.36	449,120	17,238	31	69,510
Aug-82	17,238	0	17,238	205.84	22.70	31.18	0.00	65,000	122.31	470,577	17,238	31	69,510
Sep-82	16,682	0	16,682	207.14	22.43	29.51	0.00	65,000	123.80	487,885	16,682	30	69,510
Oct-82	17,238	0	24,256	210.00	31.30	45.91	0.00	65,000	124.81	526,080	24,256	31	97,807
Nov-82	16,682	0	23,845	210.00	31.44	31.97	0.00	65,000	126.23	526,080	23,845	30	99,353
Dec-82	17,238	0	17,238	209.56	21.84	20.39	0.00	65,000	127.16	520,209	17,238	31	69,510
Jan-83	17,238	0	17,238	208.04	22.01	15.26	0.00	65,000	126.16	499,972	17,238	31	69,510
Feb-83	15,570	0	15,570	205.38	22.39	8.50	0.00	65,000	124.03	464,415	15,570	28	69,510
Mar-83	17,238	0	17,238	201.51	23.00	6.20	0.00	65,000	120.70	417,227	17,238	31	69,510
Apr-83	16,682	0	16,682	197.07	23.83	5.44	0.00	65,000	116.52	367,577	16,682	30	69,510
May-83	17,238	0	17,238	200.10	24.00	36.65	0.00	65,000	115.71	400,279	17,238	31	69,510
Jun-83	16,682	0	16,682	199.66	23.72	22.20	0.00	65,000	117.04	395,450	16,682	30	69,510
Jul-83	17,238	0	17,238	198.50	23.89	19.63	0.00	65,000	116.22	382,937	17,238	31	69,510
Aug-83	17,238	0	17,238	197.80	24.09	21.66	0.00	65,000	115.26	375,422	17,238	31	69,510
Sep-83	16,682	0	16,682	198.60	24.08	27.70	0.00	65,000	115.31	383,993	16,682	30	69,510
Oct-83	17,238	0	17,238	201.04	23.73	34.32	0.00	65,000	117.03	411,536	17,238	31	69,510
Nov-83	16,682	0	16,682	204.59	23.13	39.99	0.00	65,000	120.04	454,370	16,682	30	69,510
Dec-83	17,238	0	37,333	210.00	49.35	76.61	0.00	65,000	121.85	526,080	37,333	31	150,537

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 65 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-84	17,238	0	19,546	210.00	24.79	25.60	0.00	65,000	127.03	526,080	19,546	31	78,815
Feb-84	16,126	0	16,126	208.64	21.92	15.46	0.00	65,000	126.69	507,900	16,126	29	69,510
Mar-84	17,238	0	17,238	205.77	22.30	8.95	0.00	65,000	124.53	469,645	17,238	31	69,510
Apr-84	16,682	0	16,682	202.11	22.90	6.32	0.00	65,000	121.24	424,537	16,682	30	69,510
May-84	17,238	0	17,238	200.96	23.39	18.66	0.00	65,000	118.73	410,594	17,238	31	69,510
Jun-84	16,682	0	16,682	202.38	23.36	30.33	0.00	65,000	118.86	427,741	16,682	30	69,510
Jul-84	17,238	0	17,238	205.81	22.87	39.11	0.00	65,000	121.39	470,128	17,238	31	69,510
Aug-84	17,238	0	35,512	210.00	46.64	67.91	0.00	65,000	122.63	526,080	35,512	31	143,193
Sep-84	16,682	0	35,936	210.00	47.99	48.43	0.00	65,000	124.63	526,080	35,936	30	149,734
Oct-84	17,238	0	42,186	210.00	54.73	55.14	0.00	65,000	124.16	526,080	42,186	31	170,105
Nov-84	16,682	0	41,350	210.00	55.46	55.85	0.00	65,000	124.11	526,080	41,350	30	172,290
Dec-84	17,238	0	27,018	210.00	34.58	35.15	0.00	65,000	125.85	526,080	27,018	31	108,942
Jan-85	17,238	0	17,238	209.29	21.86	19.17	0.00	65,000	127.02	516,553	17,238	31	69,510
Feb-85	15,570	0	15,570	207.47	22.09	12.89	0.00	65,000	125.73	492,287	15,570	28	69,510
Mar-85	17,238	0	17,238	205.39	22.44	12.94	0.00	65,000	123.73	464,473	17,238	31	69,510
Apr-85	16,682	0	16,682	202.33	22.92	9.40	0.00	65,000	121.13	427,163	16,682	30	69,510
May-85	17,238	0	17,238	201.40	23.32	19.57	0.00	65,000	119.07	415,945	17,238	31	69,510
Jun-85	16,682	0	16,682	203.70	23.18	34.18	0.00	65,000	119.77	443,608	16,682	30	69,510
Jul-85	17,238	0	17,238	204.34	22.90	26.20	0.00	65,000	121.27	451,341	17,238	31	69,510
Aug-85	17,238	0	17,238	203.90	22.88	21.21	0.00	65,000	121.37	446,025	17,238	31	69,510
Sep-85	16,682	0	16,682	206.90	22.62	37.86	0.00	65,000	122.73	484,644	16,682	30	69,510
Oct-85	17,238	0	17,238	208.51	22.21	30.61	0.00	65,000	125.04	506,220	17,238	31	69,510
Nov-85	16,682	0	16,682	209.97	21.93	29.88	0.00	65,000	126.61	525,741	16,682	30	69,510
Dec-85	17,238	0	39,594	210.00	51.27	51.97	0.00	65,000	124.39	526,080	39,594	31	159,652
Jan-86	17,238	0	17,238	209.01	21.88	17.73	0.00	65,000	126.88	512,859	17,238	31	69,510
Feb-86	15,570	0	15,570	206.95	22.16	11.78	0.00	65,000	125.32	485,411	15,570	28	69,510
Mar-86	17,238	0	17,238	204.68	22.55	12.15	0.00	65,000	123.13	455,478	17,238	31	69,510
Apr-86	16,682	0	16,682	204.34	22.80	21.98	0.00	65,000	121.77	451,371	16,682	30	69,510
May-86	17,238	0	17,238	209.68	22.33	49.36	0.00	65,000	124.36	521,767	17,238	31	69,510
Jun-86	16,682	0	21,625	210.00	28.47	30.64	0.00	65,000	126.42	526,080	21,625	30	90,106
Jul-86	17,238	0	19,611	210.00	24.87	25.35	0.00	65,000	127.02	526,080	19,611	31	79,076
Aug-86	17,238	0	17,238	209.95	21.80	22.03	0.00	65,000	127.36	525,463	17,238	31	69,510
Sep-86	16,682	0	27,140	210.00	35.95	36.65	0.00	65,000	125.66	526,080	27,140	30	113,084
Oct-86	17,238	0	44,133	210.00	57.34	57.66	0.00	65,000	123.97	526,080	44,133	31	177,954
Nov-86	16,682	0	29,825	210.00	39.64	40.16	0.00	65,000	125.24	526,080	29,825	30	124,272
Dec-86	17,238	0	23,145	210.00	29.48	30.27	0.00	65,000	126.46	526,080	23,145	31	93,327
Jan-87	17,238	0	17,238	208.08	21.97	13.34	0.00	65,000	126.41	500,507	17,238	31	69,510
Feb-87	15,570	0	15,570	206.16	22.31	12.60	0.00	65,000	124.45	474,859	15,570	28	69,510
Mar-87	17,238	0	17,238	202.86	22.79	8.21	0.00	65,000	121.84	433,545	17,238	31	69,510
Apr-87	16,682	0	16,682	203.89	23.02	28.52	0.00	65,000	120.61	445,949	16,682	30	69,510
May-87	17,238	0	19,702	210.00	25.61	55.93	0.00	65,000	123.93	526,080	19,702	31	79,443
Jun-87	16,682	0	26,907	210.00	35.62	36.05	0.00	65,000	125.73	526,080	26,907	30	112,114
Jul-87	17,238	0	28,054	210.00	35.95	36.45	0.00	65,000	125.69	526,080	28,054	31	113,123
Aug-87	17,238	0	33,895	210.00	43.70	44.24	0.00	65,000	124.94	526,080	33,895	31	136,674
Sep-87	16,682	0	38,155	210.00	51.04	51.51	0.00	65,000	124.42	526,080	38,155	30	158,978
Oct-87	17,238	0	30,558	210.00	39.29	39.76	0.00	65,000	125.29	526,080	30,558	31	123,218
Nov-87	16,682	0	44,768	210.00	60.20	60.66	0.00	65,000	123.77	526,080	44,768	30	186,533
Dec-87	17,238	0	22,916	210.00	29.18	29.79	0.00	65,000	126.50	526,080	22,916	31	92,401

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 65 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-88	17,238	0	17,238	208.17	21.96	13.71	0.00	65,000	126.45	501,648	17,238	31	69,510
Feb-88	16,126	0	16,126	206.53	22.27	14.50	0.00	65,000	124.68	479,788	16,126	29	69,510
Mar-88	17,238	0	17,238	203.48	22.69	9.15	0.00	65,000	122.36	440,966	17,238	31	69,510
Apr-88	16,682	0	16,682	199.75	23.37	6.97	0.00	65,000	118.82	396,395	16,682	30	69,510
May-88	17,238	0	17,238	199.82	23.75	24.50	0.00	65,000	116.94	397,130	17,238	31	69,510
Jun-88	16,682	0	16,682	199.40	23.78	22.34	0.00	65,000	116.76	392,595	16,682	30	69,510
Jul-88	17,238	0	17,238	203.92	23.35	43.78	0.00	65,000	118.89	446,356	17,238	31	69,510
Aug-88	17,238	0	20,857	210.00	27.15	57.29	0.00	65,000	123.76	526,080	20,857	31	84,103
Sep-88	16,682	0	30,368	210.00	40.38	40.84	0.00	65,000	125.17	526,080	30,368	30	126,535
Oct-88	17,238	0	38,962	210.00	50.42	50.81	0.00	65,000	124.46	526,080	38,962	31	157,106
Nov-88	16,682	0	32,995	210.00	43.96	44.46	0.00	65,000	124.92	526,080	32,995	30	137,480
Dec-88	17,238	0	24,863	210.00	31.74	32.40	0.00	65,000	126.19	526,080	24,863	31	100,253
Jan-89	17,238	0	17,238	209.58	21.83	20.62	0.00	65,000	127.17	520,439	17,238	31	69,510
Feb-89	15,570	0	15,570	209.06	21.92	19.94	0.00	65,000	126.69	513,497	15,570	28	69,510
Mar-89	17,238	0	17,238	206.85	22.16	12.12	0.00	65,000	125.29	483,969	17,238	31	69,510
Apr-89	16,682	0	16,682	203.83	22.63	8.64	0.00	65,000	122.68	445,187	16,682	30	69,510
May-89	17,238	0	17,238	202.41	23.07	17.19	0.00	65,000	120.35	428,088	17,238	31	69,510
Jun-89	16,682	0	16,682	204.24	23.03	31.92	0.00	65,000	120.56	450,215	16,682	30	69,510
Jul-89	17,238	0	17,238	206.63	22.62	34.47	0.00	65,000	122.76	481,044	17,238	31	69,510
Aug-89	17,238	0	17,238	209.71	22.12	37.86	0.00	65,000	125.51	522,224	17,238	31	69,510
Sep-89	16,682	0	23,013	210.00	30.35	32.28	0.00	65,000	126.21	526,080	23,013	30	95,887
Oct-89	17,238	0	44,700	210.00	58.10	58.54	0.00	65,000	123.92	526,080	44,700	31	180,241
Nov-89	16,682	0	46,800	210.00	66.97	67.43	3.92	65,000	123.55	526,080	46,800	30	195,000
Dec-89	17,238	0	27,809	210.00	35.63	36.19	0.00	65,000	125.72	526,080	27,809	31	112,133
Jan-90	17,238	0	22,882	210.00	29.13	29.74	0.00	65,000	126.50	526,080	22,882	31	92,264
Feb-90	15,570	0	15,570	209.09	21.88	17.59	0.00	65,000	126.92	513,915	15,570	28	69,510
Mar-90	17,238	0	17,238	207.34	22.11	14.05	0.00	65,000	125.56	490,514	17,238	31	69,510
Apr-90	16,682	0	16,682	207.22	22.28	22.37	0.00	65,000	124.61	489,010	16,682	30	69,510
May-90	17,238	0	45,785	210.00	60.26	74.57	0.00	65,000	122.38	526,080	45,785	31	184,616
Jun-90	16,682	0	16,682	209.76	21.82	21.01	0.00	65,000	127.26	522,870	16,682	30	69,510
Jul-90	17,238	0	17,238	209.12	21.90	19.14	0.00	65,000	126.81	514,312	17,238	31	69,510
Aug-90	17,238	0	22,912	210.00	29.28	34.10	0.00	65,000	126.05	526,080	22,912	31	92,386
Sep-90	16,682	0	33,245	210.00	44.31	44.75	0.00	65,000	124.90	526,080	33,245	30	138,522
Oct-90	17,238	0	43,892	210.00	57.02	57.43	0.00	65,000	123.99	526,080	43,892	31	176,985
Nov-90	16,682	0	43,305	210.00	58.17	58.62	0.00	65,000	123.91	526,080	43,305	30	180,436
Dec-90	17,238	0	47,990	210.00	62.54	63.10	0.00	65,000	123.60	526,080	47,990	31	193,510
Jan-91	17,238	0	17,238	209.42	21.85	19.60	0.00	65,000	127.09	518,279	17,238	31	69,510
Feb-91	15,570	0	15,570	207.57	22.06	12.66	0.00	65,000	125.85	493,695	15,570	28	69,510
Mar-91	17,238	0	17,238	206.04	22.37	15.43	0.00	65,000	124.12	473,257	17,238	31	69,510
Apr-91	16,682	0	16,682	203.65	22.73	11.75	0.00	65,000	122.18	443,092	16,682	30	69,510
May-91	17,238	0	17,238	205.44	22.79	31.44	0.00	65,000	121.84	465,230	17,238	31	69,510
Jun-91	16,682	0	16,682	205.22	22.65	21.92	0.00	65,000	122.62	462,315	16,682	30	69,510
Jul-91	17,238	0	17,238	205.20	22.67	22.85	0.00	65,000	122.49	461,961	17,238	31	69,510
Aug-91	17,238	0	17,238	205.19	22.67	23.05	0.00	65,000	122.47	461,841	17,238	31	69,510
Sep-91	16,682	0	16,682	207.22	22.48	33.36	0.00	65,000	123.51	488,975	16,682	30	69,510
Oct-91	17,238	0	17,238	209.40	22.10	33.42	0.00	65,000	125.66	518,091	17,238	31	69,510
Nov-91	16,682	0	40,144	210.00	53.92	57.40	0.00	65,000	123.91	526,080	40,144	30	167,267
Dec-91	17,238	0	25,892	210.00	33.09	33.62	0.00	65,000	126.03	526,080	25,892	31	104,405

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 65 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-92	17,238	0	17,238	208.77	21.91	16.37	0.00	65,000	126.76	509,686	17,238	31	69,510
Feb-92	16,126	0	16,126	206.54	22.22	10.93	0.00	65,000	124.99	479,829	16,126	29	69,510
Mar-92	17,238	0	17,238	203.49	22.69	8.75	0.00	65,000	122.36	441,162	17,238	31	69,510
Apr-92	16,682	0	16,682	201.43	23.20	14.05	0.00	65,000	119.68	416,286	16,682	30	69,510
May-92	17,238	0	17,238	206.47	22.89	46.64	0.00	65,000	121.28	478,944	17,238	31	69,510
Jun-92	16,682	0	20,006	210.00	26.63	45.23	0.00	65,000	125.04	526,080	20,006	30	83,357
Jul-92	17,238	0	27,000	210.00	34.56	34.92	0.00	65,000	125.85	526,080	27,000	31	108,869
Aug-92	17,238	0	38,280	210.00	49.51	49.84	0.00	65,000	124.53	526,080	38,280	31	154,353
Sep-92	16,682	0	30,636	210.00	40.75	41.12	0.00	65,000	125.15	526,080	30,636	30	127,650
Oct-92	17,238	0	25,801	210.00	32.97	33.39	0.00	65,000	126.04	526,080	25,801	31	104,037
Nov-92	16,682	0	36,239	210.00	48.41	48.82	0.00	65,000	124.60	526,080	36,239	30	150,997
Dec-92	17,238	0	24,050	210.00	30.67	31.12	0.00	65,000	126.32	526,080	24,050	31	96,976
Jan-93	17,238	0	19,596	210.00	24.85	25.32	0.00	65,000	127.02	526,080	19,596	31	79,016
Feb-93	15,570	0	15,570	208.13	21.96	12.21	0.00	65,000	126.43	501,114	15,570	28	69,510
Mar-93	17,238	0	17,238	206.97	22.23	17.02	0.00	65,000	124.88	485,690	17,238	31	69,510
Apr-93	16,682	0	16,682	207.76	22.27	26.82	0.00	65,000	124.70	496,192	16,682	30	69,510
May-93	17,238	0	19,310	210.00	24.70	36.33	0.00	65,000	125.92	526,080	19,310	31	77,865
Jun-93	16,682	0	35,551	210.00	47.46	47.83	0.00	65,000	124.67	526,080	35,551	30	148,130
Jul-93	17,238	0	27,838	210.00	35.67	36.11	0.00	65,000	125.72	526,080	27,838	31	112,250
Aug-93	17,238	0	20,053	210.00	25.44	25.86	0.00	65,000	126.95	526,080	20,053	31	80,860
Sep-93	16,682	0	28,148	210.00	37.33	37.69	0.00	65,000	125.52	526,080	28,148	30	117,284
Oct-93	17,238	0	44,475	210.00	57.80	58.20	0.00	65,000	123.94	526,080	44,475	31	179,333
Nov-93	16,682	0	30,414	210.00	40.44	40.78	0.00	65,000	125.17	526,080	30,414	30	126,723
Dec-93	17,238	0	20,525	210.00	26.06	26.51	0.00	65,000	126.87	526,080	20,525	31	82,762
Jan-94	17,238	0	17,238	207.99	21.97	12.86	0.00	65,000	126.36	499,305	17,238	31	69,510
Feb-94	15,570	0	15,570	205.34	22.40	8.64	0.00	65,000	123.98	463,852	15,570	28	69,510
Mar-94	17,238	0	17,238	201.71	22.99	7.31	0.00	65,000	120.78	419,618	17,238	31	69,510
Apr-94	16,682	0	16,682	197.56	23.76	6.40	0.00	65,000	116.88	372,810	16,682	30	69,510
May-94	17,238	0	17,238	197.79	24.19	25.46	0.00	65,000	114.77	375,286	17,238	31	69,510
Jun-94	16,682	0	16,682	200.73	23.85	36.73	0.00	65,000	116.44	407,915	16,682	30	69,510
Jul-94	17,238	0	17,238	203.92	23.23	37.95	0.00	65,000	119.54	446,273	17,238	31	69,510
Aug-94	17,238	0	17,238	206.02	22.71	32.99	0.00	65,000	122.29	472,881	17,238	31	69,510
Sep-94	16,682	0	16,682	208.29	22.31	34.41	0.00	65,000	124.47	503,216	16,682	30	69,510
Oct-94	17,238	0	21,951	210.00	28.11	37.07	0.00	65,000	125.77	526,080	21,951	31	88,511
Nov-94	16,682	0	46,800	210.00	64.89	65.28	1.85	65,000	123.56	526,080	46,800	30	195,000
Dec-94	17,238	0	23,306	210.00	29.69	30.30	0.00	65,000	126.44	526,080	23,306	31	93,975
Jan-95	17,238	0	17,238	208.56	21.92	15.43	0.00	65,000	126.65	506,855	17,238	31	69,510
Feb-95	15,570	0	15,570	205.89	22.29	8.33	0.00	65,000	124.55	471,227	15,570	28	69,510
Mar-95	17,238	0	17,238	201.81	22.92	4.79	0.00	65,000	121.15	420,908	17,238	31	69,510
Apr-95	16,682	0	16,682	197.65	23.73	6.06	0.00	65,000	116.99	373,794	16,682	30	69,510
May-95	17,238	0	17,238	196.31	24.34	19.17	0.00	65,000	114.06	359,351	17,238	31	69,510
Jun-95	16,682	0	16,682	199.18	24.18	36.39	0.00	65,000	114.84	390,240	16,682	30	69,510
Jul-95	17,238	0	17,238	203.69	23.40	43.61	0.00	65,000	118.67	443,495	17,238	31	69,510
Aug-95	17,238	0	17,238	207.49	22.59	41.32	0.00	65,000	122.94	492,578	17,238	31	69,510
Sep-95	16,682	0	16,682	208.69	22.14	28.72	0.00	65,000	125.44	508,635	16,682	30	69,510
Oct-95	17,238	0	18,912	210.00	24.09	30.98	0.00	65,000	126.46	526,080	18,912	31	76,259
Nov-95	16,682	0	28,708	210.00	38.10	38.49	0.00	65,000	125.43	526,080	28,708	30	119,617
Dec-95	17,238	0	38,282	210.00	49.52	50.01	0.00	65,000	124.53	526,080	38,282	31	154,363

Upper Chagres Project
Hydropower Development Potential

Installed Capacity 65 MW

	Firm Energy (MWh)	Energy Shortage (MWh)	Total Energy (MWh)	EOP Res. Level (m)	Reservoir Outflow (cms)	Reservoir Inflow (cms)	Spillage (cms)	Maximum Output (kW)	Net Head (m)	Reservoir Storage (,000 cm)	Total Energy (MWh)	No. Days	Firm Capacity (kW)
Jan-96	17,238	0	48,360	210.00	72.51	73.21	9.45	65,000	123.53	526,080	48,360	31	195,000
Feb-96	16,126	0	21,800	210.00	29.69	30.53	0.00	65,000	126.44	526,080	21,800	29	93,967
Mar-96	17,238	0	17,238	209.98	21.80	22.63	0.00	65,000	127.37	525,810	17,238	31	69,510
Apr-96	16,682	0	16,682	209.32	21.86	19.26	0.00	65,000	127.03	516,989	16,682	30	69,510
May-96	17,238	0	33,651	210.00	43.50	47.46	0.00	65,000	124.61	526,080	33,651	31	135,688
Jun-96	16,682	0	31,638	210.00	42.11	42.54	0.00	65,000	125.05	526,080	31,638	30	131,826
Jul-96	17,238	0	34,780	210.00	44.87	45.26	0.00	65,000	124.86	526,080	34,780	31	140,243
Aug-96	17,238	0	38,224	210.00	49.44	49.87	0.00	65,000	124.53	526,080	38,224	31	154,130
Sep-96	16,682	0	25,177	210.00	33.26	33.67	0.00	65,000	126.01	526,080	25,177	30	104,903
Oct-96	17,238	0	32,416	210.00	41.75	42.14	0.00	65,000	125.08	526,080	32,416	31	130,711
Nov-96	16,682	0	46,800	210.00	82.85	83.18	19.77	65,000	123.48	526,080	46,800	30	195,000
Dec-96	17,238	0	48,360	210.00	94.29	94.67	30.26	65,000	121.64	526,080	48,360	31	195,000
Jan-97	17,238	0	22,376	210.00	28.47	28.97	0.00	65,000	126.58	526,080	22,376	31	90,224
Feb-97	15,570	0	15,570	208.98	21.89	16.79	0.00	65,000	126.86	512,452	15,570	28	69,510
Mar-97	17,238	0	17,238	206.21	22.23	9.09	0.00	65,000	124.93	475,544	17,238	31	69,510
Apr-97	16,682	0	16,682	203.00	22.77	7.76	0.00	65,000	121.94	435,199	16,682	30	69,510
May-97	17,238	0	17,238	204.78	22.92	31.35	0.00	65,000	121.14	456,737	17,238	31	69,510
Jun-97	16,682	0	16,682	205.54	22.68	26.85	0.00	65,000	122.45	466,562	16,682	30	69,510
Jul-97	17,238	0	17,238	204.05	22.74	16.20	0.00	65,000	122.10	447,938	17,238	31	69,510
Aug-97	17,238	0	17,238	201.84	23.11	13.51	0.00	65,000	120.17	421,200	17,238	31	69,510
Sep-97	16,682	0	16,682	200.68	23.44	18.38	0.00	65,000	118.45	407,288	16,682	30	69,510
Oct-97	17,238	0	17,238	200.85	23.54	24.61	0.00	65,000	117.94	409,320	17,238	31	69,510
Nov-97	16,682	0	16,682	200.43	23.57	21.86	0.00	65,000	117.81	404,208	16,682	30	69,510
Dec-97	17,238	0	17,238	199.86	23.67	21.58	0.00	65,000	117.31	397,546	17,238	31	69,510
Jan-98	17,238	0	17,238	196.80	24.05	12.18	0.00	65,000	115.44	364,621	17,238	31	69,510
Feb-98	15,570	0	15,570	192.83	24.81	8.35	0.00	65,000	111.92	323,873	15,570	28	69,510
Mar-98	17,238	0	17,238	186.52	26.01	4.98	0.00	65,000	106.77	266,407	17,238	31	69,510
Apr-98	16,682	0	16,682	182.16	27.46	14.30	0.00	61,653	101.13	231,638	16,682	30	69,510
May-98	17,238	0	17,238	186.14	27.52	39.56	0.00	57,726	100.91	263,181	17,238	31	69,510
Jun-98	16,682	0	16,682	185.13	27.12	24.02	0.00	61,289	102.38	254,557	16,682	30	69,510
Jul-98	17,238	0	17,238	186.27	27.10	30.95	0.00	60,315	102.45	264,276	17,238	31	69,510
Aug-98	17,238	0	17,238	188.49	26.65	33.93	0.00	61,412	104.18	283,166	17,238	31	69,510
Sep-98	16,682	0	16,682	190.74	26.06	34.15	0.00	63,546	106.54	303,328	16,682	30	69,510
Oct-98	17,238	0	17,238	192.82	25.54	33.47	0.00	65,000	108.71	323,811	17,238	31	69,510
Nov-98	16,682	0	16,682	196.23	24.88	38.52	0.00	65,000	111.59	358,477	16,682	30	69,510
Dec-98	17,238	0	17,238	203.50	23.69	54.83	0.00	65,000	117.22	441,237	17,238	31	69,510
Jan-99	17,238	0	17,238	205.15	22.84	30.76	0.00	65,000	121.59	461,384	17,238	31	69,510
Feb-99	15,570	0	15,570	205.31	22.66	24.02	0.00	65,000	122.51	463,448	15,570	28	69,510
Mar-99	17,238	0	17,238	203.44	22.82	14.84	0.00	65,000	121.65	440,580	17,238	31	69,510
Apr-99	16,682	0	16,682	202.15	23.13	17.53	0.00	65,000	120.02	424,988	16,682	30	69,510
May-99	17,238	0	17,238	202.62	23.22	25.66	0.00	65,000	119.60	430,605	17,238	31	69,510
Jun-99	16,682	0	16,682	205.38	22.90	36.22	0.00	65,000	121.27	464,366	16,682	30	69,510
Jul-99	17,238	0	17,238	209.93	22.22	45.26	0.00	65,000	124.99	525,133	17,238	31	69,510
Aug-99	17,238	0	40,938	210.00	53.08	53.81	0.00	65,000	124.24	526,080	40,938	31	165,074
Sep-99	16,682	0	32,899	210.00	43.83	44.24	0.00	65,000	124.93	526,080	32,899	30	137,078
Oct-99	17,238	0	31,143	210.00	40.07	40.47	0.00	65,000	125.20	526,080	31,143	31	125,578
Nov-99	16,682	0	38,675	210.00	51.76	52.11	0.00	65,000	124.37	526,080	38,675	30	161,147
Dec-99	17,238	0	48,360	210.00	126.49	126.79	62.24	65,000	121.24	526,080	48,360	31	195,000

ATTACHMENT 4

COMPARATIVE COST ESTIMATES

COMPARATIVE COST ESTIMATES

Hydropower Component Cost Estimates
Summary

		24-MW	32-MW	40-MW	49-MW	56-MW	63-MW
POWER INTAKE							
Civil Work		$5,405,000	$5,668,000	$6,006,000	$6,348,000	$6,635,000	$7,181,000
Equipment		$791,000	$1,041,000	$1,234,000	$1,443,000	$1,609,000	$1,775,000
SHAFT, TUNNEL & MANIFOLD							
Civil Work		$1,938,000	$2,438,000	$2,926,000	$3,360,000	$3,817,000	$4,432,000
POWERHOUSE & TRANSMISSION							
Civil Work		$2,046,000	$2,262,000	$2,476,000	$2,592,000	$2,775,000	$2,980,000
Equipment		$8,031,000	$10,713,000	$11,940,000	$14,259,000	$15,731,000	$17,119,000
Transmission System		$3,998,000	$4,098,000	$4,319,000	$4,679,000	$4,720,000	$4,807,000
	Subtotal	$22,209,000	$26,220,000	$28,901,000	$32,681,000	$35,287,000	$38,294,000
Contingencies (Civil Works)	*15%*	$1,408,000	$1,555,000	$1,711,000	$1,845,000	$1,984,000	$2,189,000
Contingencies (Equipment)	*10%*	$1,282,000	$1,585,000	$1,749,000	$2,038,000	$2,206,000	$2,370,000
	Subtotal	$24,899,000	$29,360,000	$32,361,000	$36,564,000	$39,477,000	$42,853,000
Engineering & Administration	*15%*	$3,735,000	$4,404,000	$4,854,000	$5,485,000	$5,922,000	$6,428,000
Total Development Cost		**$28,634,000**	**$33,764,000**	**$37,215,000**	**$42,049,000**	**$45,399,000**	**$49,281,000**

COMPARATIVE COST ESTIMATES

24-MW Hydroelectric Power Scheme
1 x 16-MW and 1 x 8-MW Units

	Unit	Unit Cost	Quantity	Amount
POWER INTAKE				
Civil Work				
Site Preparation	sq.m	$0.55	4,200	$2,310
Overburden Excavation	cu.m	$3.70	44,000	$162,800
Rock Excavation	cu.m	$9.20	4,450	$40,940
Mass Concrete	cu.m	$116.00	3,300	$382,800
Structural Concrete	cu.m	$145.00	14,020	$2,032,900
Formwork	sq.m	$46.80	27,520	$1,287,936
Steel Reinforcement	Ton	$1,320	763.0	$1,007,160
Steel Liner	Ton	$3,200	72.0	$230,400
Miscellaneous Metal Works	%	5%		$257,362
Subtotal				**$5,404,608**
Equipment				
Wheeled Intake Gate (2.10 x 1.40) and Hoist	Each	$111,000	2	$222,000
Stoplogs	Each	$89,000	2	$178,000
Trash Screen Bays	Each	$125,000	2	$250,000
Trash Rake	Each	$110,000	1	$110,000
Power and Control Equipment	LS	$18,750	1	$18,750
Cabling, MV & LV Power, Cont/Comm	LS	$12,500	1	$12,500
Subtotal				**$791,250**
SHAFT, TUNNEL & MANIFOLD				
Civil Work				
Portal Excavation	cu.m	$14.80	500	$7,400
Tunnel Excavation	cu.m	$126.00	1,930	$243,180
Shaft Excavation	cu.m	$295.00	540	$159,300
Structural Concrete	cu.m	$145.00	490	$71,050
Shaft Concrete Lining	cu.m	$180.00	260	$46,800
Tunnel Concrete Lining	sq.m	$172.00	780	$134,160
Shotcrete	sq.m	$45.90	1,690	$77,571
Rockbolts	L.m	$67.00	767	$51,389
Steel Ribs	Ton	$6,000	20.3	$121,800
Formwork	sq.m	$46.80	930	$43,524
Steel Reinforcement	Ton	$1,320	42.6	$56,232
Steel Liner and Manifold	Ton	$3,200	260.4	$833,280
Miscellaneous	%	5%		$92,284
Subtotal				**$1,937,970**

COMPARATIVE COST ESTIMATES

24-MW Hydroelectric Power Scheme
1 x 16-MW and 1 x 8-MW Units

	Unit	Unit Cost	Quantity	Amount
POWERHOUSE & TRANSMISSION				
Civil Work				
Site Preparation	sq.m	$0.55	10,600	$5,830
Overburden Excavation	cu.m	$3.70	160,650	$594,405
Rock Excavation	cu.m	$9.20	11,900	$109,480
Cofferdam and Care of Water	LS	$350,000	1	$350,000
Mass Concrete	cu.m	$116.00	1,263	$146,508
Structural Concrete	cu.m	$145.00	721	$104,545
Formwork	sq.m	$46.80	3,876	$181,397
Steel Reinforcement	Ton	$1,320	78.4	$103,488
Finishing Platform, Pavement, etc	LS	$210,000	1	$210,000
Roof, siding, windows, doors, etc	sq.m	$310	462	$143,220
Miscellaneous	%	5%		$97,444
Subtotal				**$2,046,316**
Equipment				
Power Generating				
Main Inlet Valves (2.00 m dia)	Each	$312,500	1	$312,500
Turbine/Generator Units (16 MW)	Each	$2,500,000	1	$2,500,000
16-MW Unit Auxiliaries	Each	$375,000	1	$375,000
Main Power Transformers (20MVA)	Each	$312,500	1	$312,500
Take-off Structures and Overhead Lines	LS	$100,000	1	$100,000
Draft Tube Gates (2.20 m x 1.40 m)	Each	$43,750	2	$87,500
Main Inlet Valve (1.40 m dia)	Each	$250,000	1	$250,000
Turbine/Generator Unit (8 MW)	Each	$1,875,000	1	$1,875,000
8-MW Unit Auxiliaries	Each	$312,500	1	$312,500
Main Power Transformers (10MVA)	Each	$187,500	1	$187,500
Take-off Structures and Overhead Lines	LS	$37,500	1	$37,500
Draft Tube Gates (3.60 m x 1.10 m)	Each	$56,250	1	$56,250
Miscellaneous Mechanical				
Dewatering System	LS	$40,000	1	$40,000
Semi-Gantry Crane - 45 T	LS	$312,500	1	$312,500
Miscellaneous Electrical				
Switchgear - 13.8 kV	LS	$80,000	1	$80,000
Station Service Transformer	Each	$50,000	1	$50,000
Stand-by Diesel Generator	Each	$187,500	1	$187,500
Station Auxiliaries (light, HVAC, etc.)	LS	$200,000	1	$200,000
Control and Communication Equip	LS	$250,000	1	$250,000
Cabling, MV & LV Power, Cont/Comm	LS	$505,000	1	$505,000
Subtotal				**$8,031,250**

COMPARATIVE COST ESTIMATES

24-MW Hydroelectric Power Scheme
1 x 16-MW and 1 x 8-MW Units

	Unit	Unit Cost	Quantity	Amount
Transmission System				
Switchyard - Civil Work				
Site Preparation	sq.m	$0.55	3,000	$1,650
Overburden Excavation	cu.m	$3.70	32,000	$118,400
Rock Excavation	cu.m	$14.80	1,200	$17,760
Foundation, Subbase, Backfill	cu.m	$18.00	2,800	$50,400
Perimeter Road	sq.m	$6.00	950	$5,700
Fence, Drainage, etc.	LS	$40,000	1	$40,000
Steel Structures	LS	$400,000	1	$400,000
Switchyard - Equipment				
115-kV Equipment Bay	Each	$210,000	3	$630,000
Service Power Transformer - 5MVA	Each	$93,750	1	$93,750
Protection, Control and Comm. Equipment	LS	$290,000	1	$290,000
Cabling, MV & LV Power, Cont/Comm	LS	$170,000	1	$170,000
Control Building Auxiliaries	LS	$43,750	1	$43,750
115-kV Transmission Line				
Civil Works (survey, Found., Struc.)	km	$37,500	21.2	$795,000
Conductors and Shield Wire	km	$37,500	21.2	$795,000
Insulators and Accessories	km	$18,750	21.2	$397,500
Grounding and Miscellaneous	%	5.00%		$99,375
Cut-in of Existing Panama-Colon Line	LS	$50,000	1	$50,000
Subtotal				**$3,998,285**
			TOTAL	**$22,209,680**

32-MW Hydroelectric Power Scheme
1 x 16-MW and 2 x 8-MW Units

	Unit	Unit Cost	Quantity	Amount
POWER INTAKE				
Civil Work				
Site Preparation	sq.m	$0.55	4,200	$2,310
Overburden Excavation	cu.m	$3.70	44,000	$162,800
Rock Excavation	cu.m	$9.20	4,450	$40,940
Mass Concrete	cu.m	$116.00	3,300	$382,800
Structural Concrete	cu.m	$145.00	14,860	$2,154,700
Formwork	sq.m	$46.80	28,370	$1,327,716
Steel Reinforcement	Ton	$1,320	809.0	$1,067,880
Steel Liner	Ton	$3,200	81.0	$259,200
Miscellaneous Metal Works	%	5%		$269,917
Subtotal				**$5,668,263**
Equipment				
Wheeled Intake Gate (2.60 x 1.70) and Hoist	Each	$162,500	2	$325,000
Stoplogs	Each	$130,000	2	$260,000
Trash Screen Bays	Each	$157,500	2	$315,000
Trash Rake	Each	$110,000	1	$110,000
Power and Control Equipment	LS	$18,750	1	$18,750
Cabling, MV & LV Power, Cont/Comm	LS	$12,500	1	$12,500
Subtotal				**$1,041,250**
SHAFT, TUNNEL & MANIFOLD				
Civil Work				
Portal Excavation	cu.m	$14.80	500	$7,400
Tunnel Excavation	cu.m	$126.00	2,650	$333,900
Shaft Excavation	cu.m	$295.00	730	$215,350
Structural Concrete	cu.m	$145.00	490	$71,050
Shaft Concrete Lining	cu.m	$180.00	330	$59,400
Tunnel Concrete Lining	sq.m	$172.00	1,040	$178,880
Shotcrete	sq.m	$45.90	1,970	$90,423
Rockbolts	L.m	$67.00	767	$51,389
Steel Ribs	Ton	$6,000	23.8	$142,800
Formwork	sq.m	$46.80	1,010	$47,268
Steel Reinforcement	Ton	$1,320	47.6	$62,832
Steel Liner and Manifold	Ton	$3,200	331.7	$1,061,440
Miscellaneous	%	5%		$116,107
Subtotal				**$2,438,239**

COMPARATIVE COST ESTIMATES

32-MW Hydroelectric Power Scheme
1 x 16-MW and 2 x 8-MW Units

	Unit	Unit Cost	Quantity	Amount
POWERHOUSE & TRANSMISSION				
Civil Work				
Site Preparation	sq.m	$0.55	11,200	$6,160
Overburden Excavation	cu.m	$3.70	169,550	$627,335
Rock Excavation	cu.m	$9.20	13,890	$127,788
Cofferdam and Care of Water	LS	$350,000	1	$350,000
Mass Concrete	cu.m	$116.00	1,472	$170,752
Structural Concrete	cu.m	$145.00	953	$138,185
Formwork	sq.m	$46.80	5,025	$235,170
Steel Reinforcement	Ton	$1,320	98.7	$130,284
Finishing Platform, Pavement, etc	LS	$210,000	1	$210,000
Roof, siding, windows, doors, etc	sq.m	$310	512	$158,720
Miscellaneous	%	5%		$107,720
Subtotal				**$2,262,114**
Equipment				
Power Generating				
Main Inlet Valves (2.00 m dia)	Each	$312,500	1	$312,500
Turbine/Generator Units (16 MW)	Each	$2,500,000	1	$2,500,000
16-MW Unit Auxiliaries	Each	$375,000	1	$375,000
Main Power Transformers (20MVA)	Each	$312,500	1	$312,500
Take-off Structures and Overhead Lines	LS	$100,000	1	$100,000
Draft Tube Gates (2.20 m x 1.40 m)	Each	$43,750	2	$87,500
Main Inlet Valve (1.40 m dia)	Each	$250,000	2	$500,000
Turbine/Generator Unit (8 MW)	Each	$1,875,000	2	$3,750,000
8-MW Unit Auxiliaries	Each	$312,500	2	$625,000
Main Power Transformers (10MVA)	Each	$187,500	2	$375,000
Take-off Structures and Overhead Lines	LS	$37,500	1	$37,500
Draft Tube Gates (3.60 m x 1.10 m)	Each	$56,250	2	$112,500
Miscellaneous Mechanical				
Dewatering System	LS	$40,000	1	$40,000
Semi-Gantry Crane - 45 T	LS	$312,500	1	$312,500
Miscellaneous Electrical				
Switchgear - 13.8 kV	LS	$80,000	1	$80,000
Station Service Transformer	Each	$50,000	1	$50,000
Stand-by Diesel Generator	Each	$187,500	1	$187,500
Station Auxiliaries (light, HVAC, etc.)	LS	$200,000	1	$200,000
Control and Communication Equip	LS	$250,000	1	$250,000
Cabling, MV & LV Power, Cont/Comm	LS	$505,000	1	$505,000
Subtotal				**$10,712,500**

32-MW Hydroelectric Power Scheme
1 x 16-MW and 2 x 8-MW Units

	Unit	Unit Cost	Quantity	Amount
Transmission System				
Switchyard - Civil Work				
Site Preparation	sq.m	$0.55	3,000	$1,650
Overburden Excavation	cu.m	$3.70	32,000	$118,400
Rock Excavation	cu.m	$14.80	1,200	$17,760
Foundation, Subbase, Backfill	cu.m	$18.00	2,800	$50,400
Perimeter Road	sq.m	$6.00	950	$5,700
Fence, Drainage, etc.	LS	$40,000	1	$40,000
Steel Structures	LS	$400,000	1	$400,000
Switchyard - Equipment				
115-kV Equipment Bay	Each	$225,000	3	$675,000
Service Power Transformer - 5MVA	Each	$93,750	1	$93,750
Protection, Control and Comm. Equipment	LS	$325,000	1	$325,000
Cabling, MV & LV Power, Cont/Comm	LS	$190,000	1	$190,000
Control Building Auxiliaries	LS	$43,750	1	$43,750
115-kV Transmission Line				
Civil Works (survey, Found., Struc.)	km	$37,500	21.2	$795,000
Conductors and Shield Wire	km	$37,500	21.2	$795,000
Insulators and Accessories	km	$18,750	21.2	$397,500
Grounding and Miscellaneous	%	5.00%		$99,375
Cut-in of Existing Panama-Colon Line	LS	$50,000	1	$50,000
Subtotal				**$4,098,285**
			TOTAL	**$26,220,651**

COMPARATIVE COST ESTIMATES

40-MW Hydroelectric Power Scheme
2 x 16-MW and 1 x 8-MW Units

	Unit	Unit Cost	Quantity	Amount
POWER INTAKE				
Civil Work				
Site Preparation	sq.m	$0.55	4,200	$2,310
Overburden Excavation	cu.m	$3.70	44,000	$162,800
Rock Excavation	cu.m	$9.20	4,450	$40,940
Mass Concrete	cu.m	$116.00	3,750	$435,000
Structural Concrete	cu.m	$145.00	15,730	$2,280,850
Formwork	sq.m	$46.80	29,340	$1,373,112
Steel Reinforcement	Ton	$1,320	861.0	$1,136,520
Steel Liner	Ton	$3,200	90.0	$288,000
Miscellaneous Metal Works	%	5%		$285,977
Subtotal				**$6,005,509**
Equipment				
Wheeled Intake Gate (2.90 x 1.90) and Hoist	Each	$194,000	2	$388,000
Stoplogs	Each	$155,000	2	$310,000
Trash Screen Bays	Each	$197,500	2	$395,000
Trash Rake	Each	$110,000	1	$110,000
Power and Control Equipment	LS	$18,750	1	$18,750
Cabling, MV & LV Power, Cont/Comm	LS	$12,500	1	$12,500
Subtotal				**$1,234,250**
SHAFT, TUNNEL & MANIFOLD				
Civil Work				
Portal Excavation	cu.m	$14.80	500	$7,400
Tunnel Excavation	cu.m	$126.00	3,050	$384,300
Shaft Excavation	cu.m	$295.00	870	$256,650
Structural Concrete	cu.m	$145.00	550	$79,750
Shaft Concrete Lining	cu.m	$180.00	390	$70,200
Tunnel Concrete Lining	sq.m	$172.00	1,120	$192,640
Shotcrete	sq.m	$45.90	2,130	$97,767
Rockbolts	L.m	$67.00	767	$51,389
Steel Ribs	Ton	$6,000	25.5	$153,000
Formwork	sq.m	$46.80	1,120	$52,416
Steel Reinforcement	Ton	$1,320	54.8	$72,336
Steel Liner and Manifold	Ton	$3,200	427.9	$1,369,280
Miscellaneous	%	5%		$139,356
Subtotal				**$2,926,484**

40-MW Hydroelectric Power Scheme
2 x 16-MW and 1 x 8-MW Units

	Unit	Unit Cost	Quantity	Amount
POWERHOUSE & TRANSMISSION				
Civil Work				
Site Preparation	sq.m	$0.55	11,400	$6,270
Overburden Excavation	cu.m	$3.70	173,250	$641,025
Rock Excavation	cu.m	$9.20	16,640	$153,088
Cofferdam and Care of Water	LS	$350,000	1	$350,000
Mass Concrete	cu.m	$116.00	1,903	$220,748
Structural Concrete	cu.m	$145.00	1,059	$153,555
Formwork	sq.m	$46.80	5,927	$277,384
Steel Reinforcement	Ton	$1,320	122.2	$161,304
Finishing Platform, Pavement, etc	LS	$220,000	1	$220,000
Roof, siding, windows, doors, etc	sq.m	$310	564	$174,840
Miscellaneous	%	5%		$117,911
Subtotal				**$2,476,124**
Equipment				
Power Generating				
Main Inlet Valves (2.00 m dia)	Each	$312,500	2	$625,000
Turbine/Generator Units (16 MW)	Each	$2,500,000	2	$5,000,000
16-MW Unit Auxiliaries	Each	$375,000	2	$750,000
Main Power Transformers (20MVA)	Each	$312,500	2	$625,000
Take-off Structures and Overhead Lines	LS	$100,000	1	$100,000
Draft Tube Gates (2.20 m x 1.40 m)	Each	$43,750	4	$175,000
Main Inlet Valve (1.40 m dia)	Each	$250,000	1	$250,000
Turbine/Generator Unit (8 MW)	Each	$1,875,000	1	$1,875,000
8-MW Unit Auxiliaries	Each	$312,500	1	$312,500
Main Power Transformers (10MVA)	Each	$187,500	1	$187,500
Take-off Structures and Overhead Lines	LS	$37,500	1	$37,500
Draft Tube Gates (3.60 m x 1.10 m)	Each	$56,250	1	$56,250
Miscellaneous Mechanical				
Dewatering System	LS	$45,000	1	$45,000
Semi-Gantry Crane - 45 T	LS	$312,500	1	$312,500
Miscellaneous Electrical				
Switchgear - 13.8 kV	LS	$90,000	1	$90,000
Station Service Transformer	Each	$50,000	1	$50,000
Stand-by Diesel Generator	Each	$187,500	1	$187,500
Station Auxiliaries (light, HVAC, etc.)	LS	$320,000	1	$320,000
Control and Communication Equip	LS	$285,000	1	$285,000
Cabling, MV & LV Power, Cont/Comm	LS	$656,000	1	$656,000
Subtotal				**$11,939,750**

COMPARATIVE COST ESTIMATES

40-MW Hydroelectric Power Scheme
2 x 16-MW and 1 x 8-MW Units

	Unit	Unit Cost	Quantity	Amount
Transmission System				
Switchyard - Civil Work				
Site Preparation	sq.m	$0.55	4,000	$2,200
Overburden Excavation	cu.m	$3.70	38,000	$140,600
Rock Excavation	cu.m	$14.80	1,500	$22,200
Foundation, Subbase, Backfill	cu.m	$18.00	4,050	$72,900
Perimeter Road	sq.m	$6.00	1,080	$6,480
Fence, Drainage, etc.	LS	$50,000	1	$50,000
Steel Structures	LS	$500,000	1	$500,000
Switchyard - Equipment				
115-kV Equipment Bay	Each	$225,000	3	$675,000
Service Power Transformer - 5MVA	Each	$93,750	1	$93,750
Protection, Control and Comm. Equipment	LS	$350,000	1	$350,000
Cabling, MV & LV Power, Cont/Comm	LS	$225,000	1	$225,000
Control Building Auxiliaries	LS	$43,750	1	$43,750
115-kV Transmission Line				
Civil Works (survey, Found., Struc.)	km	$37,500	21.2	$795,000
Conductors and Shield Wire	km	$37,500	21.2	$795,000
Insulators and Accessories	km	$18,750	21.2	$397,500
Grounding and Miscellaneous	%	5.00%		$99,375
Cut-in of Existing Panama-Colon Line	LS	$50,000	1	$50,000
Subtotal				**$4,318,755**
			TOTAL	**$28,900,872**

49-MW Hydroelectric Power Scheme
3 x 14-MW and 1 x 7-MW Units

	Unit	Unit Cost	Quantity	Amount
POWER INTAKE				
Civil Work				
Site Preparation	sq.m	$0.55	4,200	$2,310
Overburden Excavation	cu.m	$3.70	44,000	$162,800
Rock Excavation	cu.m	$9.20	4,450	$40,940
Mass Concrete	cu.m	$116.00	4,225	$490,100
Structural Concrete	cu.m	$145.00	16,600	$2,407,000
Formwork	sq.m	$46.80	30,300	$1,418,040
Steel Reinforcement	Ton	$1,320	915.0	$1,207,800
Steel Liner	Ton	$3,200	99.0	$316,800
Miscellaneous Metal Works	%	5%		$302,290
Subtotal				**$6,348,080**
Equipment				
Wheeled Intake Gate (3.20 x 2.10) and Hoist	Each	$228,000	2	$456,000
Stoplogs	Each	$182,500	2	$365,000
Trash Screen Bays	Each	$240,500	2	$481,000
Trash Rake	Each	$110,000	1	$110,000
Power and Control Equipment	LS	$18,750	1	$18,750
Cabling, MV & LV Power, Cont/Comm	LS	$12,500	1	$12,500
Subtotal				**$1,443,250**
SHAFT, TUNNEL & MANIFOLD				
Civil Work				
Portal Excavation	cu.m	$14.80	500	$7,400
Tunnel Excavation	cu.m	$126.00	3,780	$476,280
Shaft Excavation	cu.m	$295.00	1,070	$315,650
Structural Concrete	cu.m	$145.00	630	$91,350
Shaft Concrete Lining	cu.m	$180.00	470	$84,600
Tunnel Concrete Lining	sq.m	$172.00	1,390	$239,080
Shotcrete	sq.m	$45.90	2,360	$108,324
Rockbolts	L.m	$67.00	767	$51,389
Steel Ribs	Ton	$6,000	28.4	$170,400
Formwork	sq.m	$46.80	1,250	$58,500
Steel Reinforcement	Ton	$1,320	64.4	$85,008
Steel Liner and Manifold	Ton	$3,200	472.6	$1,512,320
Miscellaneous	%	5%		$160,015
Subtotal				**$3,360,316**

COMPARATIVE COST ESTIMATES

49-MW Hydroelectric Power Scheme
3 x 14-MW and 1 x 7-MW Units

	Unit	Unit Cost	Quantity	Amount
POWERHOUSE & TRANSMISSION				
Civil Work				
Site Preparation	sq.m	$0.55	12,000	$6,600
Overburden Excavation	cu.m	$3.70	179,000	$662,300
Rock Excavation	cu.m	$9.20	17,850	$164,220
Cofferdam and Care of Water	LS	$350,000	1	$350,000
Mass Concrete	cu.m	$116.00	2,069	$240,004
Structural Concrete	cu.m	$145.00	1,115	$161,675
Formwork	sq.m	$46.80	6,052	$283,234
Steel Reinforcement	Ton	$1,320	124.2	$163,944
Finishing Platform, Pavement, etc	LS	$230,000	1	$230,000
Roof, siding, windows, doors, etc	sq.m	$310	666	$206,460
Miscellaneous	%	5%		$123,422
Subtotal				**$2,591,858**
Equipment				
Power Generating				
Main Inlet Valves (1.90 m dia)	Each	$293,500	3	$880,500
Turbine/Generator Units (14 MW)	Each	$2,250,000	3	$6,750,000
14-MW Unit Auxiliaries	Each	$356,250	3	$1,068,750
Main Power Transformers (15MVA)	Each	$237,500	3	$712,500
Take-off Structures and Overhead Lines	LS	$100,000	1	$100,000
Draft Tube Gates (2.00 m x 1.40 m)	Each	$37,500	6	$225,000
Main Inlet Valve (1.30 m dia)	Each	$235,000	1	$235,000
Turbine/Generator Unit (7 MW)	Each	$1,750,000	1	$1,750,000
7-MW Unit Auxiliaries	Each	$293,750	1	$293,750
Main Power Transformers (7.5MVA)	Each	$137,500	1	$137,500
Take-off Structures and Overhead Lines	LS	$37,500	1	$37,500
Draft Tube Gates (3.10 m x 1.00 m)	Each	$50,000	1	$50,000
Miscellaneous Mechanical				
Dewatering System	LS	$50,000	1	$50,000
Semi-Gantry Crane - 40 T	LS	$287,500	1	$287,500
Miscellaneous Electrical				
Switchgear - 13.8 kV	LS	$100,000	1	$100,000
Station Service Transformer	Each	$50,000	1	$50,000
Stand-by Diesel Generator	Each	$187,500	1	$187,500
Station Auxiliaries (light, HVAC, etc.)	LS	$356,250	1	$356,250
Control and Communication Equip	LS	$300,000	1	$300,000
Cabling, MV & LV Power, Cont/Comm	LS	$687,500	1	$687,500
Subtotal				**$14,259,250**

49-MW Hydroelectric Power Scheme
3 x 14-MW and 1 x 7-MW Units

	Unit	Unit Cost	Quantity	Amount
Transmission System				
Switchyard - Civil Work				
Site Preparation	sq.m	$0.55	5,000	$2,750
Overburden Excavation	cu.m	$3.70	46,000	$170,200
Rock Excavation	cu.m	$14.80	2,000	$29,600
Foundation, Subbase, Backfill	cu.m	$18.00	5,040	$90,720
Perimeter Road	sq.m	$6.00	1,200	$7,200
Fence, Drainage, etc.	LS	$60,000	1	$60,000
Steel Structures	LS	$600,000	1	$600,000
Switchyard - Equipment				
115-kV Equipment Bay	Each	$212,500	4	$850,000
Service Power Transformer - 5MVA	Each	$93,750	1	$93,750
Protection, Control and Comm. Equipment	LS	$356,250	1	$356,250
Cabling, MV & LV Power, Cont/Comm	LS	$237,500	1	$237,500
Control Building Auxiliaries	LS	$43,750	1	$43,750
115-kV Transmission Line				
Civil Works (survey, Found., Struc.)	km	$37,500	21.2	$795,000
Conductors and Shield Wire	km	$37,500	21.2	$795,000
Insulators and Accessories	km	$18,750	21.2	$397,500
Grounding and Miscellaneous	%	5.00%		$99,375
Cut-in of Existing Panama-Colon Line	LS	$50,000	1	$50,000
Subtotal				**$4,678,595**
			TOTAL	**$32,681,349**

COMPARATIVE COST ESTIMATES

56-MW Hydroelectric Power Scheme
3 x 16-MW and 1 x 8-MW Units

	Unit	Unit Cost	Quantity	Amount
POWER INTAKE				
Civil Work				
Site Preparation	sq.m	$0.55	4,200	$2,310
Overburden Excavation	cu.m	$3.70	44,000	$162,800
Rock Excavation	cu.m	$9.20	4,450	$40,940
Mass Concrete	cu.m	$116.00	4,610	$534,760
Structural Concrete	cu.m	$145.00	17,480	$2,534,600
Formwork	sq.m	$46.80	31,600	$1,478,880
Steel Reinforcement	Ton	$1,320	936.0	$1,235,520
Steel Liner	Ton	$3,200	103.0	$329,600
Miscellaneous Metal Works	%	5%		$315,971
Subtotal				**$6,635,381**
Equipment				
Wheeled Intake Gate (3.30 x 2.20) and Hoist	Each	$255,000	2	$510,000
Stoplogs	Each	$204,000	2	$408,000
Trash Screen Bays	Each	$275,000	2	$550,000
Trash Rake	Each	$110,000	1	$110,000
Power and Control Equipment	LS	$18,750	1	$18,750
Cabling, MV & LV Power, Cont/Comm	LS	$12,500	1	$12,500
Subtotal				**$1,609,250**
SHAFT, TUNNEL & MANIFOLD				
Civil Work				
Portal Excavation	cu.m	$14.80	500	$7,400
Tunnel Excavation	cu.m	$126.00	4,247	$535,122
Shaft Excavation	cu.m	$295.00	1,240	$365,800
Structural Concrete	cu.m	$145.00	718	$104,110
Shaft Concrete Lining	cu.m	$180.00	540	$97,200
Tunnel Concrete Lining	sq.m	$172.00	1,480	$254,560
Shotcrete	sq.m	$45.90	2,529	$116,081
Rockbolts	L.m	$67.00	767	$51,389
Steel Ribs	Ton	$6,000	30.1	$180,600
Formwork	sq.m	$46.80	1,360	$63,648
Steel Reinforcement	Ton	$1,320	72.2	$95,304
Steel Liner and Manifold	Ton	$3,200	551.3	$1,764,160
Miscellaneous	%	5%		$181,769
Subtotal				**$3,817,143**

COMPARATIVE COST ESTIMATES

56-MW Hydroelectric Power Scheme
3 x 16-MW and 1 x 8-MW Units

	Unit	Unit Cost	Quantity	Amount
POWERHOUSE & TRANSMISSION				
Civil Work				
Site Preparation	sq.m	$0.55	12,300	$6,765
Overburden Excavation	cu.m	$3.70	189,000	$699,300
Rock Excavation	cu.m	$9.20	18,530	$170,476
Cofferdam and Care of Water	LS	$350,000	1	$350,000
Mass Concrete	cu.m	$116.00	2,486	$288,376
Structural Concrete	cu.m	$145.00	1,210	$175,450
Formwork	sq.m	$46.80	6,643	$310,892
Steel Reinforcement	Ton	$1,320	140.2	$185,064
Finishing Platform, Pavement, etc	LS	$236,000	1	$236,000
Roof, siding, windows, doors, etc	sq.m	$310	710	$220,100
Miscellaneous	%	5%		$132,121
Subtotal				**$2,774,545**
Equipment				
Power Generating				
Main Inlet Valves (2.00 m dia)	Each	$312,500	3	$937,500
Turbine/Generator Units (16 MW)	Each	$2,500,000	3	$7,500,000
16-MW Unit Auxiliaries	Each	$375,000	3	$1,125,000
Main Power Transformers (20MVA)	Each	$312,500	3	$937,500
Take-off Structures and Overhead Lines	LS	$100,000	1	$100,000
Draft Tube Gates (2.20 m x 1.50 m)	Each	$43,750	6	$262,500
Main Inlet Valve (1.40 m dia)	Each	$250,000	1	$250,000
Turbine/Generator Unit (8 MW)	Each	$1,875,000	1	$1,875,000
8-MW Unit Auxiliaries	Each	$312,500	1	$312,500
Main Power Transformers (10MVA)	Each	$187,500	1	$187,500
Take-off Structures and Overhead Lines	LS	$37,500	1	$37,500
Draft Tube Gates (3.30 m x 1.10 m)	Each	$56,250	1	$56,250
Miscellaneous Mechanical				
Dewatering System	LS	$56,250	1	$56,250
Semi-Gantry Crane - 45 T	LS	$312,500	1	$312,500
Miscellaneous Electrical				
Switchgear - 13.8 kV	LS	$106,250	1	$106,250
Station Service Transformer	Each	$50,000	1	$50,000
Stand-by Diesel Generator	Each	$187,500	1	$187,500
Station Auxiliaries (light, HVAC, etc.)	LS	$375,000	1	$375,000
Control and Communication Equip	LS	$312,500	1	$312,500
Cabling, MV & LV Power, Cont/Comm	LS	$750,000	1	$750,000
Subtotal				**$15,731,250**

COMPARATIVE COST ESTIMATES

56-MW Hydroelectric Power Scheme
3 x 16-MW and 1 x 8-MW Units

	Unit	Unit Cost	Quantity	Amount
Transmission System				
Switchyard - Civil Work				
Site Preparation	sq.m	$0.55	5,000	$2,750
Overburden Excavation	cu.m	$3.70	46,000	$170,200
Rock Excavation	cu.m	$14.80	2,000	$29,600
Foundation, Subbase, Backfill	cu.m	$18.00	5,040	$90,720
Perimeter Road	sq.m	$6.00	1,200	$7,200
Fence, Drainage, etc.	LS	$20,000	1	$20,000
Steel Structures	LS	$600,000	1	$600,000
Switchyard - Equipment				
115-kV Equipment Bay	Each	$225,000	4	$900,000
Service Power Transformer - 5MVA	Each	$93,750	1	$93,750
Protection, Control and Comm. Equipment	LS	$375,000	1	$375,000
Cabling, MV & LV Power, Cont/Comm	LS	$250,000	1	$250,000
Control Building Auxiliaries	LS	$43,750	1	$43,750
115-kV Transmission Line				
Civil Works (survey, Found., Struc.)	km	$37,500	21.2	$795,000
Conductors and Shield Wire	km	$37,500	21.2	$795,000
Insulators and Accessories	km	$18,750	21.2	$397,500
Grounding and Miscellaneous	%	5.00%		$99,375
Cut-in of Existing Panama-Colon Line	LS	$50,000	1	$50,000
Subtotal				**$4,719,845**
			TOTAL	**$35,287,413**

63-MW Hydroelectric Power Scheme
3 x 18-MW and 1 x 9-MW Units

	Unit	Unit Cost	Quantity	Amount
POWER INTAKE				
Civil Work				
Site Preparation	sq.m	$0.55	4,200	$2,310
Overburden Excavation	cu.m	$3.70	44,000	$162,800
Rock Excavation	cu.m	$9.20	4,450	$40,940
Mass Concrete	cu.m	$116.00	4,990	$578,840
Structural Concrete	cu.m	$145.00	18,650	$2,704,250
Formwork	sq.m	$46.80	35,000	$1,638,000
Steel Reinforcement	Ton	$1,320	1,033.0	$1,363,560
Steel Liner	Ton	$3,200	109.0	$348,800
Miscellaneous Metal Works	%	5%		$341,975
Subtotal				**$7,181,475**
Equipment				
Wheeled Intake Gate (3.50 x 2.30) and Hoist	Each	$282,000	2	$564,000
Stoplogs	Each	$225,500	2	$451,000
Trash Screen Bays	Each	$309,500	2	$619,000
Trash Rake	Each	$110,000	1	$110,000
Power and Control Equipment	LS	$18,750	1	$18,750
Cabling, MV & LV Power, Cont/Comm	LS	$12,500	1	$12,500
Subtotal				**$1,775,250**
SHAFT, TUNNEL & MANIFOLD				
Civil Work				
Portal Excavation	cu.m	$14.80	500	$7,400
Tunnel Excavation	cu.m	$126.00	4,930	$621,180
Shaft Excavation	cu.m	$295.00	1,370	$404,150
Structural Concrete	cu.m	$145.00	920	$133,400
Shaft Concrete Lining	cu.m	$180.00	580	$104,400
Tunnel Concrete Lining	sq.m	$172.00	1,750	$301,000
Shotcrete	sq.m	$45.90	2,690	$123,471
Rockbolts	L.m	$67.00	767	$51,389
Steel Ribs	Ton	$6,000	32.4	$194,400
Formwork	sq.m	$46.80	1,630	$76,284
Steel Reinforcement	Ton	$1,320	86.6	$114,312
Steel Liner and Manifold	Ton	$3,200	652.9	$2,089,280
Miscellaneous	%	5%		$211,033
Subtotal				**$4,431,699**

COMPARATIVE COST ESTIMATES

63-MW Hydroelectric Power Scheme
3 x 18-MW and 1 x 9-MW Units

	Unit	Unit Cost	Quantity	Amount
POWERHOUSE & TRANSMISSION				
Civil Work				
Site Preparation	sq.m	$0.55	12,600	$6,930
Overburden Excavation	cu.m	$3.70	197,000	$728,900
Rock Excavation	cu.m	$9.20	19,050	$175,260
Cofferdam and Care of Water	LS	$350,000	1	$350,000
Mass Concrete	cu.m	$116.00	2,735	$317,260
Structural Concrete	cu.m	$145.00	1,485	$215,325
Formwork	sq.m	$46.80	7,433	$347,864
Steel Reinforcement	Ton	$1,320	160.9	$212,388
Finishing Platform, Pavement, etc	LS	$250,000	1	$250,000
Roof, siding, windows, doors, etc	sq.m	$310	755	$234,050
Miscellaneous	%	5%		$141,899
Subtotal				**$2,979,876**
Equipment				
Power Generating				
Main Inlet Valves (2.15 m dia)	Each	$350,500	3	$1,051,500
Turbine/Generator Units (18 MW)	Each	$2,750,000	3	$8,250,000
18-MW Unit Auxiliaries	Each	$412,500	3	$1,237,500
Main Power Transformers (20MVA)	Each	$312,500	3	$937,500
Take-off Structures and Overhead Lines	LS	$100,000	1	$100,000
Draft Tube Gates (2.40 m x 1.60 m)	Each	$50,000	6	$300,000
Main Inlet Valve (1.50 m dia)	Each	$267,500	1	$267,500
Turbine/Generator Unit (8 MW)	Each	$2,062,500	1	$2,062,500
8-MW Unit Auxiliaries	Each	$343,750	1	$343,750
Main Power Transformers (10MVA)	Each	$187,500	1	$187,500
Take-off Structures and Overhead Lines	LS	$37,500	1	$37,500
Draft Tube Gates (3.50 m x 1.20 m)	Each	$62,500	1	$62,500
Miscellaneous Mechanical				
Dewatering System	LS	$62,500	1	$62,500
Semi-Gantry Crane - 50 T	LS	$331,250	1	$331,250
Miscellaneous Electrical				
Switchgear - 13.8 kV	LS	$112,500	1	$112,500
Station Service Transformer	Each	$50,000	1	$50,000
Stand-by Diesel Generator	Each	$187,500	1	$187,500
Station Auxiliaries (light, HVAC, etc.)	LS	$393,750	1	$393,750
Control and Communication Equip	LS	$331,250	1	$331,250
Cabling, MV & LV Power, Cont/Comm	LS	$812,500	1	$812,500
Subtotal				**$17,119,000**

63-MW Hydroelectric Power Scheme
3 x 18-MW and 1 x 9-MW Units

	Unit	Unit Cost	Quantity	Amount
Transmission System				
Switchyard - Civil Work				
Site Preparation	sq.m	$0.55	5,000	$2,750
Overburden Excavation	cu.m	$3.70	46,000	$170,200
Rock Excavation	cu.m	$14.80	2,000	$29,600
Foundation, Subbase, Backfill	cu.m	$18.00	5,040	$90,720
Perimeter Road	sq.m	$6.00	1,200	$7,200
Fence, Drainage, etc.	LS	$20,000	1	$20,000
Steel Structures	LS	$600,000	1	$600,000
Switchyard - Equipment				
115-kV Equipment Bay	Each	$237,500	4	$950,000
Service Power Transformer - 5MVA	Each	$93,750	1	$93,750
Protection, Control and Comm. Equipment	LS	$387,500	1	$387,500
Cabling, MV & LV Power, Cont/Comm	LS	$275,000	1	$275,000
Control Building Auxiliaries	LS	$43,750	1	$43,750
115-kV Transmission Line				
Civil Works (survey, Found., Struc.)	km	$37,500	21.2	$795,000
Conductors and Shield Wire	km	$37,500	21.2	$795,000
Insulators and Accessories	km	$18,750	21.2	$397,500
Grounding and Miscellaneous	%	5.00%		$99,375
Cut-in of Existing Panama-Colon Line	LS	$50,000	1	$50,000
Subtotal				**$4,807,345**
			TOTAL	**$38,294,646**

ATTACHMENT 5

ECONOMIC ANALYSIS

ECONOMIC ANALYSIS

Upper Chagres Hydropower Component
Economic Return Summary

	Construction Cost	O&M Annual Cost	Revenues			Internal Rate of Return	Marginal Rate of Return
			Avg Annual Energy (GWh)	Firm Capacity (MW)	Anuual Revenue		
24 MW Power Plant	$28,634,000	$479,100	203.9	24.0	$10,615,500	28.4%	
32 MW Power Plant	$33,764,000	$586,600	225.0	32.0	$12,045,000	27.4%	21.7%
40 MW Power Plant	$37,215,000	$649,500	239.0	40.0	$13,155,000	27.2%	24.9%
49 MW Power Plant	$42,049,000	$748,100	250.0	49.0	$14,190,000	26.1%	16.8%
56 MW Power Plant	$45,399,000	$812,900	253.5	56.0	$14,767,500	25.2%	13.5%
63 MW Power Plant	$49,281,000	$881,800	257.0	63.0	$15,345,000	24.2%	11.6%

Energy Value $45 per MWh
Firm Capacity Value $60 per kW-yr

ECONOMIC ANALYSIS

24-MW Power Plant

Annual Operation

Year	Project Cost	O&M	Energy Revenue	Capacity Revenue	Total
2008	$7,158,500				-$7,158,500
2009	$8,590,200				-$8,590,200
2010	$12,885,300				-$12,885,300
2011		$479,100	$9,175,500	$1,440,000	$10,136,400
2012		$479,100	$9,175,500	$1,440,000	$10,136,400
2013		$479,100	$9,175,500	$1,440,000	$10,136,400
2014		$479,100	$9,175,500	$1,440,000	$10,136,400
2015		$479,100	$9,175,500	$1,440,000	$10,136,400
2016		$479,100	$9,175,500	$1,440,000	$10,136,400
2017		$479,100	$9,175,500	$1,440,000	$10,136,400
2018		$479,100	$9,175,500	$1,440,000	$10,136,400
2019		$479,100	$9,175,500	$1,440,000	$10,136,400
2020		$479,100	$9,175,500	$1,440,000	$10,136,400
2021		$479,100	$9,175,500	$1,440,000	$10,136,400
2022		$479,100	$9,175,500	$1,440,000	$10,136,400
2023		$479,100	$9,175,500	$1,440,000	$10,136,400
2024		$479,100	$9,175,500	$1,440,000	$10,136,400
2025		$479,100	$9,175,500	$1,440,000	$10,136,400
2026		$479,100	$9,175,500	$1,440,000	$10,136,400
2027		$479,100	$9,175,500	$1,440,000	$10,136,400
2028		$479,100	$9,175,500	$1,440,000	$10,136,400
2029		$479,100	$9,175,500	$1,440,000	$10,136,400
2030		$479,100	$9,175,500	$1,440,000	$10,136,400
2031		$479,100	$9,175,500	$1,440,000	$10,136,400
2032		$479,100	$9,175,500	$1,440,000	$10,136,400
2033		$479,100	$9,175,500	$1,440,000	$10,136,400
2034		$479,100	$9,175,500	$1,440,000	$10,136,400
2035	$8,369,873	$479,100	$9,175,500	$1,440,000	$1,766,528
2036		$479,100	$9,175,500	$1,440,000	$10,136,400
2037		$479,100	$9,175,500	$1,440,000	$10,136,400
2038		$479,100	$9,175,500	$1,440,000	$10,136,400
2039		$479,100	$9,175,500	$1,440,000	$10,136,400
2040		$479,100	$9,175,500	$1,440,000	$10,136,400
2041		$479,100	$9,175,500	$1,440,000	$10,136,400
2042		$479,100	$9,175,500	$1,440,000	$10,136,400
2043		$479,100	$9,175,500	$1,440,000	$10,136,400
2044		$479,100	$9,175,500	$1,440,000	$10,136,400
2045		$479,100	$9,175,500	$1,440,000	$10,136,400
2046		$479,100	$9,175,500	$1,440,000	$10,136,400
2047		$479,100	$9,175,500	$1,440,000	$10,136,400
2048		$479,100	$9,175,500	$1,440,000	$10,136,400
2049		$479,100	$9,175,500	$1,440,000	$10,136,400
2050		$479,100	$9,175,500	$1,440,000	$10,136,400
2051		$479,100	$9,175,500	$1,440,000	$10,136,400
2052		$479,100	$9,175,500	$1,440,000	$10,136,400
2053		$479,100	$9,175,500	$1,440,000	$10,136,400
2054		$479,100	$9,175,500	$1,440,000	$10,136,400
2055		$479,100	$9,175,500	$1,440,000	$10,136,400
2056		$479,100	$9,175,500	$1,440,000	$10,136,400
2057		$479,100	$9,175,500	$1,440,000	$10,136,400
2058		$479,100	$9,175,500	$1,440,000	$10,136,400
2059		$479,100	$9,175,500	$1,440,000	$10,136,400
2060		$479,100	$9,175,500	$1,440,000	$10,136,400

Cost Summary

Civil Work Cost	$9,389,000
Equipment Cost	$8,822,000
Transmission System	$3,998,000
Subtotal	**$22,209,000**
Contingencies	$2,690,000
Engineering & Administration (15%)	$3,735,000
Project Development Cost	**$28,634,000**

Annual Operation & Maintenance Costs

Civil Work Maintenance	$124,170
Equipment Maintenance	$278,996
Transmission Maintenance	$75,862
Total O&M	**$479,100**

Annual Revenue

Initial Period up 2016			
Energy Production	$45	$/MWh	203,900 MWh
Firm Capacity	$60	$/kW-yr	24,000 kW
After 2016			
Energy Production	$45	$/MWh	173,600 MWh
Firm Capacity	$60	$/kW-yr	8,670 kW

Internal Rate of Return **28.4%**

ECONOMIC ANALYSIS

32-MW Power Plant

Year	Project Cost	Annual Operation O&M	Energy Revenue	Capacity Revenue	Total
2008	$8,441,000				-$8,441,000
2009	$10,129,200				-$10,129,200
2010	$15,193,800				-$15,193,800
2011		$586,600	$10,125,000	$1,920,000	$11,458,400
2012		$586,600	$10,125,000	$1,920,000	$11,458,400
2013		$586,600	$10,125,000	$1,920,000	$11,458,400
2014		$586,600	$10,125,000	$1,920,000	$11,458,400
2015		$586,600	$10,125,000	$1,920,000	$11,458,400
2016		$586,600	$10,125,000	$1,920,000	$11,458,400
2017		$586,600	$10,125,000	$1,920,000	$11,458,400
2018		$586,600	$10,125,000	$1,920,000	$11,458,400
2019		$586,600	$10,125,000	$1,920,000	$11,458,400
2020		$586,600	$10,125,000	$1,920,000	$11,458,400
2021		$586,600	$10,125,000	$1,920,000	$11,458,400
2022		$586,600	$10,125,000	$1,920,000	$11,458,400
2023		$586,600	$10,125,000	$1,920,000	$11,458,400
2024		$586,600	$10,125,000	$1,920,000	$11,458,400
2025		$586,600	$10,125,000	$1,920,000	$11,458,400
2026		$586,600	$10,125,000	$1,920,000	$11,458,400
2027		$586,600	$10,125,000	$1,920,000	$11,458,400
2028		$586,600	$10,125,000	$1,920,000	$11,458,400
2029		$586,600	$10,125,000	$1,920,000	$11,458,400
2030		$586,600	$10,125,000	$1,920,000	$11,458,400
2031		$586,600	$10,125,000	$1,920,000	$11,458,400
2032		$586,600	$10,125,000	$1,920,000	$11,458,400
2033		$586,600	$10,125,000	$1,920,000	$11,458,400
2034		$586,600	$10,125,000	$1,920,000	$11,458,400
2035	$11,151,608	$586,600	$10,125,000	$1,920,000	$306,793
2036		$586,600	$10,125,000	$1,920,000	$11,458,400
2037		$586,600	$10,125,000	$1,920,000	$11,458,400
2038		$586,600	$10,125,000	$1,920,000	$11,458,400
2039		$586,600	$10,125,000	$1,920,000	$11,458,400
2040		$586,600	$10,125,000	$1,920,000	$11,458,400
2041		$586,600	$10,125,000	$1,920,000	$11,458,400
2042		$586,600	$10,125,000	$1,920,000	$11,458,400
2043		$586,600	$10,125,000	$1,920,000	$11,458,400
2044		$586,600	$10,125,000	$1,920,000	$11,458,400
2045		$586,600	$10,125,000	$1,920,000	$11,458,400
2046		$586,600	$10,125,000	$1,920,000	$11,458,400
2047		$586,600	$10,125,000	$1,920,000	$11,458,400
2048		$586,600	$10,125,000	$1,920,000	$11,458,400
2049		$586,600	$10,125,000	$1,920,000	$11,458,400
2050		$586,600	$10,125,000	$1,920,000	$11,458,400
2051		$586,600	$10,125,000	$1,920,000	$11,458,400
2052		$586,600	$10,125,000	$1,920,000	$11,458,400
2053		$586,600	$10,125,000	$1,920,000	$11,458,400
2054		$586,600	$10,125,000	$1,920,000	$11,458,400
2055		$586,600	$10,125,000	$1,920,000	$11,458,400
2056		$586,600	$10,125,000	$1,920,000	$11,458,400
2057		$586,600	$10,125,000	$1,920,000	$11,458,400
2058		$586,600	$10,125,000	$1,920,000	$11,458,400
2059		$586,600	$10,125,000	$1,920,000	$11,458,400
2060		$586,600	$10,125,000	$1,920,000	$11,458,400

Cost Summary

Civil Work Cost	$10,368,000
Equipment Cost	$11,754,000
Transmission System	$4,098,000
Subtotal	**$26,220,000**
Contingencies	$3,140,000
Engineering & Administration (15%)	$4,404,000
Project Development Cost	**$33,764,000**

Annual Operation & Maintenance Costs

Civil Work Maintenance	$137,117
Equipment Maintenance	$371,720
Transmission Maintenance	$77,760
Total O&M	**$586,600**

Annual Revenue

Initial Period up 2016			
Energy Production	$45	$/MWh	225,000 MWh
Firm Capacity	$60	$/kW-yr	32,000 kW
After 2016			
Energy Production	$45	$/MWh	215,600 MWh
Firm Capacity	$60	$/kW-yr	8,670 kW

Internal Rate of Return **27.4%**

ECONOMIC ANALYSIS

40-MW Power Plant

Annual Operation

Year	Project Cost	O&M	Energy Revenue	Capacity Revenue	Total
2008	$9,303,750				-$9,303,750
2009	$11,164,500				-$11,164,500
2010	$16,746,750				-$16,746,750
2011		$649,500	$10,755,000	$2,400,000	$12,505,500
2012		$649,500	$10,755,000	$2,400,000	$12,505,500
2013		$649,500	$10,755,000	$2,400,000	$12,505,500
2014		$649,500	$10,755,000	$2,400,000	$12,505,500
2015		$649,500	$10,755,000	$2,400,000	$12,505,500
2016		$649,500	$10,755,000	$2,400,000	$12,505,500
2017		$649,500	$10,755,000	$2,400,000	$12,505,500
2018		$649,500	$10,755,000	$2,400,000	$12,505,500
2019		$649,500	$10,755,000	$2,400,000	$12,505,500
2020		$649,500	$10,755,000	$2,400,000	$12,505,500
2021		$649,500	$10,755,000	$2,400,000	$12,505,500
2022		$649,500	$10,755,000	$2,400,000	$12,505,500
2023		$649,500	$10,755,000	$2,400,000	$12,505,500
2024		$649,500	$10,755,000	$2,400,000	$12,505,500
2025		$649,500	$10,755,000	$2,400,000	$12,505,500
2026		$649,500	$10,755,000	$2,400,000	$12,505,500
2027		$649,500	$10,755,000	$2,400,000	$12,505,500
2028		$649,500	$10,755,000	$2,400,000	$12,505,500
2029		$649,500	$10,755,000	$2,400,000	$12,505,500
2030		$649,500	$10,755,000	$2,400,000	$12,505,500
2031		$649,500	$10,755,000	$2,400,000	$12,505,500
2032		$649,500	$10,755,000	$2,400,000	$12,505,500
2033		$649,500	$10,755,000	$2,400,000	$12,505,500
2034		$649,500	$10,755,000	$2,400,000	$12,505,500
2035	$12,498,833	$649,500	$10,755,000	$2,400,000	$6,668
2036		$649,500	$10,755,000	$2,400,000	$12,505,500
2037		$649,500	$10,755,000	$2,400,000	$12,505,500
2038		$649,500	$10,755,000	$2,400,000	$12,505,500
2039		$649,500	$10,755,000	$2,400,000	$12,505,500
2040		$649,500	$10,755,000	$2,400,000	$12,505,500
2041		$649,500	$10,755,000	$2,400,000	$12,505,500
2042		$649,500	$10,755,000	$2,400,000	$12,505,500
2043		$649,500	$10,755,000	$2,400,000	$12,505,500
2044		$649,500	$10,755,000	$2,400,000	$12,505,500
2045		$649,500	$10,755,000	$2,400,000	$12,505,500
2046		$649,500	$10,755,000	$2,400,000	$12,505,500
2047		$649,500	$10,755,000	$2,400,000	$12,505,500
2048		$649,500	$10,755,000	$2,400,000	$12,505,500
2049		$649,500	$10,755,000	$2,400,000	$12,505,500
2050		$649,500	$10,755,000	$2,400,000	$12,505,500
2051		$649,500	$10,755,000	$2,400,000	$12,505,500
2052		$649,500	$10,755,000	$2,400,000	$12,505,500
2053		$649,500	$10,755,000	$2,400,000	$12,505,500
2054		$649,500	$10,755,000	$2,400,000	$12,505,500
2055		$649,500	$10,755,000	$2,400,000	$12,505,500
2056		$649,500	$10,755,000	$2,400,000	$12,505,500
2057		$649,500	$10,755,000	$2,400,000	$12,505,500
2058		$649,500	$10,755,000	$2,400,000	$12,505,500
2059		$649,500	$10,755,000	$2,400,000	$12,505,500
2060		$649,500	$10,755,000	$2,400,000	$12,505,500

Cost Summary

Civil Work Cost	$11,408,000
Equipment Cost	$13,174,000
Transmission System	$4,319,000
Subtotal	**$28,901,000**
Contingencies	$3,460,000
Engineering & Administration (15%)	$4,854,000
Project Development Cost	**$37,215,000**

Annual Operation & Maintenance Costs

Civil Work Maintenance	$150,871
Equipment Maintenance	$416,628
Transmission Maintenance	$81,953
Total O&M	**$649,500**

Annual Revenue

Initial Period up 2016			
Energy Production	$45	$/MWh	239,000 MWh
Firm Capacity	$60	$/kW-yr	40,000 kW
After 2016			
Energy Production	$45	$/MWh	243,100 MWh
Firm Capacity	$60	$/kW-yr	8,670 kW

Internal Rate of Return **27.2%**

ECONOMIC ANALYSIS

49-MW Power Plant

Annual Operation

Year	Project Cost	O&M	Energy Revenue	Capacity Revenue	Total
2008	$10,512,250				-$10,512,250
2009	$12,614,700				-$12,614,700
2010	$18,922,050				-$18,922,050
2011		$748,100	$11,250,000	$2,940,000	$13,441,900
2012		$748,100	$11,250,000	$2,940,000	$13,441,900
2013		$748,100	$11,250,000	$2,940,000	$13,441,900
2014		$748,100	$11,250,000	$2,940,000	$13,441,900
2015		$748,100	$11,250,000	$2,940,000	$13,441,900
2016		$748,100	$11,250,000	$2,940,000	$13,441,900
2017		$748,100	$11,250,000	$2,940,000	$13,441,900
2018		$748,100	$11,250,000	$2,940,000	$13,441,900
2019		$748,100	$11,250,000	$2,940,000	$13,441,900
2020		$748,100	$11,250,000	$2,940,000	$13,441,900
2021		$748,100	$11,250,000	$2,940,000	$13,441,900
2022		$748,100	$11,250,000	$2,940,000	$13,441,900
2023		$748,100	$11,250,000	$2,940,000	$13,441,900
2024		$748,100	$11,250,000	$2,940,000	$13,441,900
2025		$748,100	$11,250,000	$2,940,000	$13,441,900
2026		$748,100	$11,250,000	$2,940,000	$13,441,900
2027		$748,100	$11,250,000	$2,940,000	$13,441,900
2028		$748,100	$11,250,000	$2,940,000	$13,441,900
2029		$748,100	$11,250,000	$2,940,000	$13,441,900
2030		$748,100	$11,250,000	$2,940,000	$13,441,900
2031		$748,100	$11,250,000	$2,940,000	$13,441,900
2032		$748,100	$11,250,000	$2,940,000	$13,441,900
2033		$748,100	$11,250,000	$2,940,000	$13,441,900
2034		$748,100	$11,250,000	$2,940,000	$13,441,900
2035	$14,897,273	$748,100	$11,250,000	$2,940,000	-$1,455,373
2036		$748,100	$11,250,000	$2,940,000	$13,441,900
2037		$748,100	$11,250,000	$2,940,000	$13,441,900
2038		$748,100	$11,250,000	$2,940,000	$13,441,900
2039		$748,100	$11,250,000	$2,940,000	$13,441,900
2040		$748,100	$11,250,000	$2,940,000	$13,441,900
2041		$748,100	$11,250,000	$2,940,000	$13,441,900
2042		$748,100	$11,250,000	$2,940,000	$13,441,900
2043		$748,100	$11,250,000	$2,940,000	$13,441,900
2044		$748,100	$11,250,000	$2,940,000	$13,441,900
2045		$748,100	$11,250,000	$2,940,000	$13,441,900
2046		$748,100	$11,250,000	$2,940,000	$13,441,900
2047		$748,100	$11,250,000	$2,940,000	$13,441,900
2048		$748,100	$11,250,000	$2,940,000	$13,441,900
2049		$748,100	$11,250,000	$2,940,000	$13,441,900
2050		$748,100	$11,250,000	$2,940,000	$13,441,900
2051		$748,100	$11,250,000	$2,940,000	$13,441,900
2052		$748,100	$11,250,000	$2,940,000	$13,441,900
2053		$748,100	$11,250,000	$2,940,000	$13,441,900
2054		$748,100	$11,250,000	$2,940,000	$13,441,900
2055		$748,100	$11,250,000	$2,940,000	$13,441,900
2056		$748,100	$11,250,000	$2,940,000	$13,441,900
2057		$748,100	$11,250,000	$2,940,000	$13,441,900
2058		$748,100	$11,250,000	$2,940,000	$13,441,900
2059		$748,100	$11,250,000	$2,940,000	$13,441,900
2060		$748,100	$11,250,000	$2,940,000	$13,441,900

Cost Summary

Civil Work Cost	$12,300,000
Equipment Cost	$15,702,000
Transmission System	$4,679,000
Subtotal	**$32,681,000**
Contingencies	$3,883,000
Engineering & Administration (15%)	$5,485,000
Project Development Cost	**$42,049,000**

Annual Operation & Maintenance Costs

Civil Work Maintenance	$162,668
Equipment Maintenance	$496,576
Transmission Maintenance	$88,784
Total O&M	**$748,100**

Annual Revenue

Initial Period up 2016			
Energy Production	$45	$/MWh	250,000 **MWh**
Firm Capacity	$60	$/kW-yr	49,000 **kW**
After 2016			
Energy Production	$45	$/MWh	250,600 **MWh**
Firm Capacity	$60	$/kW-yr	8,670 **kW**

Internal Rate of Return **26.1%**

ECONOMIC ANALYSIS

56-MW Power Plant

Annual Operation

Year	Project Cost	O&M	Energy Revenue	Capacity Revenue	Total
2008	$11,349,750				-$11,349,750
2009	$13,619,700				-$13,619,700
2010	$20,429,550				-$20,429,550
2011		$812,900	$11,407,500	$3,360,000	$13,954,600
2012		$812,900	$11,407,500	$3,360,000	$13,954,600
2013		$812,900	$11,407,500	$3,360,000	$13,954,600
2014		$812,900	$11,407,500	$3,360,000	$13,954,600
2015		$812,900	$11,407,500	$3,360,000	$13,954,600
2016		$812,900	$11,407,500	$3,360,000	$13,954,600
2017		$812,900	$11,407,500	$3,360,000	$13,954,600
2018		$812,900	$11,407,500	$3,360,000	$13,954,600
2019		$812,900	$11,407,500	$3,360,000	$13,954,600
2020		$812,900	$11,407,500	$3,360,000	$13,954,600
2021		$812,900	$11,407,500	$3,360,000	$13,954,600
2022		$812,900	$11,407,500	$3,360,000	$13,954,600
2023		$812,900	$11,407,500	$3,360,000	$13,954,600
2024		$812,900	$11,407,500	$3,360,000	$13,954,600
2025		$812,900	$11,407,500	$3,360,000	$13,954,600
2026		$812,900	$11,407,500	$3,360,000	$13,954,600
2027		$812,900	$11,407,500	$3,360,000	$13,954,600
2028		$812,900	$11,407,500	$3,360,000	$13,954,600
2029		$812,900	$11,407,500	$3,360,000	$13,954,600
2030		$812,900	$11,407,500	$3,360,000	$13,954,600
2031		$812,900	$11,407,500	$3,360,000	$13,954,600
2032		$812,900	$11,407,500	$3,360,000	$13,954,600
2033		$812,900	$11,407,500	$3,360,000	$13,954,600
2034		$812,900	$11,407,500	$3,360,000	$13,954,600
2035	$16,451,325	$812,900	$11,407,500	$3,360,000	-$2,496,725
2036		$812,900	$11,407,500	$3,360,000	$13,954,600
2037		$812,900	$11,407,500	$3,360,000	$13,954,600
2038		$812,900	$11,407,500	$3,360,000	$13,954,600
2039		$812,900	$11,407,500	$3,360,000	$13,954,600
2040		$812,900	$11,407,500	$3,360,000	$13,954,600
2041		$812,900	$11,407,500	$3,360,000	$13,954,600
2042		$812,900	$11,407,500	$3,360,000	$13,954,600
2043		$812,900	$11,407,500	$3,360,000	$13,954,600
2044		$812,900	$11,407,500	$3,360,000	$13,954,600
2045		$812,900	$11,407,500	$3,360,000	$13,954,600
2046		$812,900	$11,407,500	$3,360,000	$13,954,600
2047		$812,900	$11,407,500	$3,360,000	$13,954,600
2048		$812,900	$11,407,500	$3,360,000	$13,954,600
2049		$812,900	$11,407,500	$3,360,000	$13,954,600
2050		$812,900	$11,407,500	$3,360,000	$13,954,600
2051		$812,900	$11,407,500	$3,360,000	$13,954,600
2052		$812,900	$11,407,500	$3,360,000	$13,954,600
2053		$812,900	$11,407,500	$3,360,000	$13,954,600
2054		$812,900	$11,407,500	$3,360,000	$13,954,600
2055		$812,900	$11,407,500	$3,360,000	$13,954,600
2056		$812,900	$11,407,500	$3,360,000	$13,954,600
2057		$812,900	$11,407,500	$3,360,000	$13,954,600
2058		$812,900	$11,407,500	$3,360,000	$13,954,600
2059		$812,900	$11,407,500	$3,360,000	$13,954,600
2060		$812,900	$11,407,500	$3,360,000	$13,954,600

Cost Summary

Civil Work Cost			$13,227,000
Equipment Cost			$17,340,000
Transmission System			$4,720,000
Subtotal			**$35,287,000**
Contingencies			$4,190,000
Engineering & Administration (15%)			$5,922,000
Project Development Cost			**$45,399,000**
Annual Operation & Maintenance Costs			
Civil Work Maintenance			$174,927
Equipment Maintenance			$548,378
Transmission Maintenance			$89,562
Total O&M			**$812,900**
Annual Revenue			
Initial Period up 2016			
Energy Production	$45	$/MWh	253,500 **MWh**
Firm Capacity	$60	$/kW-yr	56,000 **kW**
After 2016			
Energy Production	$45	$/MWh	253,300 **MWh**
Firm Capacity	$60	$/kW-yr	8,670 **kW**
Internal Rate of Return			**25.2%**

ECONOMIC ANALYSIS

63-MW Power Plant

Annual Operation

Year	Project Cost	O&M	Energy Revenue	Capacity Revenue	Total
2008	$12,320,250				-$12,320,250
2009	$14,784,300				-$14,784,300
2010	$22,176,450				-$22,176,450
2011		$881,800	$11,565,000	$3,780,000	$14,463,200
2012		$881,800	$11,565,000	$3,780,000	$14,463,200
2013		$881,800	$11,565,000	$3,780,000	$14,463,200
2014		$881,800	$11,565,000	$3,780,000	$14,463,200
2015		$881,800	$11,565,000	$3,780,000	$14,463,200
2016		$881,800	$11,565,000	$3,780,000	$14,463,200
2017		$881,800	$11,565,000	$3,780,000	$14,463,200
2018		$881,800	$11,565,000	$3,780,000	$14,463,200
2019		$881,800	$11,565,000	$3,780,000	$14,463,200
2020		$881,800	$11,565,000	$3,780,000	$14,463,200
2021		$881,800	$11,565,000	$3,780,000	$14,463,200
2022		$881,800	$11,565,000	$3,780,000	$14,463,200
2023		$881,800	$11,565,000	$3,780,000	$14,463,200
2024		$881,800	$11,565,000	$3,780,000	$14,463,200
2025		$881,800	$11,565,000	$3,780,000	$14,463,200
2026		$881,800	$11,565,000	$3,780,000	$14,463,200
2027		$881,800	$11,565,000	$3,780,000	$14,463,200
2028		$881,800	$11,565,000	$3,780,000	$14,463,200
2029		$881,800	$11,565,000	$3,780,000	$14,463,200
2030		$881,800	$11,565,000	$3,780,000	$14,463,200
2031		$881,800	$11,565,000	$3,780,000	$14,463,200
2032		$881,800	$11,565,000	$3,780,000	$14,463,200
2033		$881,800	$11,565,000	$3,780,000	$14,463,200
2034		$881,800	$11,565,000	$3,780,000	$14,463,200
2035	$17,925,683	$881,800	$11,565,000	$3,780,000	-$3,462,483
2036		$881,800	$11,565,000	$3,780,000	$14,463,200
2037		$881,800	$11,565,000	$3,780,000	$14,463,200
2038		$881,800	$11,565,000	$3,780,000	$14,463,200
2039		$881,800	$11,565,000	$3,780,000	$14,463,200
2040		$881,800	$11,565,000	$3,780,000	$14,463,200
2041		$881,800	$11,565,000	$3,780,000	$14,463,200
2042		$881,800	$11,565,000	$3,780,000	$14,463,200
2043		$881,800	$11,565,000	$3,780,000	$14,463,200
2044		$881,800	$11,565,000	$3,780,000	$14,463,200
2045		$881,800	$11,565,000	$3,780,000	$14,463,200
2046		$881,800	$11,565,000	$3,780,000	$14,463,200
2047		$881,800	$11,565,000	$3,780,000	$14,463,200
2048		$881,800	$11,565,000	$3,780,000	$14,463,200
2049		$881,800	$11,565,000	$3,780,000	$14,463,200
2050		$881,800	$11,565,000	$3,780,000	$14,463,200
2051		$881,800	$11,565,000	$3,780,000	$14,463,200
2052		$881,800	$11,565,000	$3,780,000	$14,463,200
2053		$881,800	$11,565,000	$3,780,000	$14,463,200
2054		$881,800	$11,565,000	$3,780,000	$14,463,200
2055		$881,800	$11,565,000	$3,780,000	$14,463,200
2056		$881,800	$11,565,000	$3,780,000	$14,463,200
2057		$881,800	$11,565,000	$3,780,000	$14,463,200
2058		$881,800	$11,565,000	$3,780,000	$14,463,200
2059		$881,800	$11,565,000	$3,780,000	$14,463,200
2060		$881,800	$11,565,000	$3,780,000	$14,463,200

Cost Summary

Civil Work Cost	$14,593,000
Equipment Cost	$18,894,000
Transmission System	$4,807,000
Subtotal	**$38,294,000**
Contingencies	$4,559,000
Engineering & Administration (15%)	$6,428,000
Project Development Cost	**$49,281,000**

Annual Operation & Maintenance Costs

Civil Work Maintenance	$192,992
Equipment Maintenance	$597,523
Transmission Maintenance	$91,213
Total O&M	**$881,800**

Annual Revenue

Initial Period up 2016			
Energy Production	$45	$/MWh	257,000 **MWh**
Firm Capacity	$60	$/kW-yr	63,000 **kW**
After 2016			
Energy Production	$45	$/MWh	255,400 **MWh**
Firm Capacity	$60	$/kW-yr	8,670 **kW**

Internal Rate of Return **24.2%**

ECONOMIC ANALYSIS

Marginal Rate of Return Computations
From 24-MW to 32-MW

Marginal Rate of Return: *21.7%*

Year	Incremental Project Cost	Incremental O&M Cost	Incremental Energy Revenue	Incremental Capacity Revenue	Total
2008	$1,282,500				-$1,282,500
2009	$1,539,000				-$1,539,000
2010	$2,308,500				-$2,308,500
2011		$107,500	$949,500	$480,000	$1,322,000
2012		$107,500	$949,500	$480,000	$1,322,000
2013		$107,500	$949,500	$480,000	$1,322,000
2014		$107,500	$949,500	$480,000	$1,322,000
2015		$107,500	$949,500	$480,000	$1,322,000
2016		$107,500	$949,500	$480,000	$1,322,000
2017		$107,500	$949,500	$480,000	$1,322,000
2018		$107,500	$949,500	$480,000	$1,322,000
2019		$107,500	$949,500	$480,000	$1,322,000
2020		$107,500	$949,500	$480,000	$1,322,000
2021		$107,500	$949,500	$480,000	$1,322,000
2022		$107,500	$949,500	$480,000	$1,322,000
2023		$107,500	$949,500	$480,000	$1,322,000
2024		$107,500	$949,500	$480,000	$1,322,000
2025		$107,500	$949,500	$480,000	$1,322,000
2026		$107,500	$949,500	$480,000	$1,322,000
2027		$107,500	$949,500	$480,000	$1,322,000
2028		$107,500	$949,500	$480,000	$1,322,000
2029		$107,500	$949,500	$480,000	$1,322,000
2030		$107,500	$949,500	$480,000	$1,322,000
2031		$107,500	$949,500	$480,000	$1,322,000
2032		$107,500	$949,500	$480,000	$1,322,000
2033		$107,500	$949,500	$480,000	$1,322,000
2034		$107,500	$949,500	$480,000	$1,322,000
2035	$2,781,735	$107,500	$949,500	$480,000	-$1,459,735
2036		$107,500	$949,500	$480,000	$1,322,000
2037		$107,500	$949,500	$480,000	$1,322,000
2038		$107,500	$949,500	$480,000	$1,322,000
2039		$107,500	$949,500	$480,000	$1,322,000
2040		$107,500	$949,500	$480,000	$1,322,000
2041		$107,500	$949,500	$480,000	$1,322,000
2042		$107,500	$949,500	$480,000	$1,322,000
2043		$107,500	$949,500	$480,000	$1,322,000
2044		$107,500	$949,500	$480,000	$1,322,000
2045		$107,500	$949,500	$480,000	$1,322,000
2046		$107,500	$949,500	$480,000	$1,322,000
2047		$107,500	$949,500	$480,000	$1,322,000
2048		$107,500	$949,500	$480,000	$1,322,000
2049		$107,500	$949,500	$480,000	$1,322,000
2050		$107,500	$949,500	$480,000	$1,322,000
2051		$107,500	$949,500	$480,000	$1,322,000
2052		$107,500	$949,500	$480,000	$1,322,000
2053		$107,500	$949,500	$480,000	$1,322,000
2054		$107,500	$949,500	$480,000	$1,322,000
2055		$107,500	$949,500	$480,000	$1,322,000
2056		$107,500	$949,500	$480,000	$1,322,000
2057		$107,500	$949,500	$480,000	$1,322,000
2058		$107,500	$949,500	$480,000	$1,322,000
2059		$107,500	$949,500	$480,000	$1,322,000
2060		$107,500	$949,500	$480,000	$1,322,000

ECONOMIC ANALYSIS

Marginal Rate of Return Computations
From 32-MW to 40-MW

Marginal Rate of Return: *24.9%*

Year	Project Cost	O&M	Energy Revenue	Capacity Revenue	Total
2008	$862,750				-$862,750
2009	$1,035,300				-$1,035,300
2010	$1,552,950				-$1,552,950
2011		$62,900	$630,000	$480,000	$1,047,100
2012		$62,900	$630,000	$480,000	$1,047,100
2013		$62,900	$630,000	$480,000	$1,047,100
2014		$62,900	$630,000	$480,000	$1,047,100
2015		$62,900	$630,000	$480,000	$1,047,100
2016		$62,900	$630,000	$480,000	$1,047,100
2017		$62,900	$630,000	$480,000	$1,047,100
2018		$62,900	$630,000	$480,000	$1,047,100
2019		$62,900	$630,000	$480,000	$1,047,100
2020		$62,900	$630,000	$480,000	$1,047,100
2021		$62,900	$630,000	$480,000	$1,047,100
2022		$62,900	$630,000	$480,000	$1,047,100
2023		$62,900	$630,000	$480,000	$1,047,100
2024		$62,900	$630,000	$480,000	$1,047,100
2025		$62,900	$630,000	$480,000	$1,047,100
2026		$62,900	$630,000	$480,000	$1,047,100
2027		$62,900	$630,000	$480,000	$1,047,100
2028		$62,900	$630,000	$480,000	$1,047,100
2029		$62,900	$630,000	$480,000	$1,047,100
2030		$62,900	$630,000	$480,000	$1,047,100
2031		$62,900	$630,000	$480,000	$1,047,100
2032		$62,900	$630,000	$480,000	$1,047,100
2033		$62,900	$630,000	$480,000	$1,047,100
2034		$62,900	$630,000	$480,000	$1,047,100
2035	$1,347,225	$62,900	$630,000	$480,000	-$300,125
2036		$62,900	$630,000	$480,000	$1,047,100
2037		$62,900	$630,000	$480,000	$1,047,100
2038		$62,900	$630,000	$480,000	$1,047,100
2039		$62,900	$630,000	$480,000	$1,047,100
2040		$62,900	$630,000	$480,000	$1,047,100
2041		$62,900	$630,000	$480,000	$1,047,100
2042		$62,900	$630,000	$480,000	$1,047,100
2043		$62,900	$630,000	$480,000	$1,047,100
2044		$62,900	$630,000	$480,000	$1,047,100
2045		$62,900	$630,000	$480,000	$1,047,100
2046		$62,900	$630,000	$480,000	$1,047,100
2047		$62,900	$630,000	$480,000	$1,047,100
2048		$62,900	$630,000	$480,000	$1,047,100
2049		$62,900	$630,000	$480,000	$1,047,100
2050		$62,900	$630,000	$480,000	$1,047,100
2051		$62,900	$630,000	$480,000	$1,047,100
2052		$62,900	$630,000	$480,000	$1,047,100
2053		$62,900	$630,000	$480,000	$1,047,100
2054		$62,900	$630,000	$480,000	$1,047,100
2055		$62,900	$630,000	$480,000	$1,047,100
2056		$62,900	$630,000	$480,000	$1,047,100
2057		$62,900	$630,000	$480,000	$1,047,100
2058		$62,900	$630,000	$480,000	$1,047,100
2059		$62,900	$630,000	$480,000	$1,047,100
2060		$62,900	$630,000	$480,000	$1,047,100

ECONOMIC ANALYSIS

Marginal Rate of Return Computations
From 40-MW to 49-MW

Marginal Rate of Return: *16.8%*

Year	Project Cost	O&M	Energy Revenue	Capacity Revenue	Total
2008	$1,208,500				-$1,208,500
2009	$1,450,200				-$1,450,200
2010	$2,175,300				-$2,175,300
2011		$98,600	$495,000	$540,000	$936,400
2012		$98,600	$495,000	$540,000	$936,400
2013		$98,600	$495,000	$540,000	$936,400
2014		$98,600	$495,000	$540,000	$936,400
2015		$98,600	$495,000	$540,000	$936,400
2016		$98,600	$495,000	$540,000	$936,400
2017		$98,600	$495,000	$540,000	$936,400
2018		$98,600	$495,000	$540,000	$936,400
2019		$98,600	$495,000	$540,000	$936,400
2020		$98,600	$495,000	$540,000	$936,400
2021		$98,600	$495,000	$540,000	$936,400
2022		$98,600	$495,000	$540,000	$936,400
2023		$98,600	$495,000	$540,000	$936,400
2024		$98,600	$495,000	$540,000	$936,400
2025		$98,600	$495,000	$540,000	$936,400
2026		$98,600	$495,000	$540,000	$936,400
2027		$98,600	$495,000	$540,000	$936,400
2028		$98,600	$495,000	$540,000	$936,400
2029		$98,600	$495,000	$540,000	$936,400
2030		$98,600	$495,000	$540,000	$936,400
2031		$98,600	$495,000	$540,000	$936,400
2032		$98,600	$495,000	$540,000	$936,400
2033		$98,600	$495,000	$540,000	$936,400
2034		$98,600	$495,000	$540,000	$936,400
2035	$2,398,440	$98,600	$495,000	$540,000	-$1,462,040
2036		$98,600	$495,000	$540,000	$936,400
2037		$98,600	$495,000	$540,000	$936,400
2038		$98,600	$495,000	$540,000	$936,400
2039		$98,600	$495,000	$540,000	$936,400
2040		$98,600	$495,000	$540,000	$936,400
2041		$98,600	$495,000	$540,000	$936,400
2042		$98,600	$495,000	$540,000	$936,400
2043		$98,600	$495,000	$540,000	$936,400
2044		$98,600	$495,000	$540,000	$936,400
2045		$98,600	$495,000	$540,000	$936,400
2046		$98,600	$495,000	$540,000	$936,400
2047		$98,600	$495,000	$540,000	$936,400
2048		$98,600	$495,000	$540,000	$936,400
2049		$98,600	$495,000	$540,000	$936,400
2050		$98,600	$495,000	$540,000	$936,400
2051		$98,600	$495,000	$540,000	$936,400
2052		$98,600	$495,000	$540,000	$936,400
2053		$98,600	$495,000	$540,000	$936,400
2054		$98,600	$495,000	$540,000	$936,400
2055		$98,600	$495,000	$540,000	$936,400
2056		$98,600	$495,000	$540,000	$936,400
2057		$98,600	$495,000	$540,000	$936,400
2058		$98,600	$495,000	$540,000	$936,400
2059		$98,600	$495,000	$540,000	$936,400
2060		$98,600	$495,000	$540,000	$936,400

ECONOMIC ANALYSIS

Marginal Rate of Return Computations
From 49-MW to 56-MW

Marginal Rate of Return: *13.5%*

Year	Project Cost	O&M	Energy Revenue	Capacity Revenue	Total
2008	$837,500				-$837,500
2009	$1,005,000				-$1,005,000
2010	$1,507,500				-$1,507,500
2011		$64,800	$157,500	$420,000	$512,700
2012		$64,800	$157,500	$420,000	$512,700
2013		$64,800	$157,500	$420,000	$512,700
2014		$64,800	$157,500	$420,000	$512,700
2015		$64,800	$157,500	$420,000	$512,700
2016		$64,800	$157,500	$420,000	$512,700
2017		$64,800	$157,500	$420,000	$512,700
2018		$64,800	$157,500	$420,000	$512,700
2019		$64,800	$157,500	$420,000	$512,700
2020		$64,800	$157,500	$420,000	$512,700
2021		$64,800	$157,500	$420,000	$512,700
2022		$64,800	$157,500	$420,000	$512,700
2023		$64,800	$157,500	$420,000	$512,700
2024		$64,800	$157,500	$420,000	$512,700
2025		$64,800	$157,500	$420,000	$512,700
2026		$64,800	$157,500	$420,000	$512,700
2027		$64,800	$157,500	$420,000	$512,700
2028		$64,800	$157,500	$420,000	$512,700
2029		$64,800	$157,500	$420,000	$512,700
2030		$64,800	$157,500	$420,000	$512,700
2031		$64,800	$157,500	$420,000	$512,700
2032		$64,800	$157,500	$420,000	$512,700
2033		$64,800	$157,500	$420,000	$512,700
2034		$64,800	$157,500	$420,000	$512,700
2035	$1,554,053	$64,800	$157,500	$420,000	-$1,041,353
2036		$64,800	$157,500	$420,000	$512,700
2037		$64,800	$157,500	$420,000	$512,700
2038		$64,800	$157,500	$420,000	$512,700
2039		$64,800	$157,500	$420,000	$512,700
2040		$64,800	$157,500	$420,000	$512,700
2041		$64,800	$157,500	$420,000	$512,700
2042		$64,800	$157,500	$420,000	$512,700
2043		$64,800	$157,500	$420,000	$512,700
2044		$64,800	$157,500	$420,000	$512,700
2045		$64,800	$157,500	$420,000	$512,700
2046		$64,800	$157,500	$420,000	$512,700
2047		$64,800	$157,500	$420,000	$512,700
2048		$64,800	$157,500	$420,000	$512,700
2049		$64,800	$157,500	$420,000	$512,700
2050		$64,800	$157,500	$420,000	$512,700
2051		$64,800	$157,500	$420,000	$512,700
2052		$64,800	$157,500	$420,000	$512,700
2053		$64,800	$157,500	$420,000	$512,700
2054		$64,800	$157,500	$420,000	$512,700
2055		$64,800	$157,500	$420,000	$512,700
2056		$64,800	$157,500	$420,000	$512,700
2057		$64,800	$157,500	$420,000	$512,700
2058		$64,800	$157,500	$420,000	$512,700
2059		$64,800	$157,500	$420,000	$512,700
2060		$64,800	$157,500	$420,000	$512,700

ECONOMIC ANALYSIS

Marginal Rate of Return Computations
From 56-MW to 63-MW

Marginal Rate of Return: 11.6%

Year	Project Cost	O&M	Energy Revenue	Capacity Revenue	Total
2008	$970,500				-$970,500
2009	$1,164,600				-$1,164,600
2010	$1,746,900				-$1,746,900
2011		$68,900	$157,500	$420,000	$508,600
2012		$68,900	$157,500	$420,000	$508,600
2013		$68,900	$157,500	$420,000	$508,600
2014		$68,900	$157,500	$420,000	$508,600
2015		$68,900	$157,500	$420,000	$508,600
2016		$68,900	$157,500	$420,000	$508,600
2017		$68,900	$157,500	$420,000	$508,600
2018		$68,900	$157,500	$420,000	$508,600
2019		$68,900	$157,500	$420,000	$508,600
2020		$68,900	$157,500	$420,000	$508,600
2021		$68,900	$157,500	$420,000	$508,600
2022		$68,900	$157,500	$420,000	$508,600
2023		$68,900	$157,500	$420,000	$508,600
2024		$68,900	$157,500	$420,000	$508,600
2025		$68,900	$157,500	$420,000	$508,600
2026		$68,900	$157,500	$420,000	$508,600
2027		$68,900	$157,500	$420,000	$508,600
2028		$68,900	$157,500	$420,000	$508,600
2029		$68,900	$157,500	$420,000	$508,600
2030		$68,900	$157,500	$420,000	$508,600
2031		$68,900	$157,500	$420,000	$508,600
2032		$68,900	$157,500	$420,000	$508,600
2033		$68,900	$157,500	$420,000	$508,600
2034		$68,900	$157,500	$420,000	$508,600
2035	$1,474,358	$68,900	$157,500	$420,000	-$965,758
2036		$68,900	$157,500	$420,000	$508,600
2037		$68,900	$157,500	$420,000	$508,600
2038		$68,900	$157,500	$420,000	$508,600
2039		$68,900	$157,500	$420,000	$508,600
2040		$68,900	$157,500	$420,000	$508,600
2041		$68,900	$157,500	$420,000	$508,600
2042		$68,900	$157,500	$420,000	$508,600
2043		$68,900	$157,500	$420,000	$508,600
2044		$68,900	$157,500	$420,000	$508,600
2045		$68,900	$157,500	$420,000	$508,600
2046		$68,900	$157,500	$420,000	$508,600
2047		$68,900	$157,500	$420,000	$508,600
2048		$68,900	$157,500	$420,000	$508,600
2049		$68,900	$157,500	$420,000	$508,600
2050		$68,900	$157,500	$420,000	$508,600
2051		$68,900	$157,500	$420,000	$508,600
2052		$68,900	$157,500	$420,000	$508,600
2053		$68,900	$157,500	$420,000	$508,600
2054		$68,900	$157,500	$420,000	$508,600
2055		$68,900	$157,500	$420,000	$508,600
2056		$68,900	$157,500	$420,000	$508,600
2057		$68,900	$157,500	$420,000	$508,600
2058		$68,900	$157,500	$420,000	$508,600
2059		$68,900	$157,500	$420,000	$508,600
2060		$68,900	$157,500	$420,000	$508,600

ECONOMIC ANALYSIS

Upper Chagres Hydropower Component
Economic Return Summary

	Construction Cost	O&M Annual Cost	Initial Period up to 2017			Period after 2017			Internal Rate of Return	Marginal Rate of Return
			Avg Annual Energy (GWh)	Firm Capacity (MW)	Anuual Revenue	Avg Annual Energy (GWh)	Firm Capacity (MW)	Anuual Revenue		
24 MW Power Plant	$28,634,000	$479,100	203.9	24.0	$10,615,500	173.6	8.7	$8,332,200	27.4%	
32 MW Power Plant	$33,764,000	$586,600	225.0	32.0	$12,045,000	215.6	8.7	$10,222,200	26.7%	23.2%
40 MW Power Plant	$37,215,000	$649,500	239.0	40.0	$13,155,000	243.1	8.7	$11,459,700	26.6%	25.5%
49 MW Power Plant	$42,049,000	$748,100	250.0	49.0	$14,190,000	250.6	8.7	$11,797,200	25.3%	11.0%
56 MW Power Plant	$45,399,000	$812,900	253.5	56.0	$14,767,500	253.3	8.7	$11,918,700	24.3%	3.6%
63 MW Power Plant	$49,281,000	$881,800	257.0	63.0	$15,345,000	255.4	8.7	$12,013,200	23.1%	-3.2%

Energy Value	$45 per MWh
Firm Capacity Value	$60 per kW-yr
Year of maximum water demand	2017

ECONOMIC ANALYSIS

Upper Chagres Hydropower Component
Economic Return Summary

	Construction Cost	O&M Annual Cost	Initial Period up to 2020			Period after 2020			Internal Rate of Return	Marginal Rate of Return
			Avg Annual Energy (GWh)	Firm Capacity (MW)	Anuual Revenue	Avg Annual Energy (GWh)	Firm Capacity (MW)	Anuual Revenue		
24 MW Power Plant	$28,634,000	$479,100	203.9	24.0	$10,615,500	173.6	8.7	$8,332,200	27.9%	
32 MW Power Plant	$33,764,000	$586,600	225.0	32.0	$12,045,000	215.6	8.7	$10,222,200	27.1%	22.5%
40 MW Power Plant	$37,215,000	$649,500	239.0	40.0	$13,155,000	243.1	8.7	$11,459,700	26.9%	25.2%
49 MW Power Plant	$42,049,000	$748,100	250.0	49.0	$14,190,000	250.6	8.7	$11,797,200	25.7%	13.5%
56 MW Power Plant	$45,399,000	$812,900	253.5	56.0	$14,767,500	253.3	8.7	$11,918,700	24.7%	7.8%
63 MW Power Plant	$49,281,000	$881,800	257.0	63.0	$15,345,000	255.4	8.7	$12,013,200	23.7%	3.5%

Energy Value	$45 per MWh
Firm Capacity Value	$60 per kW-yr
Year of maximum water demand	2020

ECONOMIC ANALYSIS

Upper Chagres Hydropower Component
Economic Return Summary

	Construction Cost	O&M Annual Cost	Initial Period up to 2025			Period after 2025			Internal Rate of Return	Marginal Rate of Return
			Avg Annual Energy (GWh)	Firm Capacity (MW)	Anuual Revenue	Avg Annual Energy (GWh)	Firm Capacity (MW)	Anuual Revenue		
24 MW Power Plant	$28,634,000	$479,100	203.9	24.0	$10,615,500	173.6	8.7	$8,332,200	28.2%	
32 MW Power Plant	$33,764,000	$586,600	225.0	32.0	$12,045,000	215.6	8.7	$10,222,200	27.3%	22.0%
40 MW Power Plant	$37,215,000	$649,500	239.0	40.0	$13,155,000	243.1	8.7	$11,459,700	27.1%	25.0%
49 MW Power Plant	$42,049,000	$748,100	250.0	49.0	$14,190,000	250.6	8.7	$11,797,200	25.9%	15.5%
56 MW Power Plant	$45,399,000	$812,900	253.5	56.0	$14,767,500	253.3	8.7	$11,918,700	25.1%	11.1%
63 MW Power Plant	$49,281,000	$881,800	257.0	63.0	$15,345,000	255.4	8.7	$12,013,200	24.1%	8.4%

Energy Value	$45 per MWh
Firm Capacity Value	$60 per kW-yr
Year of maximum water demand	2025

ECONOMIC ANALYSIS

Upper Chagres Hydropower Component
Economic Return Summary

	Construction Cost	O&M Annual Cost	Initial Period up to 2028			Period after 2028			Internal Rate of Return	Marginal Rate of Return
			Avg Annual Energy (GWh)	Firm Capacity (MW)	Anuual Revenue	Avg Annual Energy (GWh)	Firm Capacity (MW)	Anuual Revenue		
24 MW Power Plant	$28,634,000	$479,100	203.9	24.0	$10,615,500	173.6	8.7	$8,332,200	28.3%	
32 MW Power Plant	$33,764,000	$586,600	225.0	32.0	$12,045,000	215.6	8.7	$10,222,200	27.3%	21.9%
40 MW Power Plant	$37,215,000	$649,500	239.0	40.0	$13,155,000	243.1	8.7	$11,459,700	27.1%	25.0%
49 MW Power Plant	$42,049,000	$748,100	250.0	49.0	$14,190,000	250.6	8.7	$11,797,200	26.0%	16.0%
56 MW Power Plant	$45,399,000	$812,900	253.5	56.0	$14,767,500	253.3	8.7	$11,918,700	25.1%	12.0%
63 MW Power Plant	$49,281,000	$881,800	257.0	63.0	$15,345,000	255.4	8.7	$12,013,200	24.2%	9.6%

Energy Value	$45 per MWh
Firm Capacity Value	$60 per kW-yr
Year of maximum water demand	2028

FEASIBILITY DESIGN FOR THE UPPER CHAGRES WATER SUPPLY PROJECT

APPENDIX F

COST ESTIMATES

Prepared by

MWH

In association with

TAMS

AN EARTH TECH COMPANY

FEASIBILITY DESIGN FOR THE UPPER CHAGRES WATER SUPPLY PROJECT

APPENDIX F – COST ESTIMATES

LIST OF TABLES

1. Project Management and Support
2. Local Labor Hourly Rates
3. Equipment Hourly Rates
4. Common Equipment
5. Other Costs
6. Common Excavation
7. Structural Rock Excavation
8. Bulk Rock Excavation
9. Operate Quarry
10. Concrete Mix and Transport
11. Concrete Placement
12. Steel Reinforcement
13. Formwork
14. RCC
15. Power Tunnel

Project Management and Support

Description	Monthly Salary ($)	Cost of Salary	Number	Duration (month) Pre	Const.	Post	Total
Project Manager	$8,500	$12,750	1	6	42	3	$650,250
Superintendent	$7,500	$11,250	1	6	42	3	$573,750
Staff Engineers	$5,500	$8,250	3	2	42		$1,089,000
Purchasing Agent	$6,500	$9,750	1	6	42		$468,000
Coordinator (subs)	$6,000	$9,000	1	6	42		$432,000
Accountant	$6,500	$9,750	1	2	42	3	$458,250
Administrative Assistant	$2,000	$3,000	3	3	42	2	$423,000
Secretary	$1,000	$1,500	2	3	42	2	$141,000
							$4,235,250
Airfare for Expatriate and Family							
	$1,500		150 RT				**$225,000**
Office Equipment							
Computers	$2,500		14 each				**$35,000**
Copiers, printers, video, etc.	$20,000		1 LS				**$20,000**
Supplies	$1,000		45 mth				**$45,000**
Telephone (satellite, other)	$1,500		45 mth				**$67,500**
Vehicles							
Compact Pickup	$415		5 each		48 mth		**$99,600**
3/4 ton pickup	$615		3 each		48 mth		**$88,560**
							$4,815,910

Local Labor Hourly Rates

Description	Rate ($/hr)	Stanby Rate	Comments
Crew Leader	$ 10.00		Estimate
Equipment Operator	$ 8.00		Estimate
Truck Driver	$ 6.30		Estimate
Skilled Labor	$ 6.70		Guidance from the COE for Estimates in Panama: $3.50/hr (Apr 98) escalated at 2%p.a. plus 50% for social cost and adjusted for overtime (60-hr work week)
Unskilled Labor	$ 5.60		Guidance from the COE for Estimates in Panama: $2.90/hr (Apr 98) escalated at 2%p.a. plus 50% for social cost and adjusted for overtime (60-hr work week)

Equipment Hourly Rates

Equipment Description	Ownership Cost		Operating Cost			Repair Cost		Total
	Depr.	FCCM	Fuel	FOG	Tire	Tire	General	Hourly
Compressor 375cfm	$ 3.25	$ 0.91	$ 5.88	$ 1.45	$ 0.16	$ 0.02	$ 2.59	$ 14.26
Batching Plant 45 cm/hr	$ 9.53	$ 2.34	$ 18.74	$ 9.34	$ 1.94	$ 0.24	$ 10.76	$ 52.89
Cement Silo & loading	$ 2.55	$ 0.57	$ 1.89	$ 1.83	$ -	$ -	$ 2.81	$ 9.64
Pugmill, 10cm feederhopper, twin shaft, etc	$ 21.88	$ 4.99	$ 9.15	$ 3.62	$ 0.44	$ 0.05	$ 24.32	$ 64.45
Concrete Pump	$ 5.77	$ 1.09	$ 3.78	$ 0.93	$ 0.03	$ -	$ 5.62	$ 17.21
15-ton Yard Crane	$ 7.08	$ 2.47	$ 5.61	$ 1.48	$ 0.54	$ 0.07	$ 5.83	$ 23.08
50-ton Crane (Crawler)	$ 20.21	$ 9.61	$ 4.04	$ 0.71	$ -	$ -	$ 16.49	$ 51.06
80-ton Crane (Crawler)	$ 31.33	$ 13.33	$ 9.64	$ 2.88	$ -	$ -	$ 28.98	$ 86.16
Tower Crane	$ 19.81	$ 7.69	$ 5.20	$ 5.33	$ -	$ -	$ 17.69	$ 55.72
Drill Rig with Compressor	$ 8.56	$ 3.54	$ 13.96	$ 3.44	$ -	$ -	$ 10.06	$ 39.55
Generator 275kW	$ 3.51	$ 0.80	$ 17.50	$ 3.69	$ -	$ -	$ 2.34	$ 27.85
Generator 455kW	$ 6.32	$ 1.45	$ 29.69	$ 6.27	$ -	$ -	$ 4.22	$ 47.96
Hydraulic Excavator 6cy bucket CAT 375-L	$ 27.11	$ 18.77	$ 18.49	$ 3.91	$ -	$ -	$ 37.78	$ 106.06
Front End Loader CAT 953 Crawler - 1.7cm	$ 16.68	$ 3.77	$ 5.70	$ 1.91	$ -	$ -	$ 25.12	$ 53.18
Front End Loader CAT 939-C Crawler - 1.15cm	$ 10.77	$ 2.43	$ 4.24	$ 1.42	$ -	$ -	$ 16.22	$ 35.08
Front End Loader CAT 980-G Wheel - 4.6cm	$ 24.92	$ 8.44	$ 12.96	$ 3.42	$ 7.84	$ 0.97	$ 19.38	$ 77.93
Front End Loader CAT 990-SeriesII Wheel - 9.2cm	$ 60.17	$ 20.65	$ 27.01	$ 7.13	$ 9.88	$ 1.23	$ 46.90	$ 172.96
Roller, Double-drum, self Propelled	$ 13.44	$ 3.03	$ 6.81	$ 1.92	$ -	$ -	$ 15.96	$ 41.16
Staking Conveyor	$ 2.46	$ 0.58	$ 0.62	$ 0.24	$ 0.20	$ 0.02	$ 1.68	$ 5.81
Conveyor	$ 3.60	$ 0.86	$ 1.66	$ 0.66	$ 0.38	$ 0.05	$ 2.47	$ 9.68
Crushing Plant (Secondary)	$ 12.28	$ 6.63	$ 13.09	$ 5.19	$ 0.62	$ 0.08	$ 14.38	$ 52.27
Screening Plant	$ 11.89	$ 2.76	$ 3.33	$ 1.32	$ 0.41	$ 0.05	$ 9.29	$ 29.04
Crushing Plant (Primary)	$ 10.26	$ 5.49	$ 7.77	$ 1.92	$ 0.57	$ 0.07	$ 6.44	$ 32.52
Dozer/Ripper D8	$ 14.79	$ 8.60	$ 14.37	$ 3.54	$ -	$ -	$ 17.59	$ 58.89
Dozer/Ripper D6	$ 11.70	$ 4.65	$ 7.77	$ 2.47	$ -	$ -	$ 17.90	$ 44.50
Water Truck	$ 9.25	$ 2.91	$ 13.33	$ 3.28	$ 1.08	$ 0.13	$ 6.47	$ 36.44
Flatbed Trailer, 48 ft long	$ 1.41	$ 0.37	$ -	$ -	$ 0.53	$ 0.06	$ 0.70	$ 3.07
Bottom Dum Truck	$ 19.20	$ 5.47	$ 12.11	$ 3.39	$ 7.60	$ 0.94	$ 13.31	$ 62.03
Lowboy 50 ton	$ 4.52	$ 0.51	$ 1.65	$ 0.09	$ 0.49	$ 0.06	$ 1.00	$ 8.32
3/4 Ton Pickup F250 4X4	$ 1.76	$ 0.42	$ 2.96	$ 0.73	$ 0.39	$ 0.05	$ 1.33	$ 7.63
Transit Mixer	$ 4.81	$ 1.15	$ 5.96	$ 1.87	$ 0.36	$ 0.04	$ 3.44	$ 17.62
Tractor trailer	$ 6.70	$ 2.30	$ 14.13	$ 3.48	$ 1.94	$ 0.24	$ 4.71	$ 33.51
Truck, off-highway; rear dump 58 ton	$ 19.77	$ 14.56	$ 15.32	$ 4.58	$ 11.73	$ 1.46	$ 12.42	$ 79.84
Truck, off-highway; rear dump 25 ton	$ 8.68	$ 6.32	$ 6.13	$ 1.83	$ 6.58	$ 0.82	$ 5.44	$ 35.80
Compressor & Vibrators	$ 4.67	$ 3.40	$ 3.30	$ 0.98	$ 3.53	$ 0.44	$ 2.91	$ 19.23

Commun Equipment

Equipment Description	Hourly Operating Rate	Standby Hourly Rate
50 ton Crawler Mounted Crane	$51.06	$19.43
Forklift truck	$25.60	$6.96
50 ton Lowboy	$8.32	$2.96
Flatbed trailer	$3.07	$1.06
Fuel Bowser	$6.79	$2.36
Tractor trailer	$33.51	$5.57
Utility Trialer	$1.15	$0.42
75 mm submersible pump	$1.09	$0.27
100 mm diaphragm pump	$2.00	$0.50
150 mm submersible pump	$8.04	$1.23
3/4 Pickup Truck	$7.63	$1.28
Welding set	$5.61	$0.68
	$153.87	$42.72

Assume 70% standby and 30% operating on the basis of 40 hr per week

Cost of Commun Equipment	$13,185	48 mth		**$632,863**
Operating Crew				
Crew Leader	$10.00	1	$10.00	
Drivers	$6.30	3	$18.90	
Mechanics	$6.70	3	$20.10	
Electrician	$6.70	1	$6.70	
Welder	$8.00	1	$8.00	
Equipment Operator	$8.00	1	$8.00	
			$71.70	
Assume 40 hr per week				
Cost of Operating Crew	$12,428	48 mth		**$596,544**
			Total	**$1,229,407**

Other Cost

Mobilization of Equipment

40-ft container from US port including Shipping, US port handling, Panama Port Handling			**$10,000**	
Trucking Container to construction Site				
Loading	4 hr			
Travel 65 km to site	2 hr			
Unload	4 hr			
Return	2 hr			
Transportation Cost	$ 27.94	14 hr	**$391.16**	
Loading/Unloading	$ 70.25	8 hr	**$562.00**	
	Estimated cost per container		**$11,000**	
Assume same cost for demobilization				
Estimated Numbert of containers	70		**$1,540,000**	

Power

Generators 275kW	$40,000	3 each	$120,000	*(one standby)*
Generators 545 kW	$86,000	1 each	$86,000	
Housing	$8,000	4 each	$32,000	
Transmission	$16,500	7 km	$115,500	
Operating Cost at $0.08/kWh	$0.08	19,184,400 kWh	$1,534,752	(50% load)
			$1,888,252	

Common Excavation

Description	Hourly Rates Labor	Hourly Rates Equip.	Quantity	Amount
Dozer/Ripper D8	$ 8.00	$ 58.89	1	$ 66.89
Hyd Excavator 4.6 cm bucket	$ 8.00	$ 106.06	1	$ 114.06
Dozer D6	$ 8.00	$ 44.50	1	$ 52.50
Loader 9.2 cm bucket	$ 8.00	$ 172.96	1	$ 180.96
58-ton Rear Dump Truck	$ 6.30	$ 79.84	4	$ 344.56
Crew Leader	$ 10.00		1	$ 10.00
Unskilled Labor	$ 5.60		4	$ 22.40
			Total	$ 791.36
Production Rate	280 cm/hr		Rate	$ 2.83
			Indirect Cost 30%	$ 0.85
			Total Rate	$ 3.67

Structural Rock Excavation

Description	Hourly Rates Labor	Equip.	Quantity	Amount
Dozer/Ripper D6	$ 8.00	$ 44.50	1	$ 52.50
Drill Rig	$ 8.00	$ 39.55	1	$ 47.55
Compressor & 4 hand drills	$ 22.40	$ 17.78	2	$ 80.36
Loader 1.7 cm bucket	$ 8.00	$ 53.18	1	$ 61.18
25-ton Rear Dump Truck	$ 6.30	$ 35.80	2	$ 84.20
Crew Leader	$ 10.00		1	$ 10.00
Unskilled Labor	$ 5.60		4	$ 22.40
			Subtotal	$ 358.19

Production Rate	40 cm/hr	Rate	$ 8.95
Explosives	1.00 kg/cm @	$ 1.50	$ 1.50
Misc consummable (10%)			$ 0.90
		Subtotal	$ 11.35
		Indirect Cost 30%	$ 3.41
		Total Rate	$ 14.76

Bulk Rock Excavation

Description	Hourly Rates Labor	Equip.	Quantity	Amount
Dozer/Ripper D8	$ 8.00	$ 58.89	1	$ 66.89
Drill Rig	$ 8.00	$ 39.55	2	$ 95.11
Compressor & 4 hand drills	$ 22.40	$ 17.78	2	$ 80.36
Loader 4.6 cm bucket	$ 8.00	$ 77.93	1	$ 85.93
25-ton Rear Dump Truck	$ 6.30	$ 35.80	4	$ 168.40
Crew Leader	$ 10.00		1	$ 10.00
Unskilled Labor	$ 5.60		4	$ 22.40
			Subtotal	$ 529.09

Production Rate	95 cm/hr	Rate	$ 5.57
Explosives	0.65 kg/cm @	$ 1.50	$ 0.98
Misc consummable (10%)			$ 0.56
		Subtotal	$ 7.10
		Indirect Cost 30%	$ 2.13
		Total Rate	$ 9.23

Operate Quarry

Description	Hourly Rates Labor	Equip.	Quantity	Amount
Dozer/Ripper D6	$ 8.00	$ 44.50	1	$ 52.50
Drill Rig incl. Compressor	$ 8.00	$ 39.55	2	$ 95.11
Compressor & 4 hand drills	$ 22.40	$ 17.78	2	$ 80.36
Crushing and Screening Plant	$ 8.00	$ 61.45	1	$ 69.45
Secondary Crushing Plant		$ 52.27	1	$ 52.27
Conveyor		$ 5.81	2	$ 11.62
Front End Loader CAT 939-C Crawler - 1.15cm	$ 8.00	$ 35.08	1	$ 43.08
25-ton Rear Dump Truck	$ 6.30	$ 35.80	2	$ 84.20
Crew Leader	$ 10.00		1	$ 10.00
Unskilled Labor	$ 5.60		10	$ 56.00
			Subtotal	$ 554.59

Production Rate	80 cm/hr	Rate	$ 6.93
Explosives	0.80 kg/cm @	$ 1.50	$ 1.20
Misc consummable (10%)			$ 0.69
		Subtotal	$ 8.83
		Indirect Cost 30%	$ 2.65
		Total Rate	$ 11.47

Concrete Mix & Transport

Description	Hourly Rates Labor	Hourly Rates Equip.	Quantity	Amount
Batching Plant 75 cm/hr	$ 8.00	$ 52.89	1	$ 60.89
Cement Silo & loading		$ 9.65	1	$ 9.65
Standby Generator		$ 5.00	1	$ 5.00
Transit Mixer	$ 6.30	$ 17.62	8	$ 191.36
Dumper 2cm		$ 5.00	4	$ 20.00
Water Storage & Cooling Plant	$ 8.00	$ 47.00	1	$ 55.00
25-ton Rear Dump Truck	$ 6.30	$ 35.80	2	$ 84.20
Expatriate	$ 60.00		1	$ 60.00
Crew Leader	$ 10.00		3	$ 30.00
Unskilled Labor	$ 5.60		10	$ 56.00
			Subtotal	$ 572.10

Production Rate	40 cm/hr	Rate	$ 14.30
Cement	0.36 T/cm @	$ 122.00	$ 43.92
Additive	0.5 gal/cm	$ 15.00	$ 7.50
Aggregates	1 cm/cm @	$ 8.83	$ 8.83
		Subtotal	$ 74.55
		Indirect Cost 30%	$ 22.36
		Total Rate	$ 96.91

Concrete Placement

Description	Hourly Rates Labor	Equip.	Quantity	Amount
50-ton Crane	$ 8.00	$ 51.06	1	$ 59.06
80-ton Crane	$ 8.00	$ 86.16	1	$ 94.16
Tower Crane	$ 8.00	$ 55.72	1	$ 63.72
Concrete Pump	$ 8.00	$ 17.21	2	$ 50.43
Compressor & Vibrators	$ 6.30	$ 19.25	2	$ 88.90
Expatriate	$ 60.00		1	$ 60.00
Crew Leader	$ 10.00		3	$ 30.00
Unskilled Labor	$ 5.60		10	$ 56.00
Miscellaneous			15%	$ 75.34
			Subtotal	$ 577.62
Production Rate	40 cm/hr		Rate	$ 14.44
Concrete				$ 74.55
			Subtotal	$ 88.99
			Indirect Cost 30%	$ 26.70
			Total Rate	$ 115.69

Steel Reinforcement

Description	Hourly Rates Labor	Hourly Rates Equip.	Quantity	Amount
Unload, Sort and Pile				
Crew Leader	$ 10.00		1	$ 10.00
15-ton Yard Crane	$ 8.00	$ 23.08	1	$ 31.08
Unskilled Labor	$ 5.60		4	$ 22.40
			Subtotal	$ 63.48
Production Rate	9 T/hr		Rate	$ 7.05
Cut, Bend and Place				
Crew Leader	$ 10.00		1	$ 10.00
15-ton Yard Crane	$ 8.00	$ 23.08	1	$ 31.08
Unskilled Labor	$ 6.70		30	$ 201.00
			Subtotal	$ 242.08
Production Rate	1 T/hr		Rate	$ 242.08
Reinforcement Steel	1 T/T @		$ 725.00	$ 725.00
Miscellaneous			5%	$ 36.25
			Subtotal	$ 1,010.38
			Indirect Cost 30%	$ 303.12
			Subtotal	$ 1,313.50

Formwork

Description	Hourly Rates Labor	Equip.	Quantity	Amount
Fabrication				
Crew Leader	$ 10.00		1	$ 10.00
Skilled Labor	$ 6.70		3	$ 20.10
Unskilled Labor	$ 5.60		2	$ 11.20
			Subtotal	$ 41.30
Material				
Production Rate	2	sm/hr	Rate	$ 20.15
Wood & Plywood	1.15	sm/sm @	$ 20.50	$ 23.58
Miscellaneous			10%	$ 2.36
			Subtotal	$ 46.08
Reuse	5			$ 9.22
Cleanup & Erection				
Crew Leader	$ 10.00		1	$ 10.00
Unskilled Labor	$ 5.60		3	$ 16.80
			Subtotal	$ 26.80
			Indirect Cost 30%	$ 10.80
			Total Rate	$ 46.82

RCC

Description	Hourly Rates Labor	Hourly Rates Equip.	Quantity	Amount	Labor
Pugmill	$ 8.00	$ 64.45	2	$ 144.91	$ 16.00
Conveyors		$ 31.80	10	$ 318.00	$ -
Cement Silo & loading		$ 9.50	5	$ 47.50	$ -
Bottom Dump Truck	$ 6.30	$ 62.03	6	$ 409.96	$ 37.80
Dozer D8	$ 8.00	$ 58.89	8	$ 535.12	$ 64.00
Roller, Double-drum, self Propelled	$ 8.00	$ 41.16	8	$ 393.27	$ 64.00
Loader 1.7 cm bucket	$ 8.00	$ 53.18	5	$ 305.88	$ 40.00
Transit Mixer	$ 6.30	$ 17.62	4	$ 95.68	$ 25.20
Water Storage & Cooling Plant	$ 8.00	$ 54.70	2	$ 125.40	$ 16.00
Loader 9.2 cm bucket	$ 8.00	$ 172.96	2	$ 361.91	$ 24.80
25-ton Rear Dump Truck	$ 6.30	$ 35.80	6	$ 252.59	$ 60.00
Mobile lighting Set 4 x 1000 W		$ 6.00	8	$ 48.00	
Water Truck	$ 6.20	$ 36.44	4	$ 170.55	$ 40.00
Expatriate	$ 60.00		1	$ 60.00	$ 112.00
Crew Leader	$ 10.00		4	$ 40.00	$ 74.97
Unskilled Labor	$ 5.60		20	$ 112.00	$ 574.77
Miscellaneous			15%	$ 513.12	
			Subtotal	$ 3,933.89	

Production Rate	265 cm/hr	Rate	$ 14.84	
Cement	0.08 T/cm @	$ 122.00	$ 9.76	
Fly Ash/Pozzolan	0.05 T/cm @	$ 25.00	$ 1.25	
Miscellaneous		10%	$ 0.98	
Aggregates	1 cm/cm @	$ 8.83	$ 8.83	
		Subtotal	$ 35.66	
		Indirect Cost 30%	$ 10.70	
		Total Rate	$ 46.35	
			Say $46.50	

Power Tunnel

PANAMA CANAL UPPER CHAGRES HYDROELECTRIC SCHEME
Panama
Feasibility Level Cost for Tunneling

Feature:	**Power Tunnel**
Length	**200 meters (Outlet portal to Shaft)**
Diameter	**4.20 meters (Circular Section)**
Method	Basic Drill/Blast

SUMMARY

The following summary is prepared from the detailed analysis that follows

	Total
Total Tunnel Excavation Price	**$888,000**
Total Tunnel Concrete Lining Price	**$249,000**
Total at January 2003 Level	**$1,137,000**

	Analysis				Totals
Method of Excavation	Drill and Blast Method				
Type of Support Requirements	Type I	Type II	Type III	Type IV	
Finished Diameter (m)	4.20	4.20	4.20	4.20	
Finished Area (sq.m.)	13.85	13.85	13.85	13.85	
Excavated tunnel diameter	4.90	4.90	4.90	4.90	
Tunnel Length (m)	10	100	60	30	200
Excavation Volume (Pay cu.m/m)	18.9	18.9	18.9	18.9	
Excavation Volume (Pay cu.m)	190	1,890	1,130	570	3,780
Concrete Lining Thickness (m)	0.35	0.35	0.35	0.35	
Overbreak assumed (m)	0.10	0.10	0.15	0.15	
Shotcrete Lining Thickness (m)	0.00	0.05	0.05	0.05	
Shotcrete Area (sq.m)	0	770	920	460	2,150
Excavated Volume (Actual cu.m/m)	21.2	21.2	21.2	21.2	
Excavated Volume (Actual cu.m)	210	2,120	1,270	640	4,240
Loose Volume Mucking (cu.m)	336	3,392	2,032	1,024	6,784
Concrete Lining Volume (cu.m)	68	688	461	231	1,448
2-meter long (#8) Rockbolts	0	250	280	30	560
Steel Sets (kg)				30,100	30,100
Excavation Production (days)	3	29	19	15	66
Labor Cost - Excavation, Local	9,400	90,500	59,300	46,800	206,000
Equipment Cost, Local	12,500	120,000	78,700	62,100	273,300
Material Cost, Local	3,900	57,100	46,200	96,500	203,700
Tunnel Excavation Cost	**25,800**	**267,600**	**184,200**	**205,400**	**683,000**
Concrete Lining Cost, Total	**9,600**	**95,700**	**57,400**	**28,700**	**191,400**
Contractors OH&P	30%	30%	30%	30%	
Tunnel Excavation Price	**$33,500**	**$347,900**	**$239,500**	**$267,000**	**$887,900**
Tunnel Lining Price	**$12,500**	**$124,400**	**$74,600**	**$37,300**	**$248,800**
Tunnel Price	**$48,100**	**$469,500**	**$312,600**	**$305,700**	**$1,136,700**

Excavation Unit Price

	Excavation	Shotcrete Lining	Rockbolts	Steel Sets	Misc.
Labor Cost	**$115,150**	**$13,480**	**$12,650**	**$27,256**	**$37,765**
Equipment Cost	**$89,840**	**$16,500**	**$1,190**	**$6,388**	**$159,338**
Material Cost	**$72,525**	**$21,285**	**$25,200**	**$60,200**	**$24,285**
Subtotal	**$277,515**	**$51,265**	**$39,040**	**$93,844**	**$221,388**
Miscellaneous	**$133,081**	**$24,584**	**$18,721**	**$45,002**	
	$410,596	**$75,849**	**$57,761**	**$138,847**	**$683,052**
Contractors OH&P	**$123,179**	**$22,755**	**$17,328**	**$41,654**	**$204,916**
	$533,774	**$98,603**	**$75,089**	**$180,501**	**$887,968**
Quantities	**4,240**	**2,150**	**1,120**	**30,100**	
Unit Price	**$125.89**	**$45.86**	**$67.04**	**$6.00**	
	$/cu.m	**$/sq.m**	**$/l.m**	**$/kg**	

Concrete Lining Unit Price

	Avg. Price
Unit Price ($/cu.m) Concrete Lining	**$171.81**

Power Tunnel

PANAMA CANAL UPPER CHAGRES HYDROELECTRIC SCHEME
Panama
Feasibility Level Cost for Tunneling

Feature:	**Power Tunnel**
Length:	**200 meters (Outlet portal to Shaft)**
Diameter:	**4.20 meters (Circular Section)**
Method:	Basic Drill/Blast

GEOLOGY

Rock type as interpreted from site visits and geol mapping suggests four types of supports for the following lengths

Tunneling Condition	Segment 1
Roca Buena - Designation Type I	5%
Roca Regular - Designation Type II	50%
Roca Mala - Designation Type III	30%
Roca Muy Mala - Designation Type IV	15%
	100%

Type I - Roca Buena best rock conditions, minimal overbreak, generally self-supporting or requiring minimal support with shotcre and spot bolting; full face excavation with normal advance

Type II - Roca Regular, good to fair rock conditions, moderate overbreak with rockbolt support and shotcrete; normal advance possible with proper bolting and shotcreting

Type III - Roca Mala, poor rock conditions, weathered or weak rock, loosely jointed, possible water inflows; Full face excavation with slower short advance and large overbreaks. Requires prompt support with pattern rockbolting and shot

Type IV - Roca Muy Mala/Pesima, very poor rock conditions, full of fault and shear zones, mod to highly weathered, potential sq in gouge; water inflows; possibly top heading and benching; prompt support within the open face with steel ribs and lagging, bac shotcete with fabric; grouting may be necessary to control water; spiling possible in worst conditions.

Type V - Not mentioned above but worse than type IV and with high waterflows. Specific areas are not identified for above tunnels at this time

Condition/Rock Type	Q Values	Rock Mass Rating (RMR)
I	> 7	>60
II	7 > Q >1	60>RMR>40
III	1 > Q >.4	40>RMR>35
IV	.4> Q	35 > RMR

Blastability	Good	Medium
SPR =	0.38	0.47
	Basalt/Sandstones	

Power Tunnel

PANAMA CANAL UPPER CHAGRES HYDROELECTRIC SCHEME
Panama
Feasibility Level Cost for Tunneling

Feature:	**Power Tunnel**	
Length	**200**	**meters (Outlet portal to Shaft)**
Diameter	**4.20**	**meters (Circular Section)**
Method		Basic Drill/Blast

SUPPORT

Shotcrete Thickness	5	cm Layers	Fiber or wire reinf
Rockbolts	25	mm X 2 meter long w/epoxy	
Steel Ribs	6" X 12"	I section @ .5 to 1.5 spacing	
Lagging	5	cm corrugated	
Dry Pack	0.5	in. from Tunnel Muck	

All tunnel analysis is based on geological interpretation presented on the Geology Studies

Length of Segment	200	Meters
Finished Diameter	4.20	Meters
Concrete Lining Thickness	0.35	Meters
Length of tunnel for each type		
Type I	10	Meters
Type II	100	Meters
Type III	60	Meters
Type IV	30	Meters

Shotcrete with wire(or fibrous), 5 cm layer	0	SqM, Type I	None
	770	SqM, Type II	Crown only
	920	SqM, Type III	Crown and Ribs
	460	SqM, Type IV	Crown and Ribs
Total Shotcrete	2,150	SqM	

Rockbolts, 25 mm X 2 M Long	0	EA, Type I	3	Bolts/@ 7.5 M Spacing
	250	EA, Type II	5	Bolts/@ 2 M Spacing
	280	EA, Type III	7	Bolts/@ 1.5 M Spacing
	30	EA, Type IV	5	Bolts/@ 5 M Spacing
Total Rockbolts	560	EA		
Steel ribs, 6" X 12" X 45 KG/M	30,100	KG, Type IV		

Power Tunnel

PANAMA CANAL UPPER CHAGRES HYDROELECTRIC SCHEME
Panama
Feasibility Level Cost for Tunneling
Feature: Power Tunnel
Length: 200 meters (Outlet portal to Shaft)
Diameter: 4.20 meters (Circular Section)
Method: Basic Drill/Blast

TUNNEL EXCAVATION

	Tunnel Crew	Local $$/HR Production	Local $$/HR Production
1	Walker	$12.50	$12.50
1	Foreman	$10.00	$10.00
	Jumbo Drill Foreman	$10.00	$0.00
8	Miners	$6.70	$53.60
1	Blaster	$6.70	$6.70
1	Compressor Operator	$6.30	$6.30
1	Mucker Operator	$8.00	$8.00
2	Truck Drivers	$6.30	$12.60
	Dozer Operator	$8.00	$0.00
1	HVAC Electrician/Mechanics	$6.70	$3.35
1	Oilers	$6.30	$3.15
2	Rockbolters	$6.70	$13.40
2	Shotcreters	$6.70	$13.40
1	Pump Operators	$6.30	$6.30
1	Mechanics	$6.70	$3.35
1	Electricians	$6.70	$3.35
22	Total Crew, $$/Hr		$156.00

ROUNDS	Type I	Type II	Type III	Type IV
Meters/Round	3.0	2.5	2.0	1.0
Vol/Round	56.6	47.1	37.7	18.9
Holes/SqM	2.5	2.5	2.2	2.0
No. of Holes	78	78	73	69
Length of Holes (total, cum.)	234	195	146	69
Drill Holes, Meters/Hr	10	10	10	10
No. of drills	4	4	4	4
Total Drilling/Hr	40	40	40	40
Drilling Time	5.9	4.9	3.7	1.8
Move in	0.3	0.3	0.3	0.3
Total drilling Time	6.2	5.2	4.0	2.1
Blasting				
Kg/CuM	2.0	1.8	1.7	1.5
Kg/Round	113	85	64	28
Load Time @ 80 Kg/Hr	1.5	1.1	0.9	0.4
Add for blasting & Ventilating	1.0	1.0	1.0	1.0
Total Blast time	2.5	2.1	1.9	1.4
Excavation Supports				
Scaling	0.3	0.3	0.3	0.5
Place supports	0.2	1.0	1.5	3.0
Total Support Time	0.5	1.3	1.8	3.5
Muck				
Move in	0.5	0.5	0.5	0.5
Mucking at 10 CM/hr	5.7	4.8	3.8	1.9
Total Muck Cycle	6.2	5.3	4.3	2.4
Total Cycle Hours	15.4	13.9	12.0	9.4
No of Rds with of 2 X 10 Hr Shifts	1.3	1.4	1.7	2.1
Advance/Day	3.8	3.5	3.3	2.1
Total number of Days for one Crew	3	29	19	15
Total explosives required	400	3,400	2,000	900
Detonators	140	1,530	1,500	720
Drill Bits & Steel	800	7,800	4,400	2,100

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Power Tunnel

PANAMA CANAL UPPER CHAGRES HYDROELECTRIC SCHEME
Panama
Feasibility Level Cost for Tunneling
Feature: Power Tunnel
Length: 200 meters (Outlet portal to Shaft)
Diameter: 4.20 meters (Circular Section)
Method: Basic Drill/Blast

Plant & Equipment	Unit Operating	Standby Cost	
1 4 Drill Jumbo	$56.50	$14.13	$43.79
1 4 CuM Mucker	$31.25	$7.81	$24.22
2 Trucks, 5 CuM	$24.46	$6.12	$37.91
1 Shotcrete Pump	$23.56	$5.89	$18.26
1 Dozer	$44.50	$11.13	$34.49
2 Compressors, Electrical	$14.26	$3.57	$22.10
1 Dewatering Equipment	$7.53	$1.88	$5.84
2 100 HP Fans	$6.04	$1.51	$9.36
1 Drifters	$0.75	$0.19	$0.58
1 Flatbeds	$13.35	$3.34	$10.35
Equipment Cost per hour	$222.20	$55.55	$206.89
Utilization Factor	70%		
Actual Cost/Hr	$206.89		

	Type I	Type II	Type III	Type IV
Equipment & Plant, Local	$12,414	$119,999	$78,620	$62,068

Materials		
Explosives	$1.50	$$/KG
Detonators	$2.50	$$/EA
Bits & Steel	$2.50	$$/LM
Spiling	$150.00	$$/EA
Shotcrete Cement	$122.00	$$/TON
Shotcrete Aggregate	$4.00	$$/TON
Steel Fibers	$1.20	$$/KG
Wiremesh	$1.00	$$/KG
Timber	$0.35	$$/BF
Rockbolts	$45.00	$$/EA
Steel Sets	$2.00	$$/KG
Vent air line	$40.00	$$/LM
Utility lines	$30.00	$$/LM
ST&S	5.00%	

	Type I	Type II	Type III	Type IV	Total
Explosives	$600	$5,100	$3,000	$1,350	$10,050
Detonators	$350	$3,825	$3,750	$1,800	$9,725
Bits & Steel	$2,000	$19,500	$11,000	$5,250	$37,750
Spiling	$0	$0	$0	$15,000	$15,000
Shotcrete Cement	$0	$2,818	$3,367	$1,684	$7,869
Shotcrete Aggregate	$0	$508	$607	$304	$1,419
Steel Fibers	$0	$2,495	$2,981	$1,490	$6,966
Wiremesh	$0	$1,848	$2,208	$1,104	$5,160
Timber	$0	$0	$333	$263	$595
Rockbolts	$0	$11,250	$12,600	$1,350	$25,200
Steel Sets	$0	$0	$0	$60,200	$60,200
Vent air line	$400	$4,000	$2,400	$1,200	$8,000
Utility lines	$300	$3,000	$1,800	$900	$6,000
ST&S	$183	$2,715	$2,200	$4,593	$9,690
Total Materials for tunnel work	$3,833	$57,061	$46,248	$96,489	$203,631

Power Tunnel

PANAMA CANAL UPPER CHAGRES HYDROELECTRIC SCHEME
Panama
Feasibility Level Cost for Tunneling

Feature:	Power Tunnel
Length:	200 meters (Outlet portal to Shaft)
Diameter:	4.20 meters (Circular Section)
Method:	Basic Drill/Blast

TUNNEL CONCRETE LINING					Total
Length	10	100	60	30	200
Quantity	74	738	443	221	1,477
Use Prefabricated Steel Forms on Dolly Each set 20 M Long and a 24 hour concrete placing will be used with 8 hours for placing forms and reinforcing (if any), 8 hours of concrete placing and 8 hours to cure, clean and move					
Average placing Rate (cu. M / day)	50	50	50	50	
No. of Steel Sets	0	0	0	0	0
Number of 10 hour work days	2	15	9	5	31

Concrete Lining Crew

		Local	Local Total	
1	Walker	$12.50	$12.50	0
1	Foreman	$10.00	$10.00	
0	Form Foreman	$10.00	$0.00	
8	Miners	$6.70	$53.60	
2	Carpenters	$6.70	$13.40	
1	Compressor Operator	$6.30	$6.30	
1	Mucker Operator	$8.00	$8.00	
2	Flat Bed Operators	$6.30	$12.60	
1	HVAC Electrician/Mechanics	$6.70	$6.70	
1	Pump Operators	$6.30	$6.30	
1	Mechanics	$6.70	$6.70	
1	Electricians	$6.70	$6.70	
20	Total Crew, $$/Hr		$142.80	
			$44,268	
	Total Labor Cost, foreign		0	

	Plant & Equipment	Unit Oper	Unit Standby	Average
1	Johnson Type Low Profile + Ice Plant	$52.00	$13.00	$42.25
2	Concrete Haulers	$17.62	$4.41	$28.63
2	Lot Pumping Equipment	$17.21	$4.30	$27.97
1	Lot fans	$5.25	$1.31	$4.27
				$103.11
	Utility Factor	75.00%		
	Actual Cost/Hr	$103.11		
	Equipment Cost/Day	$2,062.29		

MATERIALS					
Cement	443	Tons @	$122.00	54,046	
Aggregate & Sand	3,248	Tons @	$4.00	12,994	
Admixtures	738	Gals @	$15.00	11,074	
Timber for Bulkheads	200	SqM @	$25.00	5,003	16,077
				83,117	

Concrete Costs by Sections	Type I	Type II	Type III	Type IV	
Labor Cost - Concrete, Local	2,215	22,150	13,290	6,645	44,300
Equipment Cost, Local	3,197	31,963	19,177	9,589	63,926
Material Cost, Local	4,156	41,559	24,936	12,468	83,119
TOTAL CONCRETE COST	$9,568	$95,672	$57,403	$28,702	$191,345
Tunnel concrete Lining Cost	$9,568	$95,672	$57,403	$28,702	$191,345

UNAUTHORIZED USE OR DUPLICATION IS PROHIBITED
PROHIBIDA LA REPRODUCCION SIN AUTORIZACION DEL AUTOR

CENTRO DE RECURSOS TECNICOS
AUTORIDAD DEL CANAL DE PANAMA