Technical Analysis to Deepen Gatun Lake and Gaillard Cut to Design Channel Bottom of 27.5’ PLD

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TECHNICAL ANALYSIS
GATUN LAKE AND GAILLARD CUT DEEPENING TO DESIGN CHANNEL BOTTOM 27.5' PLD

GENERAL DESCRIPTION OF THE STUDY

The study consists of deepening the Panama Canal navigation channel through Gatun Lake and Gaillard Cut, and is a major component of the Panama Canal Expansion Study, an investigation into the possibility of accommodating ships with deeper and wider beam than the current Panamax size through the Panama Canal. The deepening study investigates the following activities:

a. Initial dredging: From 37' PLD to 34' PLD
b. Drilling & blasting: From 34' to 19.5' PLD
c. Final dredging: From 34' to 27.5' PLD

The Gantt chart in Appendix No. 1 shows the sequence of these activities.

The initial dredging to 34' PLD and drilling & blasting to 19.5' PLD will be executed almost simultaneously, with the drilling & blasting lagging behind the initial dredging by a couple of months. The approved and ongoing project to deepen the navigation channel through Gatun Lake and Gaillard Cut to 34' PLD already covers the initial dredging to elevation 34' PLD, and drilling and blasting to elevation 19.5' PLD.

The deepening from elevation 37' to 34' PLD is a water project as it augments Gatun Lake water capacity by lowering the lake minimum operation level from elevation 81.5' to 78.5' PLD without affecting Panamax ships maximum transiting draft of 39.5'. After the deepening, 362.8 million cubic meters of additional water would be available, that is, about 5.6 lockages per day. Each lockage represents 55 million gallons of water.

The new design channel bottom of 34' PLD will also serve as an alternative under the Canal expansion program by raising Gatun Lake level minimum operation level to elevation 85' PLD, which will allow the traffic of Post-Panamax and Panamax vessels loaded to 45' draft. Refer to Appendix No. 17 for a draft phase sketch. However, this draft phase alternative will diminish lake water availability. Therefore, further deepening of Gatun Lake to elevation 27.5' PLD or other alternatives such as the creation of new water reservoirs represent options to increase water availability.

Although it is only required to drill and blast to elevation 26' PLD for subsequent dredging to a design channel bottom at elevation 34' PLD, it was decided to drill & blast to elevation 19.5' PLD so channel bottom material would be fragmented and ready for future dredging operations. Also, drilling & blasting is usually the

critical path of any dredging operation, and its execution in just one phase comparing to two phases is more effective and efficient in terms of cost, production, and less interruption for existing Canal traffic.

During the initial dredging, dredges will be the forward team to dredge all the previously drilled and blasted material to a design bottom of 34' PLD. Then drilling and blasting will follow to fragment the high hard points, that dredges were not be able to remove, to elevation 19.5' PLD. After fragmentation, the dredges will proceed to remove the material and obtain a design channel bottom of 34' PLD. Finally, if Canal Expansion Program becomes effective, the dredges could begin dredging to a design bottom of 27.5' PLD.

DREDGING VOLUMES

DREDGING PARAMETERS

a. The following parameters were used to estimate the **initial dredging** volumes to 34' PLD:

   - Dredging: From 37' to 34' PLD
   - Dredging tolerance: From 34' to 32' PLD
   - In Gaillard Cut, dredging volume was estimated within the navigation channel prism lines.
   - In Gatun Lake, the dredging volume includes an over-swing of about 25' outside the navigational channel prism lines, according to a meeting held with ACP dredges masters-in-charge on November 20, 2002. Refer to a schematic attached in Appendix 2.

b. The following parameters were used to estimate the **final dredging** volumes to 27.5' PLD:

   - Dredging: From 32' to 27.5' PLD
   - Dredging tolerance: From 27.5' to 25.5' PLD
   - A slope of 1H:1V to estimate the volumes for the final dredging was designed by the ACP Geo-technical Branch (EIEG). This slope design only applies to Gaillard Cut.
   - As mentioned, an over-swing of about 25' at each prism line is required in Gatun Lake to accomplish the desired channel bottom. This 25' of dredging over-swing is included in estimates for the dredging volumes to 27.5' PLD channel bottom. Refer to a schematic shown in Appendix No. 3.

DREDGING VOLUME ESTIMATES

a. ACP Geo-technical Branch estimated the dredging volumes by using the civil engineering application software INROADS and the digital bathymetry provided by the ACP Survey Branch, updated on February 2002. Appendix No. 4 shows the estimated volume by reach for design channel bottoms of 34' and 27.5' PLD. Appendix No. 14 shows the bathymetry of Gatun Lake and Gaillard Cut.

b. The dredging volume includes all the material to be removed from elevation 85' PLD and below. In the case of Gaillard Cut, all the material above 85' PLD is considered dry excavation material.

c. Reliable historical records on ACP dredging production exist and are based on volume as opposed to area. Therefore, estimates of the duration and cost of the proposed deepening are based on volume rather than on progress by area.

Design Channel Bottom to 34' PLD

a. The following table shows a summary of dredging volumes for a channel bottom of 34' PLD. For the Gaillard Cut, the dredging volume does not include any slope, since dredging would be performed within navigation channel prism lines, as shown in Appendix No. 2, per ACP Geo-technical Branch recommendation. For Gatun Lake, the dredging volume does contemplate an over-swing of 25' outside of each navigational channel prism line. Refer to Appendixes No. 4 & 5 for dredging volume by reach.

DREDGING VOLUME IN m^3

AREAS	Dredging 37' to 34' PLD	Dredging Tolerance 34' to 32' PLD
Gatun Lake	1,561,743	2,477,712
Gaillard Cut	1,678,754	1,384,385
TOTAL	3,240,497	3,862,097
TOTAL - ACCUMULATIVE	3,240,497	7,102,594

Design Channel Bottom to 27.5' PLD

a. The dredging volume estimated for a channel bottom of 27.5' PLD contemplates a slope of 1H:1V along the Gaillard Cut channel shorelines from elevation 85' to 25.5' PLD. For Gatun Lake, the dredging volume includes an over-swing at each navigational channel prism line of about 25', a tactic that delays the drifting of bottom material into the deepest channel section and accomplishes the desired design channel bottom.

b. The dry excavation volume required in Gaillard Cut to obtain a channel bottom of 27.5' PLD is found under the section of "Dry Excavation" of this report.

c. The proposed deepening to a 27.5' design channel bottom excludes the Pedro Miguel and Paraiso reaches, since access to the Pacific site for the proposed new locks is most likely to begin at Cucaracha Reach in Gaillard Cut and would bypass the aforementioned reaches. In other words, dredging would take place from Gatun Reach to and including Cucaracha Reach. However, in the practice the dredge would make a transition zone from Paraiso to Cucaracha reach, to minimize the effect of sudden depth changes for the transiting ships. Appendix No. 5 shows the volume estimate, which excludes the two aforementioned reaches.

d. The following table shows a summary of dredging volume for a channel bottom of 27.5' PLD:

DREDGING VOLUME IN m^3

AREAS	Dredging 32' to 27.5' PLD	Dredging Tolerance 27.5' to 25.5' PLD
Gatun Lake	8,881,400	4,483,839
Gaillard Cut	4,240,793	1,830,511
TOTAL	13,122,193	6,314,350
TOTAL - ACCUMULATIVE	13,122,193	19,436,543

DREDGING TIMEFRAME ESTIMATE

GENERAL PARAMETERS

a. ACP has two dredges for Canal navigation channel maintenance and capital dredging: the cutter suction dredge MINDI and the dipper dredge RIALTO M. CHRISTENSEN (RMC). Their historical performances, with special emphasis on recent data from the Gaillard Cut Widening Project (widening to 630'), and their masters-in-charge opinions regarding dredge productivity in the Panama Canal were used to estimate the time required to accomplish the new proposed deepening of the Gatun Lake and Gaillard Cut navigational channel.

b. The average time frame to execute a dredging task includes a total of three months of channel maintenance dredging work per year, one month of preventive maintenance each year for each ACP dredge, and six months of dry dock overhaul performed every 5 years for each dredge.

c. Average productivity of ACP dredges includes out-of-service time such as emergency repairs.

d. The ACP dredges' current work schedule is 24 hours per day, 7 days per week, and will continue as required for future dredging work.

e. Appendix No. 11 contains the productivity records of the MINDI and CHRISTENSEN. Following is a summary of both ACP dredges:

ACP DREDGES AVERAGE PRODUCTION

DREDGES	Project	Area	Dates	Bank cubic meter per week
MINDI	Gaillard Cut Widening 630'	Gaillard Cut	Oct. '97 to June '00	**31,801**
RMC	Gaillard Cut Widening 630'	Gaillard Cut	June '94 to Sept. '00	**31,771**
MINDI	Various	Gatun Lake	Mar. '80 to Oct. '84	**32,387**

DREDGES AVAILABLE FOR INITIAL DREDGING TO 34' PLD

a. The ACP cutter suction dredge MINDI and dipper dredge CHRISTENSEN are already executing the deepening of the Gatun Lake and Gaillard Cut navigation channels to 34' PLD.

b. Based on historical records as shown in Appendix No. 11, the MINDI and CHRISTENSEN could each have an individual average productivity of 30,000 m^3 per week in Gaillard Cut and Gatun Lake. However, according to a meeting held with the MINDI and CHRISTENSEN masters-in-charge on November 20, 2002, a figure of 28,000 m^3 per week would be a better deepening productivity rate for estimating the time frame for dredging up to 32' PLD.

c. The MINDI and CHRISTENSEN are dredging the Gatun Lake and Gaillard Cut navigation channel almost simultaneously; that is, one dredge is working in the lake while the other is in the cut, as shown in the Gantt Chart. However the MINDI is projected to complete the Atlantic Entrance widening to 75' east, which could take approximately 6 months. Therefore including this widening program, the duration of dredging to 34' PLD is 4.25 years. As any other project, this dredging program might change to conform to ACP needs.

d. A summary of the time frame required to complete the initial dredging to 34' PLD is as follows:

DREDGING TIME FRAME TO 34' PLD NAVIGATION BOTTOM - INITIAL DREDGING

AREAS	Dredging volume (m^3)	ACP dredges average productivity (m^3/wk)	Productivy years required
Gatun Lake	**4,039,455**	**28,000**	4.25
Gaillard Cut	**3,063,139**	**28,000**	3.00
TOTAL	**7,102,594**		**4.25**

Notes:

1. Productivity years include maintenance dredging, dredge overhaul, preventive maintenance, crew relief, and emergency repairs.

e. For more details, refer to Appendix No. 1 and 5. The Gantt Chart in Appendix No. 1 shows the dredges' overhaul, maintenance dredging period, and preventive maintenance schedules as well as their dredging activity to 32' PLD.

DREDGES FOR PROPOSED FINAL DREDGING TO 27.5'PLD

a. ACP dredges MINDI and CHRISTENSEN, and a new dredge, shall be available to execute the final dredging to 27.5' PLD.

b. As mentioned previously, the MINDI and CHRISTENSEN masters-in-charge have estimated that these ACP dredges can each maintain an average productivity of 28,000 m^3 per week for dredging up to a maximum channel bottom of 25' PLD, under the condition that the lake level is at a maximum 85' PLD.

c. The new dredge is assumed to have a productivity similar to ACP dredges, estimated at 28,000 m^3 per week when dredging to 25.5' PLD. .

d. To estimate the proposed final dredging to 27.5' PLD time frame, the CHRISTENSEN is assigned mainly to dredge the cut, the MINDI and the new dredge to dredge in the lake. As shown in the Gantt Chart, Appendix No. 1, the lake and the cut will be dredged almost simultaneously. The chart shows the dredge overhaul, maintenance dredging, and dredge preventive maintenance period in addition to the dredging activity to 25.5' PLD.

e. The summary of the average time frame required to complete the proposed final dredging to 27.5' PLD is as follows:

DREDGING TIME FRAME TO 27.5' PLD NAVIGATION BOTTOM UNDER 3-DREGE SCENARIO

AREAS	Dredging volume (m^3)	Number of dredges operating	Dredges average productivity (m^3/wk)	Productivy years
Gatun Lake	**13,365,239**	**2**	**28,000**	8.00
Gaillard Cut	**6,071,304**	**1**	**28,000**	8.00
TOTAL	**19,436,543**			**8.00**

Notes:

1. Productivity years include maintenance dredging, dredge overhaul, preventive maintenance, and emergency repairs.
2. Total time was estimated by assuming that a new dredge will start operations in July 2005.
3. RMC will be assigned mostly in Gaillard Cut, and MINDI and new dredge will work mainly in Gatun Lake.
4. Total years to complete dredging to 27.5' is 8 years with 3 dredges working almost simultaneously.

DREDGING COSTS

GENERAL PARAMETERS

a. MINDI and CHRISTENSEN operation costs for fiscal years 1995, 1996, 1997 and 1998 were reviewed and are shown in Appendixes No. 6 and 7. The operation cost includes availability, labor, overhead and auxiliary equipment support costs. The overhead for Dredging Division was estimated to be 12%.

b. The yearly cost indexes for channels and canals, developed and revised on September 30, 2002, by the US Corps of Engineers (USACE), were used to convert the ACP dredges operation average cost of fiscal years 1995, 1996, 1997 and 1998 to 2002 dollars, and are attached in Appendix No. 16. As shown in this appendix, the average inflation rate for fiscal years 1995 through 2002 is 1.023.

c. The dredges' availability, fuel cost, and auxiliary support costs were converted into 2002 dollars using the conversion factor of 1.023. This conversion factor was not applied to ACP dredges' labor costs because labor costs were estimated at the maximum step for each man-category wage effective on January 3, 1999 and have not been increased since then.

d. The dredges' availability costs were averaged, based on 270 days of operation per year, to account for maintenance, overhaul and emergency repairs.

e. The total costs for deepening to 34' PLD and for the proposed deepening to 27.5' PLD do not include the investment required to acquire a new dredge and auxiliary equipment.

ACP DREDGES OPERATION AND UNIT COSTS

a. The following table shows a summary of the MINDI and CHRISTENSEN costs per hour for a maximum discharge pumping distance of 3 km and transportation distance of 20 km, respectively. For more details refer to Appendixes No. 6 and 7.

ACP DREDGES COST IN 2002 DOLLARS

	CHRISTENSEN Transportation distance of 20 km	MINDI Pumping distance 3 km
Availability cost ($ per hour)	306	781
Labor cost ($ per hour)	531	624
Overhead cost ($ per hour)	64	75
Fuel cost ($ per hour)	56	233
Auxiliary equipment cost ($ per hour)	888	439
TOTAL COST ($ per hour)	**1,845**	**2,152**
TOTAL COST ($ per week)	**307,545**	**351,866**

b. For an average productivity of 28,000 m^3 per week, dredging unit costs are as follows:

DREDGING UNIT COST

DREDGE	Cost per hour ($)	Cost per week ($)	Estimated production per week (m^3)	Unit cost ($/$m^3$)
CHRISTENSEN	1,834	305,715	28,000	**10.98**
MINDI	2,153	351,866	28,000	**12.57**

c. It is assumed that the new dredge would have the same operational and consequently, the same unit cost as the MINDI.

d. The above unit costs only reflect the dredges operational costs but not the initial investment for new dredge acquisition.

DREDGING COST FOR 34' PLD CHANNEL BOTTOM

a. Using the aforementioned unit cost, the dredging cost per reach is in Appendix No. 5, and the total cost for 34' PLD channel bottom is as follows:

DREDGING COST TO 34' PLD NAVIGATION BOTTOM

AREAS	Dredging volume (m^3)	ACP dredges unit cost ($/$m^3$)		Total cost ($)
Gatun Lake	4,039,455	12.57	1/	50,775,945
Gaillard Cut	3,063,139	10.98	2/	33,633,266
TOTAL	7,102,594			84,409,211

Note:
1. In Gatun Lake, the dredge average unit cost reflects the dredge MINDI performance.
2. In Gaillard, the dredge unit cost reflects the dredge RMC performance

DREDGING COST FOR 27.5' PLD CHANNEL BOTTOM

a. Using again the above unit cost, the dredging cost per reach is in Appendix No. 5, and the total cost, which does not include the investment of acquiring a new dredge, is as follows:

DREDGING COST TO 27.5' PLD NAVIGATION BOTTOM

AREAS	Dredging volume (m^3)	ACP dredges unit cost ($/$m^3$)	Total cost ($)
Gatun Lake	13,365,239	12.57	168,001,059
Gaillard Cut	6,071,304	10.98	67,722,547
TOTAL	19,436,543		235,723,606

Note:
1. In Gatun Lake, the dredges average unit cost includes the dredge MINDI and the new dredge.
2. In Gaillard, the dredge unit cost only includes the dredge RMC.
3. Dredging total cost reflects the operation cost but does not include the initial investment to acquire a new dredge and auxiliary equipment.

DRILLING & BLASTING (D&B) AREA AND VOLUME ESTIMATES

a. To estimate the D&B required in preparing the channel bottom material for effective dredging, the methodology used is "progress by area" (square meters) rather than "volume" (cubic meters).

b. The progress by area methodology was used because in November 2001 a time test was made for drilling at different borehole depths on the ACP D&B barge THOR; the test produced data for time per area. These time measurements were used to determine THOR productivity and are shown in Appendix No. 8.

c. Gatun Lake and Gaillard Cut navigation channel area was estimated using the computer-aided design application program AUTOCAD.

d. D&B operations exclude the Pedro Miguel and Paraiso reaches in Gaillard Cut, since Post-Panamax vessels would not transit these areas as they approach or exit the location of the proposed new locks.

e. Because of geologic conditions, certain areas of Gatun Lake and Gaillard Cut will require less D&B than others. Based on geologic records obtained from the Gaillard Cut Widening Program (widening to 630', completed in 2001), the experience of Dredging Division in blasting the lake and cut channel bottom, and MINDI and RMC masters-in-charge experience, a D&B percentage of the total was estimated for each reach. Appendix No. 18 contains some geologic information of Gatun Lake and Gaillard Cut.

f. The percentage of D&B required in each Gatun Lake and Gaillard Cut reach is shown in Appendix No. 5. The following table shows the average percentage of D&B required in Gatun Lake and Gaillard Cut:

DRILLING & BLASTING IN m2

AREAS	Total Areas	Estimated % of Areas that could require D&B according to Geologic Condition	Net Areas that could require D&B
Gatun Lake	11,720,686	34	4,006,084
Gaillard Cut	2,307,682	76	1,744,793
TOTAL	14,028,368		5,750,877

D&B TIMEFRAME ESTIMATES

GENERAL PARAMETERS TO MEASURE THOR AND NEW DRILLBOAT PRODUCTIVITY

a. The ACP D&B barge THOR and a new drill-boat would perform the blasting of Gatun Lake and Gaillard Cut channel bottoms for the proposed dredging to 27.5' PLD. ACP is planning to acquire a new drill-boat with 4 towers, similar to the THOR, by August, 2004.

b. To obtain a design channel bottom of 27.5' PLD, D&B is required up to 19.5' PLD, that is, 6' below the over-dredge line of 25.5' PLD. The boreholes will be 14.5' deep. Refer to Appendix No. 3 for a schematic.

c. The D&B to 19.5' PLD will serve the existing Gatun Lake and Gaillard Cut dredging to a design channel bottom of 34' PLD, as well as prepare the sub-bottom for future deepening projects; otherwise, D&B to 26' PLD is sufficient for deepening projects up to 32' PLD, including the over-dredge.

d. In 2002, the THOR received hydraulic system improvements that could increase its productivity to a minimum of 13%, as estimated by the ACP Mechanical Branch (EIEM). This 13% productivity increase has been included in the THOR productivity estimate.

e. The THOR and the new barge will perform the deepening on a 24 hours-per-day, 7 days-per-week schedule, differing from the THOR's previous schedule of 16 hours per day, 5 days per week for the Gaillard Cut Widening Project.

f. An average pattern of 100' x 52' was used to estimate THOR and new drill barge productivity. Each pattern would have 12.5' of spacing and 13' of burden, which results in 4 lines with 8 boreholes each, for a total of 32 boreholes. Each borehole has a 6.5" diameter. The pattern size might change to fulfill dredging operation needs and according to the type of material found in the channel bottom. For instance, the pattern spacing and burden should be smaller for hard material

g. Time measurements taken on board the THOR in November 2001 were used as the baseline to estimate THOR productivity, with the projected 13% efficiency increase included. Appendix No. 8 shows the measurement taken for each D&B activity.

h. ACP has recorded the historical performances of the TAMROCK drill towers on land as shown in Appendix No. 5, which can be used to estimate the new drill-boat performance with drills similar to the

TAMROCKs; however, it is estimated that the new drill-boat could achieve a 25% productivity increase over the THOR because drilling underwater is quite different from drilling on land. The mobilization and blasting time was assumed to be the same for both barges (THOR and new drill-boat).

i. The THOR productivity estimate includes the use of cartridge explosives; some experts say that the use of bulk explosives could boost D&B efficiency. However, data on bulk explosive use is not available and therefore was not considered in the estimate. The estimated blasting time is based on cartridge explosive information, despite the fact that the new barge could possibly use bulk explosives for blasting.

j. *Blasting Analysis International* (BAI) evaluated the cartridge and proposed bulk explosive systems for the submarine blasting in May 2002. According to BAI, ACP should test and prove the proposed bulk system in the submarine environment before acquiring it, and re-evaluate the borehole loading procedures, reliability and safety for both cartridge and bulk systems. A copy of this report is included in Appendix No. 15.

k. Appendix No.5 shows in detail the calculations used to estimate THOR and the new drill-boat activity. Following is a table that summarizes THOR and new 4-tower drill-boat productivity:

DRILLING & BLASTING "THOR" AT 19.5' PLD WITH A PATTERN OF 100' X 52'

	THOR	New drill-boat with 4 towers
D&B total time to complete a pattern (hours)	9.53	5.56
Number of patterns per week	**13**	**16**
Advancing area (m^2 per week)	6,283	7,732
D&B volume (m^3 per week)	27,776	34,185

Notes:

1. THOR (number of patterns per week) = Effective working time per week / time required to perform a pattern
2. New drill-boat = 1.25 x THOR productivity

D&B TIMEFRAME ESTIMATE

a. Based on an average theoretical productivity estimate of 13 and 16 patterns measuring 100' x 52' per week for the THOR and new drill-boat respectively, the D&B can be accomplished in 10.5 years, as shown in Appendix No. 1 (Gantt Chart), and No. 5.

b. The following table summarizes the duration of D&B to 19.5' PLD:

DRILLING & BLASTING TIME FRAME FOR 27.5' PLD NAVIGATION BOTTOM

AREAS	Areas that could require D&B (m^2)	Drilling & Blasting barges average productivity (m^2 per week)	Productivy years
Gatun Lake	**4,006,084**	**7,008**	8.50
Gaillard Cut	**1,744,793**	**6,283**	6.50
TOTAL	**5,750,877**		**10.50**

Nota:

1. Drilling & blasting timeframe includes 1 month of preventive maintenance each year, and 6 months of overhaul every 5 years.

UNCERTAIN DRILLING AND BLASTING FACTORS

The above THOR and new drill-boat productivity estimates are subject to several variables or factors that could affect their performance in greater or lesser degrees:

a. The exact productivity of the new drill-boat is uncertain; however, the specifications for the new drill-boat state that technical requirements such as pull-down, drilling rate, torque, automatic bit changer, automatic bar changer, etc. shall be higher than the THOR, and consequently the new drill-boat should have a higher drilling production than the THOR. It is assumed that the new drill-boat could have at least a 25% productivity increase compared to the THOR.

b. The THOR has never operated in the 24-hour mode, i.e. 3-watch / 7-day. Therefore, no historical records are available to confirm the THOR estimated productivity under this schedule scenario.

c. Data information is available only for widening projects, no data for deepening is available; the same applies for dredging information.

d. No precise geologic information on the Gatun Lake and Gaillard Cut channel bottom is available; the THOR and new drill-boat performances are expected to vary according to the type of material found.

e. Canal vessel traffic is the greatest interruption or impediment to obtaining an effective D&B performance. Very precise coordination with ACP Marine Traffic Control Branch is required to efficiently carry out the navigational channel D&B for the channel deepening.

f. The drill barges will require at least 10 hours to complete and blast one pattern. However, the only time permitted for detonation or blasting is between 06:00 to 18:00 hrs **and** when transiting ships are at a minimum 500 m distance from the blasting area, increasing to 610 m for those ships carrying dangerous cargo.

COMPARISON BETWEEN HISTORICAL RECORDS AND REVISED VOLUME PRODUCTIVITY ESTIMATES

a. Dredging Division has historical records of the THOR's productivity from 1980 to present; however, the THOR went through a major conversion from a pneumatic to a hydraulic system in 1992. Therefore, to obtain the following values, the productivity record was analyzed for only the years 1993 to 2001, as shown in Appendix No. 9.

b. A comparison was made between the historical records and the productivity estimate that is based on time data taken in November 2001. The following table shows this comparison:

COMPARISON BETWEEN THOR PRODUCTIVITY RECORDS AND ESTIMATED FUTURE PRODUCTIVITY

DRILLING AND BLASTING BARGE	HISTORICAL VALUE based on 2w / 5d	HISTORICAL VALUE extrapolated to 3w / 7d	ESTIMATED VALUE BASED ON MEASURED TIME & 13% PRODUCTIVITY INCREASE 3w/7d
THOR Production (m3 per week)	**17,195**	**27,082**	**27,776**

Note:
1. The historical value is based on an average of 25' deep borehole and for Gaillard Cut **Widening** to 630'.
2. Assuming 6 effective working hours per watch due to watch relay and other operational factors.

c. THOR estimated future productivity, based on the time measurement test, is close to the extrapolated historical records, provided that the improved hydraulic system works 13% faster, as projected. Note that the historical value is based on an average 25'-deep borehole, and the estimated future productivity is for a 14.5'-deep borehole.

d. The estimated production of 27,776 m^3 per week assumes the THOR ability to drill and blast at least 2 patterns of 100'x52' per day to elevation 19.5' PLD. This production is close to the historical records extrapolated to 3 watches / 7 days, considering 6 hours per watch. However, the data belongs to the program for cut widening to 630', in which the THOR was operating in an ideal situation, that is, along the channel prism line without or with fewer traffic interruptions than it would have when operating in the centerline of the navigational channel.

e. At deeper drilling depths, the THOR is more efficient; therefore, at an elevation of 19.5' PLD, in theory, better production should be accomplished. In other words, 27,776 m^3 per week is a reasonable

production to estimate the duration and cost of drilling to elevation 19.5’ PLD.

DRILLING & BLASTING COST ESTIMATES

COST ESTIMATES FOR D&B TO 19.5' PLD

a. D&B historical cost records were used to estimate the future D&B operation costs.

b. The D&B barge THOR had an average cost of $1,087,195 per month in the year 2001 when executing the Gaillard Cut Widening Program (to 630'). The cost per week was $251,084.33, which includes the cost for explosives.

c. It is assumed that the new D&B barge average operational cost is estimated at the same rate as the THOR, $251,084.33 per week because the new barge will have 4 towers, the same as the THOR.

d. Appendix No. 10 details the crew and operation cost for the THOR.

e. Appendix No.5 shows the cost of D&B by reach. The D&B total cost does not reflect the initial investment to acquire a new drill boat.

f. In addition to drilling the hard channel bottom, it will be required to drill and blast, and pre-split the Gaillard Cut east and west banks for proper dredging.

g. For the pre-split and D&B in Gaillard Cut, the slopes are estimated around 4% of D&B Gaillard Cut channel bottom to elevation 19.5' PLD. However, this percentage could vary according to the volume required for drilling and blasting.

h. The following table summarizes the cost of D&B to 19.5' PLD, including the pre-split and D&B cut slopes.

DRILLING & BLASTING COST ESTIMATE

AREAS	Areas that could require D&B (m^2)	Productivy weeks required	Cost ($/week)	Total Cost ($)
Gatun Lake	4,006,084	549	251,084	137,918,123
Gaillard Cut	1,744,793	278	251,084	72,821,545
TOTAL	5,750,877	827		210,739,668

Note:
1. Cost per week in Gatun Lake is the average cost of the THOR and new drilling & blasting barge.
2. The drillboat THOR will execute the D&B in Gaillard Cut.
3. The total cost reflects the operation of the THOR and new drill boat but does not include the initial investment to acquire the new drill boat.
4. The total cost includes the Gaillard Cut slopes pre-split and D&B cost.

COST COMPARISON BETWEEN PRODUCTION BY AREA AND BY VOLUME

a. To validate the previous estimated cost $210.7 million for D&B by "progress by area" to 19.5' PLD, a comparison of the cost was made with D&B productivity cost in terms of volume at 19.5' PLD.

b. The THOR D&B unit cost is based on its operation cost, as shown in Appendix No. 10. Following is a summary of THOR operation cost per hour, converted to 2002 dollars:

ACP DRILLING & BLASTING BARGE THOR OPERATION COST

	Cost per hour ($)
Availability cost	164
Labor cost	517
Overhead cost	62
Fuel cost	54
Auxiliary equipment cost	216
TOTAL COST per hour	**$1,013**

c. The D&B unit cost for the THOR is estimated at $8.04 per cubic meter, for productivity of 27,776 cubic meters per week, as shown in Appendix No. 10. The following table is a summary of the unit cost estimate:

DRILLING & BLASTING UNIT COST

D&B BARGE	Cost per hour ($)	Cost per week ($)	Estimated production per week (m^3)	Unit cost ($/$m^3$)
THOR	1,013	167,894	27,776	**6.04**
Exposives cost				**2.00**
TOTAL COST				**8.04**

d. The net area (m^2) required for D&B, based on Dredging Division experience and extrapolation of geologic data from the Gaillard Cut Widening Program (to 630'), is around 5,750,877 m^2. As a result, the volume for D&B should be 25.4 million cubic meters, found by multiplying the total area by the borehole depth of 4.42m (14.5'). A separate method using the INROADS civil engineering application program estimated the volume at 24.4 million cubic meters. The INROADS estimated volume is lower because the channel bottom is very irregular, and the computer program takes these irregularities into account when calculating volume.

e. Using the estimated volumes, historical cost per week and unit cost, the following results are obtained:

DRILLING & BLASTING BARGE "THOR" COST COMPARISON BETWEEN AREA AND VOLUME METHODOLOGY - 14.5' - DEPTH BOREHOLE

	Quantity	Cost ($)	Total Cost ($)
Area for D&B (m2)	5,750,877	$ 251,084 per week	**$ 207,646,468**
Volume = area x dredging depth (m3)	25,415,336	$ 8.04 per m3	**$ 204,339,299**
Volume by INROADS (m3)	22,974,314	$ 8.04 per m3	**$ 184,713,485**

f. The above table shows that there is a 1.6% difference between estimated costs by area and geometrically estimated volume. Using the INROADS estimated volume, the difference is around 11%. In other words, the cost estimate by "progress by area" is reasonable.

DRY EXCAVATION

PARAMETERS

a. In 2002, the ACP Geotechnical Branch developed the preliminary slope design for dry excavation required in Gaillard Cut for proposed projects to deepen the navigation channels to 27' and 22' PLD. These studies are contained in the following reports and are available at the ACP Engineering and Projects Department:

   - Study on the effect of the deepening on Gaillard Cut slopes
     i. Volume 1, General Description
     ii. Volume 2, Appendix A, Stability Analysis – West Bank
     iii. Volume 3, Appendix B, Stability Analysis – East Bank

b. For the Gaillard Cut Widening Program (to 630'), ACP contracted all of the dry excavation services. Historical information is available in the Geotechnical Branch and was used to estimate the cost and duration of future dry excavation. Appendix No. 12 contains this information.

DRY EXCAVATION VOLUME

a. The ACP Geotechnical Branch estimated the volume for dry excavation from a starting point of 85' PLD. All volume above this elevation is dry excavation, and all below is sub-aquatic excavation (dredging).

b. Using the civil engineering application program INROADS, the estimated dry excavation volume is 6,675,713 million cubic meters. Appendixes No. 4 and 5 show this volume by reach.

DRY EXCAVATION TIMEFRAME

a. The ACP Geotechnical Branch will develop the final designs for excavation plans, which will also include access road, drainage system, disposal site, disposal access and navigational aids designs. The design schedule will be coordinated with the proposed deepening program.

b. The contracting process to acquire services for Gaillard Cut dry excavation takes about 2 to 3 months.

c. The dry excavation operation should start at least one year before initiating any Gaillard Cut dredging. However, the final design and contract process should start at least nine months before the dry excavation work begins. In other words, the dry excavation logistics shall start at least two years before initiating the Gaillard Cut dredging.

DRY EXCAVATION COSTS

a. It is estimated that contractors can perform the dry excavation at $4.00 per cubic meter, which is an average taken from the Gaillard Cut Widening Program (to 630') dry excavation records.

b. The figure of $4.00 per cubic meter includes the cost of drilling and blasting on land.

c. In addition to the $4.00 per cubic meter, an additional $200,000 is required to provide rock anchorage and shotcrete application to the area known as "Purple Rock" that contains fragmented material and rock. This area is located at station No. 60K+412 between Cucaracha Slide and Cucaracha South Extension Slide.

d. The estimated cost for final design is about $1 million. This cost includes site investigation (exploratory drilling, geological mapping and laboratory testing) and excavation plan designs.

e. Refer to Appendix No. 5 for dry excavation costs by reach in Gaillard Cut. Following is a summary table showing the dry excavation total cost.

DRY EXCAVATION COST

	Volume (m3)	Unit Cost ($)	Total Cost ($)
Dry excavation operation	6,675,713	4.00	26,702,852
Special work at Purple Rock			200,000
Gaillard Cut slope design assessment			1,000,000
Total Cost			**$27,902,852**

DISPOSAL SITES FOR DREDGING & EXCAVATION MATERIAL

GENERAL PARAMETERS

a. The total amount of dredging and excavation material from the Gatun Lake and Gaillard Cut deepening, including the 2' of over-dredging, will require disposal of the following volumes:

   - Initial dredging for a design channel bottom of 34' PLD: 7.1 M m^3
   - Final dredging for a design channel bottom of 27.5' PLD: 19.4 M m^3
   - Dry excavation for a design channel bottom of 27.5' PLD: 6.7 M m^3

b. The current disposal site capacities to receive material are estimated for a maximum of 30' below mean lake level. This level was chosen to avoid the proliferation of aquatic plants and to provide enough under-keel clearance so barges and tugboats continue to have access to other locations to deposit material dredged by the CHRISTENSEN.

c. The cutter suction MINDI discharges dredging material onto the small islands found along the navigation channels, especially in Gatun Lake. This material is deposited above the mean lake level. In Gaillard Cut, the MINDI can discharge material to potential terrestrial disposal sites identified by Dredging Division, shown in Appendix No. 13.

d. In addition to existing disposal sites No. 14 and Frijoles in Gatun Lake, the Surveys Branch and Canal Capacity Division have identified other potential disposal sites. Refer to Appendix No. 13 to see sketches of existing and potential disposal site locations and estimated capacities.

e. Disposal site No. 14 has a remaining capacity of 1.4 million cubic meters after the Gaillard Cut Widening Program (to 630'), while Frijoles's remaining capacity is 14 million cubic meters. However, due to the dredging material bulking factor and imperfect precision of the barges and tugboats when depositing the material, it is estimated that the total capacity of both sites is around 10 million cubic meters.

DISPOSAL SITES FOR INITIAL DREDGING

a. As mentioned previously, the initial dredging will produce 7.1 million cubic meters, of which 3 million correspond to the dredging of Gaillard Cut, and the remaining 4 million to Gatun Lake.

b. Disposal sites No. 14 and Frijoles were selected to accommodate the 3 million cubic meters from the Gaillard Cut dredging.

c. The 4 million cubic meters of dredging material from Gatun Lake would be deposited on the islands along the lake navigation channels. Also, wetlands can be created with this dredging material deposited on the islands.

d. After the initial dredging for a design channel bottom of 34' PLD, the remaining capacity of Frijoles would be 7 million cubic meters.

DISPOSAL SITES FOR PROPOSED FINAL DREDGING

a. The final dredging involves removing 19.4 million cubic meters of material, of which 6 million corresponds to the dredging of Gaillard Cut.

b. Gaillard Cut's 6.1 million cubic meters of dredged material could be deposited in the Frijoles disposal site, which would have a remaining capacity of 7 million cubic meters after the deepening to 34' PLD.

c. Gatun Lake's 13.3 million cubic meters of dredging material can be deposited either in Frijoles, after accommodating Gaillard Cut dredging material, or on the islands along Gatun Lake navigation channels or at the potential disposal sites shown in Appendix No. 13.

DISPOSAL SITES FOR DRY EXCAVATION MATERIAL

a. The ACP Surveys Branch should perform topography studies of existing terrestrial disposal sites along Gaillard Cut to determine their remaining capacities. Refer to Appendix No. 13 to see sketches of Gaillard Cut terrestrial disposal sites.

b. The existing terrestrial sites could be redesigned to augment their remaining capacity.

c. The ACP Geotechnical Branch will evaluate other alternatives for terrestrial disposal sites during the design of Gaillard Cut slopes appropriate for a design channel bottom of 27.5' PLD.

d. The existing dry excavation material from the Gaillard Cut Widening Program might be sold to create more volumetric storage in existing terrestrial disposal sites. Also, the proposed new dry excavation material might also be sold or re-used.

SUMMARY

a. In summary, the total dredging and excavation volume, time frame and costs of deepening Gatun Lake and Gaillard Cut **without any contingency factor** are as follows:

SUMMARY OF VOLUME, AREAS, DURATION, AND COSTS FOR DEEPENING GATUN LAKE AND GAILLARD CUT TO DESIGN CHANNEL BOTTOM OF 27.5' PLD

	Volume or area	Equipment Qty	Duration (years)	Cost ($)
Dredging from 37' to 32' PLD	7,102,594 m^3	2 dredges	4.25	84,409,211
Drilling and blasting from 34' to 19.5' PLD	5,750,877 m^2	2 drill-boats	10.30	210,739,668
Dredging from 32' to 25.5' PLD	19,436,543 m^3	3 dredges	8.00	235,723,606
Dry excavation to 25.5' PLD	6,675,713 m^3	Contractors	6.50	27,902,852
TOTAL COST ONE PHASE D&B				**558,775,337**

b. If it is decided to drill and blast just for a design channel bottom of 34' PLD, that is drilling to 26' PLD instead of going directly to 19.5' PLD for future dredging, the total cost for dredging to a design channel bottom of 27.5' PLD could increase up to 11% as shown in the following table:

DEEPENING GATUN LAKE AND GAILLARD CUT TO 27.5' PLD CHANNEL BOTTOM

Design Channel Bottom	34' PLD	27.5' PLD	TOTAL
Dredging Volume (m3)	7,102,594	19,436,543	26,539,137
Drilling & Blasting areas (m2)	3,033,544	5,750,877	5,750,877
Duration (years)	6	8.5	11.5
Dry excavation (m3)	0	6,675,713	6,675,713
TOTAL COST, ONE - PHASE D&B ($)	**163,564,425**	**395,210,912**	**558,775,337**
TOTAL COST, TWO - PHASE D&B ($)	**163,564,425**	**455,718,784**	**619,283,209**

Notes:
1. D&B cost from 34' to 19.5' PLD is $ 210.7 M.
2. D&B cost from 34' to 26' PLD is $ 79.2 M, and from 32' to 19.5' PLD is $192.1 M.

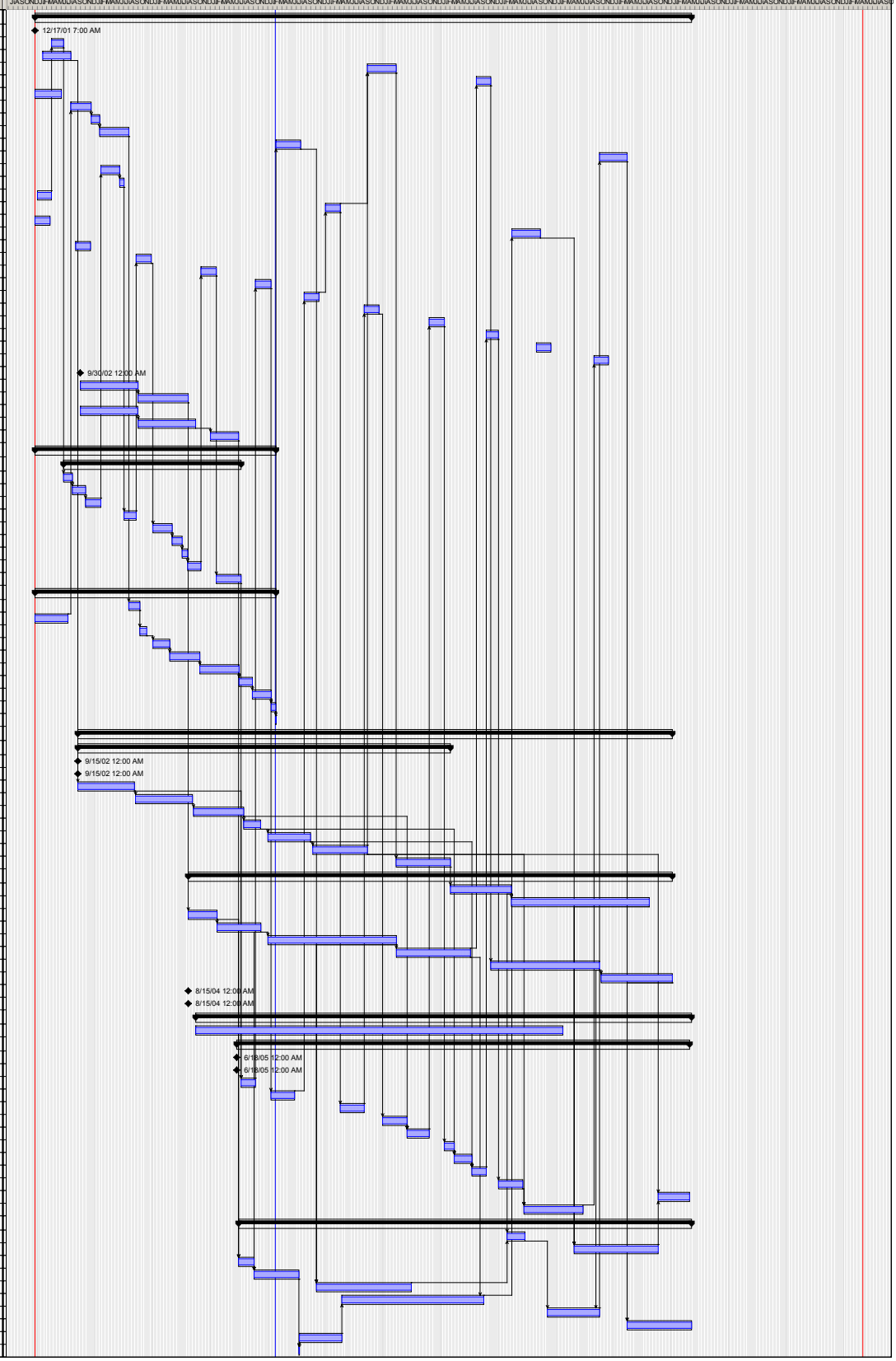
c. Appendix No. 5 contains the estimate for drilling and blasting to 26'PLD for a design channel bottom of 34' PLD; and from 32' to 19.5' PLD for a design channel bottom of 27.5' PLD.

APPENDIX No. 1

Gatun Lake and Gaillard Cut Deepening to 27.5’ PLD GANT CHART

Unlizenzierte Version! --- Unlicensed Version! Project: Proyecto de Prof.-PLD 37@19.5-rev.21GY-(D.Inicial+Perf.+D.Final+Co PM: Date: 17.02.2006

Name	Start	Finish
Proyecto de Profundización de 37' @ 19.5' PLD	17.12.2001	10.05.2013
Actividades Relacionadas	17.12.2001	17.12.2001
Estación de Amarre(R.M.Christensen)	01.04.2002	15.06.2002
Mantenimiento del Thor- Dique Seco-AF 2002	04.02.2002	01.08.2002
Mantenimiento del Thor- Dique Seco - AF 2007	24.09.2007	25.03.2008
Mantenimiento de TAMROCKS - Dique Seco-AF 2010	16.08.2009	15.11.2009
Mantenimiento del Thor- Dique Seco - AF 2012	17.12.2001	02.06.2002
Reparación de Draga Mindi-Dique Seco-AF 2002	01.08.2002	08.12.2002
Reparación de Draga Mindi-Gamboa-AF 2002	09.12.2002	31.01.2003
Ampliación del Atlántico - AF 2003	31.01.2003	04.08.2003
Reparación de Draga Mindi-Dique Seco-AF 2006	22.02.2006	28.07.2006
Reparación de Draga Mindi-Dique Seco-AF 2012	05.10.2011	28.03.2012
Reparación de Draga R.M.Christensen-Dique Seco BrasWell-AF 2003	07.02.2003	06.06.2003
Reparación de Draga R.M.Christensen-Gamboa-AF 2003	06.06.2003	04.07.2003
Reparación de Draga R.M.Christensen-AF 2002	02.01.2002	31.03.2002
Reparación de Draga R.M.Christensen-AF 2007	02.01.2007	06.04.2007
Reparación de Draga R.M.Christensen-AF 2013	17.12.2001	22.03.2002
Reparación de Draga Nueva-AF 2010	28.03.2010	26.09.2010
Dragado de Mantenimiento - 2002	01.09.2002	04.12.2002
Dragado de Mantenimiento - 2003	19.09.2003	23.12.2003
Dragado de Mantenimiento - 2004	04.11.2004	09.02.2005
Dragado de Mantenimiento - 2005	15.10.2005	21.01.2006
Dragado de Mantenimiento - 2006	20.08.2006	21.11.2006
Dragado de Mantenimiento - 2007	04.09.2007	07.12.2007
Dragado de Mantenimiento - 2008	20.10.2008	24.01.2009
Dragado de Mantenimiento - 2009	17.10.2009	02.01.2010
Dragado de Mantenimiento - 2010	01.09.2010	01.12.2010
Dragado de Mantenimiento - 2011	01.09.2011	01.12.2011
OTROS COSTOS	30.09.2002	30.09.2002
Diseño y compra de Nueva Barcaza de Perforación-AF 2003	01.10.2002	01.10.2003
Instalación de Tamrocks-AF 2004	01.10.2003	15.08.2004
Especificaciones, anuncio y licitación para la compra de Nueva Draga-/	01.10.2002	30.09.2003
Adquisición de Nueva Draga de Corte Succión	02.10.2003	30.09.2004
Entrenamiento y Calibración de la Nueva Draga	03.01.2005	30.06.2005
DRAGADO INICIAL DE 37' A 34' PLD, CON 2' DE DRAGADO DE TOL	17.12.2001	22.02.2006
CORTE GAILLARD	15.06.2002	16.07.2005
Bordada de Pedro Miguel (Draga RMC)	15.06.2002	10.08.2002
Bordada de Paraiso (Draga RMC)	10.08.2002	02.11.2002
Bordada de Cucaracha (Draga RMC)	02.11.2002	07.02.2003
39% Bordada de Culebra (Draga RMC)	04.07.2003	19.09.2003
61% Bordada de Culebra (Draga RMC)	04.01.2004	05.05.2004
Bordada de Empire (Draga RMC)	05.05.2004	07.07.2004
Bordada de Cunette (Draga RMC)	07.07.2004	11.08.2004
Bordada de Cascadas (Draga RMC)	11.08.2004	03.11.2004
Bordada de Bas Obispo (Draga RMC)	09.02.2005	16.07.2005
LAGO GATÚN	17.12.2001	22.02.2006
Bordada Cruce del Chagres (Draga MINDI)	04.08.2003	13.10.2003
(*)Bordada de Gamboa (Draga MINDI)	17.12.2001	14.07.2002
Curva de Juan Grande (Draga MINDI)	13.10.2003	26.11.2003
Curva de Mamei (Draga MINDI)	04.01.2004	20.04.2004
Bordada de San Pablo (Draga MINDI)	20.04.2004	27.10.2004
Bordada de Tabernilla (Draga MINDI)	27.10.2004	02.07.2005
Bordada de Buena Vista (Draga MINDI)	02.07.2005	25.09.2005
Bordada de Bohío (Draga MINDI)	25.09.2005	22.01.2006
Bordada de Peña Blanca (Draga MINDI)	22.01.2006	20.02.2006
Bordada de Gatún (Draga MINDI)	20.02.2006	22.02.2006
PERFORACIÓN Y VOLADURA DE 34' a 19.5' PLD	15.09.2002	08.01.2013
CORTE GAILLARD	15.09.2002	03.03.2009
Bordada de Pedro Miguel	15.09.2002	15.09.2002
Bordada de Paraiso	15.09.2002	15.09.2002
Bordada de Cucaracha (Barcaza THOR)	15.09.2002	09.09.2003
Bordada de Culebra (Barcaza THOR)	16.09.2003	10.09.2004
Bordada de Empire (Barcaza THOR)	17.09.2004	01.08.2005
Bordada de Cunette (Barcaza THOR)	01.08.2005	16.11.2005
Bordada de Cascadas (Barcaza THOR)	02.01.2006	29.09.2006
Bordada de Bas Obispo (Barcaza THOR)	13.10.2006	24.09.2007
Bordada de Bas Obispo (Barcaza THOR)	25.03.2008	03.03.2009
LAGO GATÚN	15.08.2004	08.01.2013
Bordada Cruce del Chagres (Barcaza THOR)	03.03.2009	26.03.2010
Bordada de Gamboa (Barcaza THOR)	26.03.2010	15.08.2012
Curva de Juan Grande (Barcaza nueva-4T/ROCKS)	15.08.2004	13.02.2005
Curva de Mamei (Barcaza nueva- 4T/ROCKS)	13.02.2005	18.11.2005
Bordada de San Pablo (Barcaza nueva-4T/ROCKS)	02.01.2006	26.03.2008
Bordada de Tabernilla (Barcaza nueva-4T/ROCKS)	26.03.2008	09.07.2009
Bordada de Buena Vista (Barcaza nueva-4T/ROCKS)	15.11.2009	05.10.2011
Bordada de Bohío (Barcaza nueva-4T/ROCKS)	16.10.2011	08.01.2013
Bordada de Peña Blanca	15.08.2004	15.08.2004
Bordada de Gatún	15.08.2004	15.08.2004
DRAGADO FINAL DE 32' A 27' PLD, CON 2' DE DRAGADO DE TOLE	01.10.2004	10.05.2013
Excavación Seca	01.10.2004	15.02.2011
CORTE GAILLARD	18.06.2005	28.04.2013
Bordada de Pedro Miguel	18.06.2005	18.06.2005
Bordada de Pedro Miguel	18.06.2005	18.06.2005
38% Bordada de Cucaracha (Draga RMC)	16.07.2005	15.10.2005
62% Bordada de Cucaracha (Draga RMC)	21.01.2006	20.06.2006
50% Bordada de Culebra (Draga RMC)	06.04.2007	04.09.2007
50% Bordada de Culebra (Draga RMC)	30.12.2007	02.06.2008
69% Bordada de Empire(Draga RMC)	02.06.2008	20.10.2008
31% Bordada de Empire(Draga RMC)	24.01.2009	28.03.2009
Bordada de Cunette (Draga RMC)	28.03.2009	18.07.2009
37% Bordada de Cascadas (Draga RMC)	18.07.2009	17.10.2009
63% Bordada de Cascadas (Draga RMC)	03.01.2010	06.06.2010
40% Bordada de Bas Obispo (Draga NUEVA)	11.10.2012	28.04.2013
60% Bordada de Bas Obispo (Draga RMC)	13.06.2010	23.06.2011
LAGO GATÚN	30.06.2005	10.05.2013
Bordada Cruce del Chagres (Draga Mindi)	26.02.2010	18.06.2010
Bordada de Gamboa (Draga Nueva)	27.04.2011	11.10.2012
Curva de Juan Grande (Draga Nueva)	30.06.2005	06.10.2005
Curva de Mamei (Draga Nueva)	06.10.2005	17.07.2006
Bordada de San Pablo (Draga Mindi)	05.11.2006	28.06.2008
Bordada de Tabernilla (Draga Nueva)	16.04.2007	01.10.2009
Bordada de Buena Vista (Draga Mindi)	09.11.2010	05.10.2011
Bordada de Bohío (Draga Nueva)	28.03.2012	10.05.2013
Bordada de Peña Blanca (Draga Nueva)	21.07.2006	16.04.2007
Bordada de Gatún (Draga Nueva)	17.07.2006	21.07.2006

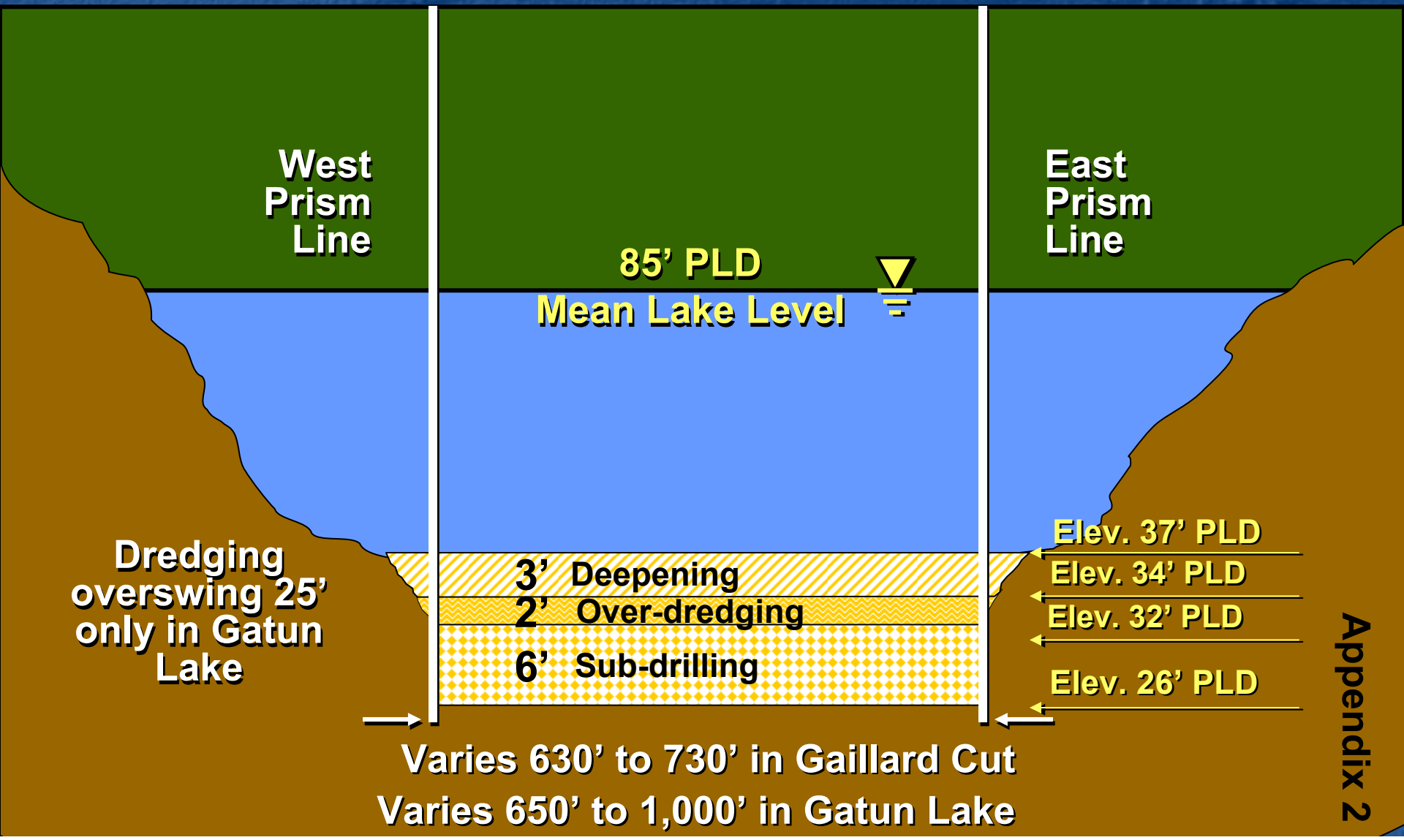


APPENDIX No. 2

Gatun Lake and Gaillard Cut Deepening to 34’ PLD SKETCH

Gatun Lake and Gaillard Cut Deepening to 34' PLD

(not to scale)



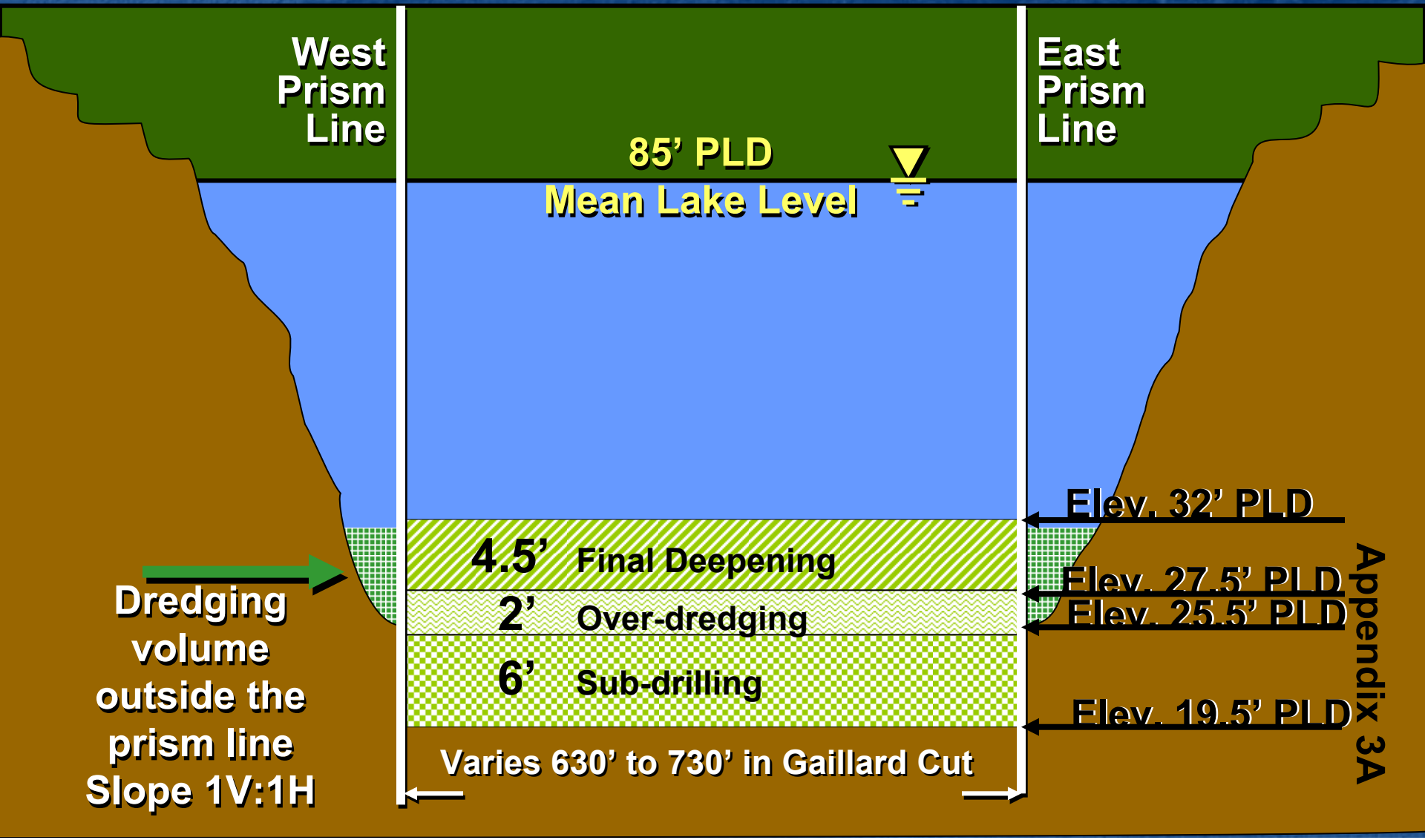
Appendix 2

APPENDIX No. 3

Gatun Lake and Gaillard Cut Deepening to 27.5’ PLD SKETCH

Gaillard Cut Deepening to 27.5' PLD

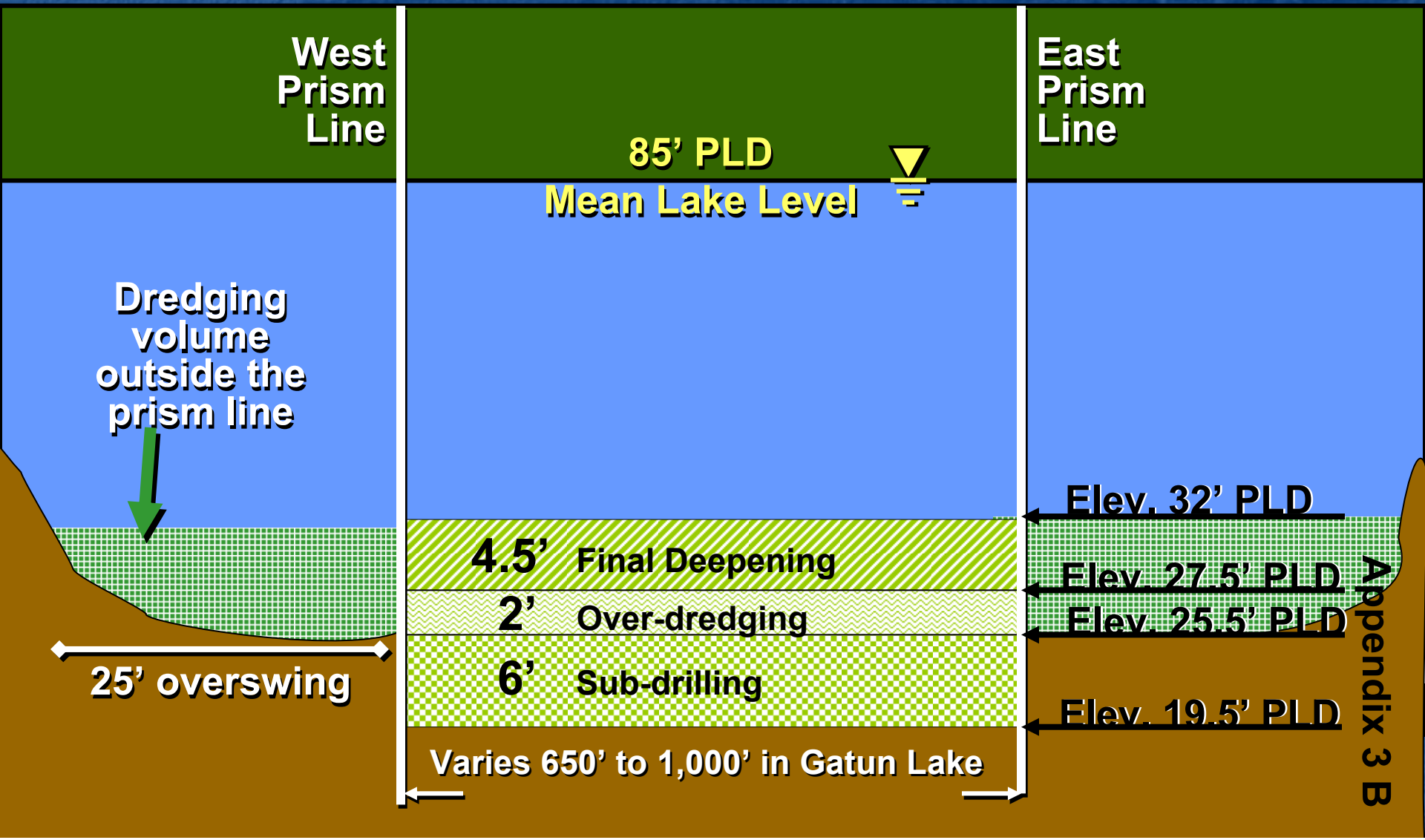
(not to scale)



Appendix 3A

Gatun Lake Deepening to 27.5' PLD

(not to scale)



Appendix 3 B

APPENDIX No. 4

Dredging, Dry Excavation, and Drilling & Blasting Volume Estimate

DREDGING TOTAL VOLUME FROM 37' PLD FOR A NAVIGATIONAL CHANNEL OF 27.5' PLD

REACHES	DREDGING VOLUME OUTSIDE FROM PRISM LINE ELEV. 37' TO 27.5' PLD	DREDGING VOLUME INSIDE THE PRISM LINE ELEV. 37' TO 27.5' PLD	DREDGING TOTAL VOLUME FROM ELEV. 37' TO 27.5' PLD	OVERDREDGE VOLUME OUTSIDE THE PRISM LINE FROM ELEV. 27.5' TO 25.5' PLD	OVERDREDGE VOLUME INSIDE THE PRISM LINE ELEV. 27.5' TO 25.5' PLD	DREDGING TOTAL VOLUME FROM 37' TO 25.5' PLD	DRILLING & BLASTING VOLUME INSIDE THE PRISM LINE ELEV. 25.5' TO 19.5' PLD
	m^3	m^3	m^3	m3	m^3	m^3	m^3
Gatun Reach	5,218	7,366	12,585	2,288	4,777	19,650	115,013
Peña Blanca	66,198	629,592	695,790	63,290	292,823	1,051,903	1,268,257
Bohio Reach	96,609	1,213,095	1,309,704	28,995	512,454	1,851,153	1,495,202
Buena Vista	109,970	1,092,089	1,202,058	30,721	426,720	1,659,500	1,499,544
Tabernilla	198,762	2,852,886	3,051,648	83,862	1,026,120	4,161,629	2,600,640
San Pablo	234,775	1,986,528	2,221,303	49,094	691,429	2,961,826	2,013,636
Mamei Curve	99,785	1,063,291	1,163,076	15,901	336,434	1,515,411	1,035,148
Juan Grande	61,356	364,210	425,566	7,985	119,034	552,585	388,451
Gamboa	301,365	1,962,423	2,263,787	49,469	605,153	2,918,409	1,917,853
Chagres Cross	51,616	523,722	575,338	3,722	133,568	712,628	464,400
SUB-TOTAL	**1,225,653**	**11,695,202**	**12,920,855**	**335,329**	**4,148,510**	**17,404,694**	**12,798,144**
Bas Obispo	351,117	1,433,192	1,784,309	116,838	394,301	2,295,448	1,246,506
Cascadas	207,034	820,850	1,027,884	50,731	219,768	1,298,383	725,892
Cunette	39,776	402,508	442,284	41,634	106,463	590,381	297,640
Empire	92,216	717,704	809,920	66,898	201,298	1,078,116	582,648
Culebra	176,086	1,472,093	1,648,179	50,343	301,724	2,000,246	881,160
Cucaracha	124,393	930,778	1,055,171	36,699	243,814	1,335,684	682,702
Paraiso	33,910	663,347	697,257	8,855	153,608	859,720	523,762
Pedro Miguel	62,794	436,379	499,173	12,559	86,538	598,270	198,774
SUB-TOTAL	**1,087,326**	**6,876,851**	**7,964,177**	**384,557**	**1,707,514**	**10,056,248**	**5,139,083**
TOTAL	**2,312,979**	**18,572,053**	**20,885,032**	**442,872**	**5,856,025**	**27,460,942**	**17,937,227**

Appendix No. 4 A

DREDGING TOTAL VOLUME FOR A DESIGN CHANNEL BOTTOM OF 27.5' PLD

REACHES	DREDGING TOTAL VOLUME INSIDE AND OUTSIDE THE PRISM LINE 37' TO 27.5' PLD	OVERDREDGE VOLUME INSIDE AND OUTSIDE THE PRISM LINE 27.5' TO 25.5' PLD	TOTAL DREDGING VOLUME FROM 37' TO 25.5' PLD	DREDGING VOLUME INSIDE THE PRISM LINE FROM 37' TO 34' PLD	OVERDREDGE INSIDE THE PRISM LINE FROM 34' A 32' PLD	DREDGING VOLUME OUTSIDE THE PRISM LINE FROM 37' TO 34' PLD	OVERDREDGE OUTSIDE THE PRISM LINE FROM 34' A 32' PLD	DREDGING TOTAL VOLUME FROM 37' TO 32' PLD	DREDGING VOLUME FROM 32' TO 27.5' PLD	DREDGING VOLUME FROM 32' TO 25.5' PLD
	m^3	m3	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3
Gatun Reach	12,585	7,066	19,650	2,811	3,173	47	0	6,030	6,554	13,620
Peña Blanca	695,790	356,113	1,051,903	23,819	82,473	7,013	10,384	123,689	572,101	928,214
Bohio Reach	1,309,704	541,449	1,851,153	66,833	218,884	28,428	14,619	328,764	980,940	1,522,389
Buena Vista	1,202,058	457,441	1,659,500	60,411	227,532	28,081	21,865	337,889	864,170	1,321,611
Tabernilla	3,051,648	1,109,981	4,161,629	197,533	550,134	48,875	45,405	841,947	2,209,701	3,319,682
San Pablo	2,221,303	740,523	2,961,826	212,368	398,020	111,432	34,346	756,165	1,465,138	2,205,661
Mamei Curve	1,163,076	352,335	1,515,411	166,978	187,462	48,635	15,546	418,622	744,454	1,096,789
Juan Grande	425,566	127,020	552,585	46,466	66,434	35,262	8,164	156,325	269,241	396,261
Gamboa	2,263,787	654,621	2,918,409	192,750	426,296	140,904	42,171	802,121	1,461,666	2,116,288
Chagres Cross	575,338	137,290	712,628	104,370	120,247	38,314	4,972	267,903	307,435	444,725
SUB-TOTAL	**12,920,855**	**4,483,839**	**17,404,694**	**1,074,339**	**2,280,655**	**486,990**	**197,472**	**4,039,455**	**8,881,400**	**13,365,239**
Bas Obispo	1,784,309	511,139	2,295,448	308,439	320,926	0	0	629,365	1,154,944	1,666,083
Cascadas	1,027,884	270,499	1,298,383	145,740	186,425	0	0	332,165	695,719	966,218
Cunette	442,284	148,097	590,381	67,576	81,031	0	0	148,607	293,677	441,774
Empire	809,920	268,196	1,078,116	100,219	156,310	0	0	256,529	553,391	821,587
Culebra	1,648,179	352,067	2,000,246	534,127	256,178	0	0	790,305	857,874	1,209,941
Cucaracha	1,055,171	280,513	1,335,684	175,815	194,168	0	0	369,983	685,188	965,701
Paraiso	697,257	162,463	859,720	201,376	124,538	0	0	325,914	371,343	533,806
Pedro Miguel	499,173	99,097	598,270	145,462	64,809	0	0	210,271	288,902	387,999
SUB-TOTAL	**7,964,177**	**2,092,071**	**10,056,248**	**1,678,754**	**1,384,385**	**0**	**0**	**3,063,139**	**4,901,038**	**6,993,109**
TOTAL	**20,885,032**	**6,575,910**	**27,460,942**	**2,753,093**	**3,665,040**	**486,990**	**197,472**	**7,102,594**	**13,782,438**	**20,358,348**

Appendix No. 4 B

DRILLING AND BLASTING VOLUME FROM 34' TO 19.5' PLD

REACHES	DREDGING VOLUME FROM 37' TO 25.5' PLD	DRILLING & BLASTING VOLUME INSIDE THE PRISM LINE FROM 25.5' TO 19.5' PLD	DRILLING & BLASTING VOLUME FROM 37' TO 19.5' PLD	DREDGING VOLUME FROM 37' TO 34' PLD	DRILLING & BLASTING VOLUME FROM 34' TO 19.5' PLD	HARD MATERIAL ESTIMATE PERCENTAGE	DRILLNG AND BLASTING NET VOLUME 34' TO 19.5' PLD
	m^3	m^3	m^3	m^3	m^3		m^3
Gatun Reach	19,650	115,013	134,663	3,272	131,391	0%	0
Peña Blanca	1,051,903	1,268,257	2,320,160	30,832	2,289,328	0%	0
Bohio Reach	1,851,153	1,495,202	3,346,356	95,261	3,251,094	50%	1,625,547
Buena Vista	1,659,500	1,499,544	3,159,044	88,492	3,070,552	50%	1,535,276
Tabernilla	4,161,629	2,600,640	6,762,269	246,408	6,515,861	30%	1,954,758
San Pablo	2,961,826	2,013,636	4,975,462	323,799	4,651,663	60%	2,790,998
Mamei Curve	1,515,411	1,035,148	2,550,559	215,614	2,334,945	65%	1,517,714
Juan Grande	552,585	388,451	941,036	81,727	859,309	60%	515,585
Gamboa	2,918,409	1,917,853	4,836,262	333,654	4,502,608	70%	3,151,826
Chagres Cross	712,628	464,400	1,177,028	142,684	1,034,345	100%	1,034,345
SUB-TOTAL	**17,404,694**	**12,798,144**	**30,202,838**	**1,561,743**	**28,641,095**		**14,126,049**
Bas Obispo	2,295,448	1,246,506	3,541,954	308,439	3,233,515	90%	2,910,163
Cascadas	1,298,383	725,892	2,024,275	145,740	1,878,535	70%	1,314,975
Cunette	590,381	297,640	888,020	67,576	820,444	60%	492,267
Empire	1,078,116	582,648	1,660,764	100,219	1,560,545	80%	1,248,436
Culebra	2,000,246	881,160	2,881,406	534,127	2,347,279	60%	1,408,367
Cucaracha	1,335,684	682,702	2,018,386	175,815	1,842,571	80%	1,474,057
Paraiso	859,720	523,762	1,383,482	201,376	1,182,106	80%	945,685
Pedro Miguel	598,270	198,774	797,044	145,462	651,582	80%	521,265
SUB-TOTAL	**10,056,248**	**5,139,083**	**15,195,331**	**1,678,754**	**13,516,577**		**10,315,215**
TOTAL	**27,460,942**	**17,937,227**	**45,398,169**	**3,240,497**	**42,157,672**		**24,441,264**

Appendix No. 4 C

DRY EXCAVATION VOLUME PER REACH **Appendix No. 4 D**

REACHES	Dry Excavation	
	DRY EXC. FROM 27.5' PLD (m3)	DRY EXC. FROM 25.5' PLD (m3)
Gaillard Cut		
Pedro Miguel Reach	0	0
Paraiso Reach	0	0
Cucaracha Reach	736,304	1,107,495
Culebra Reach	2,829,896	3,095,581
Empire Reach	524,876	758,220
Cunette Reach	146,202	249,524
Cascadas Reach	690,506	978,978
Bas Obispo Reach	350,938	485,915
SUBTOTAL	**5,278,722**	**6,675,713**

DREDGING TOTAL VOLUME FROM 37' PLD FOR A NAVIGATIONAL CHANNEL OF 27.5' PLD

REACHES	DREDGING VOLUME OUTSIDE FROM PRISM LINE ELEV. 37' TO 27.5' PLD	DREDGING VOLUME INSIDE THE PRISM LINE ELEV. 37' TO 27.5' PLD	DREDGING TOTAL VOLUME FROM ELEV. 37' TO 27.5' PLD	OVERDREDGE VOLUME OUTSIDE THE PRISM LINE FROM ELEV. 27.5' TO 25.5' PLD	OVERDREDGE VOLUME INSIDE THE PRISM LINE ELEV. 27.5' TO 25.5' PLD	DREDGING TOTAL VOLUME FROM 37' TO 25.5' PLD	DRILLING & BLASTING VOLUME INSIDE THE PRISM LINE ELEV. 25.5' TO 19.5' PLD
	m^3	m^3	m^3	m3	m^3	m^3	m^3
Gatun Reach	6,164	49,651	55,815	1,233	25,105	82,153	115,013
Peña Blanca	4,834	550,860	555,694	967	289,854	846,515	1,268,257
Bohio Reach	7,547	937,461	945,008	1,509	383,956	1,330,473	1,495,202
Buena Vista	26,340	1,270,388	1,296,728	5,268	500,617	1,802,613	1,499,544
Tabernilla	20,828	2,398,989	2,419,817	4,166	826,122	3,250,105	2,600,640
San Pablo	70,236	1,927,322	1,997,558	14,047	661,259	2,672,864	2,013,636
Mamei Curve	18,122	1,024,629	1,042,751	3,624	323,957	1,370,332	1,035,148
Juan Grande	15,053	522,879	537,932	3,011	152,332	693,275	388,451
Gamboa	73,095	2,162,139	2,235,234	14,619	640,055	2,889,908	1,917,853
Chagres Cross	49,355	841,866	891,221	9,871	214,388	1,115,480	464,400
SUB-TOTAL	**291,574**	**11,686,184**	**11,977,758**	**58,315**	**4,017,645**	**16,053,718**	**12,798,144**
Bas Obispo	351,117	1,433,192	1,784,309	116,838	394,301	2,295,448	1,246,506
Cascadas	207,034	820,850	1,027,884	50,731	219,768	1,298,383	725,892
Cunette	39,776	402,508	442,284	41,634	106,463	590,381	297,640
Empire	92,216	717,704	809,920	66,898	201,298	1,078,116	582,648
Culebra	176,086	1,472,093	1,648,179	50,343	301,724	2,000,246	881,160
Cucaracha	124,393	930,778	1,055,171	36,699	243,814	1,335,684	682,702
Paraiso	33,910	663,347	697,257	8,855	153,608	859,720	523,762
Pedro Miguel	62,794	436,379	499,173	12,559	86,538	598,270	198,774
SUB-TOTAL	**1,087,326**	**6,876,851**	**7,964,177**	**384,557**	**1,707,514**	**10,056,248**	**5,139,083**
TOTAL	**1,378,900**	**18,563,035**	**19,941,935**	**442,872**	**5,725,159**	**26,109,966**	**17,937,227**

Appendix No. 4 A

DREDGING TOTAL VOLUME FOR A DESIGN CHANNEL BOTTOM OF 27.5' PLD

REACHES	DREDGING TOTAL VOLUME INSIDE AND OUTSIDE THE PRISM LINE 37' TO 27.5' PLD	OVERDREDGE VOLUME INSIDE AND OUTSIDE THE PRISM LINE 27.5' TO 25.5' PLD	TOTAL DREDGING VOLUME FROM 37' TO 25.5' PLD	DREDGING VOLUME INSIDE THE PRISM LINE FROM 37' TO 34' PLD	OVERDREDGE INSIDE THE PRISM LINE FROM 34' A 32' PLD	DREDGING TOTAL VOLUME FROM 37' TO 32' PLD	DREDGING VOLUME FROM 32' TO 27.5' PLD	DREDGING VOLUME FROM 32' TO 25.5' PLD
	m^3	m3	m^3	m^3	m^3	m^3	m^3	m^3
Gatun Reach	55,815	26,338	82,153	5,836	7,882	13,718	42,097	68,435
Peña Blanca	555,694	290,821	846,515	23,445	81,293	104,738	450,956	741,777
Bohio Reach	945,008	385,465	1,330,473	78,584	203,614	282,198	662,810	1,048,275
Buena Vista	1,296,728	505,885	1,802,613	102,647	278,609	381,256	915,472	1,421,357
Tabernilla	2,419,817	830,288	3,250,105	203,173	523,615	726,788	1,693,029	2,523,317
San Pablo	1,997,558	675,306	2,672,864	212,971	415,034	628,005	1,369,553	2,044,859
Mamei Curve	1,042,751	327,581	1,370,332	157,689	231,752	389,441	653,310	980,891
Juan Grande	537,932	155,343	693,275	68,145	90,154	158,299	379,633	534,976
Gamboa	2,235,234	654,674	2,889,908	249,686	494,508	744,194	1,491,040	2,145,714
Chagres Cross	891,221	224,259	1,115,480	124,784	126,745	251,529	639,692	863,951
SUB-TOTAL	**11,977,758**	**4,075,960**	**16,053,718**	**1,226,960**	**2,453,206**	**3,680,166**	**8,297,592**	**12,373,552**
Bas Obispo	1,784,309	511,139	2,295,448	308,439	320,926	629,365	1,154,944	1,666,083
Cascadas	1,027,884	270,499	1,298,383	145,740	186,425	332,165	695,719	966,218
Cunette	442,284	148,097	590,381	67,576	81,031	148,607	293,677	441,774
Empire	809,920	268,196	1,078,116	100,219	156,310	256,529	553,391	821,587
Culebra	1,648,179	352,067	2,000,246	534,127	256,178	790,305	857,874	1,209,941
Cucaracha	1,055,171	280,513	1,335,684	175,815	194,168	369,983	685,188	965,701
Paraiso	697,257	162,463	859,720	201,376	124,538	325,914	371,343	533,806
Pedro Miguel	499,173	99,097	598,270	145,462	64,809	210,271	288,902	387,999
SUB-TOTAL	**7,964,177**	**2,092,071**	**10,056,248**	**1,678,754**	**1,384,385**	**3,063,139**	**4,901,038**	**6,993,109**
TOTAL	**19,941,935**	**6,168,031**	**26,109,966**	**2,905,714**	**3,837,591**	**6,743,305**	**13,198,630**	**19,366,661**

Appendix No. 4 B

DRILLING AND BLASTING VOLUME FROM 34' TO 19.5' PLD

REACHES	DREDGING VOLUME FROM 37' TO 25.5' PLD	DRILLING & BLASTING VOLUME INSIDE THE PRISM LINE FROM 25.5' TO 19.5' PLD	DRILLING & BLASTING VOLUME FROM 37' TO 19.5' PLD	DREDGING VOLUME FROM 37' TO 34' PLD	DRILLING & BLASTING VOLUME FROM 34' TO 19.5' PLD	HARD MATERIAL ESTIMATE PERCENTAGE	DRILLNG AND BLASTING NET VOLUME 34' TO 19.5' PLD
	m^3	m^3	m^3	m^3	m^3		m^3
Gatun Reach	82,153	115,013	197,166	5,836	191,330	0%	0
Peña Blanca	846,515	1,268,257	2,114,772	23,445	2,091,327	0%	0
Bohio Reach	1,330,473	1,495,202	2,825,676	78,584	2,747,092	50%	1,373,546
Buena Vista	1,802,613	1,499,544	3,302,157	102,647	3,199,510	50%	1,599,755
Tabernilla	3,250,105	2,600,640	5,850,745	203,173	5,647,572	30%	1,694,271
San Pablo	2,672,864	2,013,636	4,686,500	212,971	4,473,529	60%	2,684,118
Mamei Curve	1,370,332	1,035,148	2,405,480	157,689	2,247,791	65%	1,461,064
Juan Grande	693,275	388,451	1,081,725	68,145	1,013,580	60%	608,148
Gamboa	2,889,908	1,917,853	4,807,761	249,686	4,558,075	70%	3,190,653
Chagres Cross	1,115,480	464,400	1,579,880	124,784	1,455,096	100%	1,455,096
SUB-TOTAL	**16,053,718**	**12,798,144**	**28,851,862**	**1,226,960**	**27,624,902**		**14,066,651**
Bas Obispo	2,295,448	1,246,506	3,541,954	308,439	3,233,515	90%	2,910,163
Cascadas	1,298,383	725,892	2,024,275	145,740	1,878,535	70%	1,314,975
Cunette	590,381	297,640	888,020	67,576	820,444	60%	492,267
Empire	1,078,116	582,648	1,660,764	100,219	1,560,545	80%	1,248,436
Culebra	2,000,246	881,160	2,881,406	534,127	2,347,279	60%	1,408,367
Cucaracha	1,335,684	682,702	2,018,386	175,815	1,842,571	80%	1,474,057
Paraiso	859,720	523,762	1,383,482	201,376	1,182,106	80%	945,685
Pedro Miguel	598,270	198,774	797,044	145,462	651,582	80%	521,265
SUB-TOTAL	**10,056,248**	**5,139,083**	**15,195,331**	**1,678,754**	**13,516,577**		**10,315,215**
TOTAL	**26,109,966**	**17,937,227**	**44,047,193**	**2,905,714**	**41,141,479**		**24,381,866**

Appendix No. 4 C

DRY EXCAVATION VOLUME PER REACH **Appendix No. 4 D**

REACHES	Dry Excavation	
	DRY EXC. FROM 27.5' PLD (m3)	DRY EXC. FROM 25.5' PLD (m3)
Gaillard Cut		
Pedro Miguel Reach	0	0
Paraiso Reach	0	0
Cucaracha Reach	736,304	1,107,495
Culebra Reach	2,829,896	3,095,581
Empire Reach	524,876	758,220
Cunette Reach	146,202	249,524
Cascadas Reach	690,506	978,978
Bas Obispo Reach	350,938	485,915
SUBTOTAL	**5,278,722**	**6,675,713**

APPENDIX No. 5

Dredging, Dry Excavation, and Drilling and Blasting Timeframe and Cost Estimates

DEEPENING PROJECT – PLD 37’ – 27.5’ – 19.5’

DEEPENING PROJECT – PLD 37’ – 34’ – 26’

DRILLING AND BLASTING COST ESTIMATE

2 PHASES:

34’ PLD to 26’ PLD

32’ PLD to 19.5’ PLD

STUDY ELEMENT
COMPARATIVE TABLE OF DRILLING TIMES PLD 34'-26'
(REVISION No. 20)

1	B	C	D
2	**DRILLING AND BLASTING AREA WITH NO RESTRICTIONS(34' @ 26' PLD)**		
3	**DESCRIPTION**	**THOR**	**4-TOWER**
4	Drilling level	PLD-26'	PLD-26'
5	**Drilling Grid (feet); Spacing=12.5'; Burden=13'.**	**12.5' x 13'**	**12.5' x 13'**
6	**Actual pattern area (feet)**	**100' x 52'**	**100' x 52'**
7	Drilling spacing (feet)	12.5	12.5
8	Spacing between drilling rows (feet)	13	13
9	Pattern length (feet)	**100**	**100**
10	Pattern width (feet)	**52**	**52**
11	Volume per pattern (cubic meters)	1179	1179
12	Number of patterns	1	1
13	Number of rows	4	4
14	Drill depth (feet)	8	8
15	Number of passes	N / A	N / A
16	Average time to connect additional drill pipe (minutes)	N / A	N / A
17	Average time to drill a blasting hole (minutes)- (1)	11.41	11.00
18	Install Casing		1
19	Lower tri-cone column		2
20	Drill to required depth		6.00
21	Raise rods, change drill bit for shoe		n/a
22	Straighten borehole, sounding and load borehole		n/a
23	Remove rods and casing		2
24	Number of drillholes per line	8	8
25	Average time required to drill an 8-hole line (hours)	0.84	0.37
26	Rate of perforation per line, per drill tower (feet per minute)	0.32	0.73
27	**Average time required to drill a pattern of 4 lines of 8 boreholes each line (in hours)**	**3.36**	**1.47**
28	Estimated time to move the towers per line (minutes)	3	3
29	Moving time for the drillboat barge (minutes)	17	17
30	Time for setting explosives per bore hole (minutes)	6.67	6.67
31	Total time for setting a line of 8 bore holes (minutes)	13.34	13.34
32	Preparation time for blasting one pattern (minutes)	116.36	116.36
33	**Preparation time for blasting one pattern (hours)**	**1.94**	**1.94**
34	**Total time for activities in addition to drilling (hours)**	**1.50**	**1.50**
35	**Total drilling and blasting time for one pattern (hours)**	**6.80**	**4.91**
36	**Number of patterns per week**	**18**	**23**
37	**Area of progress per week (square meters per week)**	**8,699**	**11,115**
38	Weekly volume (cubic meters)	**21,218**	**27,112**
39	Production percentage ratio	44	56
40	Drilling rate per pattern, estimated for one tower in feet per minute.	**0.152**	**0.195**
59	**Notes:**		
60	(1) A 13% increase in the productivity of the drillboat THOR was assumed for the times calculated for the THOR.		
61			

STUDY ELEMENT
COMPARATIVE TABLE OF DRILLING TIMES PLD 34'-26'
(REVISION No. 20)

Cell: C3
Comment: All times used to define the THOR productivity were obtained from drilling tests made by EIDV to different depths in November 2001.
Los tiempos utilizados para definir la productividad del THOR, fueron obtenidos de las pruebas de perforación realizadas por personal de EIDV a diferentes profundidades en noviembre de 2001.

Cell: D3
Comment: All times used to define the Tamrock productivity were obtained from land based drilling logs provided by EIDV.
Los tiempos utilizados para determinar la producción de las perforadoras Tamrocks, se basaron en los registros de perforaciones terrestres, proporcionados por EIDV.

Cell: C11
Comment: Volume per pattern was calculated by multiplying the pattern area by the drilling depth.
El volumen por patrón se determinó, multiplicando el área del patrón por la profundidad de perforación.

Cell: D11
Comment: Volume per pattern was calculated by multiplying the pattern area by the drilling depth.
El volumen por patrón se determinó, multiplicando el área del patrón por la profundidad de perforación.

Cell: C17
Comment: The time recorded in the test was multiplied by a factor of 0.87, to include a 13% increase in the THOR's productivity.
El tiempo registrado en la prueba se multiplicó por el factor de 0.87, para considerar el aumento de productividad del THOR en un 13 %.

Cell: D20
Comment: borehole depth multiplied by TAMROCK drilling rate

Cell: C25
Comment: The time recorded in the test was multiplied by a factor of 0.87, to include a 13% increase in the THOR's productivity.
El tiempo registrado en la prueba se multiplicó por el factor de 0.87, para considerar el aumento de productividad del THOR en un 13 %.

Cell: D25
Comment: Total time in cell No. 17 was multiplied by the number of drill holes per line, and then divided by two because two towers will be installed in the new drill barge.
El tiempo total de la celda No 17 se multiplicó por el número de barrenos por línea y se dividio entre dos debido a que se instalarán dos torres en la nueva barcaza de perforación.

Cell: C31
Comment: Total loading time has been divided by four, assuming that the four THOR towers are working sinultaneously.
El tiempo total de carga se ha dividido entre cuatro, considerando que las cuatro torres de la THOR trabajan simultaneamente.

Cell: D31
Comment: Total loading time has been divided by two because the two towers will work simultaneously.
El tiempo total de carga se ha dividido entre dos, considerando que las dos torres trabajan simultaneamente.

Cell: C32
Comment: To calculate the THOR blasting preparation time for one pattern, the following were assumed:
(A) Four movements of the tower, one per line
(B) Three movements of the drillboat, between drilling lines
(C) Four drillholes per tower, one per line
Para calcular el tiempo de preparación de voladura de un patrón del THOR, se consideró lo siguiente:
A) Cuatro movimientos de torre, a razón de uno por línea.
B) Tres movimientos de barcaza entre lineas de perforación.
C) Cuatro cargas de barreno por torre, uno por línea.

Cell: D32
Comment: To calculate the new barge blasting preparation time for one pattern, the following were assumed:
(A) Four movements of the tower, one per line
(B) Three movements of the drillboat, between drilling lines
(C) Four drillholes per tower, one per line
Para calcular el tiempo de preparación de voladura de un patrón de la nueva barcaza, se consideró lo siguiente:
A) Cuatro movimientos de torre, a razón de uno por línea.
B) Tres movimientos de barcaza entre líneas de perforación.
C) Cuatro cargas de barreno por torre, uno por línea.

STUDY ELEMENT
COMPARATIVE TABLE OF DRILLING TIMES PLD 34'-26'
(REVISION No. 20)

Cell: C34
Comment: Time estimate based on the experience of underwater drilling personnel.
Tiempo estimado en base a la experiencia del personal de perforación subacuática.

Cell: D34
Comment: Time estimate based on the experience of underwater drilling personnel.
Tiempo estimado en base a la experiencia del personal de perforación subacuática.

Cell: C37
Comment: Area of progress per week equals the number of patterns per week multiplied by the area of a pattern.
El área de avance por semana es igual al número de patrones por semana, multiplicado por el área de un patrón.

Cell: C38
Comment: Volume of progress per week equals the number of patterns per week multiplied by the volume of one pattern.
El volumen por semana se calculó multiplicando el número de patrones por semana, por el volumen de un patrón.

BLASTING AREA AND DURATION PER REACH
PLD 34'- 26'
(REVISION No. 20)

1	B	E	F	G	H	I	M
2	REACHES (BORDADAS)	Drilling & Blasting - AREA (m2)			Available Equipment	OUTPUT OF THE EQUIPMENT (MT2/WEEK) PATTERN 100'x	
3		Area per Reach (mt2)	Percentage of Hard Material Area	Drilling and Blasting from 34' to 26' PLD (1)		Output - Area	Total Duration per Reach
4	**Gaillard Cut**						
5							
6	Pedro Miguel Reach	80,910	0.80	64,728	THOR	8,699	7
7							
8	Paraiso Reach	187,093	0.80	149,674	THOR	8,699	17
9							
10	Cucaracha Reach	266,631	0.80	213,305	THOR	8,699	25
11							
12	Culebra Reach	418,500	0.60	251,100	THOR	8,699	29
13							
14	Empire Reach	218,690	0.80	174,952	THOR	8,699	20
15							
16	Cunette Reach	96,534	0.60	57,920	THOR	8,699	7
17							
18	Cascadas Reach	307,737	0.70	215,416	THOR	8,699	25
19							
20	Bas Obispo Reach	361,305	0.90	325,175	THOR	8,699	37
21	**SUBTOTAL**	**1,937,400**		**1,452,270**			**167**
22				75			
23	**Gatun Lake**						
24							
25	Chagres Crossing Reach	241,800	1.00	241,800	THOR	8,699	28
26							
27	Gamboa Reach	567,998	0.70	397,599	4 Towers	11,115	36
28							
29	Juan Grande Reach	117,366	0.60	70,420	4 Towers	11,115	6
30							
31	Mamei Reach	263,016	0.65	170,960	4 Towers	11,115	15
32							
33	San Pablo Reach	467,976	0.60	280,786	4 Towers	11,115	25
34							
35	Tabernilla Reach	479,183	0.30	143,755	4 Towers	11,115	13
36							
37	Buena Vista Reach	319,734	0.50	159,867	4 Towers	11,115	14
38							
39	Bohío Reach	232,175	0.50	116,088	4 Towers	11,115	10
40							
41	Peña Blanca Reach	103,881	0.00	0	4 Towers	11,115	0
42							
43	Gatún Reach	8,370	0.00	0	4 Towers	11,115	0
44							
45	**SUBTOTAL**	**2,801,499**		**1,581,274**			**148**
46	**TOTAL**	**4,738,899**		56			**315**

47 **Notas:**
48 1- Assuming that 58% of the Gaillard Cut area would require Drilling and Blasting, based on the geological classification of the Cut.
49 2- Assuming that 28% of the Gatun Lake areas would require Drilling and Blasting, based on the geological classificiation of the lake.

BLASTING AREA AND DURATION PER REACH
PLD 34'- 26'
(REVISION No. 20)

Cell: I2
Comment: Output values correspond to the areas determined in Spreadsheet 1 in the cells comparing drilling times for areas with and without restrictions for the THOR and the new drillboat with two Tamrocks.
Los valores de rendimientos utilizados corresponden a las áreas determinadas en la hoja No 1 del cuadro comparativo de los tiempos de perforación, para áreas con y sin restricción para el THOR y la nueva barcaza con 2 Tamrocks.

Cell: E3
Comment: Reach area is calculated using AUTOCAD software.
Las áreas fueron estimadas a través del programa de diseño AUTOCAD

Cell: F3
Comment: Percentages based on geological maps and dredging experience in the Canal.
Porcentajes basados en el mapeo geológico y experiencia de las dragas en el Canal

Cell: G3
Comment: Drilling and Blasting area for each reach was calculated by multiplying the area of each reach (Col. E) by the percentage of hard material, according to the geological classifications for depths greater than 51' Mean Lake Level.
El área de Perforación y Voladura para cada bordada se determinó, multiplicando el área de cada bordada (Col. E) por el porcentaje de material duro, de acuerdo a la clasificación geológica para profundidades mayores a 51' MLL.

Cell: I3
Comment: Output is the number of drilling patterns in a non-restricted area multiplied by the area of a pattern of 100' by 52'.
El valor corresponde al número de patrones perforados en el área sin restricción, por el área del patrón de 100' x 52'.

Cell: J3
Comment: Total duration of drilling for each corresponding reach is the sum of the durations in both areas, with and without restrictions Col. K + Col. L.
La duración total de la perforación de la bordada corresponde a la suma de la duración sin restricción - Columna K, más la duración del área con restricción - Columna L.

BLASTING AREA AND DURATION PER REACH
PLD 34'- 26'
(REVISION No. 20)

1	B	E	F	G	H	K	N	O
2	**REACHES (BORDADAS)**	**Drilling and Blasting - AREA (m2)**			Available Equipment	DURATION IN WEEKS	COST PER WEEK	COST PER REACH
3		Area per Reach (mt2)	Percentage of Hard Material	Drilling and Blasting from 34' to 26' PLD (1)		Duration - Area		
4	**Gaillard Cut**							
5								
6	Pedro Miguel Reach	80,910	0.80	64,728	THOR	7	251,084	1,868,307
7								
8	Paraiso Reach	187,093	0.80	149,674	THOR	17	251,084	4,320,197
9								
10	Cucaracha Reach	266,631	0.80	213,305	THOR	25	251,084	6,156,823
11								
12	Culebra Reach	418,500	0.60	251,100	THOR	29	251,084	7,247,742
13								
14	Empire Reach	218,690	0.80	174,952	THOR	20	251,084	5,049,809
15								
16	Cunette Reach	96,534	0.60	57,920	THOR	7	251,084	1,671,813
17								
18	Cascadas Reach	307,737	0.70	215,416	THOR	25	251,084	6,217,758
19								
20	Bas Obispo Reach	361,305	0.90	325,175	THOR	37	251,084	9,385,826
21	**SUBTOTAL**	**1,937,400**		**1,452,270**		**167**		**41,918,275**
22				75				
23	**Gatun Lake**							
24								
25	Chagres Crossing Reach	241,800	1.00	241,800	THOR	28	251,084	6,979,307
26								
27	Gamboa Reach	567,998	0.70	397,599	4 Towers	36	251,084	8,981,431
28								
29	Juan Grande Reach	117,366	0.60	70,420	4 Towers	6	251,084	1,590,722
30								
31	Mamei Reach	263,016	0.65	170,960	4 Towers	15	251,084	3,861,857
32								
33	San Pablo Reach	467,976	0.60	280,786	4 Towers	25	251,084	6,342,720
34								
35	Tabernilla Reach	479,183	0.30	143,755	4 Towers	13	251,084	3,247,307
36								
37	Buena Vista Reach	319,734	0.50	159,867	4 Towers	14	251,084	3,611,266
38								
39	Bohío Reach	232,175	0.50	116,088	4 Towers	10	251,084	2,622,323
40								
41	Peña Blanca Reach	103,881	0.00	0	4 Towers	0	251,084	0
42								
43	Gatún Reach	8,370	0.00	0	4 Towers	0	251,084	0
44	**SUBTOTAL**	**2,801,499**		**1,581,274**		**148**		**37,236,934**
45	**TOTAL**	**4,738,899**		56				**79,155,209**

46 **NotEs:**
47 1- Assuming that 58% of the Gaillard Cut area would require Drilling and Blasting, based on the geological classifi
48 2- Assuming that 28% of the Gatun Lake areas would require Drilling and Blasting, based on the geological classif
49 3- Assuming the use of Bulk Explosives with the start of operations of the new drillboat and the 4 Tamrocks.

BLASTING AREA AND DURATION PER REACH
PLD 34'- 26'
(REVISION No. 20)

Cell: I2
Comment: Output values correspond to the areas determined in Spreadsheet 1 in the cells comparing drilling times for areas with and without restrictions for the THOR and a new drillboat with two Tamrocks.
Los valores de rendimientos utilizados corresponden a las áreas determinadas en la hoja No 1 del cuadro comparativo de los tiempos de perforación para áreas con y sin restricción para el THOR y la nueva barcaza con 2 Tamrocks.

Cell: K2
Comment: Duration was calculated by assuming that 50% of a drilling and blasting area would have operation restrictions and 50% would not have restrictions.
Para la determinación de las duraciones , se consideró que un 50% del área de perforación y voladura se realizará sin restricción y el otro 50% del área se realizará bajo restricción de la operación.

Cell: L2
Comment: THOR operating costs per week were calculated by dividing the average monthly operation cost ($1,087,195) by 4.33 weeks per month.
To calculate cost of a new drillboat with two Tamrocks, the THOR cost was used as a reference, but the labor cost was reduced because only two towers would be operating.
El costo de operación del THOR por semana se determino dividiendo el costo mensual promedio de operación (B/ 1,087,195) entre 4.33 semanas por mes.
En el caso de la nueva parforadora con dos tamrocks, se utilizó como referencia el costo del THOR, se redujo el costo de la mano de obra debido a que solo se manejarán dos torres .

Cell: M2
Comment: The cost per reach is equal to the total duration per reach in weeks (M) multiplied by the operation cost per week (N), including explosives.
El costo por bordada es igual a la duración total por bordada en semanas (M), por el costo de operación del equipo por semana (N), incluyendo el explosivo.

Cell: E3
Comment: Reach area is calculated using AUTOCAD software.
Las áreas de las bordadas se determinaron a través del programa AUTOCAD

Cell: G3
Comment: Drilling and Blasting area for each reach was calculated by multiplying the area of each reach (Col. E) by the percentage of hard material, according to the geological classifications for depths greater than 51' Mean Lake Level.
El área de Perforación y Voladura para cada bordada se determinó, multiplicando el área de cada bordada (Col. E) por el porcentaje de material duro, de acuerdo a la clasificación geológica para profundidades mayores a 51' MLL.

Cell: I3
Comment: The number corresponds to the number of drilling patterns in the area without restriction multiplied by the area of the pattern (100' x 52'). The number has been imported from Spreadsheet #5, column I.
El valor corresponde al número de patrones perforados en el área sin restricción, por el área del patrón de 100' x 52'. Valor exportado de la columna I de la hoja #5.

Cell: J3
Comment: The number corresponds to the number of drilling patterns in the area without restriction multiplied by the area of the pattern (100' x 52'). The number has been imported from Spreadsheet #5, column J.
El valor corresponde al número de patrones perforados en el área con restricción, por el área del patrón de 100' x 52'. Valor exportado de la celda J de la hoja #5.

Cell: K3
Comment: Duration is calculated by dividing 50% of the drilling area from Column E by the output of the equipment working in the area without restrictions.
La duración se determinó dividiendo el 50% del área de perforación de la columna E, entre el rendimiento del equipo en el área sin restricción.

STUDY ELEMENT
COMPARATIVE TABLE OF DRILLING TIMES PLD 32'-19.5'
(REVISION No. 20)

1	B	C	D
2	**DRILLING AND BLASTING AREA WITH NO RESTRICTIONS(32' @ 19.5' PLD)**		
3	**DESCRIPTION**	**THOR**	**4-TOWER**
4	Drilling level	PLD-19.5'	PLD-19.5'
5	**Drilling Grid (feet); Spacing=12.5'; Burden=13'.**	**12.5' x 13'**	**12.5' x 13'**
6	**Actual pattern area (feet)**	**100' x 52'**	**100' x 52'**
7	Drilling spacing (feet)	12.5	12.5
8	Spacing between drilling rows (feet)	13	13
9	Pattern length (feet)	**100**	**100**
10	Pattern width (feet)	**52**	**52**
11	Volume per pattern (cubic meters)	1842	1842
12	Number of patterns	1	1
13	Number of rows	4	4
14	Drill depth (feet)	12.5	12.5
15	Number of passes	N / A	N / A
16	Average time to connect additional drill pipe (minutes)	N / A	N / A
17	Average time to drill a blasting hole (minutes)-(1)	17.82	14.38
18	Install Casing		1
19	Lower tri-cone column		2
20	Drill to required depth		9.38
21	Raise rods, change drill bit for shoe		n/a
22	Straighten borehole, sounding and load borehole		n/a
23	Remove rods and casing		2
24	Number of drillholes per line	8	8
25	Average time required to drill an 8-hole line (hours)	1.31	0.48
26	Rate of perforation per line, per drill tower (feet per minute)	0.32	0.87
27	**Average time required to drill a pattern of 4 lines of 8 boreholes each line (in hours)**	**5.25**	**1.92**
28	Estimated time to move the towers per line (minutes)	3	3
29	Moving time for the drillboat barge (minutes)	17	17
30	Time for setting explosives per bore hole (minutes)	6.67	6.67
31	Total time for setting a line of 8 bore holes (minutes)	13.34	13.34
32	Preparation time for blasting one pattern (minutes)	116.36	116.36
33	**Preparation time for blasting one pattern (hours)**	**1.94**	**1.94**
34	**Total time for activities in addition to drilling (hours)**	**1.50**	**1.50**
35	**Total drilling and blasting time for one pattern (hours)**	**8.69**	**5.36**
36	**Number of patterns per week**	**14**	**18**
37	**Area of progress per week (square meters per week)**	**6,766**	**8,699**
38	Weekly volume (cubic meters)	**25,786**	**33,154**
39	Production percentage ratio	44	56
40	Drilling rate per pattern, estimated for one tower in feet per minute.	**0.185**	**0.231**
59	**Notes:**		
60	(1) A 13% increase in the productivity of the drillboat THOR was assumed for the times calculated for the THOR.		
61			

STUDY ELEMENT
COMPARATIVE TABLE OF DRILLING TIMES PLD 32'-19.5'
(REVISION No. 20)

Cell: C3
Comment: All times used to define the THOR productivity were obtained from drilling tests made by EIDV to different depths in November 2001.
Los tiempos utilizados para definir la productividad del THOR, fueron obtenidos de las pruebas de perforación realizadas por personal de EIDV a diferentes profundidades en noviembre de 2001.

Cell: D3
Comment: All times used to define the new barge productivity were obtained from TAMROCKS land based drilling logs provided by EIDV.
Los tiempos utilizados para determinar la producción de las perforadoras Tamrocks, se basaron en los registros de perforaciones terrestres, proporcionados por EIDV.

Cell: C11
Comment: Volume per pattern was calculated by multiplying the pattern area by the drilling depth.
El volumen por patrón se determinó, multiplicando el área del patrón por la profundidad de perforación.

Cell: D11
Comment: Volume per pattern was calculated by multiplying the pattern area by the drilling depth.
El volumen por patrón se determinó, multiplicando el área del patrón por la profundidad de perforación.

Cell: C17
Comment: The time recorded in the test was multiplied by a factor of 0.87, to include a 13% increase in the THOR's productivity.
El tiempo registrado en la prueba se multiplicó por el factor de 0.87, para considerar el aumento de productividad del THOR en un 13 %.

Cell: C25
Comment: The time recorded in the test was multiplied by a factor of 0.87, to include a 13% increase in the THOR's productivity.
El tiempo registrado en la prueba se multiplicó por el factor de 0.87, para considerar el aumento de productividad del THOR en un 13 %.

Cell: D25
Comment: Total time in cell No. 17 was multiplied by the number of drill holes per line, and then divided by two because two towers will be installed in the new drill barge.
El tiempo total de la celda No 17 se multiplicó por el número de barrenos por línea y se dividio entre dos debido a que se instalarán dos torres en la nueva barcaza de perforación.

Cell: C31
Comment: Total loading time has been divided by four, assuming that the four THOR towers are working sinultaneously.
El tiempo total de carga se ha dividido entre cuatro, considerando que las cuatro torres de la THOR trabajan simultaneamente.

Cell: D31
Comment: Total loading time has been divided by two because the two towers will work simultaneously.
El tiempo total de carga se ha dividido entre dos, considerando que las dos torres de la nueva barcaza trabajan simultaneamente.

Cell: C32
Comment: To calculate the THOR blasting preparation time for one pattern, the following were assumed:
(A) Four movements of the tower, one per line
(B) Three movements of the drillboat, between drilling lines
(C) Four drillholes per tower, one per line
Para calcular el tiempo de preparación de voladura de un patrón del THOR, se consideró lo siguiente:
A) Cuatro movimientos de torre, a razón de uno por línea.
B) Tres movimientos de barcaza entre lineas de perforación.

C) Cuatro cargas de barreno por torre, uno por línea.

Cell: D32
Comment: To calculate the new barge blasting preparation time for one pattern, the following were assumed:
(A) Four movements of the tower, one per line
(B) Three movements of the drillboat, between drilling lines
(C) Four drillholes per tower, one per line
Para calcular el tiempo de preparación de voladura de un patrón de la nueva barcza, se consideró lo siguiente:
A) Cuatro movimientos de torre, a razón de uno por línea.
B) Tres movimientos de barcaza entre líneas de perforación.
C) Cuatro cargas de barreno por torre, uno por línea.

Cell: C34
Comment: Time estimate based on the experience of underwater drilling personnel.
Tiempo estimado en base a la experiencia del personal de perforación subacuática.

Cell: D34
Comment: Time estimate based on the experience of underwater drilling personnel.
Tiempo estimado en base a la experiencia del personal de perforación subacuática.

Cell: C37
Comment: Area of progress per week equals the number of patterns per week multiplied by the area of a pattern.
El área de avance por semana es igual al número de patrones por semana, multiplicado por el área de un patrón.

Cell: C38
Comment: Volume of progress per week equals the number of patterns per week multiplied by the volume of one pattern.
El volumen por semana se calculó multiplicando el número de patrones por semana, por el volumen de un patrón.

BLASTING AREA AND DURATION PER REACH
PLD 32'- 19.5'
(REVISION No. 20)

1	B	E	F	G	H	I	M
2	**REACHES (BORDADAS)**	**Drilling & Blasting - AREA (m2)**			Available Equipment	OUTPUT OF THE EQUIPMENT (MT2/WEEK) PATTERN 100' x 52'	DURATION IN WEEKS
3		Area per Reach (mt2)	Percentage of Hard Material Area	Drilling and Blasting from 32' to 19.5' PLD (1)		Output - Area	Total Duration per Reach
4	**Gaillard Cut**						
5							
6	Pedro Miguel Reach	0	0.80	0	THOR	6,766	0
7							
8	Paraiso Reach	0	0.80	0	THOR	6,766	0
9							
10	Cucaracha Reach	390,657	0.80	312,526	THOR	6,766	46
11							
12	Culebra Reach	481,289	0.60	288,773	THOR	6,766	43
13							
14	Empire Reach	315,566	0.80	252,453	THOR	6,766	37
15							
16	Cunette Reach	160,893	0.60	96,536	THOR	6,766	14
17							
18	Cascadas Reach	344,218	0.70	240,953	THOR	6,766	36
19							
20	Bas Obispo Reach	615,059	0.90	553,553	THOR	6,766	82
21	**SUBTOTAL**	**2,307,682**		**1,744,793**			**258**
22				76			
23	**Gatun Lake**						
24							
25	Chagres Crossing Reach	318,303	1.00	318,303	THOR	6,766	47
26							
27	Gamboa Reach	1,038,515	0.70	726,961	THOR	6,766	107
28							
29	Juan Grande Reach	317,504	0.60	190,502	4 Towers	8,699	22
30							
31	Mamei Reach	459,929	0.65	298,954	4 Towers	8,699	34
32							
33	San Pablo Reach	1,348,025	0.60	808,815	4 Towers	8,699	93
34							
35	Tabernilla Reach	1,589,612	0.30	476,884	4 Towers	8,699	55
36							
37	Buena Vista Reach	1,450,086	0.50	725,043	4 Towers	8,699	83
38							
39	Bohío Reach	921,245	0.50	460,623	4 Towers	8,699	53
40							
41	Peña Blanca Reach	2,289,371	0.00	0	4 Towers	8,699	0
42							
43	Gatún Reach	1,988,096	0.00	0	4 Towers	8,699	0
44							
45	**SUBTOTAL**	**11,720,686**		**4,006,084**			**495**
46	**TOTAL**	**14,028,368**		34			**753**

47 **Notas:**
48 1- Assuming that 58% of the Gaillard Cut area would require Drilling and Blasting, based on the geological classification of the Cut.
49 2- Assuming that 28% of the Gatun Lake areas would require Drilling and Blasting, based on the geological classificiation of the lake.

BLASTING AREA AND DURATION PER REACH
PLD 32'- 19.5'
(REVISION No. 20)

Cell: I2
Comment: Output values correspond to the areas determined in Spreadsheet 1 in the cells comparing drilling times for areas with and without restrictions for the THOR and the new drillboat with two Tamrocks.
Los valores de rendimientos utilizados corresponden a las áreas determinadas en la hoja No 1 del cuadro comparativo de los tiempos de perforación, para áreas con y sin restricción para el THOR y la nueva barcaza con 2 Tamrocks.

Cell: E3
Comment: Reach area is calculated using AUTOCAD software.
Las áreas fueron estimadas a través del programa de diseño AUTOCAD

Cell: F3
Comment: Percentages based on geological maps and dredging experience in the Canal.
Porcentajes basados en el mapeo geológico y experiencia de las dragas en el Canal

Cell: G3
Comment: Drilling and Blasting area for each reach was calculated by multiplying the area of each reach (Col. E) by the percentage of hard material, according to the geological classifications for depths greater than 51' Mean Lake Level.
El área de Perforación y Voladura para cada bordada se determinó, multiplicando el área de cada bordada (Col. E) por el porcentaje de material duro, de acuerdo a la clasificación geológica para profundidades mayores a 51' MLL.

Cell: I3
Comment: Output is the number of drilling patterns in a non-restricted area multiplied by the area of a pattern of 100' by 52'.
El valor corresponde al número de patrones perforados en el área sin restricción, por el área del patrón de 100' x 52'.

Cell: J3
Comment: Total duration of drilling for each corresponding reach is the sum of the durations in both areas, with and without restrictions Col. K + Col. L.
La duración total de la perforación de la bordada corresponde a la suma de la duración sin restricción - Columna K, más la duración del área con restricción - Columna L.

Cell: E6
Comment: This Reach was not included because of the proposed alignment of new Canal locks.
Se excluyó el 100% de la Bordada de Pedro Miguel, debido al alineamiento del Tercer Juego de Exclusas.

Cell: E8
Comment: This Reach was not included because of the proposed alignment of new Canal locks.
Se excluyó el 100% de la Bordada de Paraiso, debido al alineamiento del Tercer Juego de Exclusas.

BLASTING AREA AND DURATION PER REACH
PLD 32'- 19.5'
(REVISION No. 20)

1	B	E	F	G	H	K	N	O	P
2	**REACHES (BORDADAS)**	**Drilling and Blasting - AREA (m2)**			Available Equipment	DURATION IN WEEKS	COST PER WEEK	COST PER REACH	COST PER REACH (including pre-split blasting and aquatic slopes)
3		Area per Reach (mt2)	Percentage of Hard Material	Drilling and Blasting from 32' to 19.5' PLD (1)		Duration - Area			
4	**Gaillard Cut**								
5									
6	Pedro Miguel Reach	0	0.80	0	THOR	0	251,084	0	0
7									
8	Paraiso Reach	0	0.80	0	THOR	0	251,084	0	0
9									
10	Cucaracha Reach	390,657	0.80	312,526	THOR	46	251,084	11,598,080	12,151,561
11									
12	Culebra Reach	481,289	0.60	288,773	THOR	43	251,084	10,716,616	11,228,032
13									
14	Empire Reach	315,566	0.80	252,453	THOR	37	251,084	9,368,729	9,815,822
15									
16	Cunette Reach	160,893	0.60	96,536	THOR	14	251,084	3,582,522	3,753,487
17									
18	Cascadas Reach	344,218	0.70	240,953	THOR	36	251,084	8,941,948	9,368,673
19									
20	Bas Obispo Reach	615,059	0.90	553,553	THOR	82	251,084	20,542,807	21,523,146
21	**SUBTOTAL**	**2,307,682**		**1,744,793**		**258**		**64,750,703**	**67,840,721**
22				76					
23	**Gatun Lake**								
24									
25	Chagres Crossing Reach	318,303	1.00	318,303	THOR	47	251,084	11,812,484	11,812,484
26									
27	Gamboa Reach	1,038,515	0.70	726,961	THOR	107	251,084	26,978,097	26,978,097
28									
29	Juan Grande Reach	317,504	0.60	190,502	4 Towers	22	251,084	5,498,655	5,498,655
30									
31	Mamei Reach	459,929	0.65	298,954	4 Towers	34	251,084	8,628,994	8,628,994
32									
33	San Pablo Reach	1,348,025	0.60	808,815	4 Towers	93	251,084	23,345,610	23,345,610
34									
35	Tabernilla Reach	1,589,612	0.30	476,884	4 Towers	55	251,084	13,764,753	13,764,753
36									
37	Buena Vista Reach	1,450,086	0.50	725,043	4 Towers	83	251,084	20,927,618	20,927,618
38									
39	Bohío Reach	921,245	0.50	460,623	4 Towers	53	251,084	13,295,393	13,295,393
40									
41	Peña Blanca Reach	2,289,371	0.00	0	4 Towers	0	251,084	0	0
42									
43	Gatún Reach	1,988,096	0.00	0	4 Towers	0	251,084	0	0
44	**SUBTOTAL**	**11,720,686**		**4,006,084**		**495**		**124,251,605**	**124,251,605**
45	**TOTAL**	**14,028,368**		34		**753**		**189,002,307**	**192,092,326**
46	**NotEs:**								
47	1- Assuming that 58% of the Gaillard Cut area would require Drilling and Blasting, based on the geological classificati								
48	2- Assuming that 28% of the Gatun Lake areas would require Drilling and Blasting, based on the geological classificia								
49	3- Assuming the use of Bulk Explosives with the start of operations of the new drillboat and the 2 Tamrocks.								

BLASTING AREA AND DURATION PER REACH
PLD 32'- 19.5'
(REVISION No. 20)

Cell: I2
Comment: Output values correspond to the areas determined in Spreadsheet 1 in the cells comparing drilling times for areas with and without restrictions for the THOR and a new drillboat with two Tamrocks.
Los valores de rendimientos utilizados corresponden a las áreas determinadas en la hoja No 1 del cuadro comparativo de los tiempos de perforación para áreas con y sin restricción para el THOR y la nueva barcaza con 2 Tamrocks.

Cell: K2
Comment: Duration was calculated by assuming that 50% of a drilling and blasting area would have operation restrictions and 50% would not have restrictions.
Para la determinación de las duraciones , se consideró que un 50% del área de perforación y voladura se realizará sin restricción y el otro 50% del área se realizará bajo restricción de la operación.

Cell: L2
Comment: THOR operating costs per week were calculated by dividing the average monthly operation cost ($1,087,195) by 4.33 weeks per month.
To calculate cost of a new drillboat with two Tamrocks, the THOR cost was used as a reference, but the labor cost was reduced because only two towers would be operating.
El costo de operación del THOR por semana se determino dividiendo el costo mensual promedio de operación (B/ 1,087,195) entre 4.33 semanas por mes.
En el caso de la nueva parforadora con dos tamrocks, se utilizó como referencia el costo del THOR, se redujo el costo de la mano de obra debido a que solo se manejarán dos torres .

Cell: M2
Comment: The cost per reach is equal to the total duration per reach in weeks (M) multiplied by the operation cost per week (N), including explosives.
El costo por bordada es igual a la duración total por bordada en semanas (M), por el costo de operación del equipo por semana (N), incluyendo el explosivo.

Cell: N2
Comment: To include the drilling and blasting work in the aquatic Gaillard Cut slopes and pre-split blasting, the cost per reach was multiplied by a factor of 1.0742

Cell: E3
Comment: Reach area is calculated using AUTOCAD software.
Las áreas de las bordadas se determinaron a través del programa AUTOCAD

Cell: G3
Comment: Drilling and Blasting area for each reach was calculated by multiplying the area of each reach (Col. E) by the percentage of hard material, according to the geological classifications for depths greater than 51' Mean Lake Level.
El área de Perforación y Voladura para cada bordada se determinó, multiplicando el área de cada bordada (Col. E) por el porcentaje de material duro, de acuerdo a la clasificación geológica para profundidades mayores a 51' MLL.

Cell: I3
Comment: The number corresponds to the number of drilling patterns in the area without restriction multiplied by the area of the pattern (100' x 52'). The number has been imported from Spreadsheet #5, column I.
El valor corresponde al número de patrones perforados en el área sin restricción, por el área del patrón de 100' x 52'. Valor exportado de la columna I de la hoja #5.

Cell: J3
Comment: The number corresponds to the number of drilling patterns in the area without restriction multiplied by the area of the pattern (100' x 52'). The number has been imported from Spreadsheet #5, column J.
El valor corresponde al número de patrones perforados en el área con restricción, por el área del patrón de 100' x 52'. Valor exportado de la celda J de la hoja #5.

Cell: K3
Comment: Duration is calculated by dividing 50% of the drilling area from Column E by the output of the equipment working in the area without restrictions.
La duración se determinó dividiendo el 50% del área de perforación de la columna E, entre el rendimiento del equipo en el área sin restricción.

Cell: E6
Comment: Se excluyó el 100% de la Bordada de Pedro Miguel, debido al alineamiento del Tercer Juego de Exclusas.

Cell: E8
Comment: Se excluyó el 100% de la Bordada de Pedro Miguel, debido al alineamiento del Tercer Juego de Exclusas.

Gaillard Cut Slopes Drilling Blasting
(REVISION No. 20)

PRE-SPLIT GAILALRD CUT - DRILLING AND BLASTING COST ESTIMATE				
Cut Length (mts)	Blasting of Pre-Split Cut (mts)	Amount of Explosive for Pre-Split every 300 mts.	Pre-Split Blasting Unit Cost (B/)	Pre-Split Blasting Total Cost (B/)
11,302	22,604	75	2,500	**B/. 188,367**
Costo estimado de Perforación y Voladura de los Taludes-Corte Gaillard				
Slope Area (mt^2)	Cut Length (mt)	Blasting Volume (mt^3)	Blasting Unit Cost (B/./ mt^3)	Blasting Slope Total Cost
51.35	11,302	1,160,661	B/. 2.50	**B/. 2,901,652**
Pre-Split Blasting Total Cost plus Slope Blasting				**B/. 3,090,019**
entage Relationship with respect to D&B cost at Gaillard Cut from 34' to 19.5' PLD =				**4.77**

STUDY ELEMENT
DEEPENING PROJECT-PLD 37'-27.5'-19.5'
COMPARATIVE TABLE OF DRILLING TIMES
(REVISION No. 21)

1	B	C	D
2	**DRILLING AND BLASTING AREA WITH NO RESTRICTIONS**		
3	**DESCRIPTION**	**THOR**	**4-TOWER**
4	Drilling level	PLD-19.5'	PLD-19.5'
5	**Drilling Grid (feet); Spacing=12.5'; Burden=13'.**	**12.5' x 13'**	**12.5' x 13'**
6	**Actual pattern area (feet)**	**100' x 52'**	**100' x 52'**
7	Drilling spacing (feet)	12.5	12.5
8	Spacing between drilling rows (feet)	13	13
9	Pattern length (feet)	**100**	**100**
10	Pattern width (feet)	**52**	**52**
11	Volume per pattern (cubic meters)	2137	2137
12	Number of patterns	1	1
13	Number of rows	4	4
14	Drill depth (feet)	14.5	14.5
15	Number of passes	N / A	N / A
16	Average time to connect additional drill pipe (minutes)	N / A	N / A
17	Average time to drill a blasting hole (minutes)-(1)	20.67	15.88
18	Install Casing		1
19	Lower tri-cone column		2
20	Drill to required depth		10.88
21	Raise rods, change drill bit for shoe		n/a
22	Straighten borehole, sounding and load borehole		n/a
23	Remove rods and casing		2
24	Number of drillholes per line	8	8
25	Average time required to drill an 8-hole line (hours)	1.52	0.53
26	Rate of perforation per line, per drill tower (feet per minute)	0.32	0.91
27	**Average time required to drill a pattern of 4 lines of 8 boreholes each line (in hours)**	**6.09**	**2.12**
28	Estimated time to move the towers per line (minutes)	3	3
29	Moving time for the drillboat barge (minutes)	17	17
30	Time for setting explosives per bore hole (minutes)	6.67	6.67
31	Total time for setting a line of 8 bore holes (minutes)	13.34	13.34
32	Preparation time for blasting one pattern (minutes)	116.36	116.36
33	**Preparation time for blasting one pattern (hours)**	**1.94**	**1.94**
34	**Total time for activities in addition to drilling (hours)**	**1.50**	**1.50**
35	**Total drilling and blasting time for one pattern (hours)**	**9.53**	**5.56**
36	**Number of patterns per week**	**13**	**16**
37	**Area of progress per week (square meters per week)**	**6,283**	**7,732**
38	Weekly volume (cubic meters)	**27,776**	**34,185**
39	Production percentage ratio	45	55
40	Rate of perforation per pattern, estimated for one tower in feet per minute.	**0.199**	**0.246**
41	**Notes:**		
42	(1) A 13% increase in the productivity of the drillboat THOR was assumed for the times calculated for the THOR.		
43			

STUDY ELEMENT
DEEPENING PROJECT-PLD 37'-27.5'-19.5'
COMPARATIVE TABLE OF DRILLING TIMES
(REVISION No. 21)

Cell: C3
Comment: All times used to define the THOR productivity were obtained from drilling tests made by Dredging Division to different depths in November 2001, and were adjusted to reflect the borehole depth of 14.5'.

Cell: D3
Comment: All times used to define the new barge productivity were obtained from land based TAMROCK performance recorded in the drilling logs provided by Dredging Division. These times were included in this spreadsheet but were not used to estimate the minimum blasting patterns that the new barge could perform weekly.
ACP has estimated that the new barge productivity could increase at 25% more than the THOR as minimum.

Cell: C11
Comment: Volume per pattern was calculated by multiplying the pattern area by the drilling depth.

Cell: D11
Comment: Volume per pattern was calculated by multiplying the pattern area by the drilling depth.

Cell: C14
Comment: Borehole depth from 34' to 19.5' PLD

Cell: C17
Comment: The time recorded in the test was multiplied by a factor of 0.87, to include a 13% increase in the THOR's productivity. The original time recorded was for 15 ft hole and was multiplied by a factor to reflect the actual drilling depth of 14.5 ft.

Cell: C25
Comment: The time recorded in the test was multiplied by a factor of 0.87, to include a 13% increase in the THOR's productivity, and a factor of 0.97 to reflect the actual bore depth of 14.5 ft.

Cell: D25
Comment: Total time in cell No. 17 was multiplied by the number of drill holes per line, and then divided by 4 because 4 towers will be installed in the new drill barge.

Cell: C31
Comment: Total loading time has been divided by four, assuming that the four THOR towers are working simultaneously.

Cell: D31
Comment: Total loading time has been divided by four because the 4 towers will work simultaneously.

Cell: C32
Comment: To calculate the THOR blasting preparation time for one pattern, the following were assumed:
(A) Four movements of the tower, one per line
(B) Three movements of the drillboat, between drilling lines
(C) Four explosive loading of drillholes per tower, one per line

Cell: D32
Comment: To calculate the new barge blasting preparation time for one pattern, the following were assumed:
(A) Four movements of the tower, one per line
(B) Three movements of the drillboat, between drilling lines
(C) Four explosive loading of drillholes per tower, one per line

Cell: C34
Comment: Time estimate based on the experience of underwater drilling personnel.

Cell: D34
Comment: Time estimate based on the experience of underwater drilling personnel.

Cell: C36
Comment: Minimum average number of patterns per week, based on the expirience of underwater drilling personnel.

Cell: D36
Comment: New drill boat productivity has been estimated as a minimum of 25% more than drill boat Thor.

Cell: C37
Comment: Area of progress per week equals the number of patterns per week multiplied by the area of a pattern.

Cell: C38
Comment: Volume of progress per week equals the number of patterns per week multiplied by the volume of one pattern.

DREDGING VOLUMES AND BLASTING AREA
PLD 37'- 27.5'- 19.5'
(REVISION No. 21)

1	B	C	D	E
2	**REACHES**	**Initial Dredging to depths < 51' M.L.L.**		
3		Initial Dredging Area per Reach (mts2)	Dredging Volume from 37' to 34' PLD (mts3)	Tolerance Dredging Volume, from 34' to 32' PLD (mts3)
4	**Gaillard Cut**			
5				
6	Pedro Miguel Reach	80,910	145,462	64,809
7				
8	Paraiso Reach	187,093	201,376	124,538
9				
10	Cucaracha Reach	266,631	175,815	194,168
11				
12	Culebra Reach	418,500	534,127	256,178
13				
14	Empire Reach	218,690	100,219	156,310
15				
16	Cunette Reach	96,534	67,576	81,031
17				
18	Cascadas Reach	307,737	145,740	186,425
19				
20	Bas Obispo Reach	361,305	308,439	320,926
21	**SUBTOTAL**	**1,937,399**	**1,678,754**	**1,384,385**
22				
23	**Gatun Lake**			
24				
25	Chagres Crossing Reach	241,800	142,684	125,220
26				
27	Gamboa Reach	567,998	333,654	468,467
28				
29	Juan Grande Reach	117,366	81,727	74,598
30				
31	Mamei Reach	263,016	215,614	203,008
32				
33	San Pablo Reach	467,976	323,799	432,366
34				
35	Tabernilla Reach	479,183	246,408	595,539
36				
37	Buena Vista Reach	319,734	88,492	249,396
38				
39	Bohío Reach	232,175	95,261	233,503
40				
41	Peña Blanca Reach	103,881	30,832	92,857
42				
43	Gatún Reach	8,370	3,272	2,758
44	**SUBTOTAL**	**2,801,499**	**1,561,743**	**2,477,712**
45	**TOTAL**	**4,738,898**	**3,240,497**	**3,862,097**

DREDGING VOLUMES AND BLASTING AREA
PLD 37'- 27.5'- 19.5'
(REVISION No. 21)

Cell: D3
Comment: The dredging volume was estimated by the Geotechnical Section in November 2002,for Gatun Lake

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Cell: E3
Comment: The volume was estimated by the Geotechnical Section in November 2002.

Cell: C6
Comment: Because initial dredging corresponds to the deepening project to increase water capacity, the current locks alignment is used, which includes 100% of Pedro Miguel Reach.

Cell: C8
Comment: Because initial dredging corresponds to the deepening project to increase water capacity, the current locks alignment is used, which includes 100% of Paraiso Reach.

Cell: C10
Comment: Because Phase 1 corresponds to the deepening project to increase water capacity, the current locks alignment is used, which includes 100% of Cucaracha Reach.

DREDGING VOLUME AND DURATION PER REACH
PLD 37' to 34'-32'
(REVISION No. 21)

1	B	C	D	F	G	H	I
2	**REACHES (BORDADAS)**	**Initial Dredging to depths < 51 M.L.L.**					
3		**Dredging from 37' to 34' PLD**	**Tolerance Dredging, from 34' to 32' PLD**	**Total Initial Dredging Volume (m3)**	**Available Equipment**	**Output (M3 / Week)**	**Duration in Weeks**
4	**Gaillard Cut**						
5							
6	Pedro Miguel Reach	145,462	64,809	210,271	RMC	28,000	**8**
7							
8	Paraiso Reach	201,376	124,538	325,914	RMC	28,000	**12**
9							
10	Cucaracha Reach	175,815	194,168	369,983	RMC	28,000	**13**
11							
12	Culebra Reach	534,127	256,178	790,305	RMC	28,000	**28**
13							
14	Empire Reach	100,219	156,310	256,529	RMC	28,000	**9**
15							
16	Cunette Reach	67,576	81,031	148,607	RMC	28,000	**5**
17							
18	Cascadas Reach	145,740	186,425	332,165	RMC	28,000	**12**
19							
20	Bas Obispo Reach	308,439	320,926	629,365	RMC	28,000	**22**
21	**SUBTOTAL**	**1,678,754**	**1,384,385**	**3,063,139**			**109**
22							
23	**Gatun Lake**						
24							
25	Chagres Crossing Reach	142,684	125,220	267,903	Mindi	28,000	**10**
26							
27	Gamboa Reach	333,654	468,467	802,121	Mindi	28,000	**29**
28							
29	Juan Grande Reach	81,727	74,598	156,325	Mindi	28,000	**6**
30							
31	Mamei Reach	215,614	203,008	418,622	Mindi	28,000	**15**
32							
33	San Pablo Reach	323,799	432,366	756,165	Mindi	28,000	**27**
34							
35	Tabernilla Reach	246,408	595,539	841,947	Mindi	28,000	**30**
36							
37	Buena Vista Reach	88,492	249,396	337,889	Mindi	28,000	**12**
38							
39	Bohío Reach	95,261	233,503	328,764	Mindi	28,000	**12**
40							
41	Peña Blanca Reach	30,832	92,857	123,689	Mindi	28,000	**4**
42							
43	Gatún Reach	3,272	2,758	6,030	Mindi	28,000	**0.22**
44	**SUBTOTAL**	**1,561,743**	**2,477,712**	**4,039,455**			**144**
45	**TOTAL**	**3,240,497**	**3,862,097**	**7,102,594**			**254**

DREDGING VOLUME AND DURATION PER REACH
PLD 37' to 34'-32'
(REVISION No. 21)

Cell: C3
Comment: Value imported from Spreadsheet 2, Column C, corresponding to the dredging volume from 37' to 34', calculated by the Geotechnical Section in November 2002.

Cell: D3
Comment: Value imported from Spreadsheet 2, Column D, corresponding to the dredging volume from 34' to 32', calculated by the Geotechnical Section in November 2002.

Cell: F3
Comment: The Total Final Dredging Volume is the sum of Dredging from 37' to 34' PLD plus the Tolerance Dredging from 34' to 32' PLD.

Cell: G3
Comment: Based on historical experience with similar projects and dredging capability depending on material type, the dredges will be assigned to the Cut and Lake accordingly.

Cell: H3
Comment: Average historical output, provided by Operational Branch of Dredging Division.

Cell: I3
Comment: Duration was calculated by dividing Total Initial Dredging Volume by Average Dredging Output per week per equipment.

DREDGING VOLUME AND COST PER REACH
PLD 37'@ 34'-32' (REVISION No. 21)

1	B	E	F	G	H
2	**REACHES**	Initial Dredging Volume for Dredging from 37' to 32' PLD	Available Equipment	Unit Cost for Dredging	Total Cost per Reach
3					
4	**Gaillard Cut**				
5					
6	Pedro Miguel Reach	210,271	RMC	B/. 10.98	**B/. 2,308,776**
7					
8	Paraiso Reach	325,914	RMC	B/. 10.98	**B/. 3,578,536**
9					
10	Cucaracha Reach	369,983	RMC	B/. 10.98	**B/. 4,062,413**
11					
12	Culebra Reach	790,305	RMC	B/. 10.98	**B/. 8,677,549**
13					
14	Empire Reach	256,529	RMC	B/. 10.98	**B/. 2,816,688**
15					
16	Cunette Reach	148,607	RMC	B/. 10.98	**B/. 1,631,705**
17					
18	Cascadas Reach	332,165	RMC	B/. 10.98	**B/. 3,647,172**
19					
20	Bas Obispo Reach	629,365	RMC	B/. 10.98	**B/. 6,910,428**
21	**SUBTOTAL**	**3,063,139**			**B/. 33,633,266**
22					
23	**Gatun Lake**				
24					
25	Chagres Crossing Reach	267,903	Mindi	B/. 12.57	**B/. 3,367,543**
26					
27	Gamboa Reach	802,121	Mindi	B/. 12.57	**B/. 10,082,661**
28					
29	Juan Grande Reach	156,325	Mindi	B/. 12.57	**B/. 1,965,004**
30					
31	Mamei Reach	418,622	Mindi	B/. 12.57	**B/. 5,262,075**
32					
33	San Pablo Reach	756,165	Mindi	B/. 12.57	**B/. 9,504,995**
34					
35	Tabernilla Reach	841,947	Mindi	B/. 12.57	**B/. 10,583,273**
36					
37	Buena Vista Reach	337,889	Mindi	B/. 12.57	**B/. 4,247,258**
38					
39	Bohío Reach	328,764	Mindi	B/. 12.57	**B/. 4,132,569**
40					
41	Peña Blanca Reach	123,689	Mindi	B/. 12.57	**B/. 1,554,770**
42					
43	Gatún Reach	6,030	Mindi	B/. 12.57	**B/. 75,797**
44	**SUBTOTAL**	**4,039,455**			**B/. 50,775,945**
45	**TOTAL**	**7,102,594**			**B/. 84,409,211**

DREDGING VOLUME AND COST PER REACH
PLD 37'@ 34'-32' (REVISION No. 21)

Cell: E2
Comment: Amount imported from Spreadsheet 3, Column F, corresponding to the Total Dredging Volume for each Reach.

Cell: F2
Comment: Based on the characterization of geologic material, the dredge RMC was assigned to Gaillard Cut and the MINDI was assigned to Gatun Lake.

Cell: G2
Comment: Using the cost per cubic meter analyzed and prepared by the Canal Capacity Projects Division.

Cell: H2
Comment: Total Cost per Reach is the product of the Dredging Volume in Column E multiplied by the Unit Cost for Dredging in Column G.

BLASTING AREA AND DURATION PER REACH
PLD 34'- 19.5'
(REVISION No. 21)

1	B	E	F	G	H	K	L	M	N
2	**REACHES (BORDADAS)**	**Drilling and Blasting - AREA (m2)**			Available Equipment	DURATION IN WEEKS	COST PER WEEK	COST PER REACH	COST PER REACH (including pre-split blasting and aquatic slopes)
3		Area per Reach (mt2)	Percentage of Hard Material	Drilling and Blasting from 34'to 19' PLD (1)					
4	**Gaillard Cut**								
5									
6	Pedro Miguel Reach	0	0.80	0	THOR	0	251,084	0	0
7									
8	Paraiso Reach	0	0.80	0	THOR	0	251,084	0	0
9									
10	Cucaracha Reach	390,657	0.80	312,526	THOR	50	251,084	12,490,240	13,043,721
11									
12	Culebra Reach	481,289	0.60	288,773	THOR	46	251,084	11,540,972	12,052,388
13									
14	Empire Reach	315,566	0.80	252,453	THOR	40	251,084	10,089,401	10,536,493
15									
16	Cunette Reach	160,893	0.60	96,536	THOR	15	251,084	3,858,101	4,029,065
17									
18	Cascadas Reach	344,218	0.70	240,953	THOR	38	251,084	9,629,790	10,056,515
19									
20	Bas Obispo Reach	615,059	0.90	553,553	THOR	88	251,084	22,123,023	23,103,362
21	**SUBTOTAL**	**2,307,682**		**1,744,793**		**278**		**69,731,526**	**72,821,545**
22				76					
23	**Gatun Lake**								
24									
25	Chagres Crossing Reach	318,303	1.00	318,303	THOR	51	251,084	12,721,137	12,721,137
26									
27	Gamboa Reach	1,038,515	0.70	726,961	THOR	116	251,084	29,053,335	29,053,335
28									
29	Juan Grande Reach	317,504	0.60	190,502	4-TOWER	25	251,084	6,185,987	6,185,987
30									
31	Mamei Reach	459,929	0.65	298,954	4-TOWER	39	251,084	9,707,619	9,707,619
32									
33	San Pablo Reach	1,348,025	0.60	808,815	4-TOWER	105	251,084	26,263,811	26,263,811
34									
35	Tabernilla Reach	1,589,612	0.30	476,884	4-TOWER	62	251,084	15,485,347	15,485,347
36									
37	Buena Vista Reach	1,450,086	0.50	725,043	4-TOWER	94	251,084	23,543,570	23,543,570
38									
39	Bohío Reach	921,245	0.50	460,623	4-TOWER	60	251,084	14,957,317	14,957,317
40									
41	Peña Blanca Reach	2,289,371	0.00	0	4-TOWER	0	251,084	0	0
42									
43	Gatún Reach	1,988,096	0.00	0	4-TOWER	0	251,084	0	0
44	**SUBTOTAL**	**11,720,686**		**4,006,084**		**549**		**137,918,123**	**137,918,123**
45	**TOTAL**	**14,028,368**		34				**207,649,649**	**210,739,668**

46 **NotEs:**
47 1- Assuming that 76% of the Gaillard Cut area would require Drilling and Blasting, based on the geological classification of the Cut and dredge captains expirience.
48 2- Assuming that 34% of the Gatun Lake areas would require Drilling and Blasting, based on the geological classificiation of the lake and dredge captains expirience.

BLASTING AREA AND DURATION PER REACH
PLD 34'- 19.5'
(REVISION No. 21)

Cell: L2
Comment: THOR operating costs per week were calculated by dividing the average monthly operation cost ($1,087,195) by 4.33 weeks per month.
To calculate operating cost of a new drillboat with four towers, the THOR cost was used as a reference.

Cell: M2
Comment: The cost per reach is equal to the total duration per reach in weeks (K) multiplied by the operation cost per week (L), including explosives.

Cell: N2
Comment: To include the drilling and blasting work in the aquatic Gaillard Cut slopes and pre-split blasting, the cost per reach was multiplied by a factor of 1.0443, as estimated in sheet 10.

Cell: E3
Comment: Reach area is calculated using AUTOCAD software.

Cell: G3
Comment: Drilling and Blasting area for each reach was calculated by multiplying the area of each reach (Col. E) by the percentage of hard material (Col. F), according to the geological classifications for depths greater than 51' Mean Lake Level.

Cell: E8
Comment: This Reach was not included because of the proposed alignment of new Canal locks. The new alignment would most likely start in Cucarach Reach.

DREDGING VOLUME AND DURATION PER REACH
PLD 32' TO 27.5'-25.5'
(REVISION No. 21)

1	B	D	E	G	H	I	J
2	REACHES	Final Dredging to 27.5' PLD Design Channel Bottom					
3		Dredging from 32' to 27.5' PLD (m3)	Tolerance Dredging, from 27.5' to 25.5' PLD (m3)	Total Volume of Final Dredging Final ($m^{3)}$	AVAILABLE EQUIPMENT	OUTPUT (M^3/WEEK)	DURATION IN WEEKS
4	**Gaillard Cut**						
5							
6	Pedro Miguel Reach	0	0	0	RMC	28,000	**0**
7							
8	Paraiso Reach	0	0	0	RMC	28,000	**0**
9							
10	Cucaracha Reach	685,188	280,513	965,701	RMC	28,000	**34**
11							
12	Culebra Reach	857,874	352,067	1,209,941	RMC	28,000	**43**
13							
14	Empire Reach	553,391	268,196	821,587	RMC	28,000	**29**
15							
16	Cunette Reach	293,677	148,097	441,774	RMC	28,000	**16**
17							
18	Cascadas Reach	695,719	270,499	966,218	RMC	28,000	**35**
19							
20	Bas Obispo Reach	1,154,944	511,139	1,666,083	RMC/MINDI	28,000	**60**
21	**SUBTOTAL**	**4,240,793**	**1,830,511**	**6,071,304**			**217**
22							
23	**Gatun Lake**						
24							
25	Chagres Crossing Reach	307,435	137,290	444,725	Mindi	28,000	**16**
26							
27	Gamboa Reach	1,461,666	654,622	2,116,288	New Dredge	28,000	**76**
28							
29	Juan Grande Reach	269,241	127,020	396,261	Mindi	28,000	**14**
30							
31	Mamei Reach	744,454	352,335	1,096,789	New Dredge	28,000	**39**
32							
33	San Pablo Reach	1,465,138	740,523	2,205,661	Mindi	28,000	**79**
34							
35	Tabernilla Reach	2,209,701	1,109,981	3,319,682	New Dredge	28,000	**119**
36							
37	Buena Vista Reach	864,170	457,441	1,321,611	Mindi	28,000	**47**
38							
39	Bohío Reach	980,940	541,449	1,522,389	New Dredge	28,000	**54**
40							
41	Peña Blanca Reach	572,101	356,113	928,214	New Dredge	28,000	**33**
42							
43	Gatún Reach	6,555	7,066	13,620	New Dredge	28,000	**0**
44	**SUBTOTAL**	**8,881,400**	**4,483,839**	**13,365,239**			**477**
45	**TOTAL**	**13,122,193**	**6,314,350**	**19,436,543**			**694**

DREDGING VOLUME AND DURATION PER REACH
PLD 32' TO 27.5'-25.5'
(REVISION No. 21)

Cell: D3
Comment: The dredging volume was estimated by the Geotechnical Section in November 2002. This volume includes the dredging outside the prism lines with an overswing of 25 ft.

Cell: E3
Comment: The tolerance dredging volume was estimated by the Geotechnical Section in November 2002. This volume includes dredging outside the prism lines with an overswing of 25 ft.

Cell: G3
Comment: The Total Final Dredging Volume is the sum of Dredging from 32' to 27.5' PLD plus the Tolerance Dredging from 27.5' to 25.5' PLD including the volume outside the prism lines with an overswing of 25'.

Cell: I3
Comment: The average historical output for the dredges MINDI and RMC, as reported by Dredging Division, is 28,000 m3/ week.
A new dredge should provide a minimum output of 28,000 m3 per week.

Cell: J3
Comment: Duration in weeks was estimated by dividing the Total Final Dredging Volume (Col. G) by the average output per dredge (Col I).

Cell: D6
Comment: This Reach was not included because of the proposed alignment of new Canal locks. The new alignment would most likely start in Cucarach Reach.

Cell: D8
Comment: This Reach was not included because of the proposed alignment of new Canal locks. The new alignment would most likely start in Cucarach Reach.

DREDGING VOLUME AND AND COST
PLD 32' TO 27.5'-25.5'
(REVISION No. 21)

1	B	D	E	G	H	I	J
2	REACHES (BORDADAS)	Final Dredging to 27.5' PLD Design Channel Bottom					
3		Dredging from 32' to 27.5' PLD (m3)	Tolerance Dredging, from 27.5' to 25.5' PLD	Total Final Dredging Volume Final ($m^{3)}$	AVAILABLE EQUIPMENT	Dredging Cost per Unit	Total Cost per Reach
4	**Gaillard Cut**						
5							
6	Pedro Miguel Reach	0	0	0	RMC	$10.98	**0**
7							
8	Paraiso Reach	0	0	0	RMC	$10.98	**0**
9							
10	Cucaracha Reach	685,188	280,513	965,701	RMC	$10.98	**10,603,397**
11							
12	Culebra Reach	857,874	352,067	1,209,941	RMC	$10.98	**13,285,152**
13							
14	Empire Reach	553,391	268,196	821,587	RMC	$10.98	**9,021,025**
15							
16	Cunette Reach	293,677	148,097	441,774	RMC	$10.98	**4,850,679**
17							
18	Cascadas Reach	695,719	270,499	966,218	RMC	$10.98	**10,609,074**
19							
20	Bas Obispo Reach	1,154,944	511,139	1,666,083	RMC/MINDI		
21					60% RMC	$10.98	**10,976,155**
22					40% MINDI	$12.57	**8,377,065**
23	**SUBTOTAL**	**4,240,793**	**1,830,511**	**6,071,304**			**67,722,547**
24							
25	**Gatun Lake**						
26							
27	Chagres Crossing Reach	307,435	137,290	444,725	Mindi	$12.57	**5,590,195**
28							
29	Gamboa Reach	1,461,666	654,622	2,116,288	Draga Nueva	$12.57	**26,601,739**
30							
31	Juan Grande Reach	269,241	127,020	396,261	Mindi	$12.57	**4,980,994**
32							
33	Mamei Reach	744,454	352,335	1,096,789	Draga Nueva	$12.57	**13,786,643**
34							
35	San Pablo Reach	1,465,138	740,523	2,205,661	Mindi	$12.57	**27,725,158**
36							
37	Tabernilla Reach	2,209,701	1,109,981	3,319,682	Draga Nueva	$12.57	**41,728,401**
38							
39	Buena Vista Reach	864,170	457,441	1,321,611	Mindi	$12.57	**16,612,654**
40							
41	Bohío Reach	980,940	541,449	1,522,389	Draga Nueva	$12.57	**19,136,426**
42							
43	Peña Blanca Reach	572,101	356,113	928,214	Draga Nueva	$12.57	**11,667,644**
44							
45	Gatún Reach	6,555	7,066	13,620	Draga Nueva	$12.57	**171,205**
46	SUBTOTAL	**8,881,400**	**4,483,839**	**13,365,239**			**168,001,059**
47	**TOTAL**	**13,122,193**	**6,314,350**	**19,436,543**			**235,723,605**

DREDGING VOLUME AND AND COST
PLD 32' TO 27.5'-25.5'
(REVISION No. 21)

Cell: D3
Comment: The dredging volume was estimated by the Geotechnical Section in November 2002. This volume includes the dredging outside the prism lines with an overswing of 25 ft.

Cell: E3
Comment: The tolerance dredging volume was estimated by the Geotechnical Section in November 2002. This volume includes dredging outside the prism lines with an overswing of 25 ft.

Cell: G3
Comment: The Total Final Dredging Volume is the sum of Dredging from 32' to 27.5' PLD plus the Tolerance Dredging from 27.5' to 25.5' PLD including the volume outside the prism lines with an overswing of 25'.

Cell: I3
Comment: Using the cost per cubic meter estimated and prepared by the Canal Capacity Projects Division.

Cell: J3
Comment: Total cost per reach is calculated by multiplying Dredging Volume (Column G) by theDredigng Cost per Unit (Column I).

DRY EXCAVATION VOLUME PER REACH
(REVISION No. 21)

1	B	D	E	G	H	I
2	**REACHES (BORDADAS)**	**Dry Excavation**				
3		DRY EXC. FOR 27.5' PLD (m3)	DRY EXC. FOR 25.5' PLD (m3)	AVAILABLE EQUIPMENT	EXACAVATION COST PER UNIT	Total Cost per Reach
4	**Corte Gaillard**					
5						
6	Pedro Miguel Reach	0	0	CONTRACT	$4.00	**0**
7						
8	Paraiso Reach	0	0	CONTRACT	$4.00	**0**
9						
10	Cucaracha Reach	736,304	1,107,495	CONTRACT	$4.00	**4,429,980**
11						
12	Culebra Reach	2,829,896	3,095,581	CONTRACT	$4.00	**12,382,324**
13						
14	Empire Reach	524,876	758,220	CONTRACT	$4.00	**3,032,880**
15						
16	Cunette Reach	146,202	249,524	CONTRACT	$4.00	**998,096**
17						
18	Cascadas Reach	690,506	978,978	CONTRACT	$4.00	**3,915,912**
19						
20	Bas Obispo Reach	350,938	485,915	CONTRACT	$4.00	**1,943,660**
21	**SUBTOTAL**	**5,278,722**	**6,675,713**			**26,702,852**
22						
55						
24	**TOTAL**	**5,278,722**	**6,675,713**			**26,702,852**
25						
26	**SPECIAL WORK AT PURPLE ROCK**					**200,000**
27						
28	**GAILLARD CUT SLOPE DESIGN**					**1,000,000**
56	**GRAND TOTAL**	**5,278,722**	**6,675,713**			**27,902,852**

DRY EXCAVATION VOLUME PER REACH
(REVISION No. 21)

Cell: D3
Comment: Dry excavation estimated by Geotechnical Branch. The dry excavation volume corresponds to the required removal material above 85' PLD to stabilize Gaillard Cut banks due to navigational channel deepening.

Cell: E3
Comment: Dry excavation estimated by Geotechnical Branch. Dry excavation estimated by Geotechnical Branch. The dry excavation volume corresponds to the required removal material above 85' PLD to stabilize Gaillard Cut banks due to navigational channel deepening.

Cell: H3
Comment: Dry excavation unit cost is based from Gaillard Cut Widening Project to 630' historical records

Cell: B26
Comment: Special civil work to contain fragmented material and rock

Cell: I26
Comment: The work at purple work is estimated at a lump sum of $200,000 based on previous experience.

Gaillard Cut Slopes Drilling Blasting
(REVISION No. 21)

PRE-SPLIT GAILALRD CUT - DRILLING AND BLASTING COST ESTIMATE				
Cut Length (mts)	Blasting of Pre-Split Cut (mts)	Amount of Explosive for Pre-Split every 300 mts.	Pre-Split Blasting Unit Cost (B/)	Pre-Split Blasting Total Cost (B/)
11,302	22,604	75	2,500	**188,367**
Costo estimado de Perforación y Voladura de los Taludes-Corte Gaillard				
Slope Area (mt^2)	Cut Length (mt)	Blasting Volume (mt^3)	Blasting Unit Cost (B/./ mt^3)	Blasting Slope Total Cost
51.35	11,302	1,160,661	B/. 2.50	**B/. 2,901,652**
Pre-Split Blasting Total Cost plus Slope Blasting				**B/. 3,090,019**
Percentage Relationship with respect to D&B cost at Gaillard Cut from 34' to 19.5' PLD =				**4%**

Gaillard Cut Slopes Drilling Blasting
(REVISION No. 21)

Cell: A1
Comment: The drilling and blasting for Gaillard Cut East and West banks pre-split is required for proper dredging.

Cell: A3
Comment: Cut length corresponds the longitudinal distance from Bas Obispo to Cucaracha Reach.

Cell: B3
Comment: 11,302 multiplied by 2 since Gaillard Cut east and west banks will require drilling and blasting for dredging

Cell: C3
Comment: The total Gaillard Cut length is divided by 300 meters because the Pre-split explosive unit cost is for each 300 meters

Cell: A7
Comment: Gaillard Cut slope areas consists of 2 meter inside the bank multiplied by its hypotenuse (60' * 1.41)

Cell: C7
Comment: Total Gaillard Cut slope volume is slope area (cell A7) multiplied by the length (cell B7) times 2 (East and West Banks)

Cell: D7
Comment: Land drilling and blasting unit cost estimated by Dredging Division based on Gaillard Cut Widening to 630' Project

STUDY ELEMENT
DEEPENING PROJECT-PLD 37'- 34'- 26'
COMPARATIVE TABLE OF DRILLING TIMES
(REVISION No. 21)

1	B	C	D
2	**DRILLING AND BLASTING**		
3	**DESCRIPTION**	**THOR**	**4-TOWER**
4	Drilling level	PLD-26'	PLD-26'
5	**Drilling Grid (feet); Spacing=12.5'; Burden=13'.**	**12.5' x 13'**	**12.5' x 13'**
6	**Actual pattern area (feet)**	**100' x 52'**	**100' x 52'**
7	Drilling spacing (feet)	12.5	12.5
8	Spacing between drilling rows (feet)	13	13
9	Pattern length (feet)	**100**	**100**
10	Pattern width (feet)	**52**	**52**
11	Volume per pattern (cubic meters)	1179	1179
12	Number of patterns	1	1
13	Number of rows	4	4
14	Drill depth (feet)	8	8
15	Number of passes	N / A	N / A
16	Average time to connect additional drill pipe (minutes)	N / A	N / A
17	Average time to drill a blasting hole (minutes)-(1)	11.41	11.00
18	Install Casing		1
19	Lower tri-cone column		2
20	Drill to required depth		6.00
21	Raise rods, change drill bit for shoe		n/a
22	Straighten borehole, sounding and load borehole		n/a
23	Remove rods and casing		2
24	Number of drillholes per line	8	8
25	Average time required to drill an 8-hole line (hours)	0.84	0.37
26	Rate of perforation per line, per drill tower (feet per minute)	0.32	0.73
27	**Average time required to drill a pattern of 4 lines of 8 boreholes each line (in hours)**	**3.36**	**1.47**
28	Estimated time to move the towers per line (minutes)	3	3
29	Moving time for the drillboat barge (minutes)	17	17
30	Time for setting explosives per bore hole (minutes)	6.67	6.67
31	Total time for setting a line of 8 bore holes (minutes)	13.34	13.34
32	Preparation time for blasting one pattern (minutes)	116.36	116.36
33	**Preparation time for blasting one pattern (hours)**	**1.94**	**1.94**
34	**Total time for activities in addition to drilling (hours)**	**1.50**	**1.50**
35	**Total drilling and blasting time for one pattern (hours)**	**6.80**	**4.91**
36	**Number of patterns per week**	**18**	**23**
37	**Area of progress per week (square meters per week)**	**8,699**	**11,115**
38	Weekly volume (cubic meters)	**21,218**	**27,112**
39	Production percentage ratio	44	56
40	Rate of perforation per pattern, estimated for one tower in feet per minute.	**0.152**	**0.195**
41	**Notes:**		
42	(1) A 13% increase in the productivity of the drillboat THOR was assumed for the times calculated for the THOR.		
43			

STUDY ELEMENT
DEEPENING PROJECT-PLD 37'- 34'- 26'
COMPARATIVE TABLE OF DRILLING TIMES
(REVISION No. 21)

Cell: C3
Comment: All times used to define the THOR productivity were obtained from drilling tests made by Dredging Division to different depths in November 2001, and were adjusted to reflect the borehole depth of 14.5'.

Cell: D3
Comment: All times used to define the new barge productivity were obtained from land based TAMROCK performance recorded in the drilling logs provided by Dredging Division. These times were included in this spreadsheet but were not used to estimate the minimum blasting patterns that the new barge could perform weekly.
ACP has estimated that the new barge productivity could increase at 25% more than the THOR as minimum.

Cell: C11
Comment: Volume per pattern was calculated by multiplying the pattern area by the drilling depth.

Cell: D11
Comment: Volume per pattern was calculated by multiplying the pattern area by the drilling depth.

Cell: C14
Comment: Borehole depth from 34' to 26' PLD

Cell: C17
Comment: The time recorded in the test was multiplied by a factor of 0.87, to include a 13% increase in the THOR's productivity. The original time recorded was for 15 ft hole and was multiplied by a factor to reflect the actual drilling depth of 8 ft.

Cell: C25
Comment: The time recorded in the test was multiplied by a factor of 0.87, to include a 13% increase in the THOR's productivity, and a factor of 0.53 to reflect the actual bore depth of 8 ft.

Cell: D25
Comment: Total time in cell No. 17 was multiplied by the number of drill holes per line, and then divided by 4 because 4 towers will be installed in the new drill barge.

Cell: C31
Comment: Total loading time has been divided by four, assuming that the four THOR towers are working simultaneously.

Cell: D31
Comment: Total loading time has been divided by four because the 4 towers will work simultaneously.

Cell: C32
Comment: To calculate the THOR blasting preparation time for one pattern, the following were assumed:
(A) Four movements of the tower, one per line
(B) Three movements of the drillboat, between drilling lines
(C) Four explosive loading of drillholes per tower, one per line

Cell: D32
Comment: To calculate the new barge blasting preparation time for one pattern, the following were assumed:
(A) Four movements of the tower, one per line
(B) Three movements of the drillboat, between drilling lines
(C) Four explosive loading of drillholes per tower, one per line

Cell: C34
Comment: Time estimate based on the experience of underwater drilling personnel.

Cell: D34
Comment: Time estimate based on the experience of underwater drilling personnel.

Cell: C36
Comment: Minimum average number of patterns per week, based on the expirience of underwater drilling personnel.

Cell: D36
Comment: New drill boat productivity has been estimated as a minimum of 25% more than drill boat Thor.

Cell: C37
Comment: Area of progress per week equals the number of patterns per week multiplied by the area of a pattern.

Cell: C38
Comment: Volume of progress per week equals the number of patterns per week multiplied by the volume of one pattern.

DREDGING VOLUMES AND BLASTING AREA
PLD 37'- 34'- 26'
(REVISION No. 21)

A	B	C	D	E
2	**REACHES**	Area per Reach (mts2)	Dredging Volume from 37' to 34' PLD (mts3)	Tolerance Dredging Volume, from 34' to 32' PLD (mts3)
3	**Gaillard Cut**			
4				
5	Pedro Miguel Reach	80,910	145,462	64,809
6				
7	Paraiso Reach	187,093	201,376	124,538
8				
9	Cucaracha Reach	266,631	175,815	194,168
10				
11	Culebra Reach	418,500	534,127	256,178
12				
13	Empire Reach	218,690	100,219	156,310
14				
15	Cunette Reach	96,534	67,576	81,031
16				
17	Cascadas Reach	307,737	145,740	186,425
18				
19	Bas Obispo Reach	361,305	308,439	320,926
20	**SUBTOTAL**	**1,937,399**	**1,678,754**	**1,384,385**
21				
22	**Gatun Lake**			
23				
24	Chagres Crossing Reach	241,800	142,684	125,220
25				
26	Gamboa Reach	567,998	333,654	468,467
27				
28	Juan Grande Reach	117,366	81,727	74,598
29				
30	Mamei Reach	263,016	215,614	203,008
31				
32	San Pablo Reach	467,976	323,799	432,366
33				
34	Tabernilla Reach	479,183	246,408	595,539
35				
36	Buena Vista Reach	319,734	88,492	249,396
37				
38	Bohío Reach	232,175	95,261	233,503
39				
40	Peña Blanca Reach	103,881	30,832	92,857
41				
42	Gatún Reach	8,370	3,272	2,758
43	**SUBTOTAL**	**2,801,497**	**1,561,743**	**2,477,712**
44	**TOTAL**	**4,738,896**	**3,240,497**	**3,862,097**

DREDGING VOLUMES AND BLASTING AREA
PLD 37'- 34'- 26'
(REVISION No. 21)

Cell: D2
Comment: The dredging volume was estimated by the Geotechnical Section in November 2002.

Cell: E2
Comment: The volume was estimated by the Geotechnical Section in November 2002.

Cell: C5
Comment: Because initial dredging corresponds to the deepening project to increase water capacity, the current locks alignment is used, which includes 100% of Pedro Miguel Reach.

Cell: C7
Comment: Because initial dredging corresponds to the deepening project to increase water capacity, the current locks alignment is used, which includes 100% of Paraiso Reach.

Cell: C9
Comment: Because Phase 1 corresponds to the deepening project to increase water capacity, the current locks alignment is used, which includes 100% of Cucaracha Reach.

DREDGING VOLUME AND DURATION PER REACH
PLD 37' to 34'-32'
(REVISION No. 21)

A	B	C	D	F	G	H	I
2	**REACHES (BORDADAS)**	**Dredging from 37' to 34' PLD**	**Tolerance Dredging, from 34' to 32' PLD**	**Total Dredging Volume (m3)**	**Available Equipment**	**Output (M3 / Week)**	**Duration in Weeks**
3	**Gaillard Cut**						
4							
5	Pedro Miguel Reach	145,462	64,809	210,271	RMC	28,000	**8**
6							
7	Paraiso Reach	201,376	124,538	325,914	RMC	28,000	**12**
8							
9	Cucaracha Reach	175,815	194,168	369,983	RMC	28,000	**13**
10							
11	Culebra Reach	534,127	256,178	790,305	RMC	28,000	**28**
12							
13	Empire Reach	100,219	156,310	256,529	RMC	28,000	**9**
14							
15	Cunette Reach	67,576	81,031	148,607	RMC	28,000	**5**
16							
17	Cascadas Reach	145,740	186,425	332,165	RMC	28,000	**12**
18							
19	Bas Obispo Reach	308,439	320,926	629,365	RMC	28,000	**22**
20	**SUBTOTAL**	**1,678,754**	**1,384,385**	**3,063,139**			**109**
21							
22	**Gatun Lake**						
23							
24	Chagres Crossing Reach	142,684	125,220	267,904	Mindi	28,000	**10**
25							
26	Gamboa Reach	333,654	468,467	802,121	Mindi	28,000	**29**
27							
28	Juan Grande Reach	81,727	74,598	156,325	Mindi	28,000	**6**
29							
30	Mamei Reach	215,614	203,008	418,622	Mindi	28,000	**15**
31							
32	San Pablo Reach	323,799	432,366	756,165	Mindi	28,000	**27**
33							
34	Tabernilla Reach	246,408	595,539	841,947	Mindi	28,000	**30**
35							
36	Buena Vista Reach	88,492	249,396	337,888	Mindi	28,000	**12**
37							
38	Bohío Reach	95,261	233,503	328,764	Mindi	28,000	**12**
39							
40	Peña Blanca Reach	30,832	92,857	123,689	Mindi	28,000	**4**
41							
42	Gatún Reach	3,272	2,758	6,030	Mindi	28,000	**0.22**
43	**SUBTOTAL**	**1,561,743**	**2,477,712**	**4,039,455**			**144**
44	**TOTAL**	**3,240,497**	**3,862,097**	**7,102,594**			**254**

DREDGING VOLUME AND DURATION PER REACH
PLD 37' to 34'-32'
(REVISION No. 21)

Cell: C2
Comment: Value imported from Spreadsheet 2, Column C, corresponding to the dredging volume from 37' to 34', calculated by the Geotechnical Section in November 2002.

Cell: D2
Comment: Value imported from Spreadsheet 2, Column D, corresponding to the dredging volume from 34' to 32', calculated by the Geotechnical Section in November 2002.

Cell: F2
Comment: The Total Final Dredging Volume is the sum of Dredging from 37' to 34' PLD plus the Tolerance Dredging from 34' to 32' PLD.

Cell: G2
Comment: Based on historical experience with similar projects and dredging capability depending on material type, the dredges will be assigned to the Cut and Lake accordingly.

Cell: H2
Comment: Average historical output, provided by Operational Branch of Dredging Division.

Cell: I2
Comment: Duration was calculated by dividing Total Initial Dredging Volume by Average Dredging Output per week per equipment.

DREDGING VOLUME AND COST PER REACH
PLD 37'@ 34'-32' (REVISION No. 21)

1	B	E	F	G	H
2	**REACHES**	Volume for Dredging from 37' to 32' PLD	Available Equipment	Unit Cost for Dredging	Total Cost per Reach
3					
4	**Gaillard Cut**				
5					
6	Pedro Miguel Reach	210,271	RMC	B/. 10.98	**B/. 2,308,775.58**
7					
8	Paraiso Reach	325,914	RMC	B/. 10.98	**B/. 3,578,535.72**
9					
10	Cucaracha Reach	369,983	RMC	B/. 10.98	**B/. 4,062,413.34**
11					
12	Culebra Reach	790,305	RMC	B/. 10.98	**B/. 8,677,548.90**
13					
14	Empire Reach	256,529	RMC	B/. 10.98	**B/. 2,816,688.42**
15					
16	Cunette Reach	148,607	RMC	B/. 10.98	**B/. 1,631,704.86**
17					
18	Cascadas Reach	332,165	RMC	B/. 10.98	**B/. 3,647,171.70**
19					
20	Bas Obispo Reach	629,365	RMC	B/. 10.98	**B/. 6,910,427.70**
21	**SUBTOTAL**	**3,063,139**			**B/. 33,633,266.22**
22					
23	**Gatun Lake**				
24					
25	Chagres Crossing Reach	267,904	Mindi	B/. 12.57	**B/. 3,367,553.28**
26					
27	Gamboa Reach	802,121	Mindi	B/. 12.57	**B/. 10,082,660.97**
28					
29	Juan Grande Reach	156,325	Mindi	B/. 12.57	**B/. 1,965,005.25**
30					
31	Mamei Reach	418,622	Mindi	B/. 12.57	**B/. 5,262,078.54**
32					
33	San Pablo Reach	756,165	Mindi	B/. 12.57	**B/. 9,504,994.05**
34					
35	Tabernilla Reach	841,947	Mindi	B/. 12.57	**B/. 10,583,273.79**
36					
37	Buena Vista Reach	337,888	Mindi	B/. 12.57	**B/. 4,247,252.16**
38					
39	Bohío Reach	328,764	Mindi	B/. 12.57	**B/. 4,132,563.48**
40					
41	Peña Blanca Reach	123,689	Mindi	B/. 12.57	**B/. 1,554,770.73**
42					
43	Gatún Reach	6,030	Mindi	B/. 12.57	**B/. 75,797.10**
44	**SUBTOTAL**	**4,039,455**			**B/. 50,775,949.35**
45	**TOTAL**	**7,102,594**			**B/. 84,409,216**

DREDGING VOLUME AND COST PER REACH
PLD 37'@ 34'-32' (REVISION No. 21)

Cell: E2
Comment: Amount imported from Spreadsheet 3, Column F, corresponding to the Total Dredging Volume for each Reach.

Cell: F2
Comment: Based on the characterization of geologic material, the dredge RMC was assigned to Gaillard Cut and the MINDI was assigned to Gatun Lake.

Cell: G2
Comment: Using the cost per cubic meter analyzed and prepared by the Canal Capacity Projects Division.

Cell: H2
Comment: Total Cost per Reach is the product of the Dredging Volume in Column E multiplied by the Unit Cost for Dredging in Column G.

BLASTING AREA AND DURATION PER REACH
PLD 34'- 26'
(REVISION No. 21)

1	B	E	F	G	H	I	K
2	**REACHES (BORDADAS)**	**Drilling & Blasting - AREA (m2)**			Available Equipment	OUTPUT OF THE EQUIPMENT (MT2/WEEK) PATTERN 100' x 52'	DURATION IN WEEKS
3		Area per Reach (mt2)	Percentage of Hard Material Area	Drilling and Blasting from 34' to 26' PLD (1)		Output - Area	
4	**Gaillard Cut**						
5							
6	Pedro Miguel Reach	80,910	0.80	64,728	THOR	8,699	7
7							
8	Paraiso Reach	187,093	0.80	149,674	THOR	8,699	17
9							
10	Cucaracha Reach	266,631	0.80	213,305	THOR	8,699	25
11							
12	Culebra Reach	418,500	0.60	251,100	THOR	8,699	29
13							
14	Empire Reach	218,690	0.80	174,952	THOR	8,699	20
15							
16	Cunette Reach	96,534	0.60	57,920	THOR	8,699	7
17							
18	Cascadas Reach	307,737	0.70	215,416	THOR	8,699	25
19							
20	Bas Obispo Reach	361,305	0.90	325,175	THOR	8,699	37
21	**SUBTOTAL**	**1,937,400**		**1,452,270**			**167**
22				75			
23	**Gatun Lake**						
24							
25	Chagres Crossing Reach	241,800	1.00	241,800	THOR	8,699	28
26							
27	Gamboa Reach	567,998	0.70	397,599	4-TOWER	11,115	36
28							
29	Juan Grande Reach	117,366	0.60	70,420	4-TOWER	11,115	6
30							
31	Mamei Reach	263,016	0.65	170,960	4-TOWER	11,115	15
32							
33	San Pablo Reach	467,976	0.60	280,786	4-TOWER	11,115	25
34							
35	Tabernilla Reach	479,183	0.30	143,755	4-TOWER	11,115	13
36							
37	Buena Vista Reach	319,734	0.50	159,867	4-TOWER	11,115	14
38							
39	Bohío Reach	232,175	0.50	116,088	4-TOWER	11,115	10
40							
41	Peña Blanca Reach	103,881	0.00	0	4-TOWER	11,115	0
42							
43	Gatún Reach	8,370	0.00	0	4-TOWER	11,115	0
44							
45	**SUBTOTAL**	**2,801,499**		**1,581,274**			**148**
46	**TOTAL**	**4,738,899**		56			**315**

47 **Notas:**
48 1- Assuming that 75% of the Gaillard Cut area would require Drilling and Blasting, based on the geological classification of the Cut and dredge captain expirience.
49 2- Assuming that 56% of the Gatun Lake areas would require Drilling and Blasting, based on the geological classificiation of the lake and dredge captains expirience.

BLASTING AREA AND DURATION PER REACH
PLD 34'- 26'
(REVISION No. 21)

Cell: I2
Comment: Output values correspond to the equipment productivity by areas of progress determined in Spreadsheet No. 1, Comparative table of drilling times for the THOR and the new drillboat with four towers.

Cell: E3
Comment: Reach area is calculated using AUTOCAD software.

Cell: F3
Comment: Percentages based on dry and sub-aquatic excavation geological maps from Gaillard Cut Widening Project to 630', and RMC and MINDI Captain dredging experience in the Canal.

Cell: G3
Comment: Drilling and Blasting area for each reach was calculated by multiplying the area of each reach (Col. E) by the percentage of hard material, according to the geological classifications for depths greater than 51' Mean Lake Level.

Cell: I3
Comment: Output is the number of drilling patterns per week multiplied by the area of a pattern of 100' by 52'.

BLASTING AREA AND DURATION PER REACH
PLD 34'- 26'
(REVISION No. 21)

1	B	E	F	G	H	K	L	M
2	**REACHES (BORDADAS)**	**Drilling and Blasting - AREA (m2)**			Available Equipment	DURATION IN WEEKS	COST PER WEEK	COST PER REACH
3		Area per Reach (mt2)	Percentage of Hard Material	Drilling and Blasting from 34'to 26' PLD (1)				
4	**Gaillard Cut**							
5								
6	Pedro Miguel Reach	80,910	0.80	64,728	THOR	7	251,084	1,868,307
7								
8	Paraiso Reach	187,093	0.80	149,674	THOR	17	251,084	4,320,197
9								
10	Cucaracha Reach	266,631	0.80	213,305	THOR	25	251,084	6,156,823
11								
12	Culebra Reach	418,500	0.60	251,100	THOR	29	251,084	7,247,742
13								
14	Empire Reach	218,690	0.80	174,952	THOR	20	251,084	5,049,809
15								
16	Cunette Reach	96,534	0.60	57,920	THOR	7	251,084	1,671,813
17								
18	Cascadas Reach	307,737	0.70	215,416	THOR	25	251,084	6,217,758
19								
20	Bas Obispo Reach	361,305	0.90	325,175	THOR	37	251,084	9,385,826
21	**SUBTOTAL**	**1,937,400**		**1,452,270**		**167**		**41,918,275**
22				75				
23	**Gatun Lake**							
24								
25	Chagres Crossing Reach	241,800	1.00	241,800	THOR	28	251,084	6,979,307
26								
27	Gamboa Reach	567,998	0.70	397,599	4-TOWER	36	251,084	8,981,431
28								
29	Juan Grande Reach	117,366	0.60	70,420	4-TOWER	6	251,084	1,590,722
30								
31	Mamei Reach	263,016	0.65	170,960	4-TOWER	15	251,084	3,861,857
32								
33	San Pablo Reach	467,976	0.60	280,786	4-TOWER	25	251,084	6,342,720
34								
35	Tabernilla Reach	479,183	0.30	143,755	4-TOWER	13	251,084	3,247,307
36								
37	Buena Vista Reach	319,734	0.50	159,867	4-TOWER	14	251,084	3,611,266
38								
39	Bohío Reach	232,175	0.50	116,088	4-TOWER	10	251,084	2,622,323
40								
41	Peña Blanca Reach	103,881	0.00	0	4-TOWER	0	251,084	0
42								
43	Gatún Reach	8,370	0.00	0	4-TOWER	0	251,084	0
44	**SUBTOTAL**	**2,801,499**		**1,581,274**		**148**		**37,236,934**
45	**TOTAL**	**4,738,899**		56		**315**		**79,155,209**

46 **Notes:**

47 1- Assuming that 75% of the Gaillard Cut area would require Drilling and Blasting, based on the geological classification of the Cut and dredge captains expirience.

48 2- Assuming that 56% of the Gatun Lake areas would require Drilling and Blasting, based on the geological classificiation of the lake and dredge captains expirience.

BLASTING AREA AND DURATION PER REACH
PLD 34'- 26'
(REVISION No. 21)

Cell: L2
Comment: THOR operating costs per week were calculated by dividing the average monthly operation cost ($1,087,195) by 4.33 weeks per month.
To calculate operating cost of a new drillboat with four towers, the THOR cost was used as a reference.

Cell: M2
Comment: The cost per reach is equal to the total duration per reach in weeks (K) multiplied by the operation cost per week (L), including explosives.

Cell: E3
Comment: Reach area is calculated using AUTOCAD software.

Cell: G3
Comment: Drilling and Blasting area for each reach was calculated by multiplying the area of each reach (Col. E) by the percentage of hard material (Col. F).

APPENDIX No. 6

Dipper Dredge CHRISTENSEN Cost

"CHRISTENSEN" DREDGE

Overhead	12%
Employee Benefits	38%
Night Shift Differential	10%
Complementary Sunday	25%
Overtime	50%

DAY CREW

On-deck Department:	Grado	No.	Tarifa por hora	Tarifa total por hora	Annual Rate	With Benefits Annually	Ten hours/each of 2 weeks with benefits annually	Eight hours overtime weekly with benefits annually
Captain in Charge	FE-17	1	$ 34.21	$ 34.21	$ 71,157	$ 98,211	$ 18,414	$ 29,463
Welder	MG-10	1	17.56	17.56	36,525	50,412	9,452	15,123
Laborer	MG-03	1	5.75	5.75	11,960	16,507	3,095	4,952
Seaman	MG-07	2	6.96	13.92	28,954	39,962	7,493	11,989
Subtotal		**5**		**$ 71.44**	**148,595**	**205,091**	**38,455**	**61,527**
Engine Department:								
Chief Engineer	ME-16	1	$ 32.02	$ 32.02	$ 66,602	$ 91,924	$ 17,236	$ 27,577
Deputy Chief Engineer	ME-15	1	29.99	29.99	62,379	86,096	16,143	25,829
Electrician	FE-11	1	24.35	24.35	50,648	69,904	13,107	20,971
Machinist	MG-10	1	17.56	17.56	36,525	50,412	9,452	15,123
Nautical Equipment Mechanic	MG-10	1	17.56	17.56	36,525	50,412	9,452	15,123
Electrical Equipment Repairer	MG-09	1	11.12	11.12	23,130	31,923	5,986	9,577
Subtotal		**6**		**132.60**	**275,808**	**380,670**	**71,376**	**114,201**
TOTAL- DAY CREW		**11**		**$ 204.04**	**424,403**	**585,761**	**109,830**	**175,728**
ROTATION CREW								
On-deck Department:								
Dredge Operator	FE-14	1	$ 28.15	$ 28.15	$ 58,552	$ 80,813	$ 15,153	$ 24,244
Dredge Officer	FE-11	1	24.35	24.35	50,648	69,904	13,107	20,971
First Dredge Seaman	ML-08	1	9.74	9.74	20,259	27,962	5,243	8,389
Winch Operator	MG-08	1	8.25	8.25	17,160	23,684	4,441	7,105
Dredge Seaman	MG-07	4	6.96	27.84	57,907	79,924	14,986	23,977
Subtotal		**8**		**$ 98.33**	**204,526**	**282,287**	**52,929**	**84,686**
Engine Department:								
Dredge Engineer	ME-14	1	$ 28.15	$ 28.15	$ 58,552	$ 80,813	$ 15,153	$ 24,244
Oiler	MG-08	2	8.25	16.50	34,320	47,368	8,882	14,211
Subtotal		**3**		**$ 44.65**	**92,872**	**128,182**	**24,034**	**38,455**
SUBTOTAL- ROTATION CREW		**11**		**$ 142.98**	**297,398**	**410,469**	**76,963**	**123,141**
BARGE STATION								
On-deck Department:								
Dredge Seaman Leader	ML-08	1	$ 9.74	$ 9.74	$ 20,259	$ 27,962	$ 5,243	$ 8,389
Dredge Seaman	MG-07	2	6.96	13.92	28,954	39,962	7,493	11,989
Engine Department:								

Repairers	MG-09	5	$ 11.12	$ 55.60	$ 115,648	$ 159,617	$ 29,928	$ 47,885
SUBTOTAL- ROTATING CREW		**8**		**$ 79.26**	**164,861**	**227,541**	**42,664**	**68,262**
TOTAL - ROTATING CREW		**19**		**$ 222.24**	**462,259**	**638,010**	**119,627**	**191,403**
TOTAL - 4 ROTATING CREWS					**1,849,037**	**2,552,041**	**588,338**	**941,341**
TOTAL - 5 ROTATING CREWS					**2,311,296**	**3,190,051**		
TOTAL WITH 4 CREWS, 1 DAY AND OVERTIME							**3,835,970**	**4,254,871**
							438	**486**
TOTAL WITH 5 CREWS, 1 DAY, AND NO OVERTIME						**3,775,812**		
						431		

Total Average Rate with cargo - 4 rotating crews and 8 hours overtime per week for each crew

Monday to Friday	547.37	
Saturday	425.34	
Sunday	531.68	
Total Average Rate per hour	**$ 527.70**	**4,622,632**

Total Average Rate with cargo - 5 rotating crews and 1 hour overtime per week

Monday to Friday	542.93	
Saturday	445.53	
Sunday	556.92	
Total Average Rate per hour	**$ 531.01**	**4,651,659**

1/ There are 5 steps in each hourly wage grade, and the rate of the last step was used.

2/ Employee benefits were figured at 38.02% of the average hourly wages

3/ Included in the average hourly wages were 10% for night differential, 25% for complementary Sunday and 50% for overtime.

4/ Eight hours of overtime a week were included for each crew.

Div Ovh 12%

Dredging Division - Christensen Dipper Dredge-

Expenses	FY 1995 Actual	FY 1996 Actual	FY 1997 Actual	FY 1998 Actual	Estimated Annual	
Labor	$ -	$ -			$ -	
Materials/Supplies (excluding fuel)	286,583	407,158	1,031,000	835,000	639,935	1/
Other Direct Expenses	9,352	270,295			139,823	
General Maintenance	96,786	197,600	331,000	593,000	304,597	
Indirect Maintenance CC 556					79,200	2/
Overhaul Expenses	16,375	596,588			306,482	
Maritime Insurance					39,020	3/
Depreciation	442,720	432,317	417,209	415,198	426,861	4/
Total	$851,816	$1,903,958	$1,779,209	$ 1,843,198	$ 1,935,918	

Annual Estimate	$ 1,935,918
Number of available days	270
Daily Cost for Availability without crew (demand)	$ 7,170
Hourly Cost for Availability without crew (demand)	**$ 299**

	Inter-Divisional	Capital (includes Division Overhead)	Com-mercial (w/RGG)
Hourly Cost for Availability	$ 299	$ 299	$ 406
On-Call Crew - Hourly Cost	$ 204	$ 229	$ 311
Total Hourly Cost for Availability	**$ 503**	**$ 527**	**$ 717**
Hourly Cost for Availability	$ 299	$ 299	$ 406
Operations Crew - hourly cost	$ 531	$ 595	$ 809
Hourly Cost of fuel	$ 55 5/	$ 55	$ 75
Hourly Cost of operation (excluding support equipment)	**$ 885**	**$ 948**	**$ 1,290**
Large Tug Support	$ 341	$ 365	$ 496
Small Tug Support	$ 106	$ 112	$ 152
Mid-size Tug Support	$ 202	$ 217	$ 295
Guard or Passenger Support Boat	$ 68	$ 74	$ 100
Launch Support for disposal of dredged material	$ 77	$ 87	$ 118
Hydrography Services Suport (2 days a week - day shift)	$ 13	$ 14	$ 18
Hourly Cost of operation (including support equipment)	**$ 1,692**	**$ 1,817**	**$ 2,470**

Mobilization Rate

Hourly Cost for Availability (without crew)	$ 299	$ 299	$ 406
Hourly Cost of Operations Crew	$ 531	$ 595	$ 809
Hourly Cost for Pilot (required to mobilize dredge)	$ 45	$ 51	$ 69
Cost of a large tug to move dredge	$ 341	$ 365	$ 496
Cost of a small tug to move dredge	$ 106	$ 112	$ 152
Cost of a mid-size tug to move dredge	$ 202	$ 217	$ 295
Total Hourly Mobilization Rate	**$ 1,525**	**$ 1,639**	**$ 2,228**

1/Approximately 8.5% of the purchase of supplies and materials are for the barges.

2/ Support Distribution of "other 554" is based on an assignment of 58% of the costs of the costs center. This percentage was determined for 554, based on the effort of 556 in accordance with the JCS report.

3/ The cost of the maritime insurance paid by ACP in 2002 was proportionately allotted to all insured floating equipment.

4/ The depreciation includes the dredge and its improvements, as well as the 5 barges for disposal of dredged material. Sixty-four percent of the depreciation is allotted to the 5 barges.

5/ Average consumption of 50 gallons an hour at $1.10 a gallon.

DREDGING RATE FOR THE "CHRISTENSEN" FOR A HAULING DISTANCE OF UP TO 20 KMS.

Inflation Conversion Factor 1.023

Division Overhead 12%

		Total Costs		Incidental Costs
Hourly Cost for Availability	$	306		n.a.
Hourly cost of labor		531		531
Indirect Costs related to labor		64		64
Average Hourly Cost of Fuel		56	/1	56
Large tugboat Support		373		373
Mid-size tugboat Support		222		222
Small tugboat Support		115		115
Guard or Passenger Boat Support		75		75
Launch Support for Disposal Sites		89		89
Launch Support for Hydrographies		14		14
Support Subtotal		888		888
Total	**$**	**1,845**	**$**	**1,539**
Cost by Shift				
Cost for Availability for 8 hours	$	2,445		n.a.
Cost of Labor for 8 hours		4,758		4,758
Fuel Consumption for 6 hours		338	/2	338
Support for 8 hours		7,105		7,105
Total Cost by Shift	**$**	**14,645**		**12,200**
Daily Cost				
Cost for Availability		7,335		n.a.
Cost of Labor		14,274		14,274
Fuel Consumption		1,013		1,013
Support		21,314		21,314
Total Cost per Day	**$**	**43,935**		**$36,600**
Weekly Cost				
Cost for Availability		51,345		n.a.
Cost of Labor		99,915		99,915
Fuel Consumption		7,089		7,089
Support		149,195		149,195
Total Cost per Week	**$**	**307,545**		**$256,200**

Estimated Weekly Volume of Excavation (Cubic Meters in Bank)	
Productivity a	**30,000**
Productivity b	**28,000**

Cost of Cubic Meter in Bank			
Productivity a	**$**	**10.25**	**$8.54**
Productivity b	**$**	**10.98**	**$9.15**

1/ Average Consumption of 50 gallons/hour, $1.10/gallon

2/ It was assumed that the CHRISTENSEN would have an average of 6 idle hours a day; therefore, the dredge would be consuming fuel for 18 hours daily, or an average of 6 hours each shift.

APPENDIX No. 7

Cutter Suction MINDI Costs

"MINDI" DREDGE

Overhead	12%
Employee Benefits	38%
Night Shift Differential	10%
Complementary Sunday	25%
Overtime	50%

DAY SHIFT

On Deck Department:	Grade	No.	Hourly Rate	Total Hourly Rate	Annual Rate	With Benefits Annually	5 hours weekly with benefits annually	8 hours overtime weekly with benefits annually
Captain in charge	FE-17	1	$ 34.21	$ 34.21	$ 71,157	$ 98,211	$ 18,414	$ 29,463
Welder	MG-10	3	17.56	52.68	109,574	151,235	28,356	45,370
Seaman	MG-07	1	6.96	6.96	14,477	19,981	3,746	5,994
Laborer	MG-03	1	5.75	5.75	11,960	16,507	3,095	4,952
Subtotal		**6**		**$ 99.60**	**207,168**	**285,933**	**53,612**	**85,780**
Engine Department:								
Chief Engineer	ME-16	1	$ 32.02	$ 32.02	$ 66,602	$ 91,924	$ 17,236	$ 27,577
Deputy Chief Engineer	ME-15	1	29.99	29.99	62,379	86,096	16,143	25,829
Engineer	ME-14	1	28.15	28.15	58,552	80,813	15,153	24,244
Electrician	FE-11	1	24.35	24.35	50,648	69,904	13,107	20,971
Machinist	MG-10	1	17.56	17.56	36,525	50,412	9,452	15,123
Nautical engine mechanic	MG-10	2	17.56	35.12	73,050	100,823	18,904	30,247
Electrical Equipment Repairer	MG-09	1	11.12	11.12	23,130	31,923	5,986	9,577
Subtotal		**8**		**178.31**	**370,885**	**511,895**	**95,980**	**153,569**
Staff at Dredged Material Disposal Sites								
Leader	ML-10	1	$ 19.31	$ 19.31	$ 40,165	$ 55,435	$ 10,394	$ 16,631
Helpers	MG-05	2	6.23	12.46	25,917	35,770	6,707	10,731
Subtotal		**3**		**31.77**	**66,081.60**	**91,205.82**	**17,101.09**	**27,361.75**
TOTAL- DAY SHIFT CREW		**14**		**$ 309.68**	**644,134**	**889,034**	**166,694**	**266,710**
ROTATION CREW								
On-deck Department:								
Dredge Operator	FE-14	1	$ 28.15	$ 28.15	$ 58,552	$ 80,813	$ 15,153	$ 24,244
Dredge Officer	FE-11	1	24.35	24.35	50,648	69,904	13,107	20,971
Dredge Seaman Leader	ML-08	1	9.74	9.74	20,259	27,962	5,243	8,389
Winch Operator	MG-08	2	8.25	16.50	34,320	47,368	8,882	14,211
Dredge Seaman	MG-07	7	6.96	48.72	101,338	139,866	26,225	41,960
Subtotal		**12**		**$ 127.46**	**265,117**	**365,914**	**68,609**	**109,774**
Engine Department:								
Dredge Engineer	ME-14	1	$ 28.15	$ 28.15	$ 58,552	$ 80,813	$ 15,153	$ 24,244
Dredge Engineer	ME-11	1	$ 24.35	24.35	50,648	69,904	13,107	20,971
Oiler	MG-08	2	8.25	16.50	34,320	47,368	8,882	14,211
Subtotal		**4**		**$ 69.00**	**143,520**	**198,086**	**37,141**	**59,426**
Staff at Dredged Material Disposal Sites								
Tractor Operators	MG-10	2	$ 17.56	$ 35.12	$ 73,050	$ 100,823	$ 18,904	$ 30,247
Helper	MG-08	2	8.25	16.50	34,320	47,368	8,882	14,211
Subtotal				**$ 51.62**	**107,370**	**148,192**	**27,786**	**44,457**
TOTAL- ROTATION CREW		**16**		**$ 248.08**	**516,006**	**712,192**	**133,536**	**213,658**
TOTAL - 4 ROTATION CREWS					**2,064,026**	**2,848,768**	**534,144**	**854,630**
TOTAL - 5 ROTATION CREWS					**2,580,032**	**3,560,960**		
TOTAL WITH 4 CREWS, 1 DAY SHIFT AND OVERTIME							**3,904,496**	**4,859,143**
							446	**555**
TOTAL WITH 5 CREWS 1 DAY SHIFT AND NO OVERTIME						**4,449,994**		
						508		

Total Average Rate with cargo - 4 rotation crews and 8 hours of overtime weekly for each crew

Monday to Friday	660.01	
Saturday	474.79	
Sunday	593.49	
Total Average Hourly Rate	**$ 624.05**	**5,466,664**

Total Average Rate with cargo - 5 rotation crews and 1 hour of overtime weekly

Monday to Friday	645.15	
Saturday	497.34	
Sunday	621.67	
Total Average Hourly Rate	**$ 620.68**	**5,437,166**

1/ There are 5 steps in the hourly wage grade, and the last step was used.

2/ Employee benefits were included at 38.02% of the average hourly wages

3/ Included in the average hourly wages were 10% for night differential, 25% for complementary Sunday, and 50% for overtime.

4/ Eight hours of weekly overtime were included for each crew.

12% Division Overhead (applied to labor)

Dredging Division - Mindi Suction Dredge

Costs	FY 1995 Actual	FY 1996 Actual	FY 1997 Actual	FY 1998 Actual	Yearly Estimate	
Labor	$ -	$ -	$ -	$ -	-	
Supplies/Materials (excluding fuel)	905,333	676,442	1,232,400	1,038,000	963,044	
Supplies/Materials for Disposal Sites			58,000	313,000	185,500	
Other Direct Expenses	1,328,672	1,612,966			1,470,819	
General Maintenance	531,943	310,300	1,180,000	852,000	718,561	
Indirect Maintenance CC 556					79,200	1/
Equipment Maintenance at Disposal Sites			32,000	88,000	60,000	
Overhaul Expenses	328,029	691,217	1,571,000		863,415	
Depreciation	508,597	491,390	544,654	601,226	536,467	2/
Maintenance at Disposal Sites						
Maritime Insurance					72,837	3/
Total	$3,602,574	$ 3,782,315	$ 4,618,054	$ 2,892,226	$ 4,949,842	
Total Annual Estimate					$ 4,949,842	
Number of Available Days					270	
Daily Cost for Availability without crew (demand)					$ 18,333	
Hourly Cost for Availability without crew (demand)					$ 764	

	Inter-Divisional		Capital (with Division overhead)		Commercial (w/RGG)
Hourly Cost for Availability	$ 764		$ 764		$ 1,039
Stand-by or day crew, hourly	$ 310		$ 347		$ 472
Total Hourly Cost for Availability	**$ 1,074**		**$ 1,111**		**$ 1,511**
Hourly Cost for Availability	$ 764		$ 764		$ 1,039
Operations Crew - hourly cost	$ 624		$ 699		$ 951
Hourly Cost of Fuel	$ 228	4/	$ 228		$ 310
Hourly Cost of Operation (without support equipment)	**$ 1,616**		**$ 1,691**		**$ 2,299**
Support of 3 small tugboats	$ 319	5/	$ 336		$ 457
Guard or Passenger Support Boat	$ 73		$ 79		$ 107
Hydrography Support Launches (5 days a week - day shift)	$ 14		$ 15		$ 20
Hourly Cost of Operation (with support equipment)	**$ 2,022**		**$ 2,120**		**$ 2,883**

Rate for Mobilization

Hourly Cost for Availability (without crew)	$ 764		$ 764		$ 1,039
Hourly Cost of Operations Crew	$ 624		$ 699		$ 951
Hourly Cost of Pilot (required to move dredge)	$ 45		$ 51		$ 69
Cost of a large tugboat to move the dredge	$ 332		$ 354		$ 482
Cost of a small tugboat to move the dredge	$ 106		$ 112		$ 152
Cost of a mid-size tugboat to move pipes and pontoons	$ 202		$ 217		$ 295
Cost of a small tugboat to move pipes and pontoons	$ 106		$ 112		$ 152
Total Hourly Rate for Mobilization	**$ 2,180**		**$ 2,309**		**$ 3,140**

1/ Distribution of Support of "other 550" of 556 was based on the equitable assignment of the 5 largest equipment of the central cost system.
2/ The depreciation includes the dredge and its improvements, its auxiliary equipment, the discharge pipes and pontoons, as well a 4 tractors.
3/ The cost of maritime insurance paid by ACP in 2000 was proportionately allocated to all insured floating equipment.
4/ Usage of 290 gallons/hour, 42 gallons/barrel, $33/barrel.
5/ One CHAME class and two ULUA types.

Appendix No. 7 A
Updated on Nov 19, 2002

DREDGING RATES OF THE "MINDI"

Inflation Factor Conversion	**1.023**	
Division Overhead	**12%**	

		Total Costs		Marginal Costs
Hourly Cost for Availability	$	781		n.a.
Hourly Cost for Labor		624		624
Indirect Costs relating to Labor		75		75
Average Hourly Cost of Fuel		233		233
Support for 3 small tugboats		344	/1	344
Guard or Passenger Boat Support		81	/1	81
Hydrographic Launches Support (5 days a week - day shift)		15		
Sub-total for Support		439		439
Total	**$**	**2,153**	**$**	**1,371**
Cost by Shift				
Cost for Availability for 8 hours	$	6,251		n.a.
Cost of Labor for 8 hours		5,591		5,591
Fuel Consumption for 8 hours		1,399		1,399
Support for 8 hours		3,514		3,514
Total Cost by Shift	**$**	**16,756**		**10,504**
Daily Cost				
Cost for Availability		18,754		n.a.
Labor Cost		16,774		16,774
Fuel Consumption		4,196		4,196
Support		10,542		10,542
Total Daily Cost	**$**	**50,267**		**$31,512**
Weekly Cost				
Cost for Availability		131,281		n.a.
Labor Cost		117,421		117,421
Fuel Consumption		29,370		29,370
Support		73,794		73,794
Total Weekly Cost	**$**	**351,866**		**$220,585**

Estimated Excavated Volumes by Week (Cubic Meters in Bank)		
Productivity a	**36,000**	
Productivity b	**28,000**	
Productivity c	**24,000**	
Productivity d	**60,000**	
Cost of Cubic Meter in Bank		
Productivity a	**$9.77**	**$6.13**
Productivity b	**$12.57**	**$7.88**
Productivity c	**$14.66**	**$9.19**
Productivity d	**$5.86**	**$3.68**

APPENDIX No. 8

Drill Boat THOR Productivity Test

PARAMETERS FOR MEASURING PRODUCTION AND COSTS OF THE THOR

	TEST ON THE THOR		GRADE OF DRILLING			
			26' PLD	22' PLD	20' PLD	17' PLD
			Nov 8 - 2001	Nov 12 - 2001	Nov 13 - 2001	Nov 14 - 15, 2001
1	Diameter of Drill (inches)		6.5	6.5	6.5	6.5
2	Effective Pattern Area Used (a 12.5'x10' pattern)		100' x 60'	100' x 60'	100' x 60'	100' x 60'
3	Number of Patterns		1	1	1	1
4	Nominal Depth of a Drill (feet)		11	15	17	20
5	Average Depth of Drill (feet)		7.4	10.51	13.65	16.88
6	Lake Elevation (PLD feet)		87	87	87	87
7	Longitude of tower bars		72	76	78	81
8	Test Site for Drilling		Culebra - Cascadas	Cascadas	Cascadas	Cascadas
9	Characteristics of Drilled Material		Sof to medium hard	Soft to medium hard	Soft to hard	Soft to hard
10	Number of drilling attempts		Only one	Only one	Two attempts - Additional 2' Bar	Two attempts - Additional 5' Bar
11	Maximum number of drillings per line		8	8	8	8
12	Number of lines executed		6	6	6	6
13	Coordination Time with MTC: Authorization and Blasting Programming		Not predictable	Not predictable	Not predictable	Not predictable
14	Average time required to drill a line (minutes)	/1	24.50	24.58	43.80	39.48
15	Average time required to perforate an 8-drill line	/2	1.50	1.81	2.47	2.68
16	Total Drilling Time for a pattern, with no movements or explosives (hours)		**9.02**	**10.87**	**14.80**	**16.10**
17	Average time to mobilize the THOR to the following line (minutes)	/3	19.75	14.5	16.5	17.5
18	Total time to mobilize the THOR between lines in a pattern (hours)		1.65	1.21	1.38	1.46
19	Time to mobilize the THOR 500' from the pattern (minutes)	/4	15	15	15	15
20	Total time to mobilize the THOR with no perforation and no explosive		**1.90**	**1.46**	**1.63**	**1.71**
21	Time estimated to load a drill (minutes)	/5	5.67	6.67	7.33	7.67
	Total time to load a pattern - does not include time to fasten detonants (hours)		**1.13**	**1.33**	**1.47**	**1.53**
22	Total time in theory of pattern - drilling, mobilization, blasting (hours)		**12.05**	**13.66**	**17.89**	**19.34**
	% of drilling		75%	80%	83%	83%
	% de mobilization		16%	11%	9%	9%
	% de explosive charges		9%	10%	8%	8%
23	Measured time to execute a pattern (hours)	/6	9.57	13.75	18.92	16.5
23.a	Total holes drilled according to pattern		40	45	39	41
24	Time required to set up the blasting of a pattern - Fastening detonants (hours)		1.50	1.50	1.50	1.50
25	Estimated time to load a pattern (hours)		1.13	1.33	1.47	1.53
26	Measured time to drill and load a pattern, including mobilization (hours)		**12.20**	**16.58**	**21.88**	**19.53**
27	Volume of a pattern (100' x 60' x Average Depth of drill) m^3		**1,257**	**1,785**	**2,319**	**2,868**
28	Average Production of THOR (m^3/hr)		103	108	106	147
29	Average production per week 3 watch - 7 day (m3/week)		**17,310**	**18,087**	**17,802**	**24,662**
30	Length of detonating wick required for a pattern (feet)		4700	5000	5000	5200
31	Amount of detonants					
32	17 ms		52	52	52	52
33	25 ms		10	10	10	10
34	Initial detonator of 500 feet		1	1	1	1
35	Amount of explosives required per drill (lbs)		76	106.4	114	136.8

Appendix No. 8 A

Notes:

1. The time recorded begins when the casing is being lowered, and ends when the drill has been verified and tested. It includes the time required to add another bar, if needed. This time does no include loading the explosives on the drill.

2. The time recorded begins with the perforation of the first drills and ends with the last one. It includes the time required to lift the casing, but does not include the time required to load the drill nor to fasten the little buoy.

3. The time elapsed from when the casing is out of the water until the barge is in position at the new line.

4. The 15 minutes of mobilization by the THOR are included in the 1.5 hours it takes the explosives operator to fasten the detonators.

5. Average time, based on historical data. This time begins when the drill is verified or tested and when the small buoy has been fastened. It does not include the lifting of the casing.

6. The time recorded includes mobilization of the barge between the drill lines, but does not include the loading of the explosives.

APPENDIX No. 9

Drill Boat THOR Productivity Record

ACP DRILLING & BLASTING BARGE THOR

PRODUCTION REPORT

1993 - 2001

Year	Blasting days (1)	Explosives (lbs)	Explosives (lbs / day)	Primacord (ft / day)	Caps per day	Estimated Cu m per day	N° of Holes per day	Footage per day	Avg. footage per hole
1,993	19	33,690	1,845	3,773	6	**1,446**	39	455	16
1,994	124	933,584	6,862	3,554	13	**3,149**	42	849	23
1,995	23	168,783	7,846	3,223	16	**3,914**	37	952	26
1,996	29	152,201	5,463	2,271	26	**2,493**	28	655	22
1,997	121	1,038,866	8,438	3,487	40	**4,661**	41	999	26
1,998	120	878,866	6,534	2,443	33	**3,618**	31	895	29
1,999	99	514,137	5,071	2,850	37	**3,302**	34	740	22
2,000	43	185,301	4,842	3,062	42	**2,674**	34	695	22
2,001	82	518,113	6,228	3,165	42	**3,702**	36	912	27
Average						**3,218**			24
Average without year 1993						**3,439**			25

Notes:
(1) Do not include drilling and mobilization time

Appendix No. 9

APPENDIX No. 10

Drill Boat THOR Cost Estimate

TARIFA DE LA "THOR"

Inflation conversion factor **1.023**

Ovhd de la Div. **12%**

		Costos Totales		**Costos Marginales**
Costo de disponibilidad por hora	$	164		n.a.
Costo de mano de obra por hora		517		517
Costos indirectos aplicados a mano de obra		62		62
Costo promedio de combustible por hora		54 1/		54
Apoyo de remolcador pequeño		112		112
Apoyo de bote de guardia o pasajeros		99		99
Sub-total de apoyo		216		216
Total	**$**	**1,013**	**$**	**849**
Costo por Turno				
Costo de disponibilidad por 8 horas	$	1,309		n.a.
Costo de mano de obra por 8 horas		4,632		4,632
Consumo de combustible por 6 horas		324 2/		324
Apoyo por 8 horas		1,730		1,730
Costo Total por Turno	**$**	**7,995**		**6,686**
Costo por Día -3g				
Costo de disponibilidad		3,926		n.a.
Costo de mano de obra		13,896		13,896
Consumo de combustible		972		972
Apoyo		5,190		5,190
Costo Total por Día	**$**	**23,985**		**$20,059**
Costo por Semana - 3g/7d				
Costo de disponibilidad		27,484		n.a.
Costo de mano de obra		97,272		97,272
Consumo de combustible		6,806		6,806
Apoyo		36,333		36,333
Costo Total por Semana	**$**	**167,894**		**$140,411**
Volumen de Perforación y Voladura Estimada por Semana (Metros Cúbicos de Banco)		**27,776**		**27,776**
Costo por Metro Cúbico de Banco sin Explosivos	**$**	**6.04**	**$**	**5.06**
Costo de Explosivos por Metro Cúbico de Banco	**$**	**2.00**	**$**	**2.30**
Costo Total por Metro Cúbico	**$**	**8.04**	**$**	**7.36**

Notas:

1/ Consumo promedio de 48 galones/hora, $1.10/galón

2/ Se asumió que la THOR tiene un promedio de horas desocupadas de 6 horas diarias, por lo tanto, la barcaza consume combustible 18 horas diariamente o un promedio de 6 horas por turno.

División de Dragao- Barcaza de Perforación y Voladura THOR

Gastos Generales "overhead" de la Div. De Draga **12%**

	AF 1995	AF 1996	AF 1997	AF 1998	Estimado Annual	
Provisiones/Materiales (sin combustible)	$ 276,104	*	$ 158,000	$ 936,000	$ 456,701	
Otros Gastos Directos	$ 7,119	*			$ 7,200	
Mantenimiento General	$ 103,643	$ 189,896	$ 321,000	$ 416,000	$ 257,635	
Gastos de Reacondicionamiento	$ -	$ -			$ 320,000	
Seguro Marítimo					$ 16,648	
Depreciación (THOR está totalmente depreciado)	$ -	$ -	$ 19,861	$ 20,375	$ 20,118	
Mantenimiento Indirecto CC 556		$ 73,080			$ 73,080	1/
Gastos Totales	$ 386,866	$ 189,896			$ 1,151,383	

Gasto total annual		$ 1,151,383
Disponibilidad (en días)	÷	300
Costo de disponibilidadpor día sin cuadrilla (demanda)		$ 3,838
Costo de disponibilidad por hora sin cuadrilla (demanda)		$ 160

		Entre-Divisiones	Capital (con Ovh. De Div.)	Comercial (c/RGG)
Costo de disponibilidad por hora		$ 160	$ 160	$ 217
Cuadrilla en espera por hora	+	$ 86	$ 96	$ 130
Costo total de disponibilidad por hora		**$ 245**	**$ 256**	**$ 348**
Costo de disponibilidad por hora		$ 160	$ 160	$ 217
Cuadrilla de operación 2g/5d - costo por hora		$ 449	$ 503	$ 684
Cuadrilla de operación 3g/5d - costo por hora		$ 543	$ 608	$ 827
Cuadrilla de operación 3g/7d - costo por hora		$ 517	$ 579	$ 787
Costo de combustible por hora	+	$ 53 2/	$ 53	$ 72
Costo de operación por hora 2g/5d (sin equipo de apoyo)		**$ 661**	**$ 715**	**$ 973**
Costo de operación por hora 3g/5d (sin equipo de apoyo)		**$ 756**	**$ 821**	**$ 1,117**
Costo de operación por hora 3g/7d (sin equipo de apoyo)		**$ 730**	**$ 792**	**$ 1,077**
Apoyo de remolcador pequeño		$ 106	$ 112	$ 152
Apoyo de bote de guardia o pasajeros		$ 94	$ 99	$ 135
Costo de operación por hora 2g/5d (con equipo de apoyo)		**$ 861**	**$ 927**	**$ 1,260**
Costo de operación por hora 3g/5d (con equipo de apoyo)		**$ 956**	**$ 1,033**	**$ 1,404**
Costo de operación por hora 3g/7d (con equipo de apoyo)		**$ 930**	**$ 1,003**	**$ 1,364**

Tarifa de movilización

Costo de piloto por hora (necesario para movilizar la draga)		$ 45	$ 51	$ 69
Costo de un remolcador grande para movilizar la draga		$ 341	$ 365	$ 496
Costo de disponibilidad por hora		$ 160	$ 160	$ 217
Costo de cuadrilla de operación por hora	+	$ 449	$ 503	$ 684
Tarifa total por hora de movilización		**$ 995**	**$ 1,078**	**$ 1,466**

1/ Distribución de apoyo de "other 554" está basado en una asignación de 58% de los costos en el centro de costos. Este porcentaje fue determinado basado en el efuerzo del 556 para el 554 según el reporte en JCS.

2/ Consumo promedio de 48 galones/hora, $1.10/galón

BARCAZA DE PERFORACION Y VOLADURA "THOR"

Prestaciones Laborales	38%
Diferencial de noche	10%
Domingo complementario	25%
Sobretiempo	50%

CUADRILLA DIURNA

Departamento de Cubierta:	**Grado**	**No.**	**Tarifa por hora**	**Tarifa total por hora**
Departamento de cubierta				
Capitán encargado	FE-16	1	$ 32.02	$ 32.02
Departamento de máquinas				
Maquinista jefe encargado	ME-15	1	29.99	29.99
Cuadrilla de apoyo en tierra				
Operador de explosivos	MG-06	6	6.52	39.12
TOTAL DE CUADRILLA DIURNA		**8**		**$ 101.13**

CUADRILLA DE ROTACION

Departamento de cubierta				
Oficial	FE-14	1	$ 28.15	$ 28.15
Dinamitero	FE-09	1	22.98	22.98
Departamento de máquinas				
Maquinista de dragas	ME-14	1	28.15	28.15
Operador de equipo de perforación	MG-10	4	17.56	70.24
Operador de equipo de perforación	MG-08	9	8.25	74.25
Aceitero	MG-08	2	8.25	16.5
Operador de explosivos	MG-06	1	6.52	6.52
TOTAL DE CUADRILLA DE ROTACION		**19**		**$ 246.79**

2g/5d sin sobretiempo	
Lunes a Jueves	$ 427.38
Domingo	534.22
Tarifa promedio - 2g/5d	**$ 448.75**
3g/5d con sobretiempo	
Lunes a jueves	$ 517.37
Domingo	646.71
Tarifa promedio - 3g/5d	**$ 543.23**
3g/7d con sobretiempo	
Lunes a viernes	$ 517.37
Sábado	$ 458.63
Domingo	$ 573.29
Tarifa promedio - 3g/7d	**$ 516.97**

Nota: Se consideró 7 horas de sobretiempo para cada persona por semana.

BARCAZA DE PERFORACIÓN Y VOLADURA - COSTOS DE EXPLOSIVOS

Patrón de perforación 100' x 50', burden 10' x espaciamiento 12.5'
Número de barrenos por patrón 48 - Profundidad de barreno 11' (37' PLD - 26' PLD)
Área efectiva 100' x 60'

	Cantidad	No. total de detonadores	No. total de rollos	$ / lb	$/rollo	$/ms	$
Volumen de perforación necesaria (m^3)	15,000,508						
Área total necesaria para voladura (m^2)	4,474,243						
Área efectiva de voladura (100' x 60') (m^2)	557						
Número de patrones requeridos	8,028						
Número de barrenos por patrón	48						
Número total de barrenos requerido	385,320						
Profundidad de un barreno (m)	3.35						
Profundidad del lago (m)	16.76						
Factor de potencia requerido de explosivos	1.98			0.87			**$ 25,839,876**
Cantidad total de explosivos	29,701,006						
Cordón detonante							
Cantidad de cordón requerido (m)	9,219,034						
Un rollo (m)	305		30,248		97.74		**2,956,375**
Detonador							
17 ms (# / patrón)	6	48,165				2.53	**121,858**
25 ms (# / 100 lbs de explosivos)	1	297,010				2.53	**751,435**
"NLIL" (# rollo/ patrón)	1		8,028		25.63		**205,776**
TOTAL							**$ 29,875,319**
COSTO UNITARIO $/cubic meter							**1.99**

Appendix 10 D

"THOR" RATES

Inflation conversion factor **1.023**

Division Overhead **12%**

		Total Costs		Incidental Costs
Hourly Cost for availability	$	164		n.a.
Hourly Cost of Labor		517		517
Incidental Costs applied to Labor		62		62
Average Hourly Cost of Fuel		54 1/		54
Small Tugboat support		112		112
Guard or passenger boat support		99		99
Sub-total for support		216		216
Total	**$**	**1,013**	**$**	**849**
Cost by Shift				
Cost for availabily for 8 hours	$	1,309		n.a.
Cost of Labor for 8 hours		4,632		4,632
Fuel Usage for 6 hours		324 2/		324
Support for 8 hours		1,730		1,730
Total Cost by Shift	**$**	**7,995**		**6,686**
Daily Cost -3 shifts				
Cost for Availability		3,926		n.a.
Cost of Labor		13,896		13,896
Fuel Usage		972		972
Support		5,190		5,190
Total Daily Cost	**$**	**23,985**		**$20,059**
Weekly Cost - 3 shifts/7days				
Cost for Availability		27,484		n.a.
Cost of Labor		97,272		97,272
Fuel Usage		6,806		6,806
Support		36,333		36,333
Total Weekly Cost	**$**	**167,894**		**$140,411**
Weekly Estimate of Drilling and Blasting Volume (Cubic meters in bank)		**30,000**		**37,672**
Cost for one cubic meter in bank without explosives	**$**	**5.60**	**$**	**3.73**
Cost of Explosives for one cubic meter in bank	**$**	**2.00**	**$**	**2.30**
Total Cost of One Cubic Meter	**$**	**7.60**	**$**	**6.03**

Notes:

1/ Average Usage of 48 gallons/hour, $1.10/gallon

2/ It was assumed that the THOR spends an average of 6 hours idle daily; therefore, the barge uses fuel for 18 hours a day, or an average of 6 hours each shift.

Dredging Division - THOR Drilling and Blasting Barge

General Overhead Expenses of the Dredging Division **12%**

	FY 1995	FY 1996	FY 1997	FY 1998	Annual Estimate	
Supplies/Materials (excluding fuel)	$ 276,104	*	$ 158,000	$ 936,000	$ 456,701	
Other Direct Expenses	$ 7,119	*			$ 7,200	
General Maintenance	$ 103,643	$ 189,896	$ 321,000	$ 416,000	$ 257,635	
Overhaul Expenses	$ -	$ -			$ 320,000	
Maritime Insurance					$ 16,648	
Depreciationn (THOR is fully depreciated)	$ -	$ -	$ 19,861	$ 20,375	$ 20,118	
Indirect Maintenance CC 556		$ 73,080			$ 73,080	1/
Total Expenses	$ 386,866	$ 189,896			$ 1,151,383	

Total Annual Expenses		$ 1,151,383
Availability (in days)	÷	300
Daily Cost for Availability without crew (demand)		$ 3,838
Hourly Cost for Availability without crew (demand)		$ 160

		Inter-Divisional	Capital (with division overhead)	Com-mercial (c/RGG)
Hourly Cost for Availability		$ 160	$ 160	$ 217
Hourly Cost of on-call crew	+	$ 86	$ 96	$ 130
Total Hourly Cost for Availability		**$ 245**	**$ 256**	**$ 348**
Hourly Cost for Availability		$ 160	$ 160	$ 217
Hourly Cost of Operations Crew 2 shifts/5 days		$ 449	$ 503	$ 684
Hourly Cost of Operations Crew 3 shifts/5 days		$ 543	$ 608	$ 827
Hourly Cost of Operations Crew 3 shifts/7 days		$ 517	$ 579	$ 787
Hourly Cost of Fuel	+	$ 53 2/	$ 53	$ 72
Hourly Cost of Operations Crew 2 shifts/5 days (without support equipment)		**$ 661**	**$ 715**	**$ 973**
Hourly Cost of Operations Crew 3shifts/5 days (without support equipment)		**$ 756**	**$ 821**	**$ 1,117**
Hourly Cost of Operations Crew 3 shifts/7 days (without support equipment)		**$ 730**	**$ 792**	**$ 1,077**
Small Tugboat Support		$ 106	$ 112	$ 152
Guard or Passenger Boat Support		$ 94	$ 99	$ 135
Hourly Cost of Operations Crew 2 shifts/5 days (with support equipment)		**$ 861**	**$ 927**	**$ 1,260**
Hourly Cost of Operations Crew 3 shifts/5 days (with support equipment)		**$ 956**	**$ 1,033**	**$ 1,404**
Hourly Cost of Operations Crew 3 shifts/7 days (with support equipment)		**$ 930**	**$ 1,003**	**$ 1,364**

Mobilization Rate

Hourly Cost of Pilot (required to move dredge)		$ 45	$ 51	$ 69
Cost of a large tugboat to move dredge		$ 341	$ 365	$ 496
Hour Cost for Availability		$ 160	$ 160	$ 217
Hourly Cost of Operations Crew	+	$ 449	$ 503	$ 684
Total Hourly Rate for Mobilization		**$ 995**	**$ 1,078**	**$ 1,466**

1/ Distribution of support for "other 554" is based on the allocation of 58% of the costs at the cost center. This percentage was determined based on the effort of556 for the 554, according to the JCS report.

2/ Average Usage of 48 gallons/hour, $1.10/gallon

"THOR" DRILLING AND BLASTING BARGE

Employee Benefits	38%
Night Shift Differential	10%
Complementary Sunday	25%
Overtime	50%

DAYTIME CREW

On-deck Department:	Grade	No.	Hourly Rate	Total Hourly Rate
On-deck Department:				
Captain in Charge	FE-16	1	$ 32.02	$ 32.02
Engine Department				
Chief Engineer in Charge	ME-15	1	29.99	29.99
Land-based Support Crew				
Explosives Operator	MG-06	6	6.52	39.12
TOTAL DAYTIME CREW		**8**		**$ 101.13**

ROTATION CREW

On-deck Department				
Officer	FE-14	1	$ 28.15	$ 28.15
Blasting Technician	FE-09	1	22.98	22.98
Engine Department				
Dredge Engineer	ME-14	1	28.15	28.15
Drilling Equipment Operator	MG-10	4	17.56	70.24
Drilling Equipment Operator	MG-08	9	8.25	74.25
Oiler	MG-08	2	8.25	16.5
Explosives Operator	MG-06	1	6.52	6.52
TOTAL ROTATION CREW		**19**		**$ 246.79**

2shifts/5days with no overtime	
Monday to Thursday	$ 427.38
Sunday	534.22
Average Rate - 2shifts/5days	**$ 448.75**
3shifts/5days with overtime	
Monday to Thursday	$ 517.37
Sunday	646.71
Average Rate - 3shifts/5days	**$ 543.23**
3shifts/7days with overtime	
Monday to Thursday	$ 517.37
Saturday	$ 458.63
Sunday	$ 573.29
Average Rate - 3shifts/7days	**$ 516.97**

Note: Seven hours of overtime was estimated for each person, weekly

PERFORATING AND DRILLING BARGE - COST OF EXPLOSIVES

Updated on Aug. 30, 2002

Drilling Pattern 100' x 50', burden 10' x spacing 12.5'
Number of drills for pattern 48 - Depth of drill 11' (37' PLD - 26' PLD)
Effective Area 100' x 60'

	Amount	Total number of detonators	Total number of rolls	$ / lb	$/roll	$/ms	$
Volume of required drilling (m^3)	15,000,508						
Total area of required blasting (m^2)	4,474,243						
Effective area of blasting (100' x 60') (m^2)	557						
Required number of patterns	8,028						
Number of drills per pattern	48						
Total number of drills required	385,320						
Depth of a drill (m)	3.35						
Depth of the lake (m)	16.76						
Explosive Power Factor Required	1.98			0.87			**$ 25,839,876**
Total amount of explosives	29,701,006						
Prime chord							
Required amount of chord (m)	9,219,034						
One roll (m)	305		30,248		97.74		**2,956,375**
Detonator							
17 ms (# / pattern	6	48,165				2.53	**121,858**
25 ms (# / 100 lbs of explosives)	1	297,010				2.53	**751,435**
"NLIL" (# roll/pattern)	1		8,028		25.63		**205,776**
TOTAL							**$ 29,875,319**
COST/UNIT $/cubic meter							**1.99**

Appendix 10 D

Updated on Aug. 30, 2002

Appendix 10 D

APPENDIX No. 11

ACP Dredges historical production records

GAILLARD CUT WIDENING PROGRAM TO 630' BREAKDOWN (CAPITAL)

MINDI INDICATORS IN B.C.M.

INFORMATION FROM JANUARY 1994 UNTIL SEPTEMBER 30, 2000

PROJECT	DATE	PERIOD		STATION		RUN TIME (hrs)	WAT.	RT/WATCH (hrs)	VOLUME (m3)	CM/WATCH (m3)	CM/HR	CM/Week
		FROM	TO	FROM	TO							
OBISPO	AUG.98	16-Aug-98	31-Aug-98	1735+00	1722+00	155.99	48	3.25	27,884	581	179	12,199
	SEP.98	1-Sep-98	2-Sep-98	1718+00	1722+90	28.24	6	4.71	17,817	2,969	631	62,358
TOTAL						**184.23**	**54**	**3.41**	**45,700**	**846**	**248**	**17,772**
BORINQ.	AUG.98	9-Aug-98	15-Aug-98	1735+00	1739+00	34.98	21	1.67	18,015	858	515	18,015
	OCT.98	22-Oct-98	22-Oct-98	1748+00	1751+50	10.58	3	3.53	26,005	8,668	2,458	18,203
	JAN.99	23-Jan-99	31-Jan-99	1736+00	1743+50	75.66	27	2.80	22,298	826	295	17,343
TOTAL						**121.22**	**51**	**2.38**	**66,318**	**1,300**	**547**	**27,308**
CASCADAS	OCT.97	19-Oct-97	31-Oct-97	1749+50	1753+00	139.21	36	3.87	41,338	1,148	297	24,114
	NOV.97	1-Nov-97	30-Nov-97	1753+00	1761+45	356.13	90	3.96	142,593	1,584	400	33,272
	DEC.97	1-Dec-97	31-Dec-97	1761+45	1769+50	361.20	93	3.88	160,008	1,721	443	36,131
	JAN.98	1-Jan-98	31-Jan-98	1769+50	1776+25	345.23	90	3.84	138,634	1,540	402	32,348
	FEB.98	1-Feb-98	28-Feb-98	1749+10	1758+85	320.03	84	3.81	73,229	872	229	18,307
	MAR.98	1-Mar-98	31-Mar-98	1758+85	1770+35	332.19	93	3.57	89,683	964	270	20,251
	APR.98	1-Apr-98	30-Apr-98	1770+35	1790+39	376.92	90	4.19	167,944	1,866	446	39,187
	MAY.98	1-May-98	31-May-98	1784+80	1799+95	368.11	93	3.96	108,213	1,164	294	24,435
	JUN.98	1-Jun-98	26-Jun-98	1790+79	1804+40	351.05	78	4.50	69,148	887	197	18,617
TOTAL						**2950.07**	**747**	**3.95**	**990,791**	**1,326**	**336**	**27,854**
ESCOBAR	APR.99	1-Apr-99	30-Apr-99	2009+45	2023+90	411.06	84	4.89	70,321	837	171	17,580
	MAY.99	1-May-99	23-May-99	1998+20	2024+75	366.51	93	3.94	71,790	772	196	16,211
	JUN.99	1-Jun-99	30-Jun-99	2001+40	2020+20	465.80	90	5.18	127,156	1,413	273	29,670
	JUL.99	1-Jul-99	3-Jul-99	1997+85	2029+78	336.08	93	3.61	57,946	623	172	13,084
	AUG.99	1-Aug-99	31-Aug-99	1990+80	2030+75	340.74	93	3.66	91,289	982	268	20,614
	SEP.99	1-Sep-99	3-Sep-99	1986+60	1990+00	28.50	9	3.17	6,186	687	217	14,434
	OCT.99	18-Oct-99	31-Oct-99	2025+25	2031+35	208.49	42	4.96	62,480	1,488	300	31,240
	NOV.99	1-Nov-99	30-Nov-99	2031+35	2046+40	319.34	90	3.55	71,058	790	223	16,580
	DEC.99	1-Dec-99	4-Dec-99	1989+10	2047+90	292.50	60	4.88	199,825	3,330	683	69,939
	JAN.00	1-Jan-00	8-Jan-00	1981+20	1986+80	86.08	21	4.10	78,730	3,749	915	78,730
	FEB.00	14-Feb-00	29-Feb-00	1895+85	1918+00	215.40	46	4.68	255,783	5,561	1,187	116,771
	MAR.00	1-Mar-00	21-Mar-00	1884+30	1893+25	252.05	63	4.00	119,682	1,900	475	39,894
		31-Mar-00	31-Mar-00									
TOTAL						**3322.55**	**784**	**4.24**	**1,212,246**	**1,546**	**365**	**32,471**
TIE-UP STA	DEC.99	5-Dec-99	8-Dec-99	2047+60	2049+35	99.41	21	4.73	38,516	1,834	387	38,516
		21-Dec-99	23-Dec-99									
TOTAL						**99.41**	**21**	**4.73**	**38,516**	**1,834**	**387**	**38,516**
EMPIRE	FEB.00	14-Feb-00	29-Feb-00	1895+85	1918+00	215.40	46	4.68	255,783	5,561	1,187	116,771
	MAR.00	1-Mar-00	21-Mar-00	1884+30	1893+25	252.05	63	4.00	119,682	1,900	475	39,894
	APR.00	1-Apr-00	30-Apr-00	1869+00	1888+00	276.97	84	3.30	153,182	1,824	553	38,296
	MAY.00	1-May-00	18-May-00	1859+50	1922+90	202.17	45	4.49	36,999	822	183	17,266
TOTAL						**946.59**	**238**	**3.98**	**565,647**	**2,377**	**598**	**49,910**
HODGES	MAY.00	19-May-00	31-May-00	1923+00	1927+05	167.91	39	4.31	54,509	1,398	325	29,351
	JUN.00	1-Jun-00	7-Jun-00	1927+05	1928+55	61.33	15	4.09	19,482	1,299	318	27,274
TOTAL						**229.24**	**54**	**4.25**	**73,991**	**1,370**	**323**	**28,774**

Average/week	**31,801**	**BM³/week**

GAILLARD CUT WIDENING PROJECT BREAKDOWN (CAPITAL)												
CHRISTENSEN INDICATORS IN B.C.M.												
INFORMATION FROM JANUARY 1994 UNTIL SEPTEMBER 30, 2000												
PROJECT	DATE	PERIOD		STATION		RUN TIME (hrs)	WAT.	RT/WATCH (hrs)	VOLUME (m3)	CM/WATCH	CM/HR	CM/week
		FROM	TO	FROM	TO							
MANDINGA	JUN.94	19-Jun-94	30-Jun-94	1642+00	1654+00	203	36	5.63	38,947	1,082	192	22,719
	JUL.94	1-Jul-94	31-Jul-94	1649+00	1662+50	472	84	5.62	100,458	1,196	213	25,115
	AUG.94	1-Aug-94	6-Aug-94	1652+50	1663+08	332	60	5.53	70,321	1,172	212	24,612
		8-Aug-94	11-Aug-94									
		15-Aug-94	17-Aug-94									
		23-Aug-94	24-Aug-94									
		27-Aug-94	31-Aug-94									
	SEP.94	22-Sep-94	30-Sep-94	1656+40	1661+25	39	8	4.83	5,985	748	155	15,710
	OCT.94	3-Oct-94	13-Oct-94	1642+30	1662+40	37	8	4.62	4,183	523	113	10,981
TOTAL						**1,082**	**196**	**5.52**	**219,893**	**1,122**	**203**	**23,560**
TRES P.	AUG.94	8-Aug-94	8-Aug-94	1660+05	1666+50	178	33	5.40	53,985	1,636	303	34,354
		12-Aug-94	14-Aug-94									
		17-Aug-94	22-Aug-94									
		24-Aug-94	26-Aug-94									
	JUL.95	1-Jul-95	25-Jul-94	1667+00	1673+70	375	72	5.21	111,511	1,549	297	32,524
	AUG.95	3-Aug-95	31-Aug-95	1673+00	1682+20	443	85	5.21	130,169	1,531	294	32,159
	SEP.95	1-Sep-95	19-Sep-95	1671+50	1689+55	378	75	5.04	111,206	1,483	294	31,138
		25-Sep-95	30-Sep-95									
	OCT.95	1-Oct-95	14-Oct-95	1679+45	1685+00	217	42	5.16	61,496	1,464	284	30,748
	JUN.96	10-Jun-96	30-Jun-96	1672+65	1680+00	73	15	4.89	18,290	1,219	249	25,606
	JUL.96	9-Jul-96	18-Jul-96	1672+50	1669+00	52	9	5.76	12,611	1,401	243	29,425
TOTAL						**1,716**	**331**	**5.19**	**499,268**	**1,508**	**291**	**31,676**
ELLIOT	JUL.95	26-Jul-95	31-Jul-95	1685+25	1698+80	91	18	5.05	21,191	1,177	233	24,723
	AUG.95	1-Aug-95	1-Aug-95	1698+80	1700+40	12	3	3.89	3,267	1,089	280	22,870
	SEP.95	19-Sep-95	24-Sep-95	1686+85	1689+55	85	15	5.69	22,656	1,510	266	31,719
	JUL.96	22-Jul-96	31-Jul-96	1686+00	1690+00	53	9	5.88	11,847	1,316	224	27,644
	AUG.96	5-Aug-96	24-Aug-96	1683+40	1695+00	251	48	5.23	69,374	1,445	277	30,351
	SEP.96	24-Sep-96	30-Sep-96	1685+00	1695+00	116	21	5.53	21,466	1,022	185	21,466
	OCT.96	1-Oct-96	17-Oct-96	1688+35	1694+15	229	43	5.32	56,061	1,304	245	27,379
	JAN.97	1-Jan-97	15-Jan-97	1693+50	1700+80	205	39	5.26	52,336	1,342	255	28,181
TOTAL						**1,041**	**196**	**5.31**	**258,198**	**1,317**	**248**	**27,664**
EDUARDO	AUG.95	2-Aug-95	3-Aug-95	1700+40	1704+00	25	5	5.02	6,504	1,301	259	27,316
	OCT.96	17-Oct-96	31-Oct-96	1691+95	1720+05	211	39	5.41	60,214	1,544	285	32,423
	NOV.96	10-Nov-96	30-Nov-96	1705+00	1714+50	351	68	5.16	100,702	1,481	287	31,099
	DEC.96	1-Dec-96	23-Dec-96	1700+20	1706+25	401	69	5.82	103,786	1,504	259	31,587
	JAN.97	15-Jan-97	20-Jan-97	1700+55	1719+50	117	22	5.32	36,305	1,650	310	34,655
	JUN.97	11-Jun-97	14-Jun-97	1710+20	1715+20	64	12	5.30	17,069	1,422	268	29,870
TOTAL						**1,169**	**215**	**5.44**	**324,580**	**1,510**	**278**	**31,703**
OBISPO	OCT.96	17-Oct-96	18-Oct-96	1717+80	1720+90	26	5	5.15	8,061	1,612	313	33,856
	JAN.97	20-Jan-97	31-Jan-97	1716+00	1724+50	146	27	5.42	47,206	1,748	322	36,716
	FEB.97	1-Feb-97	23-Feb-97	1718+50	1735+80	450	81	5.56	136,977	1,691	304	35,513
		25-Feb-97	28-Feb-97									
	MAR.97	1-Mar-97	9-Mar-97	1728+00	1735+00	173	34	5.09	53,069	1,561	307	32,778
	JUN.97	28-Jun-97	28-Jun-97	1728+80	1769+00	10	3	3.39	1,924	641	189	13,466
TOTAL						**806**	**150**	**5.37**	**247,237**	**1,648**	**307**	**34,613**
BORINQ.	FEB.97	24-Feb-97	24-Feb-97	1735+80	1736+80	15	3	5.09	5,252	1,751	344	36,763

GAILLARD CUT WIDENING PROJECT BREAKDOWN (CAPITAL)												
CHRISTENSEN INDICATORS IN B.C.M.												
INFORMATION FROM JANUARY 1994 UNTIL SEPTEMBER 30, 2000												
	MAR.97	9-Mar-97	18-Mar-97	1734+00	1740+00	113	21	5.37	33,130	1,578	294	33,130
		30-Mar-97	31-Mar-97									
	APR.97	17-Apr-97	30-Apr-97	1736+75	1749+95	223	42	5.31	56,824	1,353	255	28,412
	MAY.97	1-May-97	19-May-97	1735+80	1750+00	444	83	5.35	121,160	1,460	273	30,655
	JUN.97	1-Jun-97	5-Jun-97	1719+25	1750+00	85	15	5.64	14,321	955	169	20,049
TOTAL						**880**	**164**	**5.36**	**230,687**	**1,407**	**262**	**29,539**
CASCADAS	FEB.98	16-Feb-98	16-Feb-98	1770+00	1781+50	134	27	4.97	43,664	1,617	326	33,961
	MAR.98	1-Mar-98	31-Mar-98	1775+40	1786+50	360	66	5.46	146,137	2,214	406	46,498
	APR.98	1-Apr-98	3-Apr-98	1787+14	1810+30	126	23	5.50	37,374	1,625	295	34,124
	MAY.98	1-May-98	3-May-98	1808+00	1816+00	204	34	5.99	48,489	1,426	238	29,949
	JUN.98	1-Jun-98	30-Jun-98	1808+40	1819+25	415	90	4.61	110,229	1,225	265	25,720
	JUL.98	1-Jul-98	2-Jul-98	1798+75	1805+05	286	51	5.61	68,275	1,339	238	28,113
	AUG.98	1-Aug-98	18-Aug-98	1800+30	1821+00	297	54	5.50	79,053	1,464	266	30,743
TOTAL						**1,823**	**345**	**5.28**	**533,221**	**1,546**	**292**	**32,457**
NORTH LP	MAY.98	9-May-98	13-May-98	1806+40	1815+50	82	15	5.45	22,076	1,472	270	30,907
		22-May-98	26-May-98									
	AUG.98	18-Aug-98	31-Aug-98	1810+20	1820+50	218	39	5.58	56,611	1,452	260	30,483
	SEP.98	1-Sep-98	24-Sep-98	1801+50	1819+85	343	66	5.19	74,382	1,127	217	23,667
	MAY.99	27-May-99	31-May-99	1804+30	1810+00	62	12	5.16	15,115	1,260	244	26,450
	JUN.99	1-Jun-99	9-Jun-99	1810+00	1826+50	91	17	5.37	22,260	1,309	244	27,497
TOTAL						**795**	**149**	**5.34**	**190,443**	**1,278**	**239**	**26,841**
CENT. LP	APR.98	16-Apr-98	26-Apr-98	1830+75	1874+00	158	31	5.08	25,771	831	163	17,458
	MAY.98	4-May-98	8-May-98	1820+00	1848+80	74	14	5.27	15,786	1,128	214	23,679
	SEP.98	25-Sep-98	30-Sep-98	1816+00	1827+00	100	18	5.53	21,069	1,170	212	24,580
	OCT.98	1-Oct-98	31-Oct-98	1820+00	1840+00	423	78	5.43	106,779	1,369	252	28,748
	NOV.98	1-Nov-98	30-Nov-98	1826+25	1842+00	485	86	5.64	132,336	1,539	273	32,315
	DEC.98	1-Dec-98	18-Dec-98	1833+25	1917+50	249	54	4.60	71,298	1,320	287	27,727
	JAN.99	3-Jan-99	23-Jan-99	1837+80	1848+00	311	62	5.02	83,725	1,350	269	28,359
	MAR.99	25-Mar-99	27-Mar-99	1842+10	1853+45	31	9	3.40	8,427	936	276	19,664
	JUN.99	7-Jun-99	30-Jun-99	1813+05	1847+00	370	67	5.52	87,389	1,304	236	27,391
	JUL.99	1-Jul-99	23-Jul-99	1821+00	1852+10	341	67	5.09	95,969	1,432	281	30,080
	AUG.99	16-Aug-99	22-Aug-99	1846+50	1853+20	109	21	5.17	32,183	1,533	297	32,183
TOTAL						**2,649**	**507**	**5.23**	**680,733**	**1,343**	**257**	**28,196**
SOUTH LP	APR.98	10-Apr-98	15-Apr-98	1847+00	1865+75	103	18	5.70	21,863	1,215	213	25,506
	MAR.99	5-Mar-99	24-Mar-99	1854+35	1868+25	301	58	5.19	89,282	1,539	296	32,326
	JUL.99	27-Jul-99	31-Jul-99	1861+20	1865+00	84	15	5.58	23,573	1,572	282	33,002
	AUG.99	1-Aug-99	8-Aug-99	1846+35	1864+50	315	60	5.26	96,061	1,601	305	33,621
	SEP.99	1-Sep-99	4-Sep-99	1851+50	1859+75	57	11	5.18	17,679	1,607	310	33,752
TOTAL						**860**	**162**	**5.31**	**248,458**	**1,534**	**289**	**32,208**
EMPIRE	JAN.99	30-Jan-99	31-Jan-00	1883+20	1886+65	36	7	5.14	14,229	2,033	395	42,687
	FEB.99	1-Feb-99	3-Feb-99	1886+65	1889+15	33	6	5.53	11,908	1,985	359	41,679
	APR.99	14-Apr-99	21-Apr-99	1902+20	1910+20	190	42	4.53	85,313	2,031	448	42,656
		24-Apr-99	30-Apr-99	1903+45	1910+40							
	MAY.99	1-May-99	22-May-99	1886+50	1915+00	256	61	4.20	109,771	1,800	429	37,790
	OCT.99	9-Oct-99	31-Oct-99	1907+95	1920+00	310	68	4.56	132,824	1,953	428	41,019
	NOV.99	1-Nov-99	28-Nov-99	1894+35	1910+55	422	84	5.03	177,038	2,108	419	44,260
	MAR.00	22-Mar-00	31-Mar-00	1881+60	1886+50	143	28	5.10	55,573	1,985	389	41,679

GAILLARD CUT WIDENING PROJECT BREAKDOWN (CAPITAL)												
CHRISTENSEN INDICATORS IN B.C.M.												
INFORMATION FROM JANUARY 1994 UNTIL SEPTEMBER 30, 2000												
	MAY.00	12-May-00	31-May-00	1875+65	1885+30	227	40	5.66	80,672	2,017	356	42,353
TOTAL						**1,617**	**336**	**4.81**	**667,328**	**1,986**	**413**	**41,708**
ESCOBAR	SEP.99	4-Sep-99	30-Sep-99	1985+20	1997+30	394	79	4.98	143,786	1,820	365	38,222
	OCT.99	1-Oct-99	6-Oct-99	1981+25	1983+55	76	16	4.76	24,916	1,557	327	32,702
	JAN.00	16-Jan-00	31-Jan-00	2029+80	2041+00	249	47	5.31	76,885	1,636	308	34,353
	FEB.00	1-Feb-00	15-Feb-00	2018+00	2040+00	222	45	4.94	70,595	1,569	318	32,945
TOTAL						**941**	**187**	**5.03**	**316,183**	**1,691**	**336**	**35,507**
SUMMIT	APR.98	4-Apr-98	9-Apr-98	1865+75	1875+00	66	12	5.47	17,893	1,491	273	31,313
	MAY.98	18-May-98	18-May-98	1968+05	1969+50	6	1	5.67	1,221	1,221	215	25,649
	MAY.99	22-May-99	27-May-99	1866+50	1870+00	71	15	4.74	28,580	1,905	402	40,012
	JUL.99	23-Jul-99	26-Jul-99	1867+85	1871+05	60	11	5.48	16,244	1,477	269	31,012
	OCT.00	8-Oct-00	31-Oct-00	1871+00	1880+25	324	65	4.98	111,298	1,712	344	35,958
TOTAL						**527**	**104**	**5.06**	**175,237**	**1,685**	**333**	**35,384**
GOLD HILL	JUL.98	3-Jul-98	15-Jul-98	1887+75	1976+40	169	30	5.62	22,870	762	136	16,009
	NOV.99	30-Nov-99	30-Nov-99	1960+50	1962+80	16	3	5.36	4,824	1,608	300	33,771
	DEC.99	1-Dec-99	6-Dec-99	1960+85	1968+40	88	16	5.50	16,214	1,013	184	21,281
	FEB.00	16-Feb-00	29-Feb-00	1954+75	2041+50	200	41	4.87	50,595	1,234	253	25,915
	MAR.00	1-Mar-00	8-Mar-00	1961+75	1979+00	154	30	5.13	41,374	1,379	269	28,962
	APR.00	1-Apr-00	30-Apr-00	1960+00	1977+00	477	89	5.36	144,886	1,628	304	34,186
	MAY.00	1-May-00	10-May-00	1955+65	1981+95	141	27	5.21	31,847	1,180	226	24,770
	JUN.00	8-Jun-00	8-Jun-00	1960+95	1982+70	104	20	5.21	17,202	860	165	18,062
TOTAL						**1,179**	**226**	**5.22**	**329,812**	**1,459**	**280**	**30,646**
HODGES	MAR.00	16-Mar-00	21-Mar-00	1943+00	1945+75	78	16	4.86	32,916	2,057	424	43,202
	MAY.00	10-May-00	12-May-00	1940+70	1941+80	34	6	5.64	11,023	1,837	326	38,580
	JUN.00	4-Jun-00	5-Jun-00	1939+30	1940+00	17	4	4.31	4,763	1,191	276	25,008
	SEP.00	1-Sep-00	5-Sep-00	1919+00	1943+00	341	65	5.25	110,412	1,699	323	35,672
	DEC.00	1-Dec-00	17-Dec-00	1885+70	1961+25	190	38	4.99	45,252	1,191	239	25,008
TOTAL						**660**	**129**	**5.11**	**204,366**	**1,584**	**310**	**33,269**
CONTRACTOR	JUN.00	17-Jun-00	30-Jun-00	1978+30	1984+50	209	40	5.22	59,695	1,492	286	31,340
	JUL.00	1-Jul-00	31-Jul-00	1967+60	1980+00	488	93	5.25	144,397	1,553	296	32,606
	AUG.00	1-Aug-00	31-Aug-00	1957+60	1989+40	449	83	5.41	139,145	1,676	310	35,205
	SEP.00	1-Sep-00	1-Sep-00	1959+00	1961+30	9	2	4.34	2,382	1,191	275	25,008
TOTAL						**1,155**	**218**	**5.30**	**345,618**	**1,585**	**299**	**33,294**
								Average/week	**31,771**	**BM³/week**		

CUTTER SUCTION "MINDI" PRODUCTIVITY

DATE	PROJECT	WATCHES	BCY	BCM	BCM/WAT	BCM/WEEK	AVERAGE LOW AND HIGH
MAR.80	MAMEI CURVE	10	6,819	5,205	521	10,931	
MAY.80	MAMEI CURVE	15	27,650	21,107	1,407	29,550	
SEPT.82	MAMEI CURVE	9	20,000	15,267	1,696	35,623	
OCT.82	MAMEI CURVE	93	235,900	180,076	1,936	40,662	25,797
NOV.82	MAMEI CURVE	42	93,261	71,192	1,695	35,596	
NOV.83	MAMEI CURVE	42	91,242	69,650	1,658	34,825	
DEC.83	MAMEI CURVE	60	118,770	90,664	1,511	31,732	
JAN.84	MAMEI CURVE	63	105,656	80,653	1,280	26,884	
MAR.84	MAMEI CURVE	45	101,944	77,820	1,729	36,316	
TOTAL		**379**	**801,242**	**611,635**	**1,614**	**33,890**	
APR.80	SAN PABLO	16	6,963	5,315	332	6,976	
FEB.84	SAN PABLO	42	82,294	62,820	1,496	31,410	
MAR.84	SAN PABLO	21	13,370	10,206	486	10,206	28,932
APR.84	SAN PABLO	78	139,374	106,392	1,364	28,644	
MAY.84	SAN PABLO	48	152,373	116,315	2,423	50,888	
TOTAL		**205**	**394,374**	**301,049**	**1,469**	**30,839**	
APR.83	GAMBOA	60	67,206	51,302	855	17,956	
MAY.83	GAMBOA	57	87,909	67,106	1,177	24,723	
JUN.83	GAMBOA	69	100,265	76,538	1,109	23,294	
JUL.83	GAMBOA	63	142,351	108,665	1,725	36,222	27,817
AUG.83	GAMBOA	69	162,177	123,799	1,794	37,678	
SEPT.83	GAMBOA	60	123,733	94,453	1,574	33,058	
OCT.83	GAMBOA	63	111,252	84,925	1,348	28,308	
NOV.83	GAMBOA	18	40,068	30,586	1,699	35,684	
TOTAL		**459**	**834,961**	**637,375**	**1,389**	**29,161**	
MAY.84	TABERNILLA	45	123,699	94,427	2,098	44,066	
JUN.84	TABERNILLA	90	280,401	214,047	2,378	49,944	
JUL.84	TABERNILLA	93	341,540	260,718	2,803	58,872	
AUG.84	TABERNILLA	54	144,250	110,115	2,039	42,822	41,045
OCT.84	TABERNILLA	12	17,381	13,268	1,106	23,219	
TOTAL		**294**	**907,271**	**692,573**	**2,356**	**49,470**	
AUG.84	BUENA VISTA	39	79,908	60,998	1,564	32,845	
SEPT.84	BUENA VISTA	30	50,030	38,191	1,273	26,734	
OCT.84	BUENA VISTA	24	41,880	31,969	1,332	27,973	29,789
TOTAL		**93**	**171,818**	**131,159**	**1,410**	**29,616**	
SEPT.84	BOHIO	60	169,869	129,671	2,161	45,385	
OCT.84	BOHIO	39	58,075	44,332	1,137	23,871	34,628
TOTAL		**99**	**227,944**	**174,003**	**1,758**	**36,910**	
OCT.84	PENA BLANCA	15	36,211	27,642	1,843	38,699	
TOTAL		**15**	**36,211**	**27,642**	**1,843**	**38,699**	**38,699**

Average/week 35,512 BM³/week 32,387

LOW
HIGH

APPENDIX No. 12

Dry Excavation Costs

GAILLARD CUT WIDENING TO 630' PROJECT
DRY EXCAVATION

STATUS REPORT No. 120 **November 17, 1997**

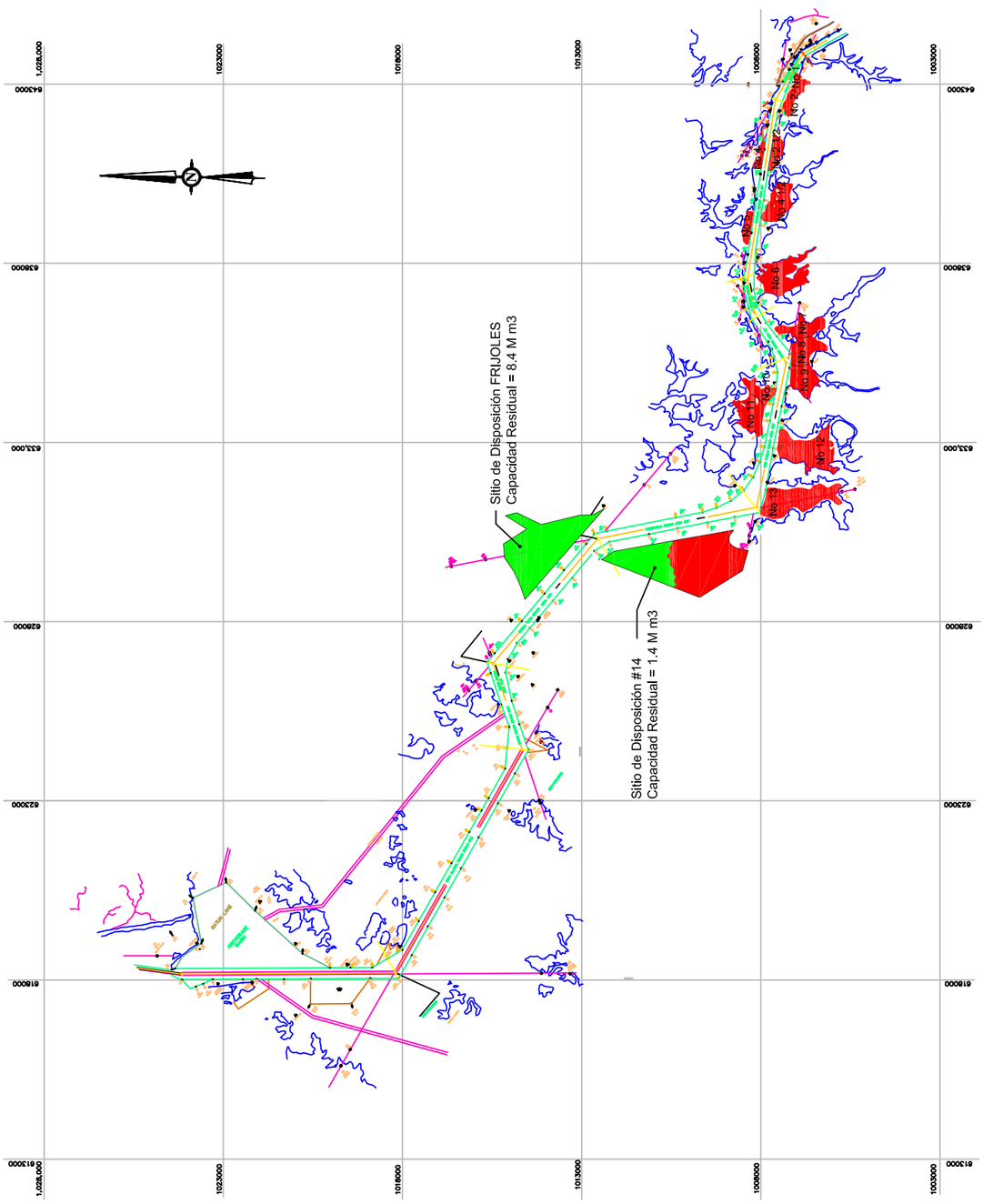
PROJECT	ACTUAL CONTRACT PRICE ($)	ESTIMATED VOLUME UNCLASSIFIED EXCAVATION (m3)	ESTIMATE EXCAVATION UNIT COST ($ per m3)
No. 10 CENTRAL LA PITA	6,534,377	3,096,893	2.11
No. 7 LAS CASCADAS PHASE III	4,806,556	2,484,589	1.93
No. 11 SUMMIT	3,300,048	1,626,000	2.03
No. 12 Empire	7,265,490	2,887,500	2.52
No. 13 HODGES	5,065,546	2,208,655	2.29
No. 14 GOLD HILL	9,543,712	1,485,000	6.43
NO. 15 CONTRACTORS HILL	7,044,949	1,860,000	3.79
NO. 16 ESCOBAR	4,902,081	1,220,000	4.02
TOTAL	**48,462,759**	**16,868,637**	
		AVERAGE	**$ 3.14**

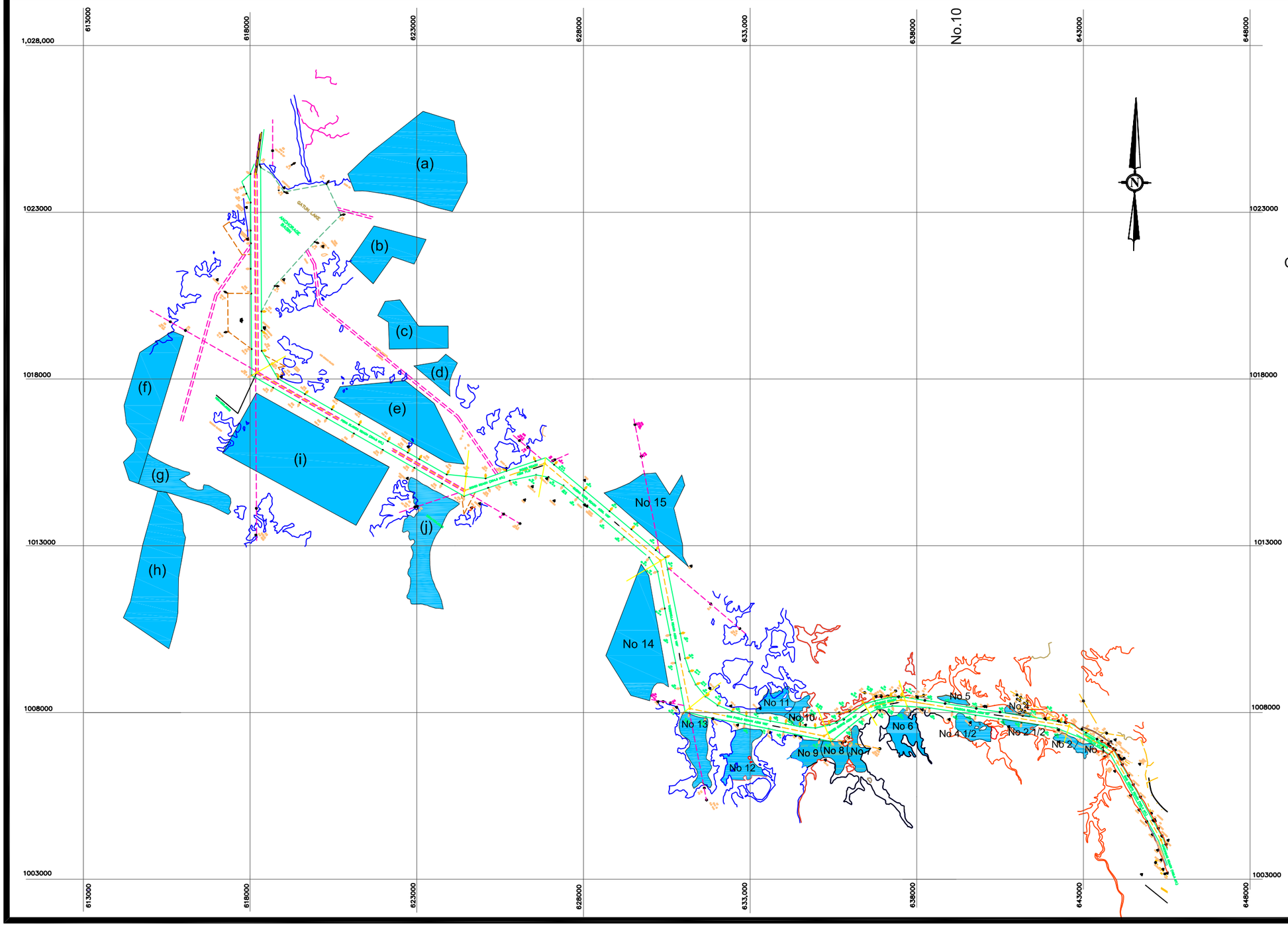
The work in general includes clearing and grubbing, excavation of common and rock material to form new slopes and elevations shown on drawings. Excavation activities require the use of heavy equipment and/or drilling and blasting. The excavated material to be disposed of at specified spoil areas. Other work includes construction or re-building gravel roads and associated drainage.

APPENDIX No. 13

Disposal Sites Sketches

Apéndice No. 13 A





GATUN LAKE
DREDGING MATERIAL
DISPOSAL SITES

Underwater

Terrestrial

CANAL DESIGNATED DISPOSAL SITES

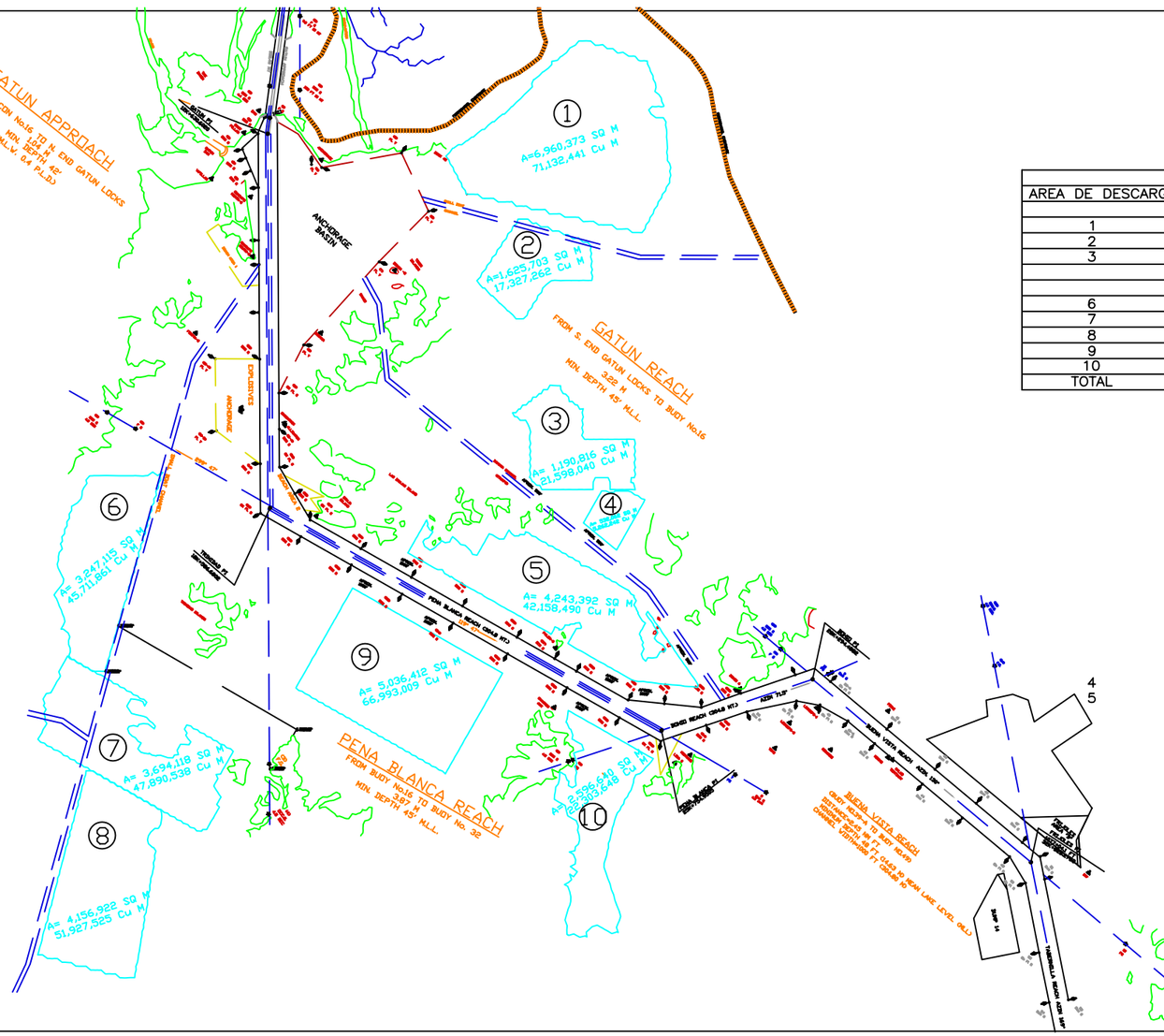
No.1 and No.2 Cruce de Chagres
No. 2 1/2
No.4
No.4 1/2
No.5
No.6
No.7
No.8
No.9

No.11
No.10
No.12
No.13
Disposal site No. 14
No.15 Frijoles

POTENTIAL DISPOSAL SITES

(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(i)
(j)

Appendix No. 13 B



AREA DE DESCARGA	CAPACIDAD A 30' MLL
	Cu M
1	71,132,441
2	17,327,262
3	21,598,040
	5,262,242
	42,158,490
6	45,711,861
7	47,890,538
8	51,927,525
9	66,993,009
10	22,303,648
TOTAL	392,305,056

ACP AUTORIDAD DEL CANAL DE PANAMA

DEPARTAMENTO DE INGENIERIA Y SERVICIOS INDUSTRIALES
DIVISION DE INGENIERIA
ALTOS DE BALBOA, REPUBLICA DE PANAMA

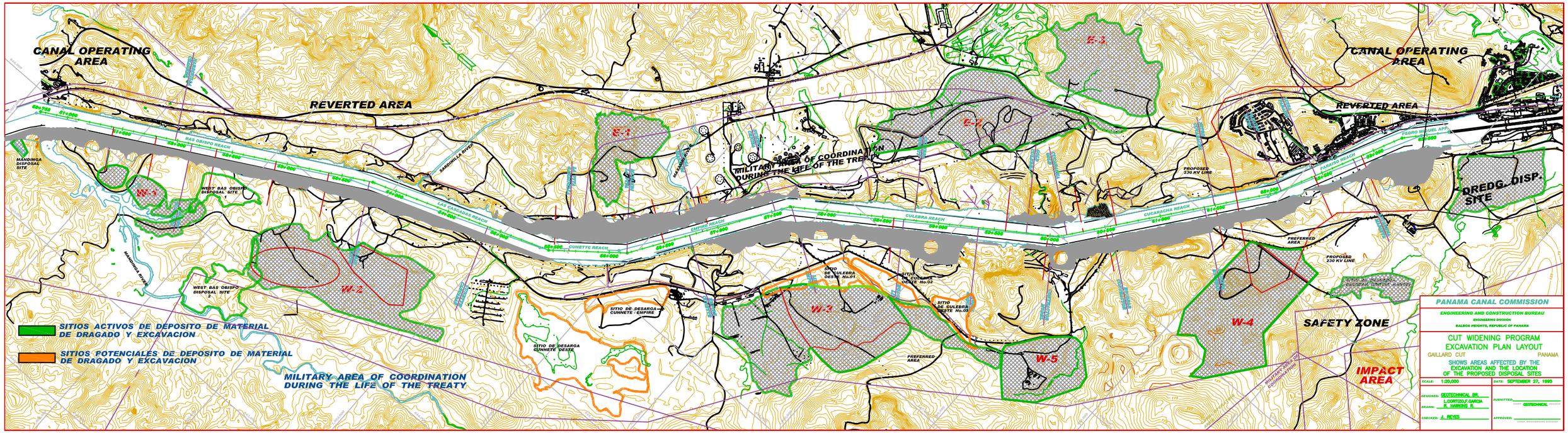
LAGO GATUN

POSIBLES SITIOS DE DESCARGA DE MATERIAL DRAGADO

ESCALA: HOR. 1:25000 MT | FECHA: ENERO 03, 2001

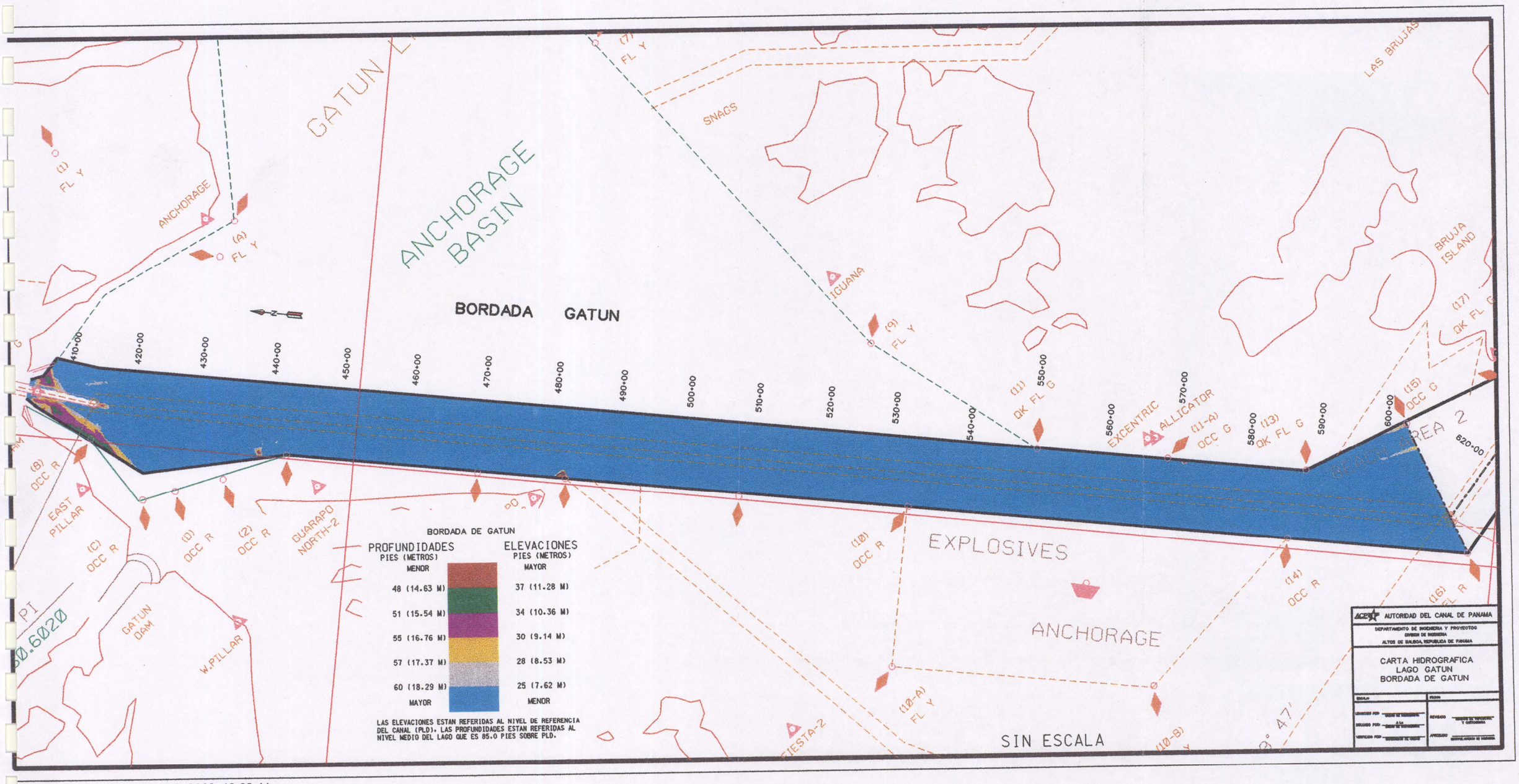
DIBUJADO POR: A.Lu
REVISADO POR: A. CASTILLO
VERIFICADO POR: [illegible]
VERIFICADO POR: [illegible]
REVISADO: [illegible] Y CONTROLES
APROBADO: [illegible] GENERAL DIVISION DE INGENIERIA

SK-H-652


CANAL OPERATING AREA
REVERTED AREA
E-1
E-2
E-3
E-4
E-5
E-6
E-7
W-1
W-2
W-3
W-4
W-5
MANDINGA DISPOSAL SITE
WEST BAS OBISPO DISPOSAL SITE
BAS OBISPO REACH
LAS VARICHAS REACH
CUNETTE REACH
EMPIRE REACH
CULEBRA REACH
CUCARACHA REACH
PAMAMO REACH
PAMAMO CUBEL APP.
SARDINILLA RIVER
MANDINGA RIVER
MAGNOLIA RIVER
MILITARY AREA OF COORDINATION DURING THE LIFE OF THE TREATY
PROPOSED 230 KV LINE
PREFERRED AREA
DREDG. DISP. SITE
SITIO DE DESAROGA CUNNETE - EMPIRE
SITIO DE DESAROGA CUNNETE DESTE
SITIO DE CULEBRA OESTE No.01
SITIO DE CULEBRA OESTE No.02
SITIO DE CULEBRA OESTE No.03
SAFETY ZONE
IMPACT AREA
SITIOS ACTIVOS DE DEPOSITO DE MATERIAL DE DRAGADO Y EXCAVACION
SITIOS POTENCIALES DE DEPOSITO DE MATERIAL DE DRAGADO Y EXCAVACION
MILITARY AREA OF COORDINATION DURING THE LIFE OF THE TREATY
PANAMA CANAL COMMISSION
ENGINEERING AND CONSTRUCTION BUREAU
ENGINEERING DIVISION
BALBOA HEIGHTS, REPUBLIC OF PANAMA
CUT WIDENING PROGRAM
EXCAVATION PLAN LAYOUT
GAILLARD CUT
PANAMA
SHOWS AREAS AFFECTED BY THE EXCAVATION AND THE LOCATION OF THE PROPOSED DISPOSAL SITES
SCALE: 1:20,000
DATE: SEPTEMBER 27, 1995
DESIGNED: GEOTECHNICAL BR.
DRAWN: L.CORTIZO,F.GARCIA R. YASIRONS R.
CHECKED: J. REYES
SUBMITTED: GEOTECHNICAL
APPROVED:
ALL EXISTING GROUND CONTOURS SHOWN IN THIS MAP ARE THE RESULT OF AIR-PHOTO INTERPRETATION.
1:20,000
1,000 500 0 1,000
CORTE CULEBRA ESPECIAL
6122-55A

APPENDIX No. 14

Gatun Lake and Gaillard Cut Bathymetry



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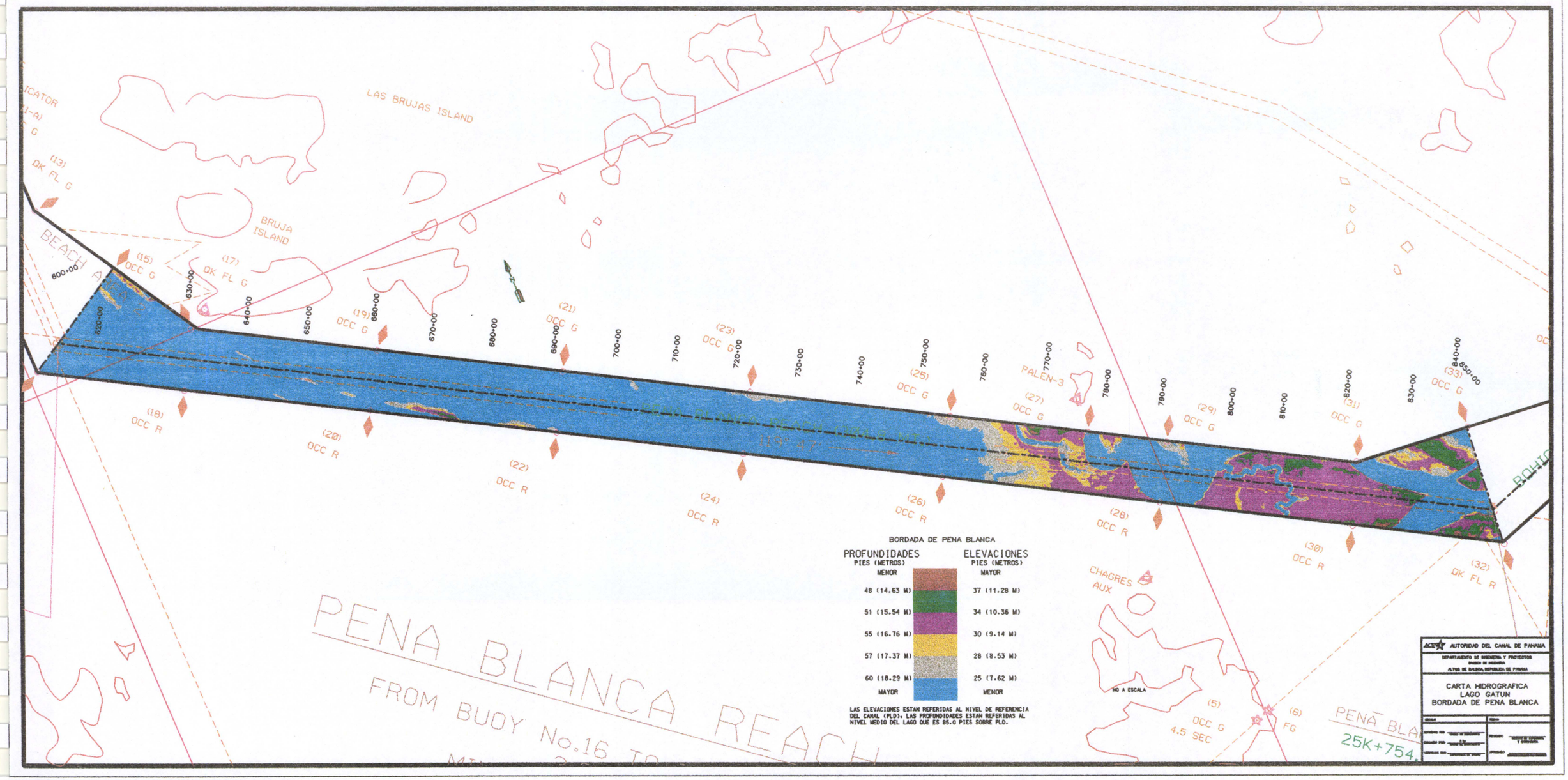

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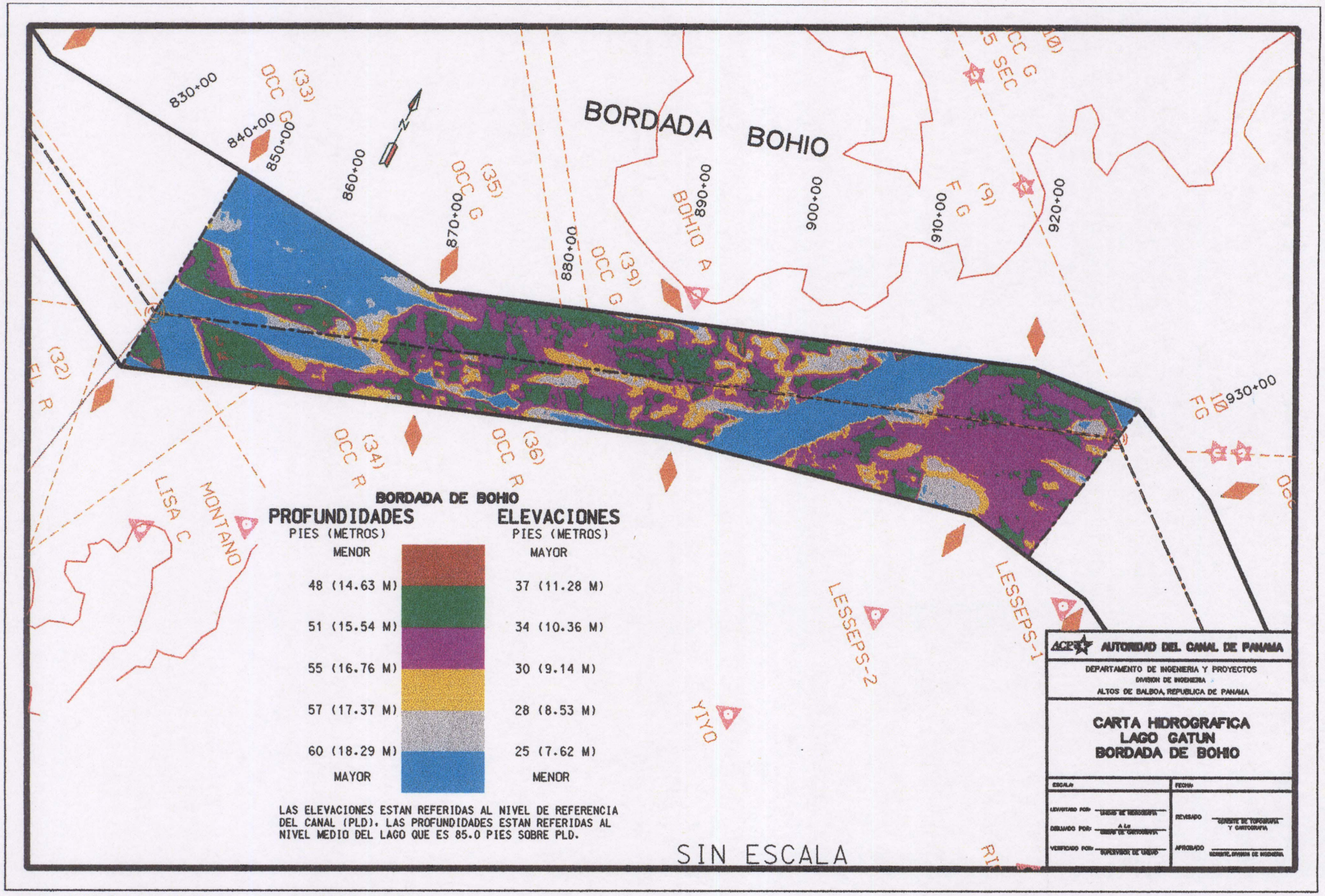

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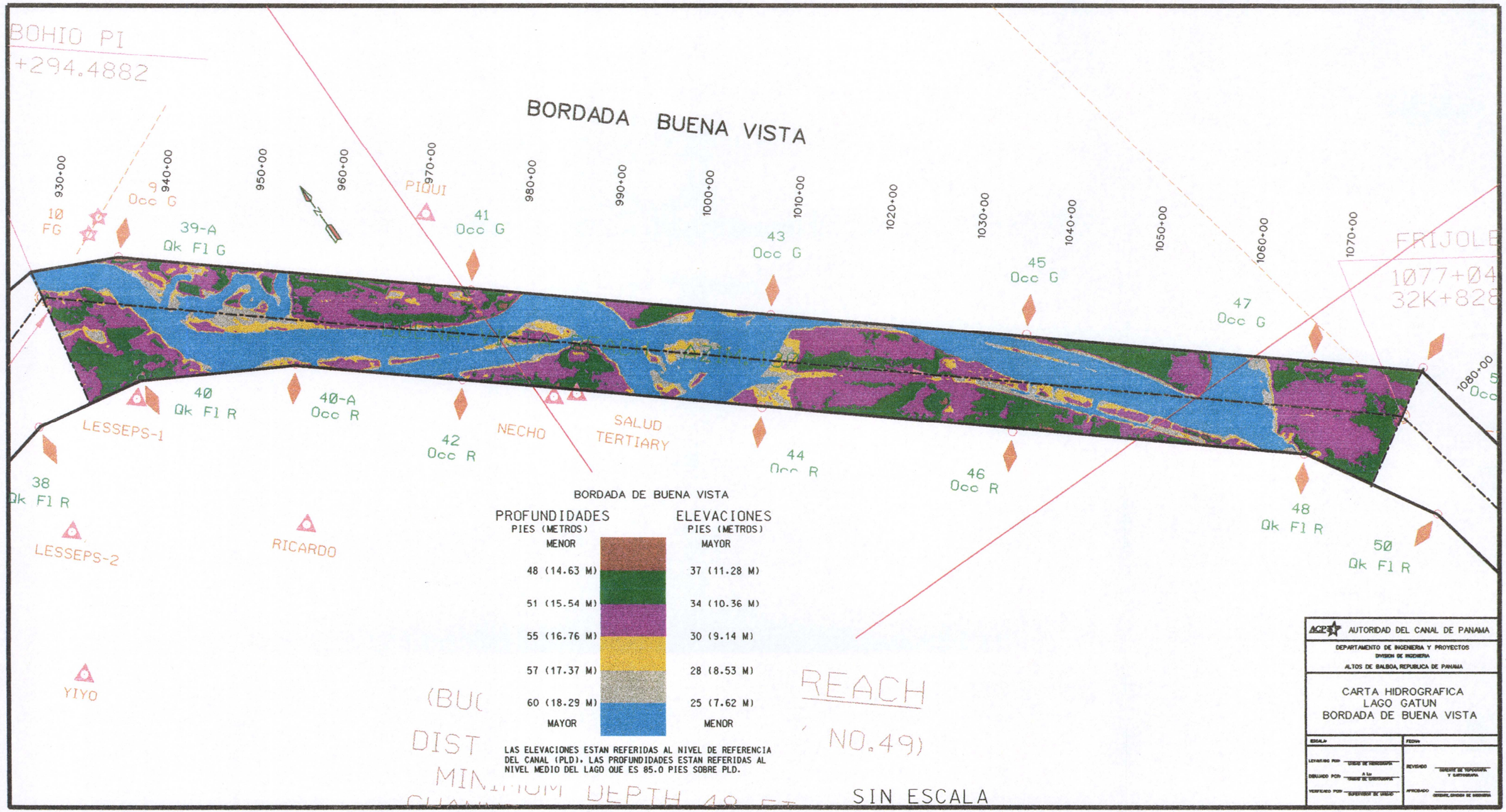

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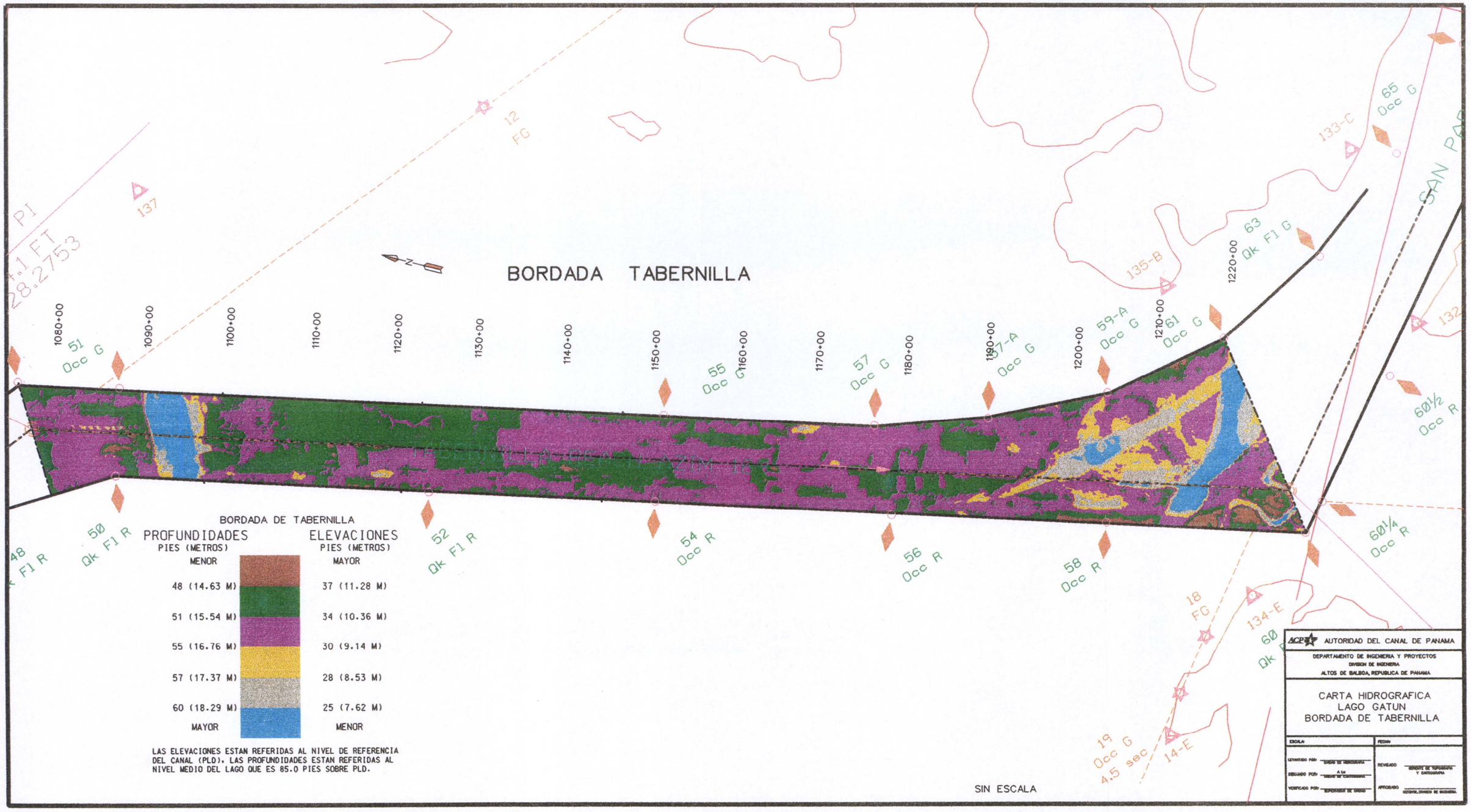

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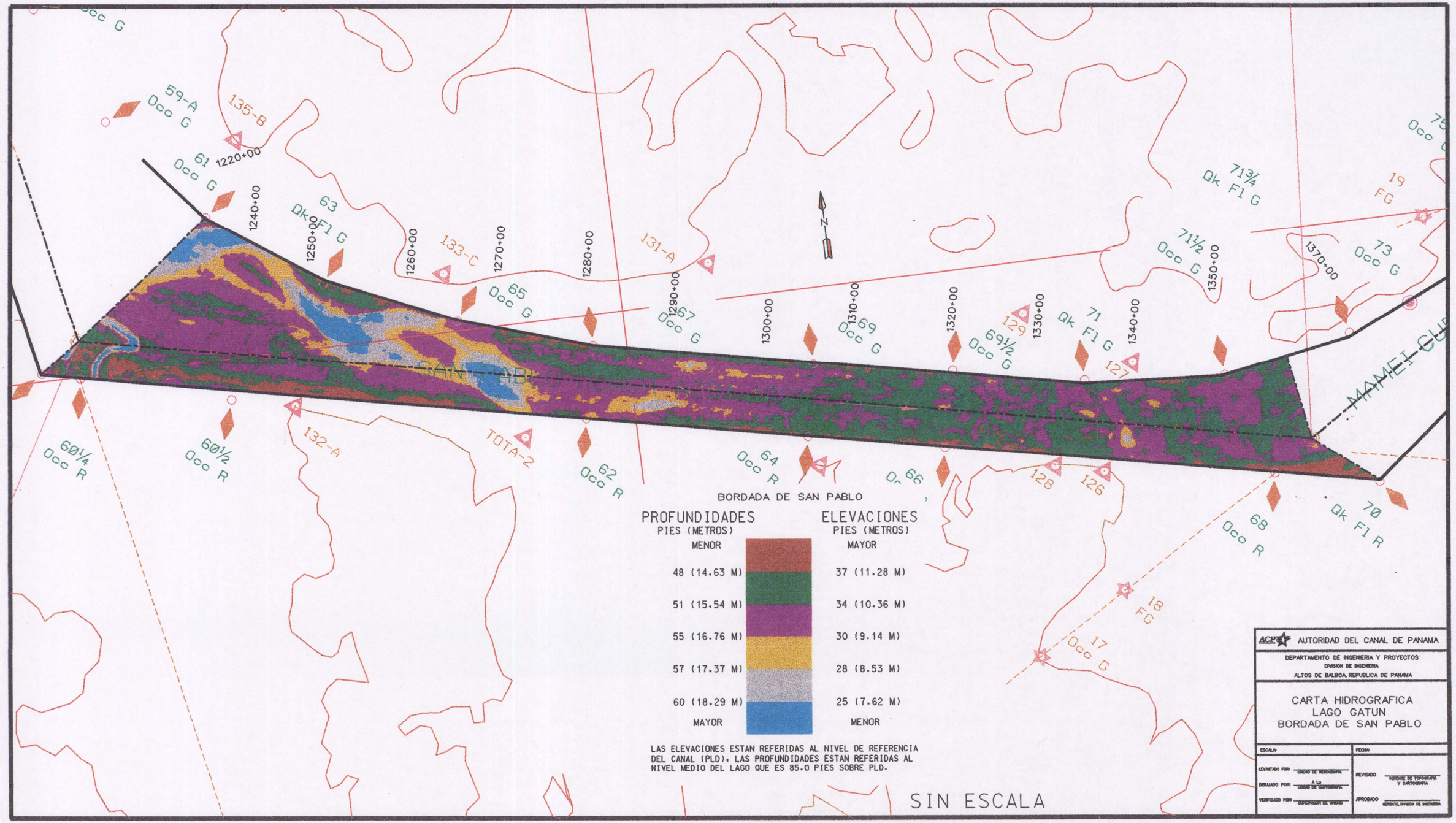

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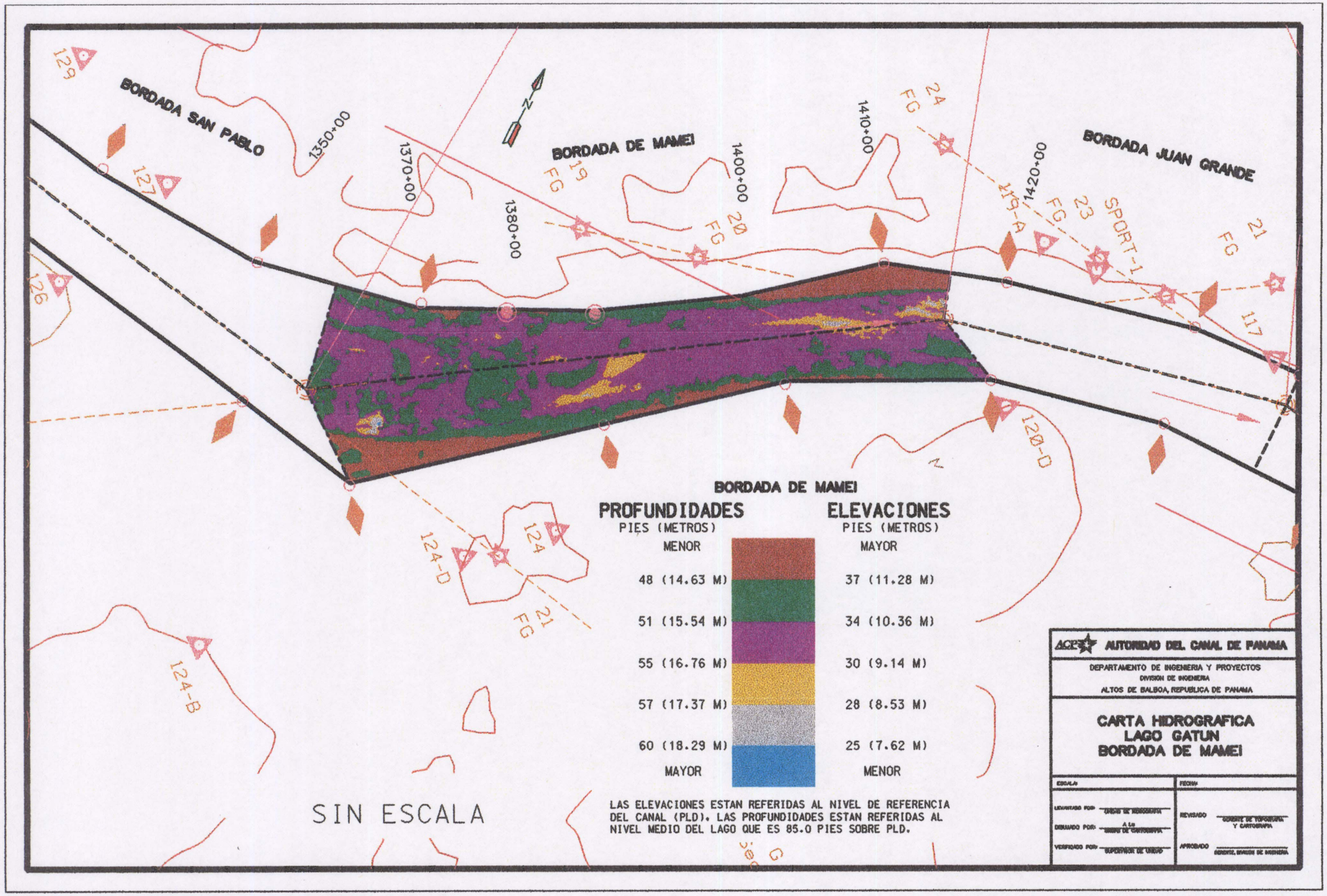

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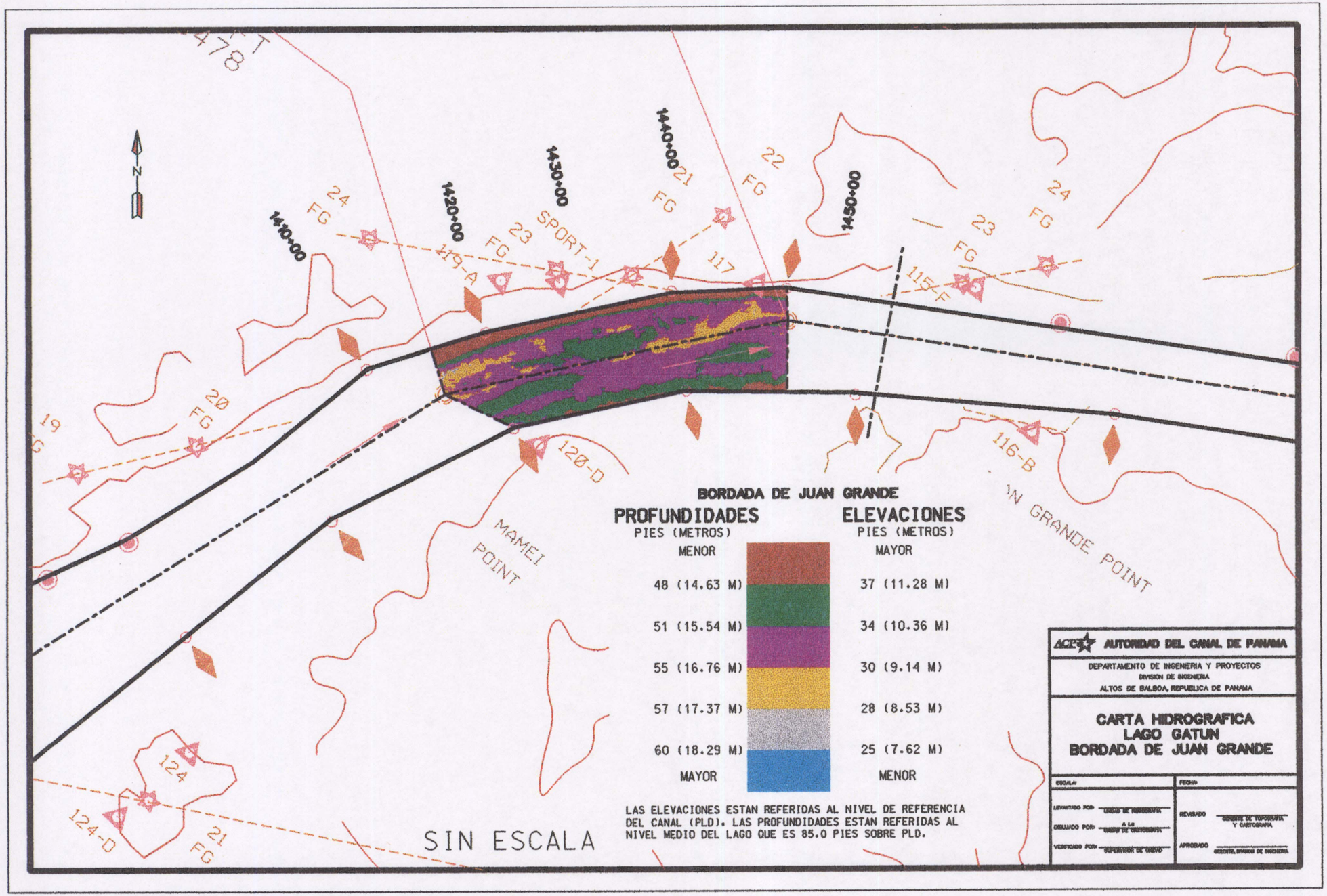

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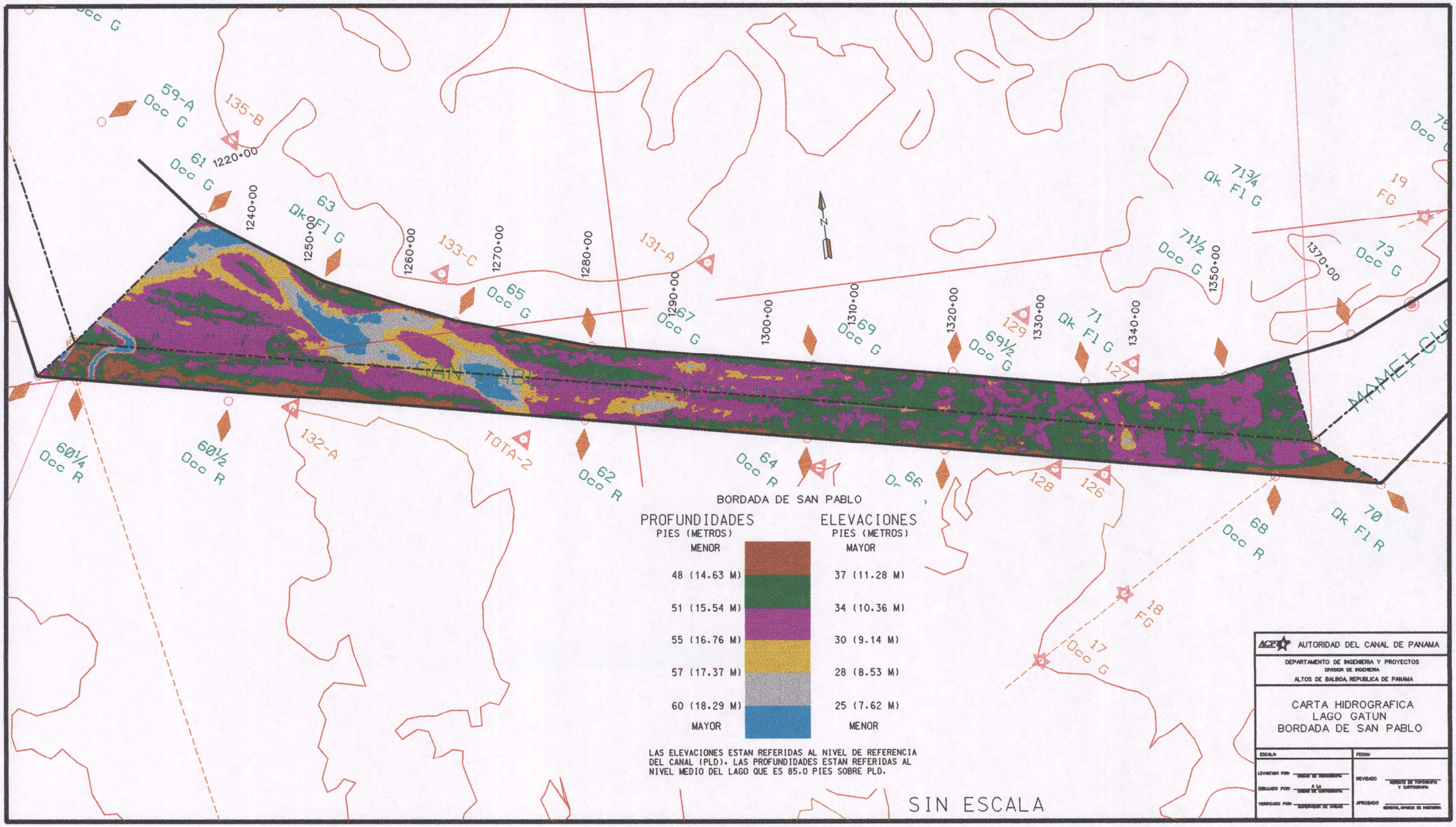

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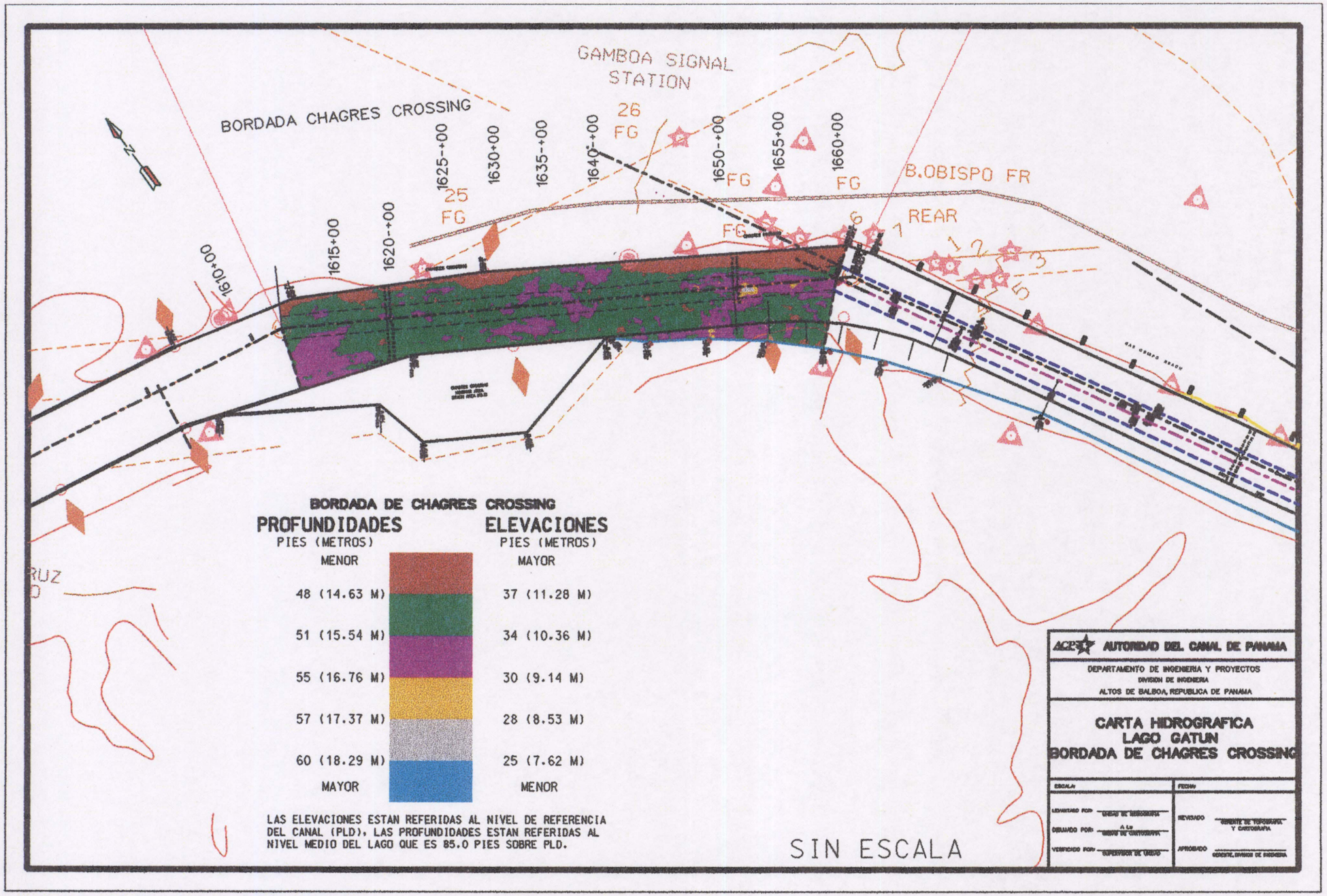

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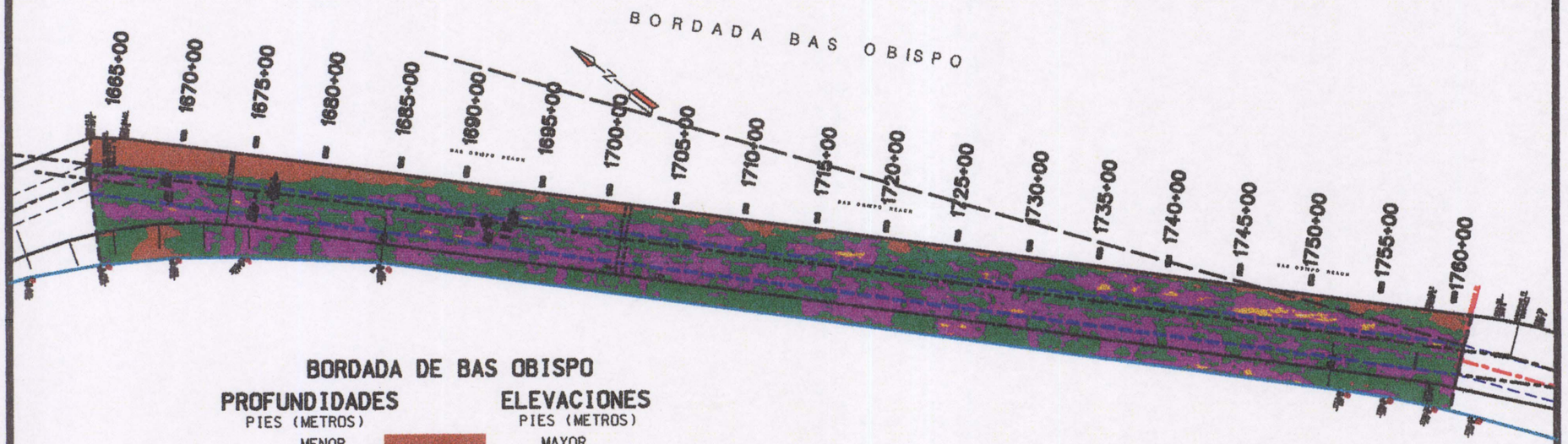

BORDADA DE BAS OBISPO

PROFUNDIDADES PIES (METROS)	ELEVACIONES PIES (METROS)
MENOR	MAYOR
48 (14.63 M)	37 (11.28 M)
51 (15.54 M)	34 (10.36 M)
55 (16.76 M)	30 (9.14 M)
57 (17.37 M)	28 (8.53 M)
60 (18.29 M)	25 (7.62 M)
MAYOR	MENOR

LAS ELEVACIONES ESTAN REFERIDAS AL NIVEL DE REFERENCIA DEL CANAL (PLD). LAS PROFUNDIDADES ESTAN REFERIDAS AL NIVEL MEDIO DEL LAGO QUE ES 85.0 PIES SOBRE PLD.

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DIBUJADO POR: A.Lu DIBUJO DE CARTOGRAFIA	APROBADO: GERENTE, DIVISION DE INGENIERIA
VERIFICADO POR: SUPERVISOR DE DIBUJO	

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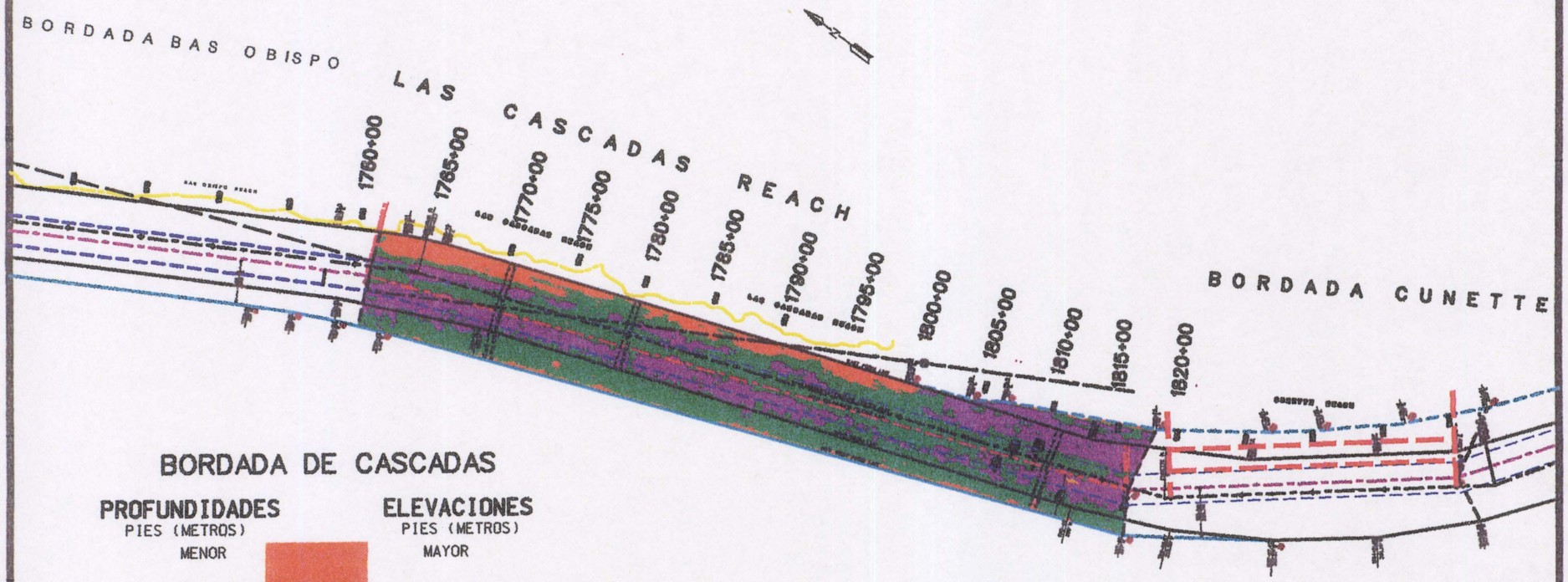

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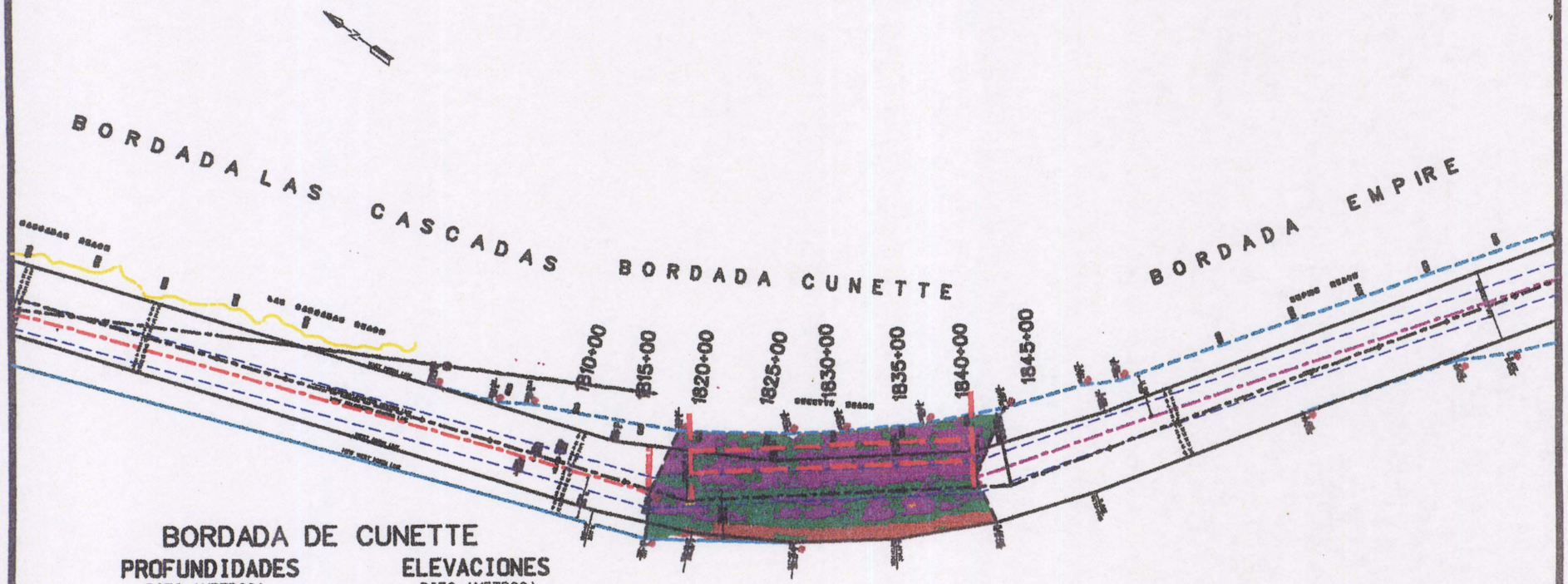

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MAYOR	MENOR

LAS ELEVACIONES ESTAN REFERIDAS AL NIVEL DE REFERENCIA DEL CANAL (PLD), LAS PROFUNDIDADES ESTAN REFERIDAS AL NIVEL MEDIO DEL LAGO QUE ES 85.0 PIES SOBRE PLD.

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CORTE GAILLARD
BORDADA DE CUNETTE

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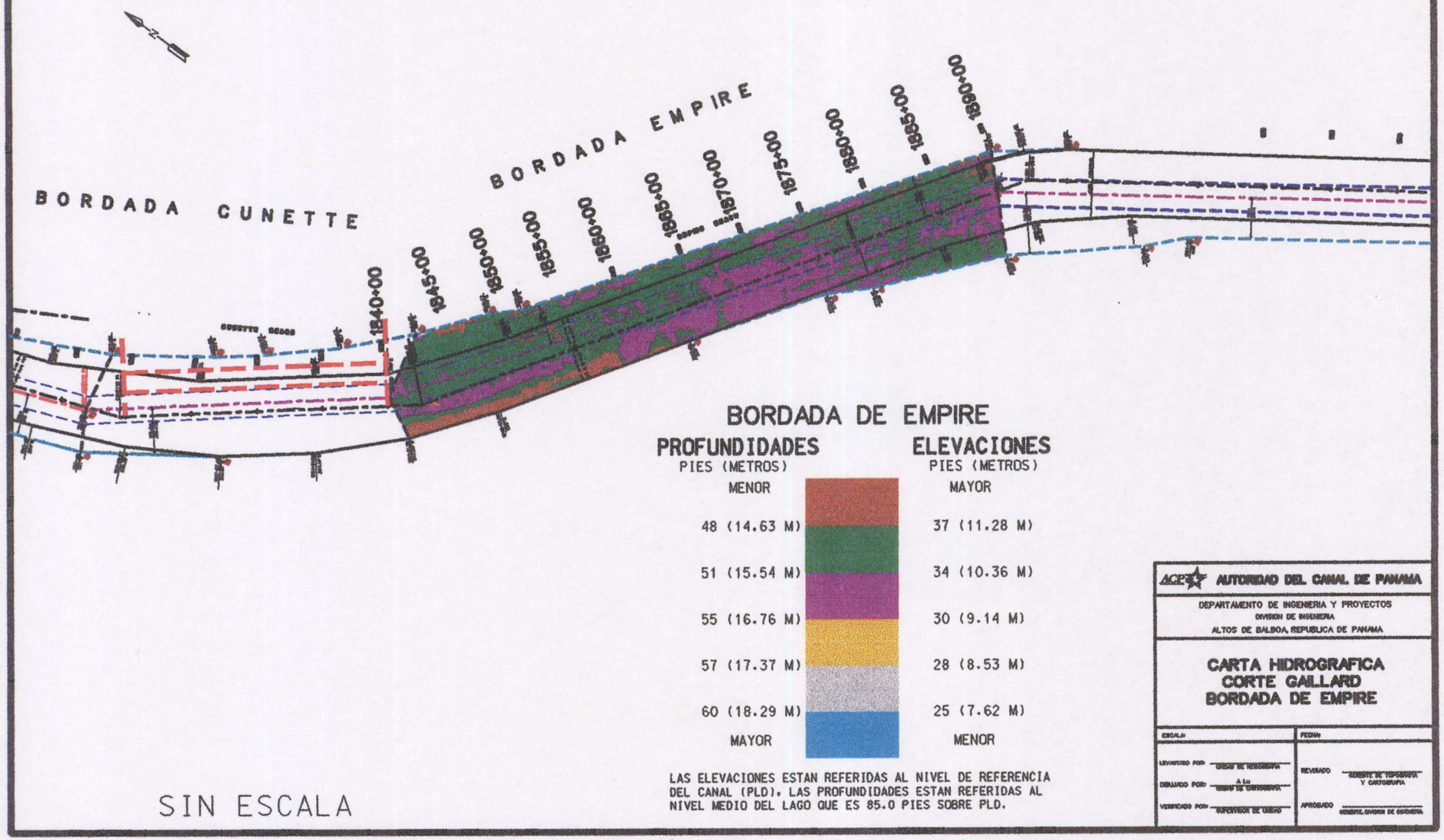

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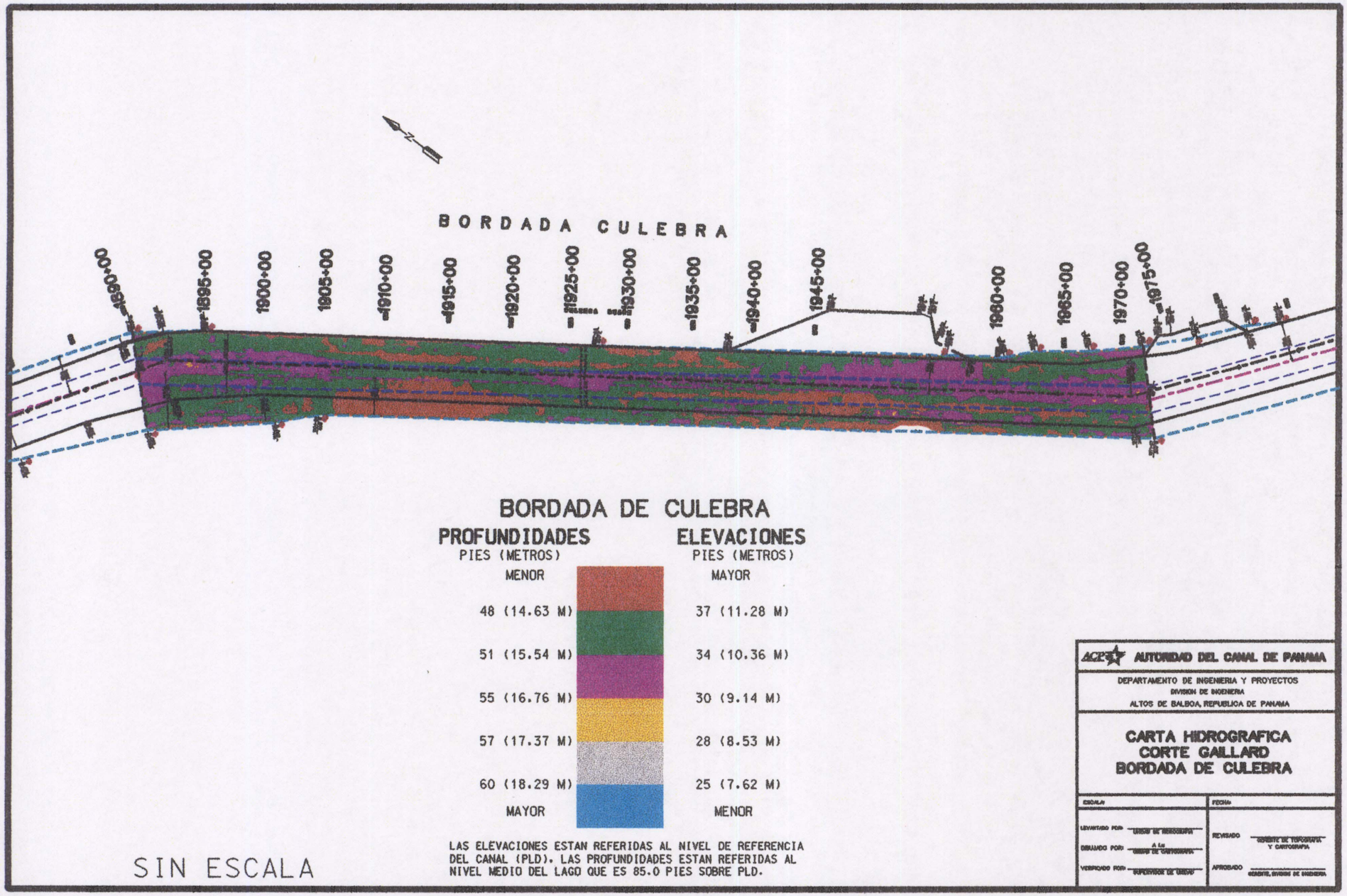

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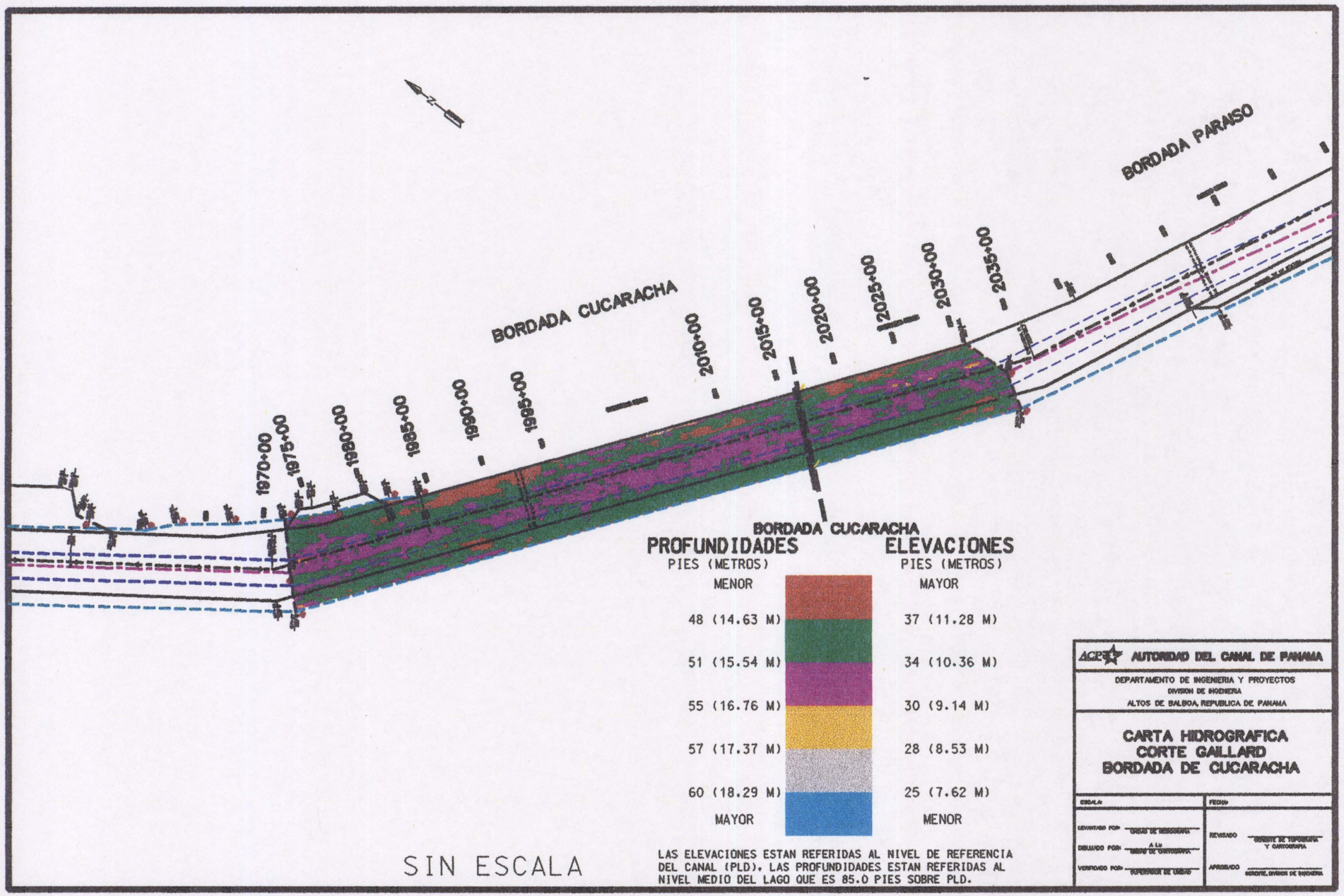

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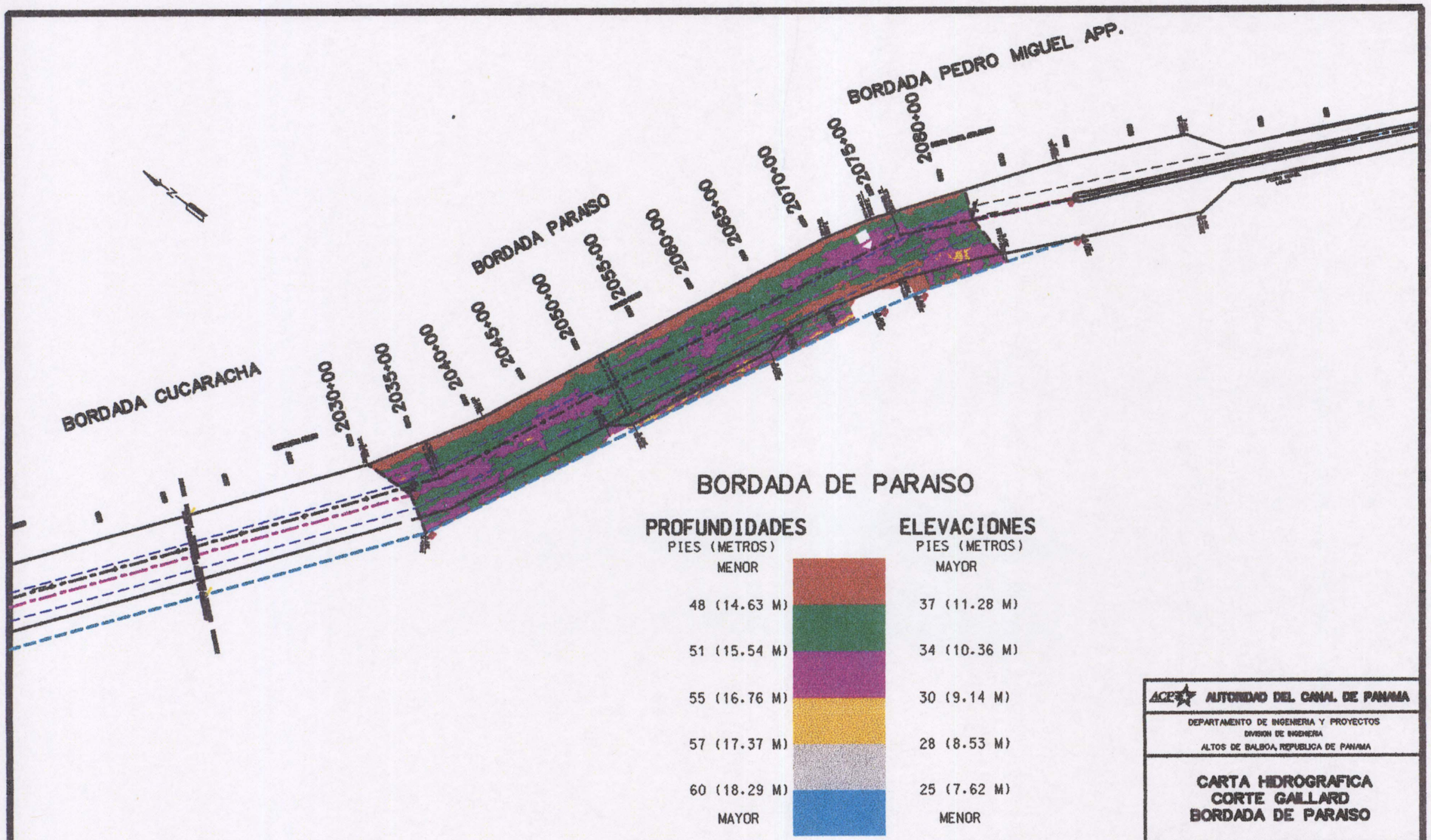

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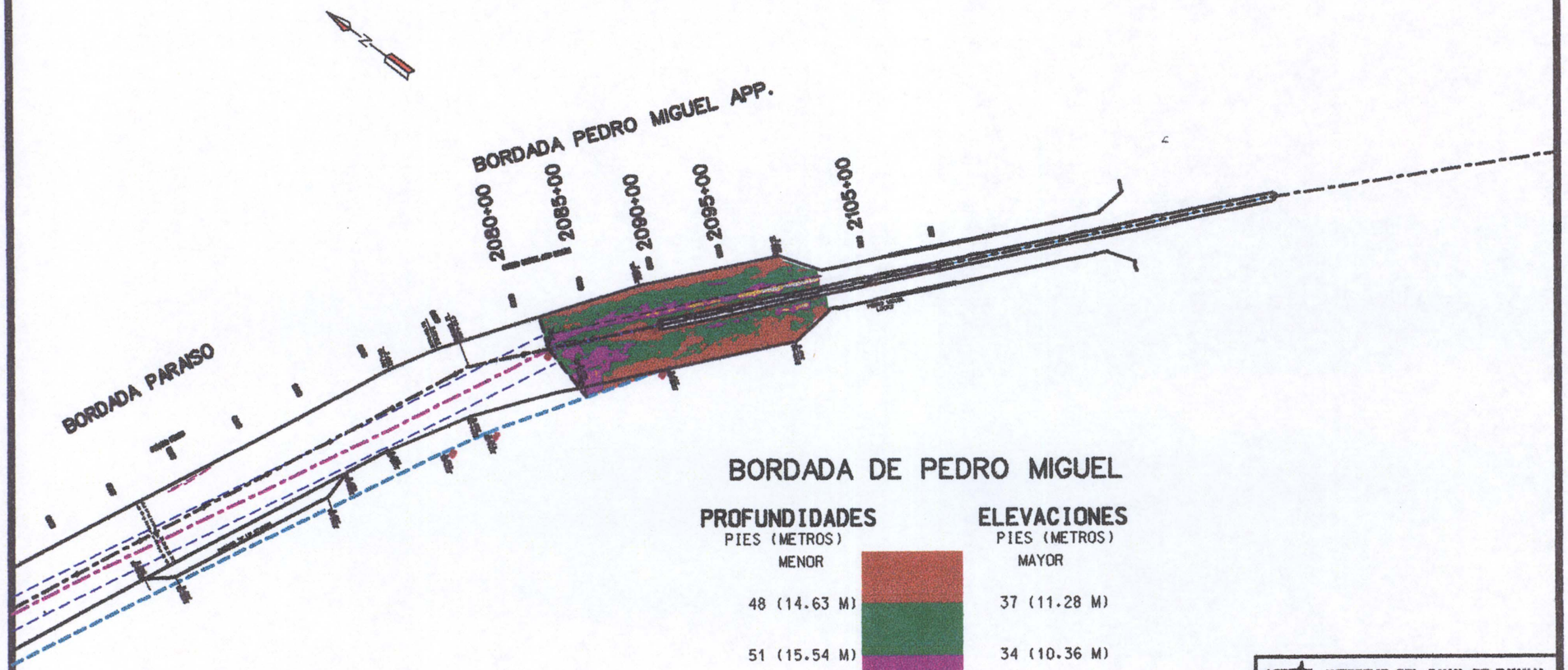

BORDADA DE PEDRO MIGUEL

PROFUNDIDADES PIES (METROS)	ELEVACIONES PIES (METROS)
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55 (16.76 M)	30 (9.14 M)
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MAYOR	MENOR

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CARTA HIDROGRAFICA
CORTE GAILLARD
BORDADA DE PEDRO MIGUEL

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REVISADO: JEFE DE TOPOGRAFIA Y CARTOGRAFIA
APROBADO: GERENTE, DIVISION DE INGENIERIA

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APPENDIX No. 15

Preliminary Assessment for the Cartridge and Proposed Bulk Explosive Systems for the Submarine Blasting Report by *Blasting Analysis International Inc.*

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PRELIMINARY ASSESSMENT FOR THE CARTRIDGE AND PROPOSED BULK EXPLOSIVE SYSTEMS FOR THE SUBMARINE BLASTING

DRAFT

SUMMARY OF CONCLUSIONS, RECOMMENDATION AND OPINIONS

Blasting Analysis International, Inc. (BAI) completed a preliminary technical study to evaluate the current Kelly bar system using cartridged explosives and a proposed modified drill platform using bulk explosives. Emphasis was placed on what was needed to make both reliable explosive systems. A summary of the conclusions, recommendations and opinions are listed as follows:

1. The best blasting system is one which can deliver reliable blast results to the intended deepening elevation, with minimal problems and at the least cost. It is highly recommended that a re-evaluation of the cartridge and proposed bulk systems be done with the new technical information contained within this report, particularly for the bulk system. Serious consideration also needs to be given to the hole loading procedures, reliability and safety for each system. If an economic re-evaluation is not performed with the new information, it could lead to false economics and conclusions.

2. It is important to note that the current cartridge system has had a very long history of reliability, and that the proposed bulk system remains untested and unproved for the severe field conditions in the submarine blasting. Thus, it is strongly recommended that one or two towers on the drill platform be converted to the bulk system for testing and evaluation purposes, to allow a phase-in period and retraining of personnel. Converting the entire drill fleet to a bulk system without testing could be irreversible, incurring a considerable expense if the bulk system proves ineffective, or is not economical in relation to the total project costs, objectives and completion schedule.

3. The proposed bulk system is more sensitive to failure than the cartridge system because loading bulk explosives in small diameter holes with very short explosive columns is not technically favorable compared to the cartridge system. In addition, the bulk system will require additional in-hole accessories and more detailed attention to the loading procedures to make it a reliable system. Specific details are provided to overcome the technical difficulties,

including explosive contamination and floating primers during the hole loading for the bulk system.

4. Any additional drilling to deepen the canal now, over and above what is needed for the immediate objectives, will improve the blast results and could save money over the very long term. This assumes that the funding is available to do this within the present schedule.

5. Relying on only one drill platform until the year 2004 with no backup system is strategically risky, should anything happen to the THOR in the interim period. Consideration should be given to getting the second drill platform on-line sooner.

6. Regardless of whether a cartridge or bulk explosive system is used, the top 5 feet of a 15 foot drill hole does not need any explosives. This upper part of the explosive column is basically wasted energy, and in some cases could cause other blasting problems. Thus, all future holes should not be loaded right to the top of the hole. This should be implemented immediately, since a savings of at least 33% in explosives consumption can be realized throughout the project duration.

7. A number of other cautionary notes are included in the report for both explosive systems. In terms of their technical merits, the cartridge system will provide a more reliable, less demanding and trouble free operation over the bulk system. The bulk system can be made to work, but will require more effort pertaining to the details. These trade-offs should be reflected in the final economic re-evaluation.

1.0 INTRODUCTION

Blasting Analysis International, Inc. (BAI) was commissioned by the Panama Canal Authority (PCA) to conduct a technical evaluation for the current drill boat THOR with a Kelly Bar System using cartridged explosives, and a proposed modified drill boat with an on-board bulk explosive loading system. The main purpose was to evaluate the technical feasibility, application logistics and what would be required to make both reliable systems. Although direct comparisons are made between the two systems to put some things into perspective, a final decision will weigh heavily on the final economics, reliability and the inherent safety of each system.

This report is based and qualified on the following:

1. An on site visit to the Panama Canal facilities during April 30 to May 2, 2002.
2. Meetings and discussions with PCA representatives from all of the relevant departments, including the legal and contracts divisions.
3. Technical information and reports supplied by PCA representatives.
4. Report on a "Proposed Bulk Explosives System", prepared by ETI Canada, dated February 21, 2002
5. Digital images taken during the on site visit
6. The author's familiarity with the former Panama Canal Commission's operation pertaining to blasting operations for the land and submarine blasting.

BAI is an international consulting group specializing in custom blast designs, technical and safety audits, blast monitoring instrumentation and training. To date, BAI has designed, monitored, evaluated and/or supervised over 6,000 full-scale blasts in a variety of field conditions spanning 22 countries.

BAI certifies that it is completely independent and is not associated with the financial business activities of the Panama Canal Authority, nor in the sale of explosives or rock products. Our services were retained strictly as an independent engineering firm to provide objective technical evaluations and advice.

2.0 GENERAL ECONOMIC CONSIDERATIONS

For purposes of discussion, the currently used drill boat THOR with the Kelly bar and use of cartridged explosives will be referred to as the "cartridge system". The proposed modified drill platform using bulk explosives will be referred to as the "bulk system".

In order to evaluate and optimize the blasting system, the drilling and blasting costs must be evaluated in conjunction with the total project costs. Economic evaluations based on a single unit cost reduction can only be valid when the operator is assured, for example, that a reduction in the explosive cost will not affect the total project costs, or the 7 year completion deadline to deepen the canal. Thus, one of the first things that must be done is a detailed cost sensitivity analysis for both the cartridge and bulk systems, which should take into account <u>all</u> unit costs, including the cost of capital, retrofitting and ownership. The intangible elements regarding reliability and safety should also be carefully considered when evaluating both systems. Failure to do this may not be in the best long term economic interests for the project, and could lead to erroneous conclusions and false economics.

On a broad basis, the overall project costs can be expressed as:

$$C = dr + bl + di + l + h + d + ov \qquad \text{…Eqn. 1}$$

Where:

- dr = drilling and accessories
- bl = explosives and accessories
- di = digging and dredging
- l = loading
- h = hauling
- d = dumping
- ov = oversize rehandle and secondary blasting

The drilling cost (Cdr), is dependent on borehole diameter, burden and spacing, thus Cdr = f1 (D, B, S). Blasting cost, (Cbl), depends primarily on the type of explosive, E, primer, P, and the initiation system, I. Thus, Cbl = f2 (E, P, I). Since the last five terms of Eqn. 1 (di, l, h, d, ov) are directly related to the fragment size distribution, they can be represented by a single function, f3 (F).

Equation 1 can now be rewritten as:

$$C = f1 + f2 + f3 \qquad \text{…Eqn. 2}$$

Where:
- f1 = drilling function costs
- f2 = blasting function costs
- f3 = fragmentation size distribution and processing costs

or

$$C = f1\ (D, B, S) + f2\ (E, P, I) + f3\ (di, l, h, d, ov) \qquad \text{…Eqn. 3}$$

Equation 3 allows one to perform a cost sensitivity analysis for a combination of input parameters for each option considered. An optimization program generally aims at lowering the highest cost element in the total project breakdown, without adversely affecting the other unit costs, production schedules, reliability or safety. In theory, an increased cost in any unit operation should not be a major concern if the total project costs are equal to or less than the system being compared. If productivity is improved or remains unchanged, an overall savings may have been realized. In practice, however, there must be a minimum improvement, since there is always a cost associated with any new operational change, retraining and to allow for some factor of safety in the calculations.

BAI's roles is to outline what is required from a technical and logistical standpoint to make both the cartridge and bulk systems work. Emphasis will be placed on the operational details, logistics and required accessories. This information will be useful input to complete and refine the economic analysis.

3.0 TECHNICAL ASPECTS APPLICABLE TO BOTH THE CARTRIDGE AND BULK SYSTEMS

3.1 Drill Hole Depth

The Panama Canal deepening project is currently planned for completion within the next 7 years. Figure 3.11 illustrates the target deepening elevation, subdrill and additional drilling for a total drill hole depth of 15 feet in the rock. The drill towers and rods for the THOR have been extended an additional 10 feet to accommodate the planned hole depth in the rock, and to maintain an efficient one pass system for the drilling setup.

The deepening objective is a large and relatively expensive project. Although the drill hole depth is already planned to go well below the necessary depth to achieve the new targeted deepening elevation, consideration should be given to drilling as deep as possible now for the future. The greatest cost is always in getting everything setup again in the initial program.

Assuming that the physical constrains on the drills are not exceeded for a one-pass system, and the economics and funding are favorable over the long term, additional hole depths will provide more flexibility for deepening the canal on an-as-needed basis in the future. The dredge Christensen will always have the option of dredging only to the desired elevation, even though the rock is broken to deeper elevations. This could save a substantial sum of money in the future should additional deepening be required, without the initial costs of setting up again from scratch.

In addition, deeper drill holes will provide the following technical advantages:

- Assured breakage to the desired deepening elevation.
- Better distribution of explosive energy, since the explosive column is elongated to more of a cylindrical charge rather than a point (i.e., crater) charge.
- Lower powder factors to break the same volume of rock, by allowing larger drill patterns.
- Allows the bottom of the hole to act as a catch basin for mud, slimes and sediment which will always end up at the hole bottom.

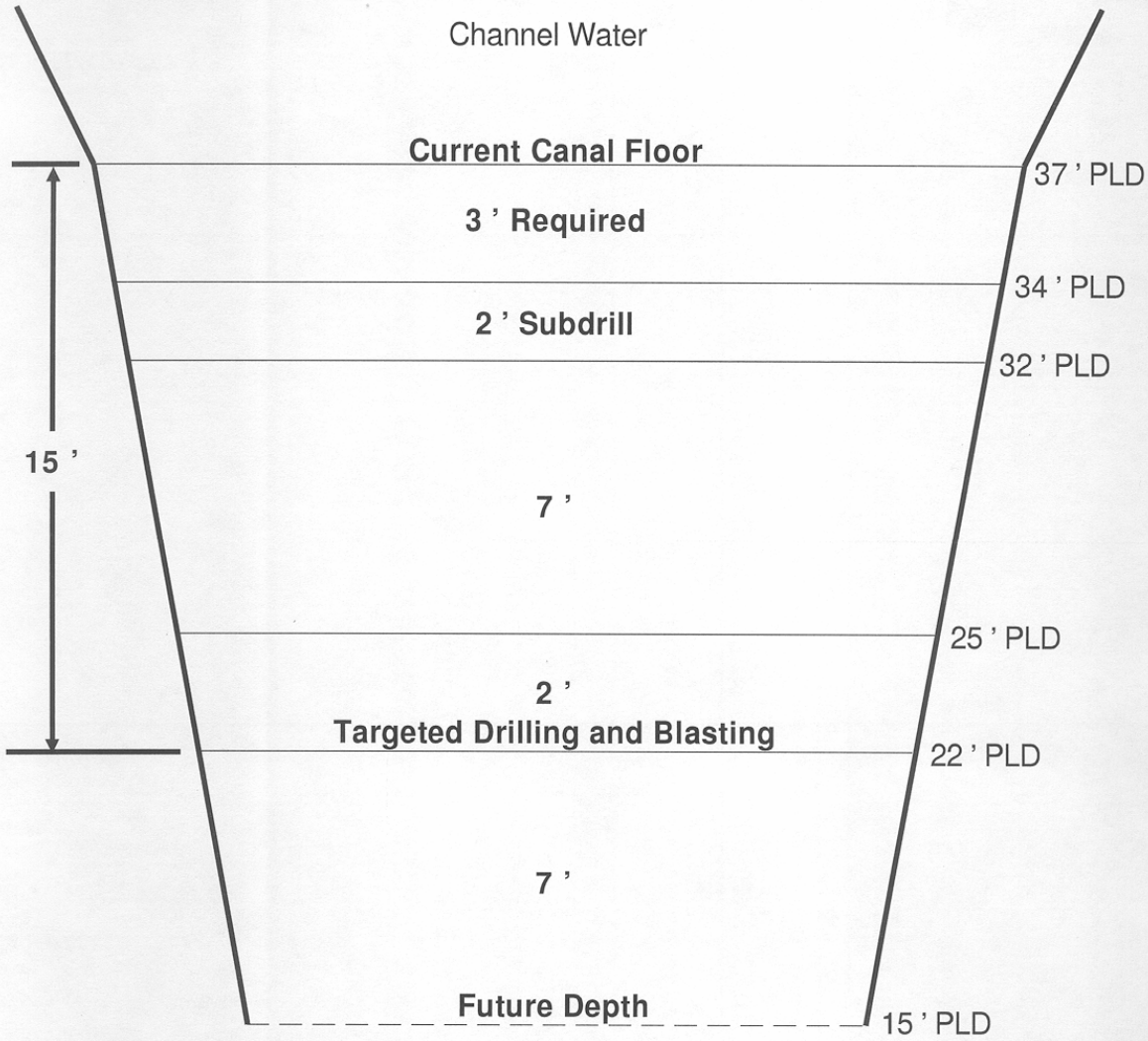


Figure 3.11 Current and future deepening plans for the Panama Canal

3.2 Drill Availability

At the present time, the drill boat THOR is the only platform available for the project. A new drill platform is planned for service by the fiscal year of 2004 by retrofitting the existing land-based drills.

Consideration should be given to getting the second drill platform prepared earlier for strategic purposes, even though the second drill platform is already budgeted into the scheduled plan for 2004.

Although no known serious accidents rendering the THOR unusable for prolonged periods have occurred from marine traffic collisions in the past, there have been a few close calls and future accidents can happen. We must also consider the effects of lightning and large quantities of explosive stored in holding tanks on the THOR or alongside the THOR on barges. Even though personnel are evacuated well before the onset of an electrical storm, a direct lightning hit could cause permanent, catastrophic and irrepairable damage to the THOR.

Most of the equipment in the Panama Canal is usually specialized and requires long lead times to acquire and put into commission. The point here is that if the THOR goes down for any reason (mechanical, fire on board, lightning, explosion, and/or vessel collision, etc.), the critical path schedule for completion of the project will be severely affected.

This is why large mining companies who use very large volumes of explosives always have two suppliers. If, for example, an explosive manufacturing plant's production is disrupted (i.e., accidental explosions, direct lightning strikes, shortage of raw materials, and/or labor disputes, etc.) the mining company can always continue operations with the second explosive supplier. The same consideration needs to be seriously given in the early stages of the deepening project. Basically, there is one drill platform until the year 2004 to carry out a very critical function, for a very important and expensive project. No backup drilling system is available until 2004.

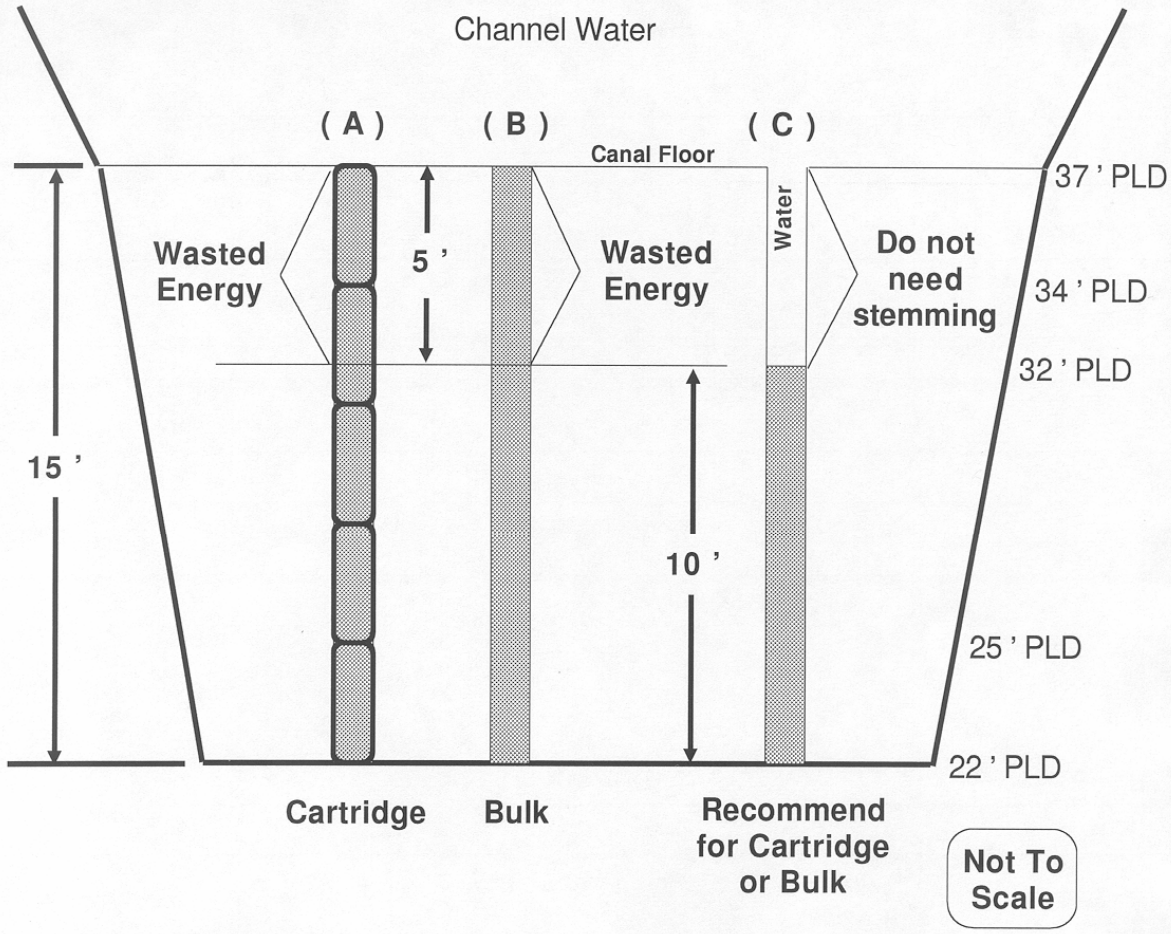
3.3 Explosive Column Load

Figure 3.21 illustrates three holes drilled 15 feet in the rock for the deepening project. The current and planned methods of loading a drill hole for the submarine blasting is to load the entire 15 feet of hole right to the top, as illustrated in A and B. But, regardless of whether the drill hole is loaded with cartridged or bulk explosives, the top 5 feet of explosives in the hole will be wasted and serves no useful function.

In fact, loading a hole with explosives right up to the top will tend to cause more problems in the form of misfires and erratic results, because the top part of the explosive could rob an adjacent hole of its collar burden. Also, the very top part of the explosive will tend to detonate in an unconfined condition, resulting in low order detonations, deflagrations or even partial explosive column failures.

In the case of bulk loaded explosives, a lower column will help to alleviate explosives being sucked out of the hole from the drag pressure created by heavy close passing vessels.

Removing a conservative 5 feet of the explosive column from the top of a 15 feet hole will reduce the explosive consumption by 33% on the project. This represents a substantial savings and should be implemented immediately, regardless of whether a cartridged or bulk system is used. In soft, weak or highly fractured rock formations, removing 6 to 7 feet of the top explosive column may also be possible. But it is doubtful that the removal of the top 5 feet of explosive will cause any measurable differences in the blast results.



Note: In soft, friable, weak or highly fractured rock areas, the explosive column could be reduced an additinal 1 - 2 feet.

Figure 3.21 Current and recommended hole loading

4.0 EXPLOSIVE CHARACTERISTICS

4.1 Critical Diameter

Both cartridge and bulk explosives can be formulated as high explosives or as blasting agents. A high explosive is defined here as one which will reliably detonate with only a No. 8 strength detonator. A blasting agent is defined as one which will not detonate with a No. 8 strength detonator, and thus will require a high-explosive (i.e., primer) in the detonation chain.

In general, cartridged explosives are better suited as high explosives, and are more conducive for use in small diameter, short explosive columns. In contrast, bulk explosives are generally better suited in the larger diameter holes and/or long explosive columns.

Another thing to consider is the critical diameter of the explosive. All explosives have a distinct critical diameter rating. If an explosive is put in a hole which is less than its critical diameter, it will fail regardless of the size or strength of primer used. If an explosive is used close to but above its critical diameter, the explosive will generally detonate, but may do so at a lower order detonation, thus robbing the hole of some of its initial available energy. Overall blast results could be unreliable, unpredictable and erratic.

Although some bulk explosive agents can be designed with specialized formulations to accommodate their use close to the critical diameter, most bulk explosive agents will struggle depending on their characteristics. High explosive cartridged products, on the other hand, can be reliably formulated for use in very small diameter holes with very little energy loss. This factor alone could equalize the effective energy output for fully coupled explosive loads compared to water decoupled cartridged explosives.

Thus, if contemplating bulk explosives agents for use in 4 7/8 inch to 6 1/2 inch holes, you want to select an explosive that is as far way from its critical diameter as possible. This factor could disqualify some explosive blasting agents. On the other hand, the smaller 4 7/8 inch hole will provide a better distribution of energy relative to the small hole depths of 15 feet.

4.2 Explosive Decoupling

Figure 4.21 illustrates the same 2 inch diameter of explosive in a fully coupled hole, in a larger 6 inch hole with air decoupling, and in a larger 6 inch hole with water decoupling. Note that the water acts as an excellent coupler of the explosive energy imparted into the surrounding rock medium compared to air decoupling.

Although a fully coupled explosive will technically produce the greater rock damage, it is not overly significant in the drill pattern expansion for purposes of obtaining the same fragmentation, given the conditions in the Panama Canal.

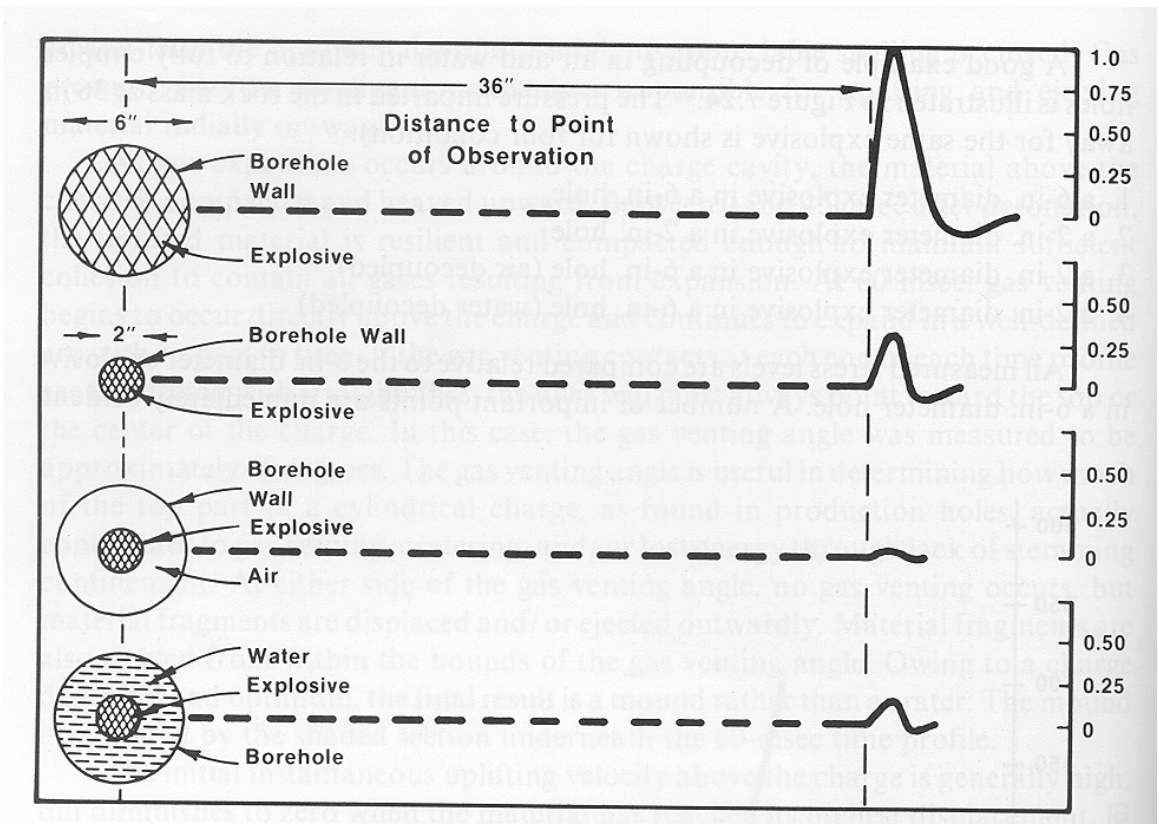


Figure 4.21 - Effects of Air and Water Decoupling

Source: Day, P. R. (1982). Controlled Blasting to Minimize Overbreak with Big Boreholes Underground. *Proceedings of the 8th Conference on Explosives and Blasting Techniques* (pp. 262-274) New Orleans, LA: Society of Explosives Engineers.

5.0 TECHNICAL CONSIDERATIONS FOR THE CARTRIDGE SYSTEM

5.1 Advantages of the Cartridge System

The present cartridge system with the Kelly bar on the drill boat THOR is a very reliable and proven blasting system. In spite of the explosive accident which occurred many years ago due to the use of NG-based high explosives, the cartridge system has withstood the test of time and has undergone many refinements in the loading procedures to be warranted a very reliable system. Today, NG based explosives are not allowed in the Panama Canal.

Significant advantages in using the cartridge system are listed as follows:

1. Once the hole is drilled and cased, there is very little or no possibility of the hole collapsing. This minimizes the number of lost holes, redrilled holes and assures that <u>all</u> holes can be properly loaded.

2. The use of sausage linked cartridged explosives with a detonating cord downline is a simple, reliable and quick one-step loading process.

3. The detonating cord downline is in contact with all of the cartridged explosives, thus providing a higher reliability of full column detonation.

4. Other than the detonating cord downline and the surface delays, no primers, in-hole delays, plugs or other accessories are required.

5. With cartridged produces, there is absolutely no possibility of contaminating or diluting the explosives with mud, slime, sediment or water. This is a very important consideration, particularly when loading very short explosive columns of 8 to 10 foot lengths in small diameter holes.

6. Cartridged products always assure the exact quantity of explosives with respect to the designed amount, for inventory and auditing purposes.

7. Other than having to extend the current drill towers and drill stems to accommodate an additional 10 feet of drill length, no other retrofitting is required.

8. Cartridged high-explosives are much better suited to smaller diameter holes for reliability.

9. A cartridge explosive system does not produce any undesirable remnants such as shock tube lines, plugs or PVC pipe floating on top of the water. This is important for marine traffic safety, environmental concerns and possibly clogging up water line intakes

10. Employees are already accustomed to the use of the cartridge system, and thus would require very little, if any training since it does not involve a major operational change.

5.2 Disadvantages of the Cartridge System

The three disadvantages with the cartridge system are:

1. On a unit cost per cwt, cartridged explosives will generally be more expensive. However, a new economic analysis is required to determine if this impacts the overall total project costs.

2. Cartridged explosives will require a slightly smaller drill pattern due to the decoupling, and hence a few more drill holes per blast block.

3. Rehandling in regards to delivery, storage and on-site use is more labor intensive, but not while loading individual holes.

6.0 TECHNICAL CONSIDERATIONS FOR THE BULK SYSTEM

6.1 Advantages of the Bulk System

The proposed bulk system also has some advantages and disadvantages in view of the specific application. The main advantages of implementing a bulk system are:

1. On a unit cost basis per cwt, bulk explosives are generally more economical, but this needs to be verified with an economic analysis within the total project costs and not on the explosive costs alone.

2. Bulk explosives are a blasting agent and thus less sensitive, but require a high-explosive primer and a No. 8 detonator for reliable detonation.

3. Larger volumes of explosives can be transported via approved ISO containers and pumped through electronically controlled systems, thus reducing the manpower required to get the explosives onto the drill barge in preparation for hole loading.

4. Slightly larger drill patterns will be possible, which leads to a few less drill holes per blast block. This assumes that each hole is properly prepared prior to loading and that everything has been implemented to assure a reliable blasting system.

6.2 Disadvantages of the Bulk System

The following disadvantages need to be seriously considered for the proposed bulk system:

1. The bulk system appears as a straight-forward simple system, but it has had no performance history for application on a drill platform and/or for the submarine blasting. Basically the bulk system remains unproven in terms of its proposed ease of use and reliability in meeting the PCA's final objectives.

   Thus, it is strongly recommended that one or two drill towers be set up on a test basis, prior to retrofitting all of the drill towers. This will allow management to perform a full unbiased evaluation in assessing the physical and economic constraints, compared to the current cartridge system. If all of the drill towers are converted over to accommodate a bulk system

without some test or phase-in period, it could be quite costly and also highly embarrassing for everyone if the system fails to meet its predictions, and then has to be reverted back to the standard cartridged system.

2. A reliable means will need to be engineered to keep a drill hole from caving-in or getting plugged when the drill bit is retracted out of the hole. In hard, competent, undisturbed, massive rock formations, this will not be so much of a problem. But in areas which consist of soft compacted sands or weak, friable and highly fractured rock, this will become a significant problem and a challenge to keep the hole cleared for loading. At this stage a means of keeping the hole open has not been very well defined. If a reliable method is not devised to keep the hole cleared in the early stages of the program, a significant number of lost and redrilled holes can be expected. This will extend the drilling time for a standard blast block.

   But, we must remember that in areas of bad ground conditions, the chances are high that an adjacent redrilled hole will also encounter the same conditions and could also be lost. The challenge then becomes to drill enough good holes that can be properly loaded. If a hole cannot be properly loaded, it will defeat the deepening project.

3. The greatest challenge, however, will be to keep the bulk explosive from being contaminated from the mud, slimes and sediment situated at the hole bottom. In any water saturated blast environment, where you have water in a hole, you will always have some accumulation of mud, slimes and sediments. Also the amount of impurities at the bottom of each hole could vary.

   When the loading hose is placed at the hole bottom through the impurities and the explosive is pumped into the hole, the impurities will get mixed into the explosive. Refer to Figure 6.21.

   This could contaminate and/or dilute the explosive for several feet into the explosive column. We must emphasize that there is only a 10 foot explosive column or approximately 100 to 120 lbs of explosives per hole. This is not a significant amount of explosive, but nevertheless a very critical and necessary amount to do the job. Even if only one foot of the sediment got mixed into the explosive while loading, this would represent a 10% dilution. A 10% dilution would result in a low order detonation and a large energy loss. A 20% dilution or 2 feet of sediment mixed into the explosive will cause a complete failure.

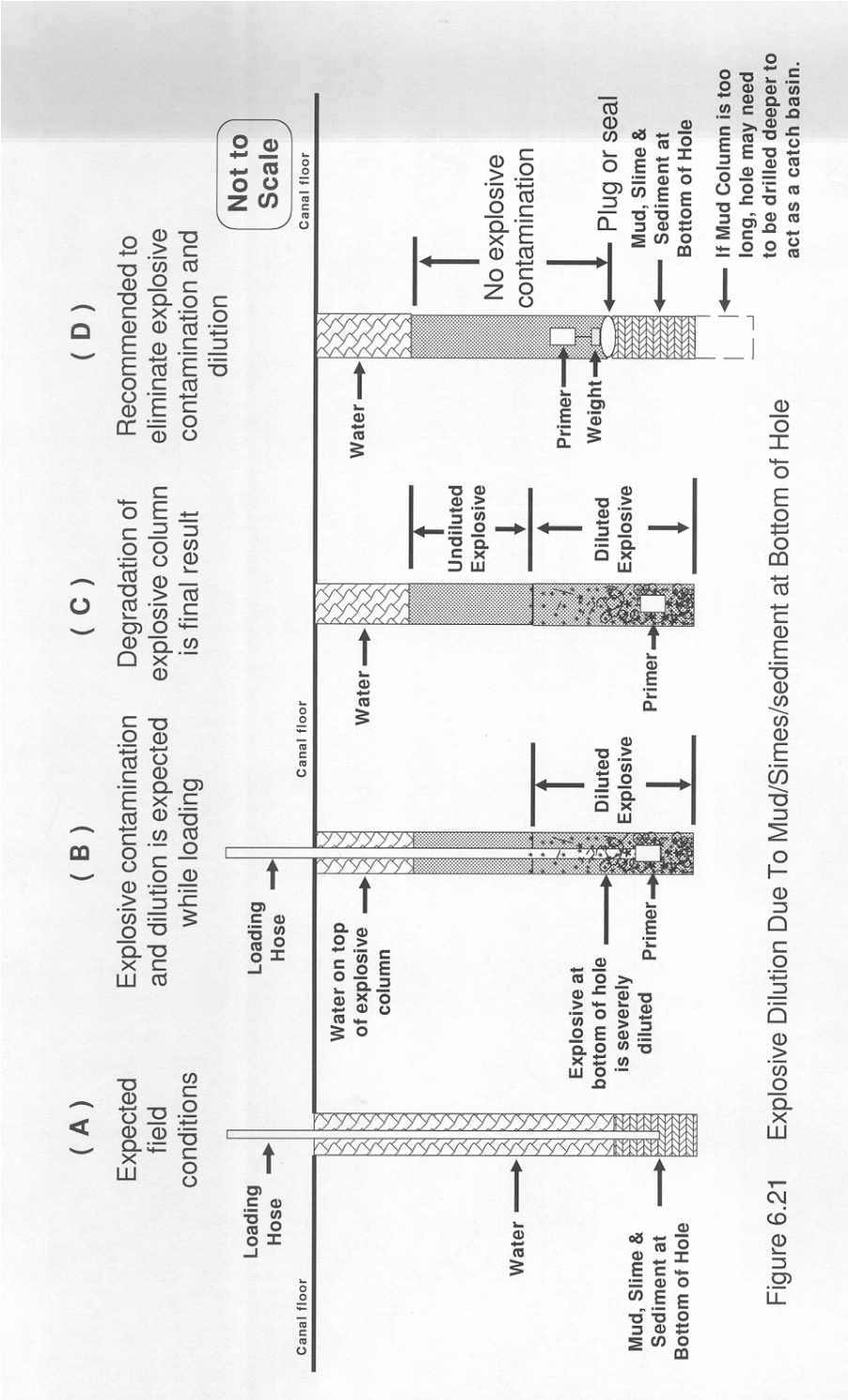


Figure 6.21 Explosive Dilution Due To Mud/Simes/sediment at Bottom of Hole

BAI has monitored the extent and effects of explosive dilution in many parts of the world. Explosive contamination is always a major problem and concern in severe wet borehole conditions. Explosive dilution in the bottom 3 to 5 feet of the explosive column would not be unusual, given the field conditions encountered in the Panama Canal. In some cases, well over 10 feet of explosive dilution have been documented, depending on the explosive density, explosive viscosity, field conditions and pumping rate. Thus, it is quite possible to get some degree of explosive dilution for the entire column height for the explosive columns anticipated in the Panama Canal application.

In order to eliminate the dilution problem, an effective plug must be inserted into each hole and placed above the sediments prior to loading. To position the plug at the correct elevation in the hole, a measurement would first need to be taken to establish where the top of the sediment is. Figure 6.22 illustrates a plug which is suitable for this application, and is highly recommended. The cost of this plug is approximately $3.00 each.

Figure 6.22

The problems associated with explosive dilution cannot be over emphasized. Remember that we do not have a large amount of explosives per hole to work with. Even a small amount of explosive dilution will have a large negative effect on the blast results. Unless the explosive dilution problem is eliminated, the bulk system will not work.

4. Another problem that needs to be overcome is floating primers while bulk loading. During hole loading when starting at the bottom of the hole, the pumped explosive will create some turbulence and upward pressure around the primer, which could cause the primer to float on top of the rising explosive column. Refer to Figure 6.23. This tends to happen more in severe wet borehole conditions than in dry holes, but can also occur in dry holes. BAI has measured primers to float above the explosive column by up to 30 feet. It is important to note that this is a common problem in the blasting industry when using bulk explosives in wet hole conditions and small diameter holes.

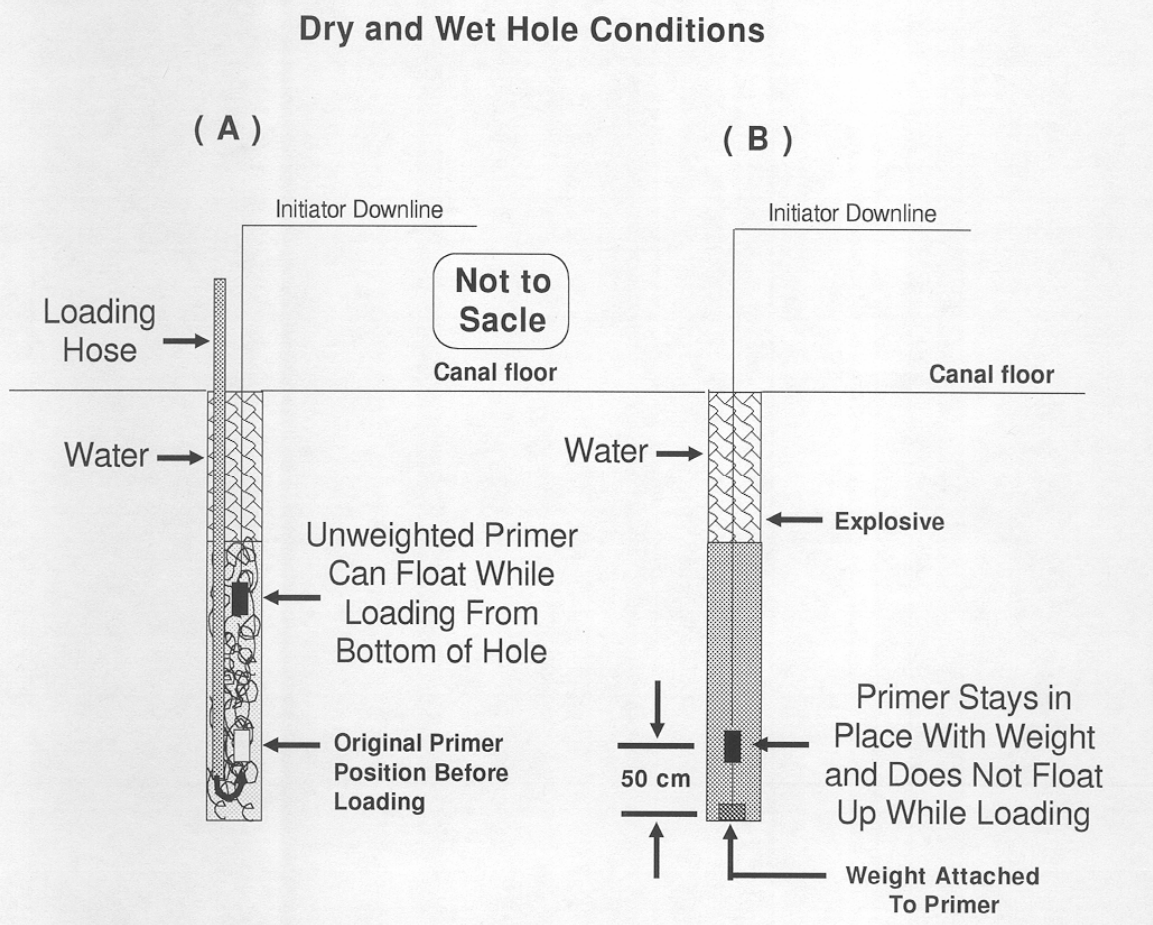


Figure 6.23 Priming floating while bulk loading in dry or wet hole conditions

The best way to solve the floating primer problem is to weigh each primer down with a suitable mass. Figure 6.24 illustrates one way to achieve this by simply hanging a rock on the primer. Others have used plastic bags or vexar netting filled with crushed rock, which is hung below the primer.

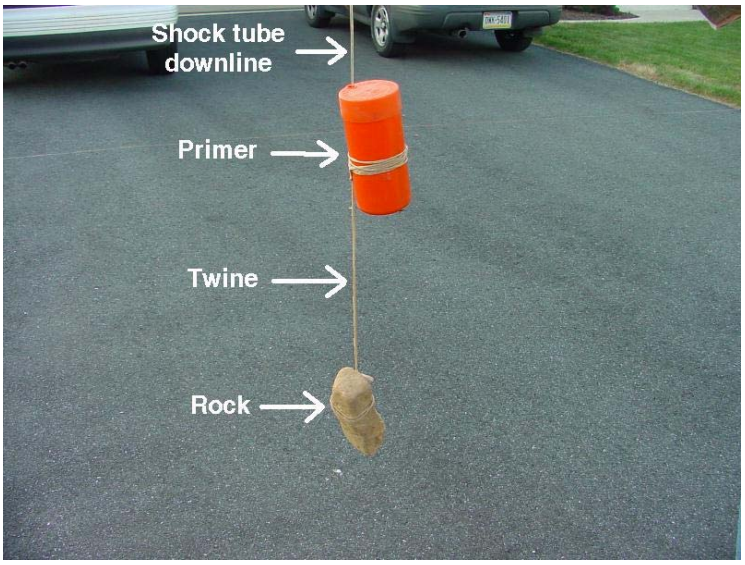


Figure 6.24

5. A bulk system generally provides the best economic alternatives for medium to large hole diameters with long explosive columns, as was used in the land blasting. Trying to load an exact amount for a relatively small amount of critical explosives per hole will be difficult for the field conditions, even with electronic flow meters. An automatic plug at the end of the hose will help in stopping excess explosives contained in the hose from dripping back into the hole when the pumps are turned off.

6. Similar to what was done with the bulk system in the land blasting, a pumping and hose retraction rate will need to be established and calibrated that allows the water to ride on top of the explosive column, while loading a hole. Pumping too fast can trap water within the explosive column in the form of water pockets or water stringers. This is another form of explosive dilution which is detrimental and could also cause unreliable and erratic blast results.

7. The bulk system will require more explosive accessories per hole. The cartridge system requires only the detonating cord downline placed alongside the cartridged sausage linked explosives and the surface detonators for timing. In contrast, the bulk system will require:

   - A plug on top of the sediment to eliminate explosive contamination while loading.
   - A bottom hole primer weighted down to eliminate "primer float".
   - An in-hole delay for the bottom primer.
   - A smaller backup primer, also weighted down, near the top part of the explosive column.
   - An in-hole delay for the top primer.
   - Surface delays.

   The additional explosive and borehole accessories will need to be taken into account in the final economic analysis

8. Loading each hole with the bulk system is more involved and expected to be more time consuming than the cartridge system. The cartridge system requires the sausage linked explosives and detonating cord downline to be placed in the hole in one single pass. The bulk system will involve the following chronological procedure for loading each hole:

   i. Locate the top of the sediment with an appropriate measuring tape.
   ii. Insert plug on top of sediment.
   iii. Place the weighted bottom hole primer in hole.
   iv. Load hole to level where the top backup primer is to be placed.
   v. Retract loading hose.
   vi. Place top back primer in hole.
   vii. Put hose back into hole and resume pumping to the desired explosive column height.
   viii. Retract hose from hole.

   It may be possible to eliminate steps v, vi and vii by placing both the bottom and top primers in the hole together, assuming that the hole is large enough to allow the hose to pass alongside the top primer. But given a 2 inch diameter loading hose, a 2 inch diameter primer, and a 4 7/8 to 6 1/2 inch hole, there is not much room left when using the smaller diameter holes for the hose to pass by the primer, without the potential of the hose being restricted by the top primer to pass through, without damaging the primer, or elongating the non-electric downline.

9. The non destructive loading and explosive accessories required per hole with the bulk system, (i.e., floating shock tube, plug remnants and/or PVC pipe, etc.) could cause an environmental and /or safety concern after the blast.

7.0 COMPARISON OF THE CARTRIDGE AND BULK SYSTEM REQUIREMENTS

Table 7.01 summarizes all of the factors discussed for the cartridge and bulk systems for comparison purposes. However, one must keep in mind that a re-evaluation of the total bulk system costs needs to be performed with the new information. Both the cartridge and bulk systems can be made to work, but the bulk system will require more retrofitting, new engineering and redesign. The bulk system will need to be tested, and it will require more detailed attention to the hole loading requirements.

TABLE 7.01

Comparison of the Cartridge and Bulk Systems		
Factors	**Cartridge**	**Bulk**
History of reliability	Proven	Not proven
Phase in tests required	No	Yes
Pumping and loading calibrations	None	Required
Modifications/retrofitting/redesign	Minor	Major and irreversible
Explosive quantity in hole	Exact	Variable
Lost/redrilled holes	Minimal	Moderate
Explosive contamination or dilution per hole	None	Requires plug on top of sediment
Primer float concerns	None	Must weigh primer down
Number of explosive accessories per hole	Minimal	Moderate
Manpower and rehandle to get explosive on drill barge	More	Less
Time to load a hole	Less	More
General maintenance	Less	More
Suitability for small diameter holes and short explosive columns	Favorable	Not favorable
Unit cost of explosives per hole	More	Less
Total cost of explosive/mining system	Known	To be re-evaluated
Environmental concerns regarding floating remnants after the blast	None	Major

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APPENDIX No. 16

Yearly Cost Indexes for Channels & Canal

And

Consumer Price Index

Consumer Price Index (CPI) Conversion Factors to Convert to 2001 Dollars
Using the CPI-U-X1 series, which applies the CPI used starting 1983 to 1950-1982
Should be used when exact comparisons are needed between years during the period since 1950

To convert dollars of a year to 2001 dollars, **divide** the dollar amount
of that year by the conversion factor (CF) for that year
For example, $1000 dollars of 1953 = $6135 dollars of 2001 ($1000 / 0.163)

Year	CF	Year	CF	Year	CF	Year	CF	Year	CF	Year	CF
1950	0.148	1960	0.182	1970	0.233	1980	0.465	1989	0.700	1999	0.941
1951	0.160	1961	0.184	1971	0.243	1981	0.509	1990	0.738	2000	0.972
1952	0.163	1962	0.185	1972	0.251	1982	0.540	1991	0.769	2001	**1.000**
1953	0.164	1963	0.188	1973	0.267	CPI-U = CPI-U-X1		1992	0.792	2002	1.018
1954	0.165	1964	0.190	1974	0.293	1983	0.562	1993	0.816	2003	1.042
1955	0.164	1965	0.193	1975	0.317	1984	0.587	1994	0.837	2004	1.067
1956	0.167	1966	0.199	1976	0.335	1985	0.608	1995	0.861	2005	1.093
1957	0.172	1967	0.205	1977	0.357	1986	0.619	1996	0.886	2006	1.120
1958	0.177	1968	0.213	1978	0.381	1987	0.641	1997	0.906	2007	1.147
1959	0.178	1969	0.223	1979	0.418	1988	0.668	1998	0.920	2008	1.176

CPI is CPI-U-X1, which applies the post-1982 CPI methods to the period 1950 to 1982.
By definition, CPI-U-X1 equals CPI-U starting in 1983, so the conversion factors are the same.
2000 conversion factors use the final 2000 year-to-year CPI (172.2). Conversion factors for 2001-2008 use the average of inflation estimates by the Office of Management and Budget and the Congressional Budget Office.
It is recommended that numbers be **rounded** to **no more than three decimal places**,
for example, $6135 in the example at the top of this page becomes $6140

Note: To reverse the process, that is, to determine what a 2000-dollar figure would be in the dollars of another year, simply **multiply** the 2001 figure by the conversion factor of that year. For example, $1000 2001 dollars would be $148 in 1950 ($1000 x 0.148 = 148), again rounded to 3 decimal places ($148).

The 1983 changes reduced the inflation rate by changing the way costs of home ownership are measured.
For reference, the following lists yearly inflation rate 1970 to 1985 using the CPI and the CPI-U-X1 series, which applies the 1983 measure to the period 1950 to 1982.

	CPI	CPI-U-X1	CPI Inflation	X1 Inflation	Difference (CPI minus X1)
1970	38.8	41.3	5.7	4.8	0.9
1971	40.5	43.1	4.4	4.4	0.0
1972	41.8	44.4	3.2	3.0	0.2
1973	44.4	47.2	6.2	6.3	-0.1
1974	49.3	51.9	11.0	10.0	1.0
1975	53.8	56.2	9.1	8.3	0.8
1976	56.9	59.4	5.8	5.7	0.1
1977	60.6	63.2	6.5	6.4	0.1
1978	65.2	67.5	7.6	6.8	0.8
1979	72.6	74.0	11.3	9.6	1.7
1980	82.4	82.3	13.5	11.2	2.3
1981	90.9	90.1	10.3	9.5	0.8
1982	96.5	95.6	6.2	6.1	0.0
1983	99.6	99.6	3.2	4.2	-1.0

Starting 1983, CPI = CPI-U-X1, but comparing changes between 1982 and 1983 price levels in CPI and CPI-U-X1 results in different rates of inflation for 1983.

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SOURCE: USACE.

TABLE A-2, YEARLY COST INDEXES BY CWBS FEATURE CODE
Base Year 1967 = 100

CWBS - FEATURE CODES	Wt %	FY68 Oct 67 - Sep 68	FY69 Oct 68 - Sep 69	FY70 Oct 69 - Sep 70	FY71 Oct 70 - Sep 71	FY72 Oct 71 - Sep 72	FY73 Oct 72 - Sep 73	FY74 Oct 73 - Sep 74	FY75 Oct 74 - Sep 75	FY76 Oct 75 - Sep 76	FY77 Oct 76 - Sep 77
02 RELOCATIONS	5%	105.52	112.79	118.78	134.70	146.50	153.85	167.31	193.03	206.77	218.70
03 RESERVOIRS	5%	104.95	115.82	126.39	146.60	161.77	167.43	175.64	201.34	215.69	226.15
04 DAMS	15%	104.99	112.21	121.16	132.02	142.58	149.41	165.26	186.45	203.20	214.55
05 LOCKS	2%	104.91	111.93	119.92	132.69	143.03	150.04	167.12	190.30	201.75	213.78
06 FISH & WILDLIFE FACILITIES	5%	104.72	112.28	120.22	132.70	143.52	150.83	171.27	193.50	205.30	216.70
07 POWER PLANT	10%	104.79	111.26	119.72	128.54	135.78	141.26	159.74	185.20	194.61	206.65
08 ROADS, RAILROADS & BRIDGES	10%	105.52	112.79	118.78	134.70	146.50	153.85	167.31	193.03	206.77	218.70
09 CHANNELS & CANALS	3%	105.43	112.16	120.51	132.28	141.12	146.21	161.64	186.46	202.12	212.28
10 BREAKWATER & SEAWALLS	5%	104.83	111.42	118.88	127.05	136.29	141.06	158.76	188.03	201.26	213.56
11 LEVEES & FLOODWALLS	5%	105.31	112.16	120.69	132.30	143.87	149.31	166.79	190.35	204.98	216.62
12 NAVIGATION PORTS & HARBORS	10%	104.36	109.78	116.39	127.54	135.81	143.73	162.24	189.32	204.99	220.93
13 PUMPING PLANT	5%	104.83	112.17	119.75	131.73	141.94	149.36	170.45	190.49	202.61	215.84
14 RECREATION FACILITIES	5%	104.83	112.17	119.75	131.73	141.94	149.36	170.45	190.49	202.61	215.84
15 FLOODWAY CONTROL & DIVERSION STRUCTURE	2%	104.72	112.28	120.22	132.70	143.52	150.83	171.27	193.50	205.30	216.70
16 BANK STABILIZATION	2%	105.08	111.41	118.87	128.79	138.40	143.26	160.28	176.63	190.48	200.18
17 BEACH REPLENISHMENT	2%	106.12	113.34	123.12	136.97	149.55	154.85	167.00	188.41	204.97	214.59
18 CULTURAL RESOURCE PRESERVATION	2%	104.83	112.17	119.75	131.73	141.94	149.36	170.45	190.49	202.61	215.84
19 BUILDINGS, GROUNDS & UTILITIES	5%	104.83	112.17	119.75	131.73	141.94	149.36	170.45	190.49	202.61	215.84
20 PERMANENT OPERATING EQUIPMENT	2%	104.83	112.17	119.75	131.73	141.94	149.36	170.45	190.49	202.61	215.84
COMPOSITE INDEX (WEIGHTED AVERAGE)	100%	104.98	112.09	119.92	132.17	142.49	149.16	166.25	189.80	203.43	215.68
YEARLY PERCENTAGE CHANGE			*6.8%*	*7.0%*	*10.2%*	*7.8%*	*4.7%*	*11.5%*	*14.2%*	*7.2%*	*6.0%*

Note: FY indicates data developed based on OMB projections.*

TABLE A-2, YEARLY COST INDEXES BY CWBS FEATURE CODE
Base Year 1967 = 100

CWBS - FEATURE CODES	Wt %	FY78 Oct 77 - Sep 78	FY79 Oct 78 - Sep 79	FY80 Oct 79 - Sep 80	FY81 Oct 80 - Sep 81	FY82 Oct 81 - Sep 82	FY83 Oct 82 - Sep 83	FY84 Oct 83 - Sep 84	FY85 Oct 84 - Sep 85	FY86 Oct 85 - Sep 86	FY87 Oct 86 - Sep 87
02 RELOCATIONS	5%	239.50	260.37	280.18	306.16	327.40	340.86	349.51	355.43	358.36	366.32
03 RESERVOIRS	5%	243.39	261.77	285.56	315.28	346.62	365.07	375.29	381.95	386.61	394.55
04 DAMS	15%	234.29	254.47	277.12	302.42	323.67	334.76	344.25	350.47	352.94	358.99
05 LOCKS	2%	233.87	254.13	276.11	301.87	323.21	334.84	343.82	348.28	350.35	356.84
06 FISH & WILDLIFE FACILITIES	5%	238.15	260.08	280.32	304.02	322.75	332.91	342.38	347.18	348.99	354.63
07 POWER PLANT	10%	222.75	241.68	266.35	294.48	314.76	324.11	333.16	337.53	341.85	348.65
08 ROADS, RAILROADS & BRIDGES	10%	239.50	260.37	280.18	306.16	327.40	340.86	349.51	355.43	358.36	366.32
09 CHANNELS & CANALS	3%	230.44	249.44	276.52	306.57	333.45	346.07	354.42	358.24	362.93	371.71
10 BREAKWATER & SEAWALLS	5%	232.34	252.07	280.18	311.09	336.64	347.98	355.31	361.66	366.25	374.63
11 LEVEES & FLOODWALLS	5%	235.94	256.08	280.75	308.97	333.68	346.21	354.99	359.69	362.50	370.28
12 NAVIGATION PORTS & HARBORS	10%	236.08	264.25	312.54	348.37	372.04	369.17	379.93	376.98	369.85	358.99
13 PUMPING PLANT	5%	235.78	257.20	277.60	302.25	320.13	330.82	341.06	346.12	347.33	353.35
14 RECREATION FACILITIES	5%	235.78	257.20	277.60	302.25	320.13	330.82	341.06	346.12	347.33	353.35
15 FLOODWAY CONTROL & DIVERSION STRUCTURE	2%	238.15	260.08	280.32	304.02	322.75	332.91	342.38	347.18	348.99	354.63
16 BANK STABILIZATION	2%	217.80	236.77	262.55	290.13	312.93	324.76	333.55	342.96	349.49	358.71
17 BEACH REPLENISHMENT	2%	231.77	249.67	273.04	299.95	327.10	342.33	351.39	358.74	365.02	373.80
18 CULTURAL RESOURCE PRESERVATION	2%	235.78	257.20	277.60	302.25	320.13	330.82	341.06	346.12	347.33	353.35
19 BUILDINGS, GROUNDS & UTILITIES	5%	235.78	257.20	277.60	302.25	320.13	330.82	341.06	346.12	347.33	353.35
20 PERMANENT OPERATING EQUIPMENT	2%	235.78	257.20	277.60	302.25	320.13	330.82	341.06	346.12	347.33	353.35
COMPOSITE INDEX (WEIGHTED AVERAGE)	100%	234.58	255.68	280.71	308.09	329.87	340.21	349.63	354.31	356.24	361.43
YEARLY PERCENTAGE CHANGE		*8.8%*	*9.0%*	*9.8%*	*9.8%*	*7.1%*	*3.1%*	*2.8%*	*1.3%*	*0.5%*	*1.5%*

Note: FY indicates data developed based on OMB projections.*

TABLE A-2, YEARLY COST INDEXES BY CWBS FEATURE CODE
Base Year 1967 = 100

CWBS - FEATURE CODES	Wt %	FY88 Oct 87 - Sep 88	FY89 Oct 88 - Sep 89	FY90 Oct 89 - Sep 90	FY91 Oct 90 - Sep 91	FY92 Oct 91 - Sep 92	FY93 Oct 92 - Sep 93	FY94 Oct 93 - Sep 94	FY95 Oct 94 - Sep 95	FY96 Oct 95 - Sep 96	FY97 Oct 96 - Sep 97
02 RELOCATIONS	5%	380.42	394.57	402.95	411.27	422.37	440.44	454.26	463.84	473.27	486.24
03 RESERVOIRS	5%	407.44	420.33	435.31	447.08	457.13	467.07	477.72	490.54	502.77	511.08
04 DAMS	15%	371.82	385.00	393.91	402.98	410.31	422.71	435.37	450.08	460.21	470.29
05 LOCKS	2%	371.05	383.63	390.92	398.73	405.85	418.00	430.98	445.65	454.94	464.50
06 FISH & WILDLIFE FACILITIES	5%	367.96	379.94	386.38	394.22	402.07	416.83	430.89	444.68	454.33	466.15
07 POWER PLANT	10%	360.93	376.54	387.78	398.99	406.50	416.04	425.62	438.32	445.08	451.66
08 ROADS, RAILROADS & BRIDGES	10%	380.42	394.57	402.95	411.27	422.37	440.44	454.26	463.84	473.27	486.24
09 CHANNELS & CANALS	3%	383.49	400.61	415.58	427.22	437.81	449.00	459.60	470.64	482.90	492.16
10 BREAKWATER & SEAWALLS	5%	385.55	405.23	422.20	435.04	446.15	457.62	467.96	478.33	490.36	499.73
11 LEVEES & FLOODWALLS	5%	384.15	400.02	410.71	419.99	429.95	441.84	453.83	467.41	477.68	486.21
12 NAVIGATION PORTS & HARBORS	10%	367.45	381.27	396.89	401.41	407.73	419.08	422.73	434.64	451.45	463.22
13 PUMPING PLANT	5%	369.45	383.14	386.75	392.35	399.07	410.63	424.91	439.72	445.58	454.99
14 RECREATION FACILITIES	5%	369.45	383.14	386.75	392.35	399.07	410.63	424.91	439.72	445.58	454.99
15 FLOODWAY CONTROL & DIVERSION STRUCTURE	2%	367.96	379.94	386.38	394.22	402.07	416.83	430.89	444.68	454.33	466.15
16 BANK STABILIZATION	2%	368.75	380.82	392.20	402.54	412.09	423.49	433.89	446.05	457.20	465.43
17 BEACH REPLENISHMENT	2%	383.51	399.48	414.03	425.67	438.77	451.27	460.91	474.09	487.28	495.55
18 CULTURAL RESOURCE PRESERVATION	2%	369.45	383.14	386.75	392.35	399.07	410.63	424.91	439.72	445.58	454.99
19 BUILDINGS, GROUNDS & UTILITIES	5%	369.45	383.14	386.75	392.35	399.07	410.63	424.91	439.72	445.58	454.99
20 PERMANENT OPERATING EQUIPMENT	2%	369.45	383.14	386.75	392.35	399.07	410.63	424.91	439.72	445.58	454.99
COMPOSITE INDEX (WEIGHTED AVERAGE)	100%	374.45	388.68	398.34	406.78	415.22	427.83	439.45	452.31	462.16	472.17
YEARLY PERCENTAGE CHANGE		*3.6%*	*3.8%*	*2.5%*	*2.1%*	*2.1%*	*3.0%*	*2.7%*	*2.9%*	*2.2%*	*2.2%*

Note: FY indicates data developed based on OMB projections.*

TABLE A-2, YEARLY COST INDEXES BY CWBS FEATURE CODE
Base Year 1967 = 100

CWBS - FEATURE CODES	Wt %	FY98 Oct 97 - Sep 98	FY99 Oct 98 - Sep 99	FY00 Oct 99 - Sep 00	FY01 Oct 00 - Sep 01	FY02* Oct 01 - Sep 02	FY03* Oct 02 - Sep 03	FY04* Oct 03 - Sep 04	FY05* Oct 04 - Sep 05	FY06* Oct 05 - Sep 06	FY07* Oct 06 - Sep 07
02 RELOCATIONS	5%	490.26	501.14	507.97	513.30	526.95	541.17	555.79	570.79	586.20	602.03
03 RESERVOIRS	5%	521.42	540.51	552.38	568.09	583.83	599.60	615.79	632.41	649.49	667.02
04 DAMS	15%	479.06	488.39	496.78	503.96	515.89	529.82	544.12	558.81	573.90	589.40
05 LOCKS	2%	472.47	480.10	488.88	495.43	507.88	521.59	535.68	550.14	564.99	580.25
06 FISH & WILDLIFE FACILITIES	5%	472.75	481.62	488.90	494.06	506.03	519.69	533.72	548.13	562.93	578.13
07 POWER PLANT	10%	458.96	465.38	472.73	479.63	489.52	502.74	516.31	530.25	544.57	559.27
08 ROADS, RAILROADS & BRIDGES	10%	490.26	501.14	507.97	513.30	526.95	541.17	555.79	570.79	586.20	602.03
09 CHANNELS & CANALS	3%	503.55	516.11	526.72	536.03	550.39	565.25	580.51	596.18	612.28	628.81
10 BREAKWATER & SEAWALLS	5%	510.50	520.83	527.86	534.68	548.77	563.59	578.80	594.43	610.48	626.96
11 LEVEES & FLOODWALLS	5%	495.99	503.35	512.62	518.66	532.71	547.10	561.87	577.04	592.62	608.62
12 NAVIGATION PORTS & HARBORS	10%	457.55	465.45	500.23	504.84	504.07	517.67	531.65	546.01	560.75	575.89
13 PUMPING PLANT	5%	459.40	460.16	468.05	472.18	483.50	496.55	509.96	523.73	537.87	552.39
14 RECREATION FACILITIES	5%	459.40	460.16	468.05	472.18	483.50	496.55	509.96	523.73	537.87	552.39
15 FLOODWAY CONTROL & DIVERSION STRUCTURE	2%	472.75	481.62	488.90	494.06	506.03	519.69	533.72	548.13	562.93	578.13
16 BANK STABILIZATION	2%	476.48	489.61	501.50	513.00	527.35	541.59	556.21	571.23	586.65	602.49
17 BEACH REPLENISHMENT	2%	507.09	521.89	532.71	543.21	562.57	577.76	593.36	609.38	625.83	642.73
18 CULTURAL RESOURCE PRESERVATION	2%	459.40	460.16	468.05	472.18	483.50	496.55	509.96	523.73	537.87	552.39
19 BUILDINGS, GROUNDS & UTILITIES	5%	459.40	460.16	468.05	472.18	483.50	496.55	509.96	523.73	537.87	552.39
20 PERMANENT OPERATING EQUIPMENT	2%	462.01	460.16	468.05	472.18	483.50	496.55	509.96	523.73	537.87	552.39
COMPOSITE INDEX (WEIGHTED AVERAGE)	100%	478.10	486.21	497.07	503.52	514.80	528.70	542.98	557.64	572.69	588.16
YEARLY PERCENTAGE CHANGE		*1.3%*	*1.7%*	*2.2%*	*1.3%*	*2.2%*	*2.7%*	*2.7%*	*2.7%*	*2.7%*	*2.7%*

Note: FY indicates data developed based on OMB projections.*

YEARLY COST INDEXES FOR CHANNEL & CANALS

SOURCE: U.S. CORPS OF ENGINEERS (USACE)

FISCAL YEARS	YEARLY COSTS	YEARLY PERCENTAGE CHANGE
1995	470.64	
1996	482.90	0.026
1997	492.16	0.019
1998	503.55	0.023
1999	516.11	0.025
2000	526.72	0.021
2001	536.03	0.018
2002 [2]	550.03	0.026
LAST 8-YEAR AVERAGE		**0.023**

Notes:

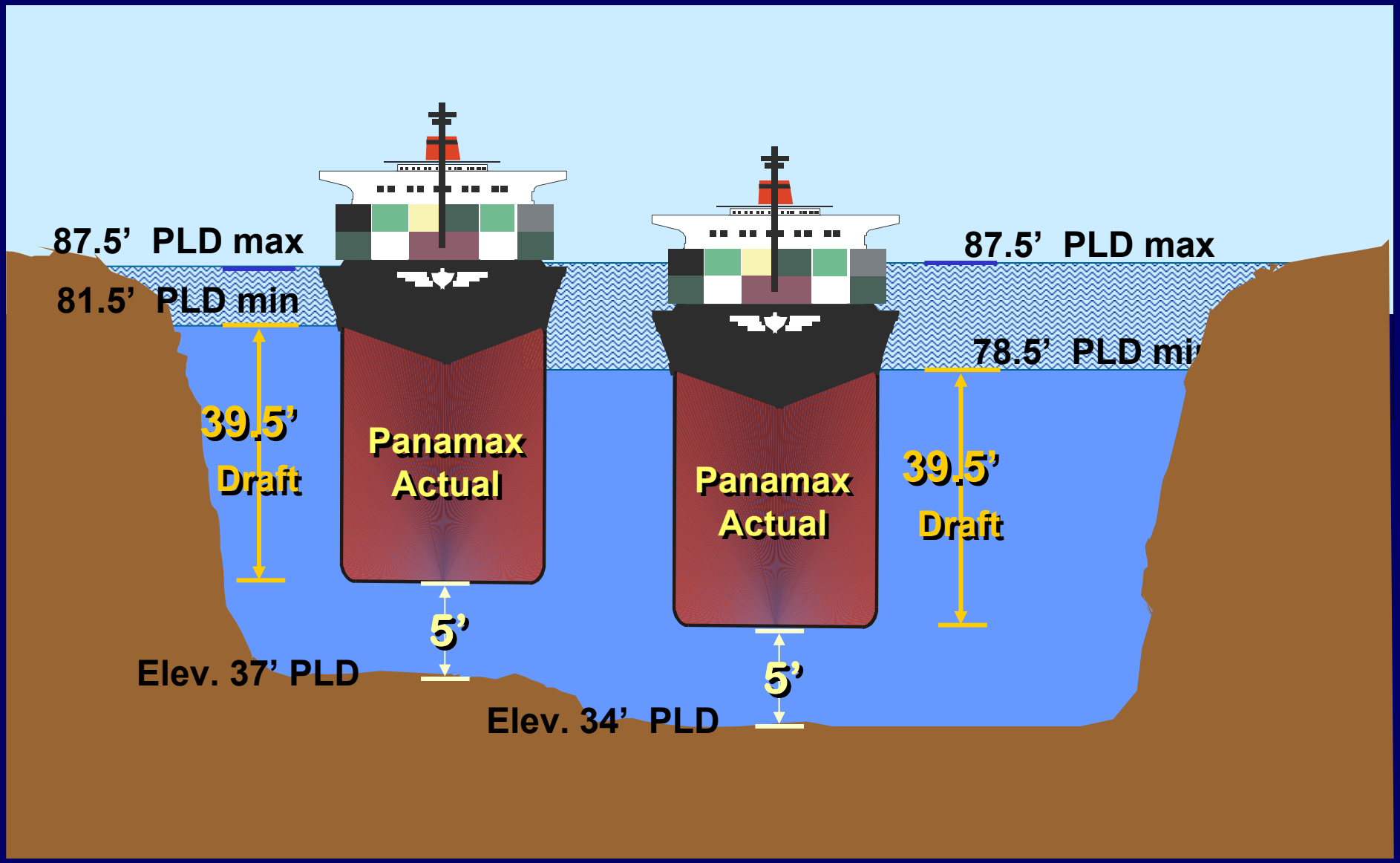
1. Fiscal year correspond the period from October 1 to September 30
2. Forecasted data developed based on US Office of Management and Budget projections.

APPENDIX No. 17

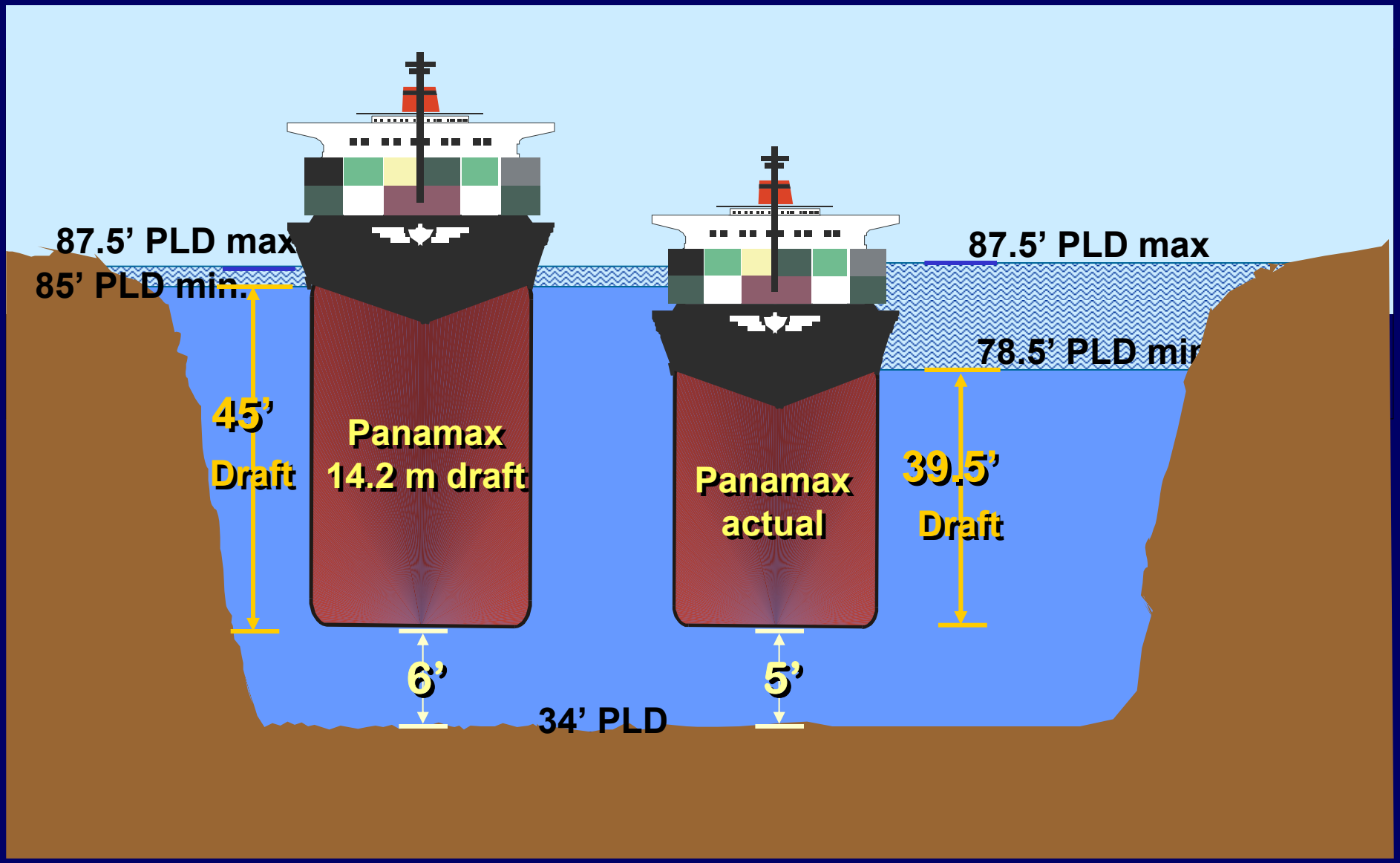
Gatun Lake and Gaillard Cut

Proposed Draft Phases for Canal Expansion Program

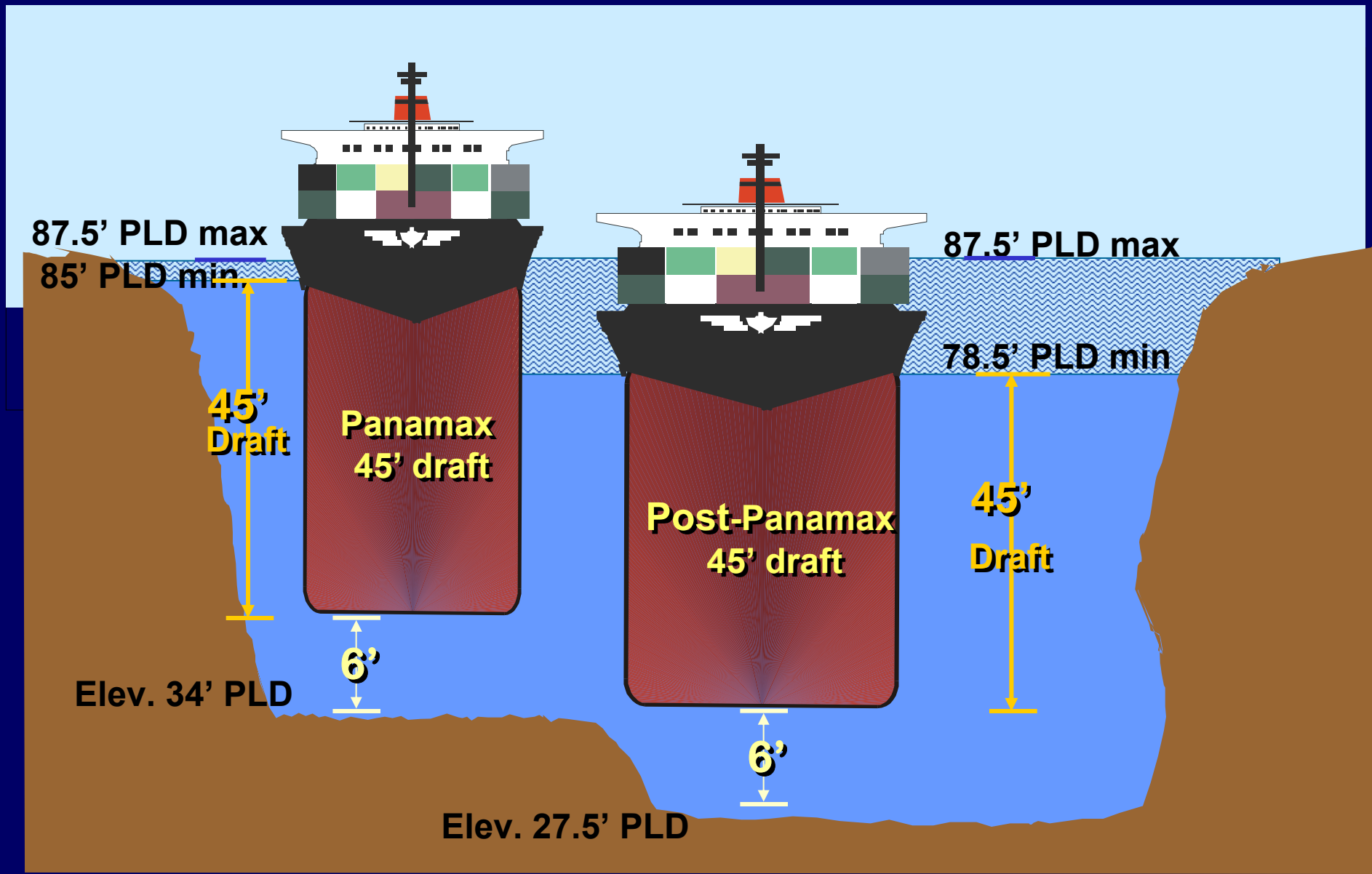
Gatun Lake Operation to a minimum level of 78.5 ft PLD



Gatun Lake Operation to a minimum level of 85’ PLD



Gatun Lake Operation at a minimum level of 78.5’ PLD



APPENDIX No. 18

Gatun Lake and Gaillard Cut

General Geologic Information

AUTORIDAD DEL CANAL DE PANAMA
Engineering Division - Geotechnical Branch

ATLANTIC MUCK

Introduction:
It is widely distributed in the Gatun Lake area between the north shore of the lake and Gamboa. Hills of the Gatun formation protrude through the black muck surface, representing islands completely surrounded by swamp and estuarine sediments. Muck deposits over 200 feet were found in some of the old borings in the area of Gatun dam. It comprises the Chagres, Trinidad and Gatun River valleys, with associated inland and coastal swamp areas.

Land Form:
The topography is of slight relief and is essentially the product of progressive sedimentation, as contrasted with the erosion processes involved in adjacent areas.

Origin:
In a relatively recent geological period, the land surface was higher than at present and the larger rivers of the Atlantic slope cut deep valleys. A period of subsidence followed, causing a reduction in the velocity of the streams, particularly along their lower courses, with resulting deposition of stream-borne silt and vegetable debris. Periodic encroachments of the sea resulted in brackish water conditions and a mingling of stream-borne clay, silt and vegetable matter with marine sediments. The latest geologic movement in the Atlantic coastal area raised the surfaces of the swampy estuary channels and tidal flats a few feet above sea level. The formation resulting from these processes of deposition is known as the Atlantic muck in the Gatun and neighboring areas.

Engineering Properties:
The muck deposits are uniformly soft and weak. They are composed predominantly of silt-sized sediments, and in their natural state of occurrence have very high moisture content. The depositional environment varied locally so that four facies are recognizable:

1. The border phase is adjacent to the contact with older formations and consists of gray to blue-gray silty clay.
2. The phase deposited in brackish marine areas contains an abundance of mollusk shells in an organic black silt matrix.
3. The swamp deposit portion of the formation is composed largely of black, very fine-grained organic materials, wood and other semi decayed vegetable substances intermixed with silt.
4. A soft, light gray or yellow-gray, weak, plastic, probably fluvial clay overlying the organic deposits.

The four facies intergrades laterally, and sandy lenses are present locally. The bedding is essentially horizontal. The surface of this formation was raised to its present position in late Pleistocene time.

Laboratory Tests:
Material obtained at 28 meters depth from core boring MHD-2, drilled at the Industrial Division of the ACP, at Mt. Hope, to the South of Cristobal, was taken to the soils lab for testing purposes. The index properties of the material, according to the UCS classification are as follows:

1. According to the UCS, the material is an MH (elastic sandy silt)
2. LL = 84
3. PI = 32
4. SG = 2.69
5. e = 2.3
6. $\gamma sat = 1434\ kg/m^3$
7. $\gamma dry = 848\ kg/m^3$
8. Consistency: OC-1 to OC-3 – Very soft to medium high consistency.

Adapted from
1947 -Isthmian Canal Studies
By Pastora Franceschi S.
26 July 2000

GATUN FORMATION

The type region of Gatun formation extends from Gatun Lake near Gatun northward to Mount Hope, near Colon. The base and the top of this formation are not exposed in the type region. It extends from the Atlantic entrance to one mile north of Puma Island in the Gatun Lake.

The formation has a thickness greater than 425 meters, as evidenced by core borings that have reached such depths, without reaching the base of the formation. In the Canal Area, the formation consists of massive, remarkably uniform beds of sandstone, siltstone, conglomerate and tuff medium soft to medium hard (RH-2 to RH-3); the formation is fairly strong, but soft enough to be excavated with ease. Most of the sandstone is fine-grained, and the sandstone and siltstone are variably calcareous, and somewhat tuffaceous. The tuff is almost invariably very fine-grained, and forms light colored outcrops in excavations. Fine-grained sandstones are interbedded with fine-textured volcanic tuffs and occasional thin conglomerate beds.

The formation is very fossiliferous, containing well-preserved mega- and microfossils of Miocene age. The massive, uniform beds of this formation represent uniform conditions of deposition, attaining thickness in excess of 100 feet.

The formation is not very jointed, being the material massive, except for the tuff beds, which are moderately jointed.

Adapted from
Stewart & Stewart
By Pastora Franceschi S.
1986

The soft rocks of the Cucaracha and Culebra formations in Gaillard Cut have an unconfined compressive strength on the order of 500 psi (3.45 MPA). The tuffs for Las Cascadas Formation (also in Gaillard Cut) have an unconfined compressive strength between 1500 to 2500 psi (10.35 to 17.24 MPA). However, there are also agglomerates that can reach the order of 3000 to 5,500 psi (20.70 to 37.93 MPA) and basalts that can reach from 6000 up to 24,000 psi (41.38 to 165.5 MPA). We have one case where the unconfined compressive strength of a very hard basalt was 31,000 psi (213.8 MPA). the andesites and basalts are more or less similar, but the highest strengths have been found in the basalts.

The specific weight for the hard rocks could be considered between 2500 and 2600 kg/m^3, and for soft rocks between 2000 and 2100 kg/m^3.

The Pacific entrance, Gaillard Cut, and Gatun Lake are composed of materials which encompass the entire range of unconfined compressive strengths, from very soft rocks to hard basalts, 500 to 24,000 psi (3.45 to 165.5 MPA).

In the Atlantic Entrance, the material belongs to the Gatun formation and has an unconfined compressive strength between 400 and 1200 psi (2.76 to 8.28 MPA).

GATUN LAKE AND GAILLARD CUT GENERAL GEOLOGIC FORMATIONS

Material type	Gatun Lake Reaches
BASALT	TABERNILLA OESTE
CAIMITO - Medium hard	GATUN,PENA BLANCA. BOHIO, TABERNILLA ESTE SUAVE Y OESTE VOLCANICA
GATUNCILLO	GATUN,PENA BLANCA. BOHIO, BUENA VISTA
BOHIO ROCA DURA EN AMBOS LADOS	GAMBOA, CURVA DE BOHIO, JUAN GRANDE,MAMEI, SAN PABLO, BUENA VISTA OESTE

Material type	Gaillard Cut Reaches
Soft material	
CUCARACHA	CULEBRA, CUCARACHA, PARAISO OESTE
CULEBRA	CULEBRA, EMPIRE,PARAISO(NITRO)
LA BOCA	CASCADAS OESTE, EMPIRE, PARAISO(ESTE) Y OESTE
Medium to hard material	
CASCADAS	CASCADAS,EMPIRE,CUNNETTE
Hard material	
PEDRO MIGUEL	CULEBRA NO AFLORA, EMPIRE, CUCARACHA OESTE LUIS, GOYO,PARAISO ESTE Y OESTE
BAS OBISPO	BAS OBISPO
Very hard material	
BASALTO	CUCARACHA EN NITRO, CULEBRA PERO NO A ORILLAS DEL CANAL,PARAISO ESTE UN POCO DE NITRO

FORMACIONES GEOGICAS GENERALES EN EL LAGO GATÚN Y CORTE

TIPO DE SUELO	BORDADAS - LAGO GATÚN
BASALTO	TABERNILLA OESTE
CAIMITO MEDIANAMENTE DURA	GATUN,PENA BLANCA. BOHIO, TABERNILLA ESTE SUAVE Y OESTE VOLCANICA
GATUNCILLO	GATUN,PENA BLANCA. BOHIO, BUENA VISTA
BOHIO ROCA DURA EN AMBOS LADOS	GAMBOA, CURVA DE BOHIO, JUAN GRANDE,MAMEI, SAN PABLO, BUENA VISTA OESTE

	BORDADAS -CORTE GAILLARD
FORMACIONES DE ROCAS SUAVES	
CUCARACHA	CULEBRA, CUCARACHA, PARAISO OESTE
CULEBRA	CULEBRA, EMPIRE,PARAISO(NITRO)
LA BOCA	CASCADAS OESTE, EMPIRE, PARAISO(ESTE) Y OESTE
FORMACIONES DE ROCA MEDIANAMENTE DURA	
CASCADAS	CASCADAS,EMPIRE,CUNNETTE
FORMACIONES DE ROCA DURA	
BOHIO	CULEBRA NO AFLORA, EMPIRE, CUCARACHA OESTE LUIS,
PEDRO MIGUEL	GOYO,PARAISO ESTE Y OESTE
BAS OBISPO	BAS OBISPO
FORMACIONES DE ROCAS MUY DURA	
BASALTO	CUCARACHA EN NITRO, CULEBRA PERO NO A ORILLAS DEL CANAL,PARAISO ESTE UN POCO DE NITRO

LA BOCA FORMATION

The La Boca formation in Gaillard Cut is a sedimentary formation of volcanic origin composed of sandstones, siltstones, limestones, lignitic shales, agglomerates, and tuffs of upper early Miocene age. All of the materials are tuffaceous, water-laid, calcareous, varyingly fossiliferous, and hydrothermally altered to clay minerals. The hardness of the formation varies from very soft to medium hard rock, RH-1 to HR-3. The Emperador Limestone, a member of the La Boca formation, is hard, RH-4 to very hard, RH-5.

There are three basic divisions of this formation:

1. The lowermost portion is a brackish water series of relatively weak, soft to medium hard (RH-1-3) siltstones and intercalated lignitic shales with a basal conglomerate frequently present. This portion is in unconformable contact with the Las Cascadas formation below.

2. The middle portion is a shallow water marine series with the limestones and lenses of sandstone and siltstone that comprise the Emperador limestone member. The limestones are hard, dense, fossiliferous, reef-type deposits and are the most competent materials in the formation.

3. The upper series is a thickness of sandstone, tuffaceous sandstone, tuffaceous agglomerate and tuff that represents gradually deepening water environmental conditions. This series is capped by a basalt flow at Las Cascadas Hill.

The La Boca formation occurs in Gaillard Cut in Las Cascadas, Empire, Paraiso, and Pedro Miguel reaches, and at the Balboa Port, and Pacific Entrance of the Canal

The La Boca formation is highly tuffaceous, low in silica, hydrothermally altered to ilmenite and montmorillonite clay minerals, and contains carbonaceous debris and abundant calcareous fossils, all varyingly cemented with secondary calcite.

Adapted from
Stewart and Stewart Descriptions
By Pastora Franceschi S.
26/July/2000

ENGINEERING PROPERTIES.—CANAL ZONE ROCK UNITS

FORMATION	DESCRIPTION	GEOLOGICAL CLASSIFICATION OF RELATIVE HARDNESS, Average	RANGE IN UNIT HARDNESS	UNIT WEIGHT, pounds per cu. ft.	SHEAR STRENGTH ø, degrees	SHEAR STRENGTH c, pounds per sq. in.	COMPRESSIVE STRENGTH,* pounds per sq. in.	ASSIGNED ALLOWABLE BEARING CAPACITY, tons per sq. ft.
OVERBURDEN**	Silts, sands, clays, gravels, etc.	Soft to very hard overburden	OH-1 to OH-5	Variable	Variable		Variable	Variable
ATLANTIC MUCK	Poorly consolidated clays and silts	Soft to medium soft overburden	OH-1 to OH-2	*90±	*17	*0	0.3-18.1	Very low
PACIFIC MUCK	Poorly consolidated clays and silts	Soft to medium soft overburden	OH-1 to OH-2	90±	17	0		Very low
CUCARACHA	Largely dense greenish-gray clay shales highly slickensided within certain horizons. Black carbonaceous shales, sandstones, and conglomerates in subordinate proportions	Soft rock	RH-1 to RH-3	*135±	*10	*16	1.3-956	***6-15
CULEBRA	Medium-hard sandstones, soft sandy and carbonaceous shales	Soft rock	RH-1 to RH-3	*135±	*11	*168	69-4020	15
LA BOCA	Dense silty or sandy dark gray shales with intercalated sandstone beds sporadically present	Soft rock	RH-1 to RH-3	*140±			75-3940	15
PANAMA TUFF	Coarse- to fine-grained acid tuffs, sandstones, and soft clay shales	Soft rock	RH-1 to RH-3	140±	Medium high strength			15
LAS CASCADAS	Agglomeratic tuff and tuff-breccia consisting of angular fragments of hard dark gray andesite in a clayey dark gray to light green altered tuff matrix	Medium hard rock	RH-2	140±			34-5922	15+
CAIMITO	Coarsely bedded medium- and fine-grained medium-hard limy sandstones and tuffs	Medium hard rock	RH-2 to RH-3	*135±			113-8470	20
GATUN	Fine-grained argillaceous and calcareous sandstones with interbedded dense tuffs and conglomerates	Medium hard rock	RH-2	*120±	*17	*220	470-940	20
CHAGRES SANDSTONE	Generally fine-grained medium-hard massively and tightly bedded dense gray friable sandstone	Medium hard rock	RH-2 to RH-3	120-125	High strength			20
TORO LIMESTONE	Slightly cemented shell- and coral-fragment limestone with minor intercalated lenses of medium- and coarse-grained sandstone	Medium hard rock	RH-2	130±	High strength			20
BOHIO CONGLOMERATE	Subangular to rounded pebbles, cobbles, and boulders up to two feet in diameter in a dark gray or brown, generally coarse, friable tuffaceous sand matrix	Hard rock	RH-3	*150±			334-2185	20+
EMPERADOR LIMESTONE	Algal and coralline reef limestone of local extent and spotty distribution	Hard rock	RH-3	170±	Very high strength			30+
PEDRO MIGUEL AGGLOMERATE	Hard light to dark gray fine- to coarse-textured agglomerates and tuffs	Hard rock	RH-3 to RH-4	*155±			4240-6970	50+
BAS OBISPO	Largely hard subangular to angular fragments of andesite and basalt in a sandy hard matrix of the same composition	Hard rock	RH-3 to RH-4	*155±			2248-4956	50+
BASALT	Hard columnar-jointed basalt flows and intrusives	Very hard rock	RH-4	*165±			2740-26150	50+
MISCELLANEOUS RHYOLITE AND ANDESITE	Generally very hard moderately jointed intrusions (dikes, etc.) and flows	Very hard rock	RH-4	160-170	Very high strength			50+

* Data determined by laboratory tests. Similar data for other rock units are estimates only, based upon lithologic similarity of the respective formations to those for which test data are available or upon local experience and field investigations.

** Includes weathered rock.

*** Data determined by field bearing test.

GEOLOGICAL HARDNESS SCALE

Overburden and Weathered Rock

OH-1	Soft	Easily squeezed through the fingers. Consistency of fresh putty. (Muck, some clays.)
OH-2	Medium Soft	Cannot be squeezed readily through the fingers, but is easily indented with finger point at moderate pressure.
OH-3	Medium Hard	Nonpenetrable at moderate finger pressure. A pencil point can be readily pushed into sample.
OH-4	Hard	Difficult to take drive sample. Difficult to push pencil point into sample.
OH-5	Very Hard	Material of near-rock character.

Sound Rock

RH-1	Soft	Harder than OH-5 and cannot be crumbled between the fingers but can be easily picked with geology hammer. (Some shales and uncemented sandstones.)
RH-2	Medium Hard	Can be picked with moderate blows of geology hammer. Can be cut with knife.
RH-3	Hard	Cannot be picked with geology hammer but can be chipped with moderate blows of hammer.
RH-4	Very Hard	Chips can be broken off with heavy blows of geology hammer.