# Technical Analysis on the Proposed Panama Canal Post Panamax Navigation Channel

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# TECHNICAL ANALYSIS ON THE PROPOSED PANAMA CANAL POST PANAMAX NAVIGATION CHANNEL

## 1 GENERAL DESCRIPTION OF THE STUDY

The construction of new Post Panamax locks at the Panama Canal would require improvements to the existing Canal navigation channels, which would involve deepening and widening work to guarantee the safe and expedite transit of Post Panamax vessels through the Canal. Preliminary analyses of Canal operations have proved that the currently used semi-convoy traffic mode is more efficient in terms of Post Panamax and Panamax throughput capacity; therefore, it is foreseen that Gaillard Cut and both Canal entrances would require as a minimum a 1-way Post Panamax channel layout, while Gatun Lake would call for a 2-way Post Panamax configuration. Additionally, if some of the current operating restrictions were lifted once the Cut straightening and widening program is complete, select Panamax ships could be allowed to conduct two-way transits through Canal entrances and the Cut.

This report includes the technical analysis to widen and deepen existing Canal navigation channels, and build new navigation channel access ways for new locks on the Atlantic and Pacific sides. The analysis includes an assessment of channel alignment and dimensions, excavation and dredging volumes, drilling and blasting requirements, channel geologic conditions, equipment and dredge selection, available and potential disposal sites, estimated execution time frames, unit and total costs, excavation and dredging work planning, contingency estimates, and cash flow development, among others.

The technical assessment for the construction of the new locks and the Pacific new lock approach channel between Gaillard Cut and the intermediate plug is reviewed in a separate report.

## 2 PARAMETERS USED TO DEVELOP POST PANAMAX NAVIGATION CHANNEL DIMENSIONS AND LAYOUT

### 2.1 Design Ship

- The design ship selected to determine the Post Panamax channel configuration as shown in Appendix No. 1 is the same containership used to develop the conceptual Post Panamax new locks design, which has the following main characteristics:
- Length: 360 m (1,180 ft)
- Beam: 46 m (152 ft)

- Initial draft: 13.7 m (45 ft)
- As part of the Canal Expansion Program, the Canal is expected to offer 13.1 m (43 ft) draft as a minimum and up to 15.2 m (50 ft) TFW[1] as a maximum, depending on Gatun Lake minimum operation levels and channel bottom elevation. These lake levels would be subject to weather conditions; ships could transit with deeper draft after the rainy season when the lake has accumulated enough water, while minimum draft restrictions would be imposed after the dry season, when no additional water has been collected at the lake.
- ACP marketing studies show that the number of Post Panamax containership new-buildings is increasing every year, and that containerized cargo is expected to be the principal commodity passing through the proposed new locks.
- As shown in Appendix No. 1, the existing Canal has experienced rapid growth in transits by Panamax container ships longer than 274 m (900 ft) during the last years. This trend is expected to increase in the future.

## 2.2 Navigation Channel Widening Guidelines

- The ACP used previous experience in navigation channel construction, as well as guidelines from two different organizations to determine the actual channel width required to allow the safe navigation of Post Panamax vessels:
- "Approach Channels, A Guide for Design" by the joint working group made up by representatives of the Permanent International Association of Navigation Congresses (PIANC), and the International Association of Ports and Harbors (IAPH), in cooperation with the International Maritime Pilots Association (IMPA), and the International Association of Lighthouse Authorities (IALA), June 1997.
- "Safe Waterways, A User's Guide to the Design, Maintenance and Safe Use of Waterways, Guidelines for the Safe Design of Commercial Shipping Channels" by Fisheries and Oceans, Canada.
- In addition to the above-mentioned guidelines, International Maritime Organization (IMO) vessel visibility requirements issued in 1998 through the International Convention on Safety of Life at Seas (SOLAS) were also adopted for redesigning of the Gaillard Cut channel.
- All the guidelines applicable to Canal waterways were discussed with ACP Maritime Operations personnel, including administrative pilots and the department director, to reach to a consensus in selecting the adequate channel design for combined 1-way Post Panamax and Panamax beam traffic.

[1] TFW stands for Tropical Fresh Water. A ship is assumed to have an increment of 0.3 m to 0.5 m (1 to 1.5 feet) draft from tropical salt water to tropical fresh water.

## 2.3 Line-of-sight visibility requirements

- IMO SOLAS, Chapter V Regulation 22, has established that the bridges of all ships over 45 m of length must be designed in such a way that the ship's line of visibility shall be two ship lengths from the bow or 500 m, whichever is the less. In other words, the helmsman and all officers on board the ship bridge must be able to see at least 500 m or two ship lengths ahead of the ship's bow as shown in Appendix No. 2.
- The proposed Post Panamax channel design complies with the line-of-sight visibility requirement for 500 m, based on a Post Panamax container ship sailing on the channel centerline, plus 1/3 of the ship's length, known as pivot point on the channel bend point of intersection (PI) as shown in Appendix No. 2.
- Although the ship starts to turn before reaching the navigation channel PI, the worst-case scenario was used to determine the 500 m line-of-sight visibility required by a ship for safe navigation, therefore placing the ship's pivot point on the PI.

## 2.4 Fresh and Salt Water Draft

- Gatun Lake and Gaillard Cut are the Canal's fresh water inland waterways, while salt water outer waterways include the Canal's Atlantic and Pacific entrances.
- Therefore, due to water density difference in ocean and lake, the ship's draft augments from 0.3 to 0.5 m (1 to 1.5 feet) as it navigates from salt water into fresh water.
- To avoid confusion, this report will refer to fresh water draft, unless otherwise specified.

## 2.5 Channel Minimum Under Keel Clearance (UKC) and Depth

- Minimum channel depth depends on many factors such as maximum ship at-rest draft, squat, tide, wave, type of channel bottom, water density, and others.
- According to PIANC, a minimum depth/draft ratio of 1.10 is recommended in sheltered waters[2]. Therefore, the proposed maximum draft of 15.2 m (50 ft) for Gatun Lake and Gaillard Cut would require a minimum depth of 16.76 m (55 ft), which includes a minimum of 1.5 m (5 ft) under keel clearance[3] (UKC).

## 2.6 Channel Width

- Channel width parameters depend on the following factors:
- Channel basic maneuvering lane and allowances for wind, currents, waves, bottom surface, waterway depth, etc.

[2] PIANC, "Approach Channels, A Guide for Design", June 1997, Page 20.
[3] Under keel clearance is the space available under the ship's keel or lowest bottom.

- Channel bank clearances
- In the case of bends, additional width, known as width of swept track, is required, which is determined by the ship's rudder angle and waterway depth.
- Additional width for 2-way traffic (in the case of 1-way Post Panamax traffic, this additional width is zero.)
- ACP experience in channel construction was considered in determining the Post Panamax navigation channel minimum width, which was also discussed with Canal pilots and related personnel.
- For straight sections, the ACP established widths of 218 m, 225 m and 280 m at Gaillard Cut and accesses to the new locks, Canal entrances, and Gatun Lake, respectively, to permit the traffic of Post Panamax and Panamax vessels. Appendix No. 2 includes a table indicating several scenarios for minimum width along Canal navigation channels.
- Following PIANC recommendations for bends, the channel should have an additional width of 1.2 times the ship's beam at a rudder angle of 20 degrees and a water depth/draught ratio of 1.13. That is, 38m for Panamax vessels, and 55 m for the Post Panamax design ship. Appendix No. 2 includes a copy of PIANC's diagram showing the recommended additional width at different rudder angles and water depth/draught ratio scenarios.

## 2.7 Channel Bend Turning Radius

- The channel bend turning radius for additional channel bend width is estimated based on the ship's ability to turn and the channel depth/draught ratio. This radius is generally expressed in terms of ship lengths.
- Appendix No. 2 includes a PIANC diagram used to determine the minimum channel bend radius. In the case of 1-way Post Panamax traffic, the minimum bend radius is 7.25 times the ship's length, or, 2,610 m. However, 2,800 m was used as minimum bend radius for ship's of 385 m, which constitutes new locks maximum ship's design.

## 2.8 Channel Distance Between Successive Bends

- According to PIANC, the minimum tangent distance between successive bends should be greater than 5 ship lengths, as shown in Appendix No. 2.
- In the case of a 1-way Post Panamax navigation channel, 5 ship lengths are equivalent to 1,800 meters. While most navigation channels comply with this guideline, there are some that do not comply with the minimum distance of 1,800 m because doing so would require additional massive excavation.
- To compensate for the lack of compliance regarding distance between successive bends, either additional bend width meters or a greater bend turning radius were added.

### 2.9 Transition from Navigation Channel Straight Sections to Bends

- According to Canada's recommendation, the transition from a straight section to a bend of the channel should be no less than a ratio of 10:1 (length/additional width).
- The transition from the straight section to the increased width of the bend is required to provide a smoother turn and compensate for the asymmetric forces exerted by the ship as it enters or exits the channel turn.
- Appendix No. 2 includes a diagram showing proper transition for a parallel-widened channel bend.

# 3 PROPOSED NAVIGATION CHANNEL LAYOUT AND DIMENSIONS FOR POST PANAMAX LOCKS

## 3.1 Existing Conditions and Ongoing Implementation of Improvements

### 3.1.1 Atlantic Entrance

- The Canal's Atlantic entrance has a minimum channel width of 198 m (650 ft), and a channel bottom elevation of –14.29 m (-46.9 ft) PLD, or a depth of 14.17 m (46.5 ft) MLW[4].

- The Atlantic entrance deepening and widening program was completed in April 2005, which involved the widening of its channel from 175 m (575 ft) to 198 m (650 ft), and deepening of 0.60 m (2 ft) to target channel elevation of 14.17 m MLW.

### 3.1.2 Gatun Lake and Gaillard Cut

- Gatun Lake channel width ranges from 254 m (830 ft) to 305 m (1000 ft) with a bottom elevation of 11.3 m (37ft) PLD. Minimum channel width at Gaillard Cut and Gamboa Reach is 192 m (630 ft) in straight sections, and 222 m (730 ft) in bends.

- Gatun Lake and Gaillard Cut are currently being dredged to elevation 10.4 m (34 ft) PLD, to augment their hydraulic storage capacity by 362.9 million cubic meters, which is equivalent to 5.8 lockages per day. This deepening will allow lowering the lake's minimum operating level by 0.91 m to provide the additional water storage capacity, while maintaining the Canal's maximum draft of 12.04 m

[4] MLW stands for mean low water, which is the average of all low tides at the Atlantic entrance. It is at –0.12 m (-0.38 ft) PLD.

(39.5 ft) for Panamax vessels. This program began in late 2001, and is scheduled for completion in 2006. Appendix No. 3 includes a Panama Canal diagram showing locks and channel elevations along the Canal.

- The Cut is also being straightened to comply with SOLAS visibility requirements, and to enable the safe transit of Panamax vessels with the following maximum dimensions: 294 m (965 ft) length, and 32.3 m (106 ft) beam. Such project would minimize angles of deviation and facilitate ship navigation through the Cut. The straightening began in 2003, and is scheduled for completion in 2007.
- In August 2005, ACP decided to convert the straightening program of the Cut into the widening program of the Cut to 218 m to enable two-way transits of Panamax ships, especially those longer than 260 m (850 ft). This channel configuration would improve navigation safety by providing additional clearance. The straightening program is scheduled for completion in 2010.
- Another improvement project to optimize existing Canal infrastructure is the installation of barriers around locks strut arms to prevent water intrusion in lock machinery rooms. Raising Miraflores Lake minimum operating level by 0.3 m (1 ft) the ACP would be able to increase the Canal's current maximum draft from 12 m (39.5 ft) to 12.3 m (40.5 ft).

### 3.1.3 Pacific Entrance

- The Canal's Pacific entrance channel width ranges from 213 m (700 ft) to 366 m (1,200 ft) south of the Bridge of the Americas, and 192 m (630 ft) north of the Bridge of the Americas. Channel bottom elevation is –15.88 m (–52.1 ft) PLD, or depth 13.56 m (44.5 ft) MLWS.[5]
- This entrance is being deepened since January 2005, to lower the channel bottom to 16.49 m (54.1 ft) PLD, or depth 14.17 m (46.5 ft) MLW, and the project is scheduled for completion by June 2005.

### 3.1.4 New locks approach channels

- The new locks approach channels would require the construction of new navigation channels. The areas selected for this project are located near the former third locks excavation site – a project initiated by the US in 1939, and suspended in 1942 due to changes in military strategic plans.
- The new Atlantic approach channel would be located east of the existing locks, while the new Pacific approach channel would be west of the existing locks.

[5] MLWS stands for mean low water spring, which is the average of low waters at time of spring tide at the Pacific entrance. It is at –2.32 m (–7.6 ft) PLD.

### 3.1.5 Summary of Conditions of Existing Navigation Channels:

- Following is a table that summarizes the conditions of existing navigation channels:

| EXISTING CANAL NAVIGATION CHANNEL CONDITIONS | | | | |
|---|---|---|---|---|
| | **Areas** | **Existing channel elevation (m PLD)** | **Existing channel width (m)** | **Maximum Draft (m)** |
| 1 | Atlantic Entrance Navigation Channel[1] | -14.29 | 198 | 12.65 |
| 2 | Northern Atlantic Post-Panamax Approach Channel | NONE | | |
| 3 | Atlantic New Post Panamax Locks | NONE | | |
| 4 | Southern Atlantic Post-Panamax Approach Channel | NONE | | |
| 5 | Gatun Reach up to Juan Grande Reach | 10.40 | 254 to 305 | 12.00 |
| 6 | Gaillard Cut, and Gamboa and Chagres Crossing Reach | 10.40 | 192 to 222 | 12.00 |
| 7 | Northern Pacific Post-Panamax Approach Channel | NONE | | |
| 8 | Pacific New Post-Panamax Locks | NONE | | |
| 9 | Southern Pacific Post-Panamax Approach Channel | NONE | | |
| 10 | Pacific Entrance Balboa Reach[1]<br>Pacific Entrance Navigation Channel[1] | -16.49 | 192<br>213 to 366 | 12.65 |
| Notes: | | | | |
| 1. Existing conditions were assumed after widening and deepening both entrances. | | | | |
| 2. The Cut will be widened to 218 m as a minimum, starting in year 2005, and this project could end during the execution of the proposed Canal expansion program if executed. | | | | |

**Table No. 1. Existing Canal navigation channel dimensions**

## 3.2 General Proposed Layout

- All the parameters explained under Section 2 were applied to determine the optimum and most feasible layout to allow Post Panamax vessel transit along the Canal.
- The new Post Panamax channel layout would allow for 1-way Post Panamax traffic in Gaillard Cut, and new lock northern and southern approach channels 218 m wide. Meanwhile, the Atlantic and Pacific entrances could allow a combined beam of Post Panamax and other smaller vessels at 225 m width, and Gatun Lake would be widened to 280 – 366 m wide to enable two-way Post Panamax ship traffic. Two-

way restricted Panamax ship transits are also being considered for the Cut and Canal entrances. This operation would very much depend on vessel transit scheduling and mix.

- Appendix No. 4 includes a figure showing a general layout of the existing navigation channel with the new proposed dimensions merged with new Post Panamax locks approach channels.
- Appendix No. 5 includes details of each navigation channel area including proposed alignments for new locks approach channels, and Appendix No. 6 details the four intersections of the new access channels with existing channels.

## 3.3 New Approach Channel Alignment for Post PanamaxPost Panamax Locks

- Alignment A-1 moved 38 m west, and Alignment PMD-1 were selected as the best options for Post Panamax vessel transits on the Atlantic and Pacific sides, respectively.

## 3.4 Minimum Required Post PanamaxPost Panamax Channel Widths

### 3.4.1 Atlantic and Pacific Entrances

- To comply with the proposed Post Panamax and Panamax two-way transit operation, the minimum width for the Atlantic and Pacific entrances was established at 225 m in straight sections and 260 m in bends. These channel width dimensions were the result of PIANC recommendations.
- It was initially established that Canal entrances should have a minimum width of 218 m all the way rather than 225 m in straight legs and 260 m in bends. However, the difference in cost between both options was around $8 to $10 million. Therefore, it was proposed to modify channel entrances to 225 m in straight sections and 260 m in bends to guarantee safer navigation, and increased Canal throughput.
- The proposed widths for Canal ocean entrances are minimum requirements, since many areas like the Pacific entrance straight sections and the new approach channel bends would have channel widths larger than specified to compensate for lack of compliance with channel minimum distance between successive bends.

### 3.4.2 Gaillard Cut

- Since it was initially established that Gaillard Cut should allow for 1-way Post Panamax passage , the proposed minimum channel width would be 218 m all the way. Meeting of Panamax vessels smaller than 275 m in length would also be permitted during daytime.
- As explained earlier, there are plans to widen the Cut to 218 m in fiscal year 2006 to allow greater flexibility for two-way transits of Panamax ships.

- The proposed 218 m navigation channel width was determined based on previous Canal experience in ship transiting through Gaillard Cut. The Cut is the narrowest and most critical section of the Canal due to the bank hydrodynamic forces it creates and its bank instability conditions. Gaillard Cut's former width of 152 m (500 ft) allowed for the safe 1-way transit of Panamax ships. The relation between the Cut's minimum width and Panamax ship beam is 152 m to 32.3 m, or 4.72 times. By using this figure, the minimum channel width for a Post Panamax vessel with 46 m (152 ft) beam was then calculated at approximately 218 m (46 m x 4.72).

### 3.4.3 Gatun Lake

- It is foreseen that under the Canal expansion scenario, Gatun Lake should be able to allow unrestricted two-way Post Panamax transits similar to today's unrestricted two-way Panamax transits.
- To allow such Post Panamax transits, the Lake must be widened to 280 m in straight sections and 366 m in bends, as a minimum. These dimensions also follow PIANC recommendations.

### 3.4.4 New Approach Channels

- As with Gaillard Cut, the new approach channels would initially allow for 1-way Post Panamax traffic; therefore, minimum channel width would be 218 m all the way.

## 3.5 Post Panamax Channel Minimum Allowable Drafts

### 3.5.1 Canal Ocean Ends

- Both ocean entrances and new locks approach channels on ocean ends would be dredged to allow a maximum draft of 13.7 m (45 ft) TSW[6]; assuming an under keel clearance of 1.83 m (6 ft). However, suggestions show that such under keel clearance could be lowered to 1.52m (5 ft) for a maximum draft of 14 m (46 ft) TSW or 14.3 m (47 ft) TFW.
- Depending on lake operation level for draft range of 13.1 m to 15.2 m, the ocean waterways would be the limited draft factor since its proposed deepening would allow draft of 13.7 m to 14 m. However, ocean waterways could be dredged in subsequent phases.

[6] TSW stands for tropical salt water. A 13.7 m TSW draft ship would have a 14.1 m draft in the lake.

### 3.5.2 Canal Inland Waterways

- Gatun lake, Gaillard Cut, and the new locks approach channel on the lake area would be dredged to allow a minimum transiting draft of 13.6 m (44.5 ft), and a maximum of 15.2 m (50 ft) depending on navigation channel elevation options.
- The proposed scenario involves deepening the lake area to 9.14 m (30 ft) PLD to allow a draft range of 13.6 m (44.5 ft) to 15.2 m (50 ft) according to the fluctuation of the Gatun Lake level, which can range from to 24.2 m (79.5 ft) PLD to 25.9 m (85 ft) PLD.
- In addition to this draft increment, the 9.14 m PLD option would become a water project since it would provide additional water availability.

## 3.6 Post Panamax Channel Minimum Depths

- As pointed out previously, minimum under keel clearance would be 1.5 m (5 ft); however, an under keel clearance of 1.8 m (6 ft) is being considered for ocean channels.
- Therefore, canal minimum channel depths at the lake and Cut would be between 15.1 m (49.5 ft) and 16.8 m (55 ft) for a variable draft of 13.6 m (44.5 ft) to 15.2 m (50 ft).
- Canal minimum channel depths at sea would be 15.5 m (51 ft). In other words, maximum salt-water draft at Canal entrances would be 13.7 m (45 ft) TSW, or 14 m (46 ft) TFW.

## 3.7 Summary of Proposed Post PanamaxPost Panamax Channel Widths and Depths

- Following is a table summarizing the different proposed lengths, widths, and drafts for Post PanamaxPost Panamax traffic along the Canal:

| POST-PANAMAX NAVIGATION CHANNEL PROPOSED DIMENSIONS | | | | | |
|---|---|---|---|---|---|
| Scenario: Locks 427 m x 55 m x 16.8 m | | | | | |
| | Areas | Approximate Length (km) | Minimum Width (m) | Depth (m) | Channel bottom minimum elevation (m PLD) |
| 1 | Atlantic Entrance Navigation Channel | 9.80 | 225 to 260 | 15.50 | -15.66 |
| 2 | Northern Atlantic Post Panamax Approach Channel | 4.00 | 218 | 15.50 | -15.66 |
| 3 | New Atlantic Post Panamax Locks | 1.70 | 55 | | |
| 4 | Southern Atlantic Post Panamax Approach Channel | 4.00 | 218 | 14.6 to 16.8 | 9.14 |
| 5 | Gatun Lake up to Juan Grande Reach | 38.00 | 280 to 366 | 14.6 to 16.8 | 9.14 |
| 6 | Gaillard Cut, and Gamboa and Chagres Crossing Reach | 18.00 | 218 | 14.6 to 16.8 | 9.14 |
| 7 | Northern Pacific Post Panamax Approach Channel | 5.50 | 218 | 14.6 to 16.8 | 9.14 |
| 8 | New Pacific Post Panamax Locks | 1.70 | 55 | | |
| 9 | Southern Pacific Post Panamax Approach Channel | 2.00 | 218 | 15.50 | -17.86 |
| 10 | Pacific Entrance Navigation Channel | 16.00 | 225 to 260 | 15.50 | -17.86 |
| Note: Assuming under keel clearance of 1.5 m in canal inner waterways, and 1.8 in canal ocean entrances. | | | | | |

**Table No. 2. Proposed dimensions for Post Panamax navigation channel**

# 4 EXCAVATION, DREDGING, AND DRILLING AND BLASTING VOLUME ESTIMATES

## 4.1 General Parameters Used for Volume Estimates

- Latest bathymetric and topographic data were used to estimate Post Panamax navigation channel excavation and dredging volumes through the civil engineering application software INROADS.
- Volume estimates were calculated at the different required channel widths and drafts.
- Excavation volumes in Gaillard Cut were estimated using bench slopes between 3H:1V to 1H:4V for all excavation material above elevation 27.5 m (90') PLD. Slopes used for dredging were 1H:1V or 2H:3V, according to geologic conditions along Gaillard Cut navigation channel.
- Dredging and excavation volume estimates for the new locks approach channels include the same slope parameters used to estimate Gaillard Cut volumes.
- All dredging volumes include 0.61 m (2 ft) of dredging tolerance below the design channel bottom, and an over-swing of 7.62 m (25 ft) at each channel, except for the narrow area close to the Bridge of the Americas on the Pacific entrance. See Appendix No. 4

- Sub-drilling and blasting volumes were estimated at 1.83 m (6 ft) below the dredging tolerance line or 2.44 m (8 ft) below the design channel bottom elevation. See Appendix No. 4.
- Several plugs would be required to allow the dry construction phase of the new approach channels and new locks infrastructure. They would also be excavated and dredged in phases once the channel and certain locks components are ready for water filling. These plugs would be made of soil found at the site, or reinforced if necessary using competent materials taken from the dry excavation. Further studies would be required to finalize plug design.
- Two plugs would be required for the Atlantic area to perform the dredging and excavation of the new locks approach channel and footprint, while three plugs would be required for the Pacific area due to the greater length of the northern approach channel.

## 4.2 Excavation Volume Estimates

- Excavation would be required mainly at the Atlantic new approach channel, Gaillard Cut, and the Pacific new approach channel.

### 4.2.1 Atlantic New Locks Approach Channel

- The Atlantic northern approach channel, Atlantic northern plug, and Atlantic southern plug would require 900 K, 160 K, and 400 K cubic meters of dry excavation before proceeding with dredging operations.

### 4.2.2 Gaillard Cut

- The deepening to 9.14 m PLD would require the excavation of 2.5 million cubic meters of material to stabilize the bank slopes along Gaillard Cut.

### 4.2.3 Pacific New Locks Approach Channel

- The Pacific northern approach channel north of Gaillard Cut plug would require the excavation of 7.18 million cubic meters.
- Gaillard Cut plug and Pacific intermediate plug excavation volumes are estimated at 17 K and 13 K, respectively.

## 4.3 Drilling and Blasting Volume Estimates

- Drilling and blasting volume estimates were based on the percentage of area that requires fragmentation multiplied by the sub-drilling depth.

### 4.3.1 Atlantic Entrance

- Based on Canal experience, no drilling and blasting would be required on the Atlantic area since most of the material is formed by sediment, clay, mud, and sand.

### 4.3.2 Atlantic New Locks Approach Channel

- As with the Atlantic entrance, it is foreseen that no drilling and blasting would be required for the Atlantic new locks approach channel. However, since the material found at the channel would be harder than that found at the Atlantic entrance, it must be dredged by a more powerful dredge.

### 4.3.3 Gatun Lake

- It is also estimated that 10% of the Gatun Lake channel area would require drilling and blasting prior to widening to 280 and 366 m (918 and 1,200 ft), and deepening to 9.14 m PLD.
- The 10% percent estimate includes the remaining lake channel area that has not undergone blasting by the Thor, which has performed fragmentation in several parts of the lake channel down to elevation 6.7 m (22 ft) PLD as part of the lake deepening program 10.4 m PLD, and would be sufficient for the dredging work to elevation 9.14 m PLD.
- Under this scenario, drilling and blasting volumes at Gatun Lake is estimated at 3.35 million cubic meters.
- Following is a table showing the percentage of the lake area that would require drilling and blasting:

| Gatun Lake areas | Deepening area (m2) | Widening area (m2) | % estimate of hard material area | Drilling & blasting of deepening areas ($m^2$) | Drilling & blasting of widening areas ($m^2$) |
|---|---|---|---|---|---|
| Gatun Reach | 1,010,406 | 150,022 | 0% | - | - |
| Peña Blanca Reach | 2,320,851 | 209,508 | 0% | - | - |
| Bohio Reach | 911,723 | 167,121 | 10% | 91,172 | 16,712 |
| Buena Vista Reach | 1,449,305 | 206,672 | 20% | 289,861 | 41,334 |
| Tabernilla Reach | 1,570,389 | 197,101 | 0% | - | - |
| San Pablo Reach | 1,368,906 | 391,780 | 10% | 136,891 | 39,178 |
| Mamei Reach | 487,100 | 116,006 | 60% | 292,260 | 69,604 |
| Juan Grande Reach | 235,571 | 92,678 | 10% | 23,557 | 9,268 |
| **TOTAL** | **9,354,251** | **1,530,888** | | **833,741** | **176,096** |

**Table No. 3. Estimate of hard material areas that would require drilling and blasting in Gatun Lake**

### 4.3.4 Gaillard Cut to 9.14 m PLD Scenario with 218 m Wide Channel

- Drilling and blasting estimates for Gaillard Cut to 9.14 m PLD were separated into 2 volume estimates:
  - Drilling and blasting within current 192 m (630 ft) navigation channel
  - Drilling and blasting at widening areas to 218 m (715 ft)

#### 4.3.4.1 Within 192 m Navigation Channel

- It is estimated that about 30% of the Cut area would require drilling and blasting to deepen channels to 9.14 m PLD. This 30% represents the remaining area of the Cut that has not been blasted by the Thor. As previously mentioned, the Thor is currently blasting down to elevation 6.7 m (22 ft) PLD as part of the ongoing deepening program to 10.4 m PLD. This blasting would serve future dredging plans to lower the channel to 9.14 m PLD.
- Drilling and blasting volumes within the 192 m channel are estimated at 3.65 million cubic meters. However, a cutter suction dredge with a 2 kw cutter could be used to remove about 50% of Cut material without previous drilling and blasting. Therefore, the net drilling and blasting volume could be estimated at 1.83 million cubic meters.

| Areas in Gaillard Cut | Deepening area (m2) | Percentage estimate of hard material area | Drilling & blasting of deepening areas ($m^2$) |
|---|---|---|---|
| Gamboa Reach | 1,038,515 | 10% | 103,852 |
| Chagres Crossings | 307,018 | 65% | 199,562 |
| Bas Obispo Reach | 600,587 | 58% | 348,340 |
| Cascadas Reach | 347,381 | 27% | 93,793 |
| Cunette Reach | 150,238 | 100% | 150,238 |
| Empire Reach | 329,029 | 92% | 302,707 |
| Culebra Reach | 478,849 | 0% | - |
| Cucaracha Reach | 389,176 | 0% | - |
| Paraiso Reach | 121,359 | 0% | - |
| Pedro Miguel Reach | - | 0% | - |
| **TOTAL** | **3,762,152** | | **1,198,491** |

**Table No. 4. Estimate of remaining hard material areas that would require drilling and blasting in Gaillard Cut to obtain a design channel bottom of 9.14 m PLD. Pedro Miguel Reach was omitted since it would not be part of Post Panamax channel.**

#### 4.3.4.2 Widening of 218 m Areas

- The Gaillard Cut widening program to 218 m and elevation 10.4 m PLD began in August 2005.
- To reach to the projected elevation of 9.14 m PLD as part of the Canal expansion program, drilling and blasting of approximately 1.58 million cubic meters of material would be required. However, assuming that a cutter suction dredge with a 2 kw cutter head could be used to dredge 50% of the Gaillard Cut area without the need for drilling and blasting, then required drilling and blasting volumes would be reduced to 792,000 cubic meters.

#### 4.3.4.3 Summary of Required Drilling and Blasting Volume at Gaillard Cut

- The required drilling and blasting volume to lower the channel bottom to 9.14 m PLD in Gaillard Cut is estimated at 2.62 million cubic meters, which includes 1.83 million cubic meters within the 192 m channel, and 792,000 cubic meters from 218 m widening areas.

### 4.3.5 Pacific New Locks Approach Channel

- It is foreseen that most of the area on the Pacific approach channel would require drilling and blasting, mostly by land rigs, up to 2.44 m (8 ft) below the design channel bottom elevation.

#### 4.3.5.1 Northern Approach Channel North of the Gaillard Cut Plug

- For the northern approach channel north of the Gaillard Cut plug, the drilling and blasting volume is estimated 3.23 million cubic meters for the 9.14 m PLD scenario, which would be executed completely using land-based drills. However, it could be difficult for a dredge to remove some of the hard material. Therefore, land based drills would execute an estimated 90% of the drilling and blasting, with the remaining 10% to be drilled using a drill-boat.

#### 4.3.5.2 Gaillard Cut or Pacific North Plug

- Drilling and blasting volume for the Gaillard Cut plug is estimated at 620,000 cubic meters for the 9.14 m PLD scenario, which would be executed by land-based drilling equipment.

#### 4.3.5.3 Pacific Intermediate Plug

- Drilling and blasting volume for the Pacific intermediate plug located north of the Pacific new locks footprint is estimated at 495,000 cubic meters for the 9.14 m PLD scenario, which would also be executed by land-based drilling equipment.

#### 4.3.5.4 Pacific South Plug

- Drilling and blasting volume for the Pacific south plug located south of the Pacific new locks footprint is estimated at 730,000 cubic meters, which would be executed by land-based drilling equipment.

#### 4.3.5.5 Pacific Southern Approach Channel

- Drilling and blasting volumes for the Pacific southern approach channel located south of the Pacific south plug are estimated at 1.41 million cubic meters. This area is not suitable to accommodate land drills or a regular-size drill-boat, which would represent a drilling and blasting challenge. Therefore, drilling and blasting might be executed using land-based drills mounted on small barges.

### 4.3.6 Pacific Entrance

- According to the seismic reflection survey performed in December 1999, and drilling investigations conducted by international dredging companies bidding on the ACP solicitation for Pacific entrance deepening to 12.6 m draft, it is foreseen that about 30% of the Pacific entrance area might require drilling and blasting, which represents 4.36 million cubic meters.

## 4.4 Dredging Volume Estimates

### 4.4.1 Atlantic Entrance

- At a width of 225 m and depth of 15.5 m, the Atlantic entrance dredging volume is estimated at 6.95 million cubic meters.

### 4.4.2 Atlantic New Locks Approach Channel

- The Atlantic new approach channel and northern plug would require dredging of 6.55 and 0.61 million cubic meters, respectively.
- Meanwhile, Atlantic southern plug dredging volume estimate is at 0.79 million cubic meters.

### 4.4.3 Gatun Lake

- Widening of the Gatun Lake channel to 280 m in straight sections, and 366 m in bends would require the removal of 16.03 million cubic meters of dredging material for the 9.14 m PLD elevation scenario.

#### 4.4.4 Gaillard Cut

- Dredging of Gaillard Cut to a channel bottom elevation of 9.14 m PLD entails the extraction of 3.88 million cubic meters from the 192 m wide channel, and an additional volume of 2.14 million cubic meters from the 218 m wide channel.
- The total dredging volume for a 9.14 m PLD deep and 218 m wide Gaillard Cut would be 6.02 million cubic meters.

#### 4.4.5 Pacific New Locks Approach Channel

##### 4.4.5.1 Pacific Northern Approach Channel North of the Gaillard Cut Plug

- Under the 9.14 m PLD scenario, dredging estimate is around 2.82 million cubic meters for a channel minimum width of 218 m.

##### 4.4.5.2 Gaillard Cut Plug

- The Gaillard Cut plug would require the extraction of 0.50 million cubic meters of material.

##### 4.4.5.3 Pacific Intermediate Plug

- Dredging volume for the Pacific intermediate plug is estimated at 0.39 million cubic meters.

##### 4.4.5.4 Pacific Southern Plug

- The Pacific southern plug would require dredging of 0.63 million cubic meters of material for a channel depth of 15.5 m MLWS.

##### 4.4.5.5 Pacific Southern Approach Channel

- Construction of this channel would require the removal of 2.51 million cubic meters of dredging material to obtain a channel width of 218 m and a depth of 15.5 m.

### 4.5 Summary of Drilling and Blasting, Excavation, and Dredging Volumes

- Following is a table that summarizes the drilling and blasting, excavation, and dredging volumes required to modify the existing channel and create new approach channels to accommodate Post Panamax vessels. The volumes shown in the table do not include volumes from Canal modernization programs to extend its capacity such as Gatun Lake and Gaillard Cut deepening to 10.4 m (34 ft) PLD, the Gaillard Cut straightening program, Gaillard Cut 218 m widening program, Pacific entrance deepening to 14.2 m MLWS, or Atlantic entrance widening to 198 m (650 ft) and deepening to 14.2 m MLW.

**EXCAVATION, DREDGING, AND DRILLING AND BLASTING VOLUME FOR POST-PANAMAX CHANNEL (million cubic meters)**

| Area | Draft (m) | Channel width (m) | 9.14 m PLD SCENARIO | | |
|---|---|---|---|---|---|
| | | | Dry excavation | Drilling and blasting | Dredging |
| Atlantic Entrance Navigation Channel | 13.7 | 225 to 260 | | | 6.95 |
| Atlantic Northern Approach Channel | 13.7 | 218 | 0.90 | | 6.55 |
| Atlantic Northern Plug | 13.7 | 218 | 0.16 | | 0.61 |
| Atlantic New locks | | 55 | | | |
| Atlantic Southern Plug | 13.1 to 15.2 | 218 | 0.40 | | 0.79 |
| Gatun Lake | 13.1 to 15.2 | 280 to 366 | | 3.35 | 16.03 |
| Gaillard Cut | 13.1 to 15.2 | 218 | 2.50 | 2.62 | 6.03 |
| Pacific Northern Approach Channel north of Gaillard Cut Plug | 13.1 to 15.2 | 218 | 7.18 | 3.23 | 2.82 |
| Pacific Gaillard Cut or Northern Plug | 13.1 to 15.2 | 218 | 0.17 | 0.62 | 0.39 |
| Pacific Northern Approach Channel between Gaillard Cut Plug and Intermediate Plug | 13.1 to 15.2 | 218 | | | |
| Pacific Intermediate Plug | 13.1 to 15.2 | 218 | 0.13 | 0.50 | 0.30 |
| Pacific New locks | | 55 | | | |
| Pacific Southern Plug | 13.1 to 15.2 | 218 | | 0.73 | 0.63 |
| Pacific Southern Approach Channel | 13.7 | 218 | | 1.41 | 2.51 |
| Pacific Entrance Navigation Channel | 13.7 | 225 to 366 | | 4.36 | 6.51 |
| **Total volume for navigation channel works** | | | **11.44** | **16.82** | **50.12** |

Notes:

1. Excavation and dredging volume highlighted in light blue corresponds to new locks works study.

2. The volumes do not include on-going dredging programs such as Gatun and Gaillard Cut deepening to 10.4 m PLD, Gaillard Cut straightening, Gaillard Cut widening to 218, Pacific entrance deepening to 12.61 m draft, and Atlantic entrance widening to 198 m

**Table No. 5. ,Excavation, drilling and blasting, and dredging volume estimates for Post Panamax navigation channel work**

# 5 GEOLOGICAL CHARACTERISTICS OF THE CANAL NAVIGATION CHANNEL

## 5.1 Primary Soil Types Found Along the Canal Navigation Channel

- The Canal area is characterized for its diverse and complex geological composition, which could be divided into five main material types:
- Sediment, clay, mud, and sand
- Gravel and clay

- Soft rock with resistance lower than 15 MPa
- Medium-hard rock with resistance between 15 and 50 MPa
- Hard rock with resistance higher than 50 Mpa

## 5.2 Geological Characterization of the Canal Navigation Channel

### 5.2.1 General Geological Characterization of the Canal Navigation Channel

- Following is a table showing a general geological characterization for each Canal area that requires Post PanamaxPost Panamax navigation channel work:

| GENERAL GEOLOGICAL CHARACTERIZATION OF THE POST PANAMAX NAVIGATION CHANNEL | | | | | | |
|---|---|---|---|---|---|---|
| | Areas | Sediment, clay, mud, and sand | Gravel and clay | Soft rock < 15 Mpa | Medium hard rock 15 to 50 Mpa | Hard rock > 50 Mpa |
| 1 | Atlantic Entrance Navigation Channel | X | | | | |
| 2 | Northern Atlantic Post Panamax Approach Channel | | | X | | |
| 3 | Atlantic New Post Panamax Locks | | | X | | |
| 4 | Southern Atlantic Post Panamax Approach Channel | | | X | | |
| 5 | Gatun Lake up to Juan Grande Reach | | X | | X | |
| 6 | Gaillard Cut, and Gamboa and Chagres Crossing Reach | | | X | X | X |
| 7 | Northern Pacific Post Panamax Approach Channel | | | | X | X |
| 8 | Pacific New Post Panamax Locks | | | | X | X |
| 9 | Southern Pacific Post Panamax Approach Channel | | | | X | X |
| 10 | Pacific Entrance Navigation Channel | | | X | X | X |

**Table No. 6 . General geological characterization of the navigation channel and new locks approach channel**

- Appendix No. 8 includes a report of the geological characterization of each area of the Canal navigation channel and the new locks approach channels developed by the ACP Geo-technical Branch. It also includes a description of the different geological formations.
- Except for Gaillard Cut and the new locks approach channels where core borings are numerous, very little information is available on the type of material found at the Atlantic entrance, Gatun Lake, and especially the Pacific entrance. Most of

the available information is based on facts provided by Canal dredge masters and previous Canal dredging experience.

### 5.2.2 Atlantic Entrance Navigation Channel

- Most of the material found at the Atlantic entrance navigation channel consists of Atlantic Muck, Gatun Formation, and a very thin heterogeneous fill consisting of soft soil and boulders. The Atlantic Muck is a very-soft to medium-soft overburden, while Gatun Formation is made up of soft to medium-soft rock, sandstones, siltstones, conglomerates and medium-soft to medium-hard tuff.
- The specific area to be dredged on the Atlantic entrance is located between stations 2K+700 m and station 7K+100 m, where most of the material found would be Gatun Formation with RH-1 to RH-2[7], that is, soft to medium-soft rock.

### 5.2.3 Atlantic New Locks Northern Approach Channel

- Atlantic Muck and RH-2 to RH-3 Gatun Formation rock are found at the Atlantic new locks northern approach channel.

### 5.2.4 Atlantic New Locks Southern Approach Channel

- The southern approach channel for the Atlantic new locks is made up of Gatun Formation.

### 5.2.5 Gatun Lake

- Gatun Lake is made up of several formations such as Gatun, Caimito, Bohio, and Bas Obispo. Some basalt can also be found near Bohio and Tabernilla Reach.
- Each of these formations are made up of different materials as described below:
  - Gatun Formation consists of sandstone, siltstone, conglomerate and medium-soft to medium-hard pumiceous tuff.
  - Caimito Formation is made up of medium-hard tuff, siltstone, sandstone, conglomerate and limestone.
  - Bohio Formation is made up of sandstone and conglomerates classified as medium to hard material.
  - Bas Obispo Formation consists of conglomerate formed by hard fragments of basalt and andesite.
- Soil in the lake is expected to become harder as dredges work closer to the southern area or near Gaillard Cut.

[7] RH is the abbreviation for rock hardness, RH-5 being very hard rock and RH-1 very soft rock. RH2 range is 25 to 50 Mpa (3,600 to 7,200 psi), and RH3 is 50 to 100 Mpa (7,250 to 14,500 psi)

### 5.2.6 Gaillard Cut

- Almost 50 percent of the Gaillard Cut navigation channel area has rock whose hardness is above RH-3, classified as medium-hard to very hard rock, and the remaining area has rock with hardness levels below RH-3, classified as soft to medium-hard rock. Therefore, substantial drilling and blasting would be required before excavation and dredging are initiated.
- Dividing Gaillard Cut in three sections for classification purposes, several types of medium to hard rock formations such as Bas Obispo, Las Cascadas, La Boca, Pedro Miguel, Culebra, and Cucaracha can be found at the northernmost section of the Cut, and medium-hard to medium-soft La Boca and Pedro Miguel formations and medium-soft to soft Culebra and Cucaracha formations can be found at the remaining two thirds of the Cut. Basalt is usually found capping most of the hills along Gaillard Cut.
- Las Cascadas Formation is made up of soft and hard agglomerate, agglomeratic tuff with andesitic, tuffaceous and basaltic pebbles and clasts. This formation is variably hard to medium soft.
- La Boca Formation consists of sandstones, siltstones, limestones, and agglomerates.
- Culebra formation consists of soft, tuffaceous sandstones and siltstones, and clay.
- Cucaracha formation consists of weak clay shales and a layer of medium hard ignimbrite (Ash Flow).
- Pedro Miguel formation consists of hard to medium-hard agglomerates formed mainly by basaltic, and tuffaceous clasts varying in size from small to large boulders. Thin weak, medium soft tuff and clay shales can be found among the agglomerates, as well as large basaltic boulders and moderately thick layers of basalt.

### 5.2.7 Pacific New Locks Northern Approach Channel

- The Pacific new locks northern approach channel is formed by Culebra, Cucaracha, Pedro Miguel, and La Boca formations, as well as basalt.

### 5.2.8 Pacific New Locks Southern Approach Channel

- The Pacific new locks southern approach channel is formed by La Boca formation and basalt.

### 5.2.9 Pacific Entrance Navigation Channel

- Based on previous Canal dredging experience, the 1999 seismic reflection survey, and 2004 drilling investigations, it is estimated that 50% of the material to be dredged would be sediment, 20% medium-hard rock that might not require

prior blasting if a rock cutter is used, and 30% hard material that would require drilling and blasting.

- The area located north of the Bridge of the Americas is formed by RH-2 to RH-5 La Boca Formation and RH-4 to RH-5 basalt.
- The area located south of the Bridge of the Americas is made up of La Boca formation, some RH-4 to RH-5 dacite, RH-2 to RH-5 Panama Formation, RH-4 to RH-5 basalt, and sediment on the southernmost 4 kilometers of the reach to the Pacific entrance.

### 5.3 Drilling Volume Estimates by Geological Condition

- As previously mentioned, no drilling and blasting would be required on the Atlantic area.
- Material requiring drilling and blasting in Gatun Lake, is in the range of medium to hard rock.
- In Gaillard Cut, 50% of the material to be drilled and blasted falls within the medium-hard rock category, while the remaining 50% is considered hard material.
- In the Pacific area, most of the material that requires drilling and blasting is considered hard rock, except for the intermediate plug where most of the material is made up of La Boca Formation, which does not require drilling and blasting.
- Following is a table showing required drilling and blasting volumes for both Gatun Lake deepening scenarios:

**DRILLING AND BLASTING VOLUME FOR POST-PANAMAX CHANNEL**

**Volume in million cubic meters**

| Area | 9.14 m PLD SCENARIO | | |
|---|---|---|---|
| | Medium hard rock 15 to 50 Mpa | Hard rock > 50 Mpa | Total volume |
| Atlantic Entrance Navigation Channel | | | |
| Atlantic Northern Approach Channel | | | |
| Atlantic Northern Plug | | | |
| Atlantic Southern Plug | | | |
| Gatun Lake | 3.02 | 0.34 | 3.36 |
| Gaillard Cut | 1.31 | 1.31 | 2.62 |
| Pacific Northern Approach Channel north of Gaillard Cut Plug | 1.62 | 1.62 | 3.24 |
| Pacific Gaillard Cut or Northern Plug | 0.31 | 0.31 | 0.62 |
| Pacific Intermediate Plug | 0.25 | 0.25 | 0.50 |
| Pacific Southern Plug | | 0.73 | 0.73 |
| Pacific Southern Approach Channel | 0.71 | 0.71 | 1.42 |
| Pacific Entrance Navigation Channel | | 4.36 | 4.36 |
| **Total volume for navigation channel works** | **7.22** | **9.63** | **16.85** |

**Table No. 7. Drilling and blasting volume estimates by geologic condition**

## 5.4 Dredging Volumes by Geologic Condition

- Using the geological compositions described above for each Post Panamax navigation channel area, the following table summarizes dredging volumes by geological conditions:

**DREDGING VOLUME FOR POST-PANAMAX CHANNEL**

**Volume in million cubic meters**

| Area | 9.14 m PLD SCENARIO | | | | | |
|---|---|---|---|---|---|---|
| | Sediment, clay, mud, and sand | Gravel and clay | Soft rock < 15 Mpa | Medium hard rock 15 to 50 Mpa | Hard rock > 50 Mpa | Total volume |
| Atlantic Entrance Navigation Channel | 6.95 | | | | | 6.95 |
| Atlantic Northern Approach Channel | | | 6.55 | | | 6.55 |
| Atlantic Northern Plug | | | 0.61 | | | 0.61 |
| Atlantic Southern Plug | | | 0.79 | | | 0.79 |
| Gatun Lake | | 14.43 | | 1.60 | | 16.03 |
| Gaillard Cut | | | | 3.02 | 3.02 | 6.04 |
| Pacific Northern Approach Channel north of Gaillard Cut Plug | | | | 1.41 | 1.41 | 2.82 |
| Pacific Gaillard Cut or Northern Plug | | | | 0.20 | 0.20 | 0.39 |
| Pacific Intermediate Plug | | | | 0.15 | 0.15 | 0.30 |
| Pacific Southern Plug | | | | | 0.63 | 0.63 |
| Pacific Southern Approach Channel | | | | 1.26 | 1.26 | 2.52 |
| Pacific Entrance Navigation Channel | | | 3.26 | 1.30 | 1.95 | 6.51 |
| **Total volume for navigation channel works** | **6.95** | **14.43** | **11.21** | **8.94** | **8.62** | **50.14** |

**Table No. 8. Dredging volume estimates by geological condition for Post Panamax channel work**

# 6 CANAL WORKING CONDITIONS FOR POST PANAMAX NAVIGATION CHANNEL WORK

## 6.1 Impact on Ongoing Canal Operations

- Normal Canal operations are expected to continue uninterrupted by the required improvement work for Post Panamax channels and the construction of the new lock approach channels.
- The construction of new approach channels would have little impact on current Canal operations since these channels would not be located within existing canal infrastructure. Noise, movement of construction materials, and visual aspects could affect Canal adjacent areas, especially those occupied by Canal personnel.
- Regarding improvements to the existing navigation channel, excavation, dredging, and drilling and blasting work should be performed in such a way that it does not interrupt current traffic. Safety and coordination measures would also be implemented to avoid accidents and negative impacts on Canal operations.

- Planning for improvements to the existing navigation channels reflects interruption of dredging and drilling and blasting operations to keep Canal traffic flow. This interruption was included in the effective working hours estimate for dredging and drilling & blasting equipment.

## 6.2 Limitations of Navigation Channel Areas

- The Canal has several limitations that would affect dredging and drilling and blasting work.
- As mentioned before, vessel traffic through the existing Canal has priority over all dredging, and drilling and blasting work. Therefore, dredging and drilling should be interrupted if it is on the way of ship navigation.
- The only times permitted for detonation or blasting are between 06:00 and 18:00 hrs, providing that transiting ships are at a minimum distance of 500 m from the blasting area. This distance must be 610 m for ships carrying dangerous cargo.
- Only certain dredges, drill-boats, and certain sizes of dump scows can work effectively in the Canal. For instance, the beams of dredges and drill-boats should not be so large that they could jeopardize ship traffic through the Canal, especially in narrow areas such as Gaillard Cut and some other areas on the Atlantic and Pacific sides. The beams of dump scows could not be too large since they work adjacent to dipper dredges, and mega or large rock cutters would not work effectively in the Cut since their anchors expand too far away for this limited area and are too heavy for maneuvering.
- Only few dredging equipment could work simultaneously in the Cut and other Canal limited areas.

## 6.3 Canal Ocean Entrance Tidal Variations

### 6.3.1 Atlantic Entrance Tidal Variations

- Unlike the large tidal range at the Pacific entrance, the Atlantic entrance has little tidal range, as shown in the Panama Canal Clearance Diagram in Appendix No. 3. The extreme high-water tide is at 0.56 m (+1.85 ft) PLD[8], and the extreme low-water tide is at -0.38 m (–1.25 ft), resulting in a 0.94 m (3.10 ft) tidal variation.
- According to the table shown below, dredge and drill-boat minimum reach should be 16.5 m to effectively remove channel bottom material to achieve 15.5 m MLW on the Atlantic entrance and accomplish the waterway's required width and depth.

[8] The Panama Canal Clearance Diagram shows the locks chambers, lake, and tidal elevations referenced to precise level datum (PLD), which is a reference line used by ACP to measure all Canal elevations. This PLD is close to the Pacific and Atlantic mean sea level

- For information purposes, the following table is shown to compare the dredge reach required for the work versus the maximum reach capacity of the ACP cutter suction dredge MINDI and drilling and blasting boats. As previously mentioned, it is foreseen that no drilling and blasting might be required for Atlantic entrance channel bottom material.

**ACP DREDGES UNDERWATER REACH CAPACITY IN meters FOR ATLANTIC ENTRANCE DEEPENING TO 15.5 m MLW**

**All figures in meters**

| REACH | High Tide | Mean Sea Level | Mean Low Water |
|---|---|---|---|
| **Required for 13.7 m draft** | **16.39** | **15.89** | **15.71** |
| Cutter suction MINDI | **21.94** | **21.94** | **21.94** |
| MINDI spuds | **25.30** | **25.30** | **25.30** |
| D&B barge THOR | **22.86** | **22.86** | **22.86** |
| D&B barge THOR spuds | **17.68** | **17.68** | **17.68** |
| New D&B barge | **25.91** | **25.91** | **25.91** |
| New D&B barge spuds | **24.38** | **24.38** | **24.38** |

Notes: ACP equipment complies with minimum requirement for proposed Atlantic entrance deepening to 15.5 m MLW.

**Table No. 9. Dredge reach capacity on the Atlantic entrance**

### 6.3.2 Pacific Entrance Tidal Variations

- The Pacific entrance has a wide tidal range as shown in the Panama Canal Diagram in Appendix No. 3. The extreme high water tide is at +3.6 m (+11.8 ft) PLD, and the extreme low-water tide is at –3.44 m (-11.3 ft) resulting in a 7.04 m (23.11 ft) tidal variation.
- According to Table No. 10, dredge and drill-boat minimum reach should be 19.5 m to effectively remove channel bottom material for 15.5 m MLWS at the Pacific entrance and accomplish the waterway's required width and depth. This table should be used for reference purposes to compare Canal dredging equipment capabilities to perform Pacific entrance dredging work if required.
- However, dredges could work during the periods of mean sea level and low tide. It is estimated that the dipper dredge RMC[9] could perform dredging about 40% of the time during mean sea level and low tide, and the drill-boat THOR about 85% assuming its spuds reach capacity or 95% assuming its ladder reach capacity, as part of dredging work for 15.5 m MLWS in the Pacific entrance.

[9] RMC is the abbreviation for the ACP dipper dredge Rialto M. Christensen.

- The dipper dredge RMC would be unable to operate adequately in Pacific entrance navigation channel work for 15.5 m MLWS. The cutter suction dredge MINDI could accomplish required dredging work if its dredging capacity to remove channel bottom material in this entrance is effective; otherwise other dredging equipment would be necessary.

**ACP DREDGES UNDERWATER REACH CAPACITY IN meters FOR PACIFIC ENTRANCE DEEPENING TO 15.5 m MLWS**

**All figures in meters**

| REACH | High Tide | Mean Sea Level | Mean Low Water |
|---|---|---|---|
| **Required for 13.7 m draft** | **19.43** | **16.13** | **13.51** |
| Dipper dredge CHRISTENSEN | **18.29** | **18.29** | **18.29** |
| CHRISTENSEN spuds | | | |
| Cutter suction MINDI | **21.94** | **21.94** | **21.94** |
| MINDI spuds | **25.30** | **25.30** | **25.30** |
| D&B barge THOR | **22.86** | **22.86** | **22.86** |
| D&B barge THOR spuds | **17.68** | **17.68** | **17.68** |
| New D&B barge | **25.91** | **25.91** | **25.91** |
| New D&B barge spuds | **24.38** | **24.38** | **24.38** |

Notes: Figures in red indicate that equipment does not comply with reach capacity requirements.

**Table No. 10. Required dredge reach capacity at Pacific entrance**

## 6.4 Disposal Sites

- Disposal sites represent the most critical issue in the management of dry and wet excavation material, because of environmental implications, limited number of available sites, their limited capacity, the hauling distance and costs, and the large number of excavated and dredged material.
- Through external consultants, Moffatt & Nichol (M&N) and Louis Berger Group (LBG), the Canal has evaluated several options to dispose of excavation and dredging material from Post Panamax construction work. Such studies were completed between May and August 2004, and are available at the ACP Department of Engineering and Projects and the Safety, Environmental Management, and Canal Protection Department.[10]

[10] Moffatt & Nichol Engineers, Louis Berger Group, Golder Associates, "Pacific Side Excavation & Dredging Material Disposal Alternatives Evaluation", Final Report, 3 Volumes, March 2004.
Moffatt & Nichol Engineers, Louis Berger Group, Golder Associated, "Feasiblity Study for Artificial Island Development at the Pacific Entrance of the Panama Canal", Final Report, 4 Volumes, May 2004.
Louis Berger Group, "Environmental Evaluation of Options for the Construction of New Locks and Deepening of the Atlantic and Pacific Entrance to the Panama Canal", August 2004.

- Through its Canal Capacity Projects Division and Environmental Management Division, the Canal has prepared technical and environmental reports[11] that propose several feasible alternatives from the technical and environmental points of view to accommodate excavation and dredging material from Post Panamax work. For more details or description on proposed disposal site alternatives, please refer to these reports. Appendix No. 9 includes graphs showing the location of proposed disposal sites.
- Following is a table showing Canal recommendations for the disposal of dredged and excavated material as part of the Canal expansion program to accommodate Post Panamax vessels:

[11] Panama Canal Authority, Department of Engineering and Projects, "Technical Analysis on Disposal Sites for Proposed Panama Canal Post Panamax Navigation and New Locks Construction Work", Version (Last), August 2004.
Panama Canal Authority, Safety, Environmental Management and Canal Protection Department, Environmental Management Division, "Environmental Evaluation of Disposal Sites for Proposed Panama Canal Post Panamax Navigation and New Locks Construction Work" Version (Last), September, 2004.

**PROPOSED DISPOSAL SITES FOR CANAL NAVIGATION CHANNEL DREDGING AND EXCAVATION WORKS**

**Scenario: Gatun Lake at 9.14 m PLD**

| | Areas | Dredging ( M $m^3$) | Excavation (M $m^3$) | Proposed dredging | | Proposed excavation | |
|---|---|---|---|---|---|---|---|
| | | | | Area | Capacity (bank M m3) | Area | Capacity (bank M m3) |
| 1 | Atlantic entrance navigation channel[1] | 6.95 | | Northwest breakwater | 6.31 | N/A | |
| 2 | Northern Approach Channel - Atlantic new locks | 6.55 | 0.90 | Sherman | 7.69 | Represa Island disposal site | 24.62 |
| 3 | Northern plug of Atlantic new locks | 0.61 | 0.16 | Sherman | 7.69 | Represa Island disposal site | 24.62 |
| 4 | Atlantic new locks southern plug 10.4 m PLD | 0.79 | 0.40 | Represa Island disposal site | 24.62 | Represa Island disposal site | 24.62 |
| 5 | Gatun Lake widening to 280m & 366 m to 9.14 m PLD | 16.03 | | Gatun Lake | | N/A | |
| 6 | Gaillard Cut 218 m at 9.14 m PLD | 6.03 | 2.50 | Frijoles | 8.46 | Site E2<br>Site T2<br>Site T3<br>Site T5 | 16.69<br>18.33<br>13.15<br>3.25 |
| 7 | Pacific new locks northern approach channel north of Gaillard Cut plug, 10.4 m PLD | 2.82 | 7.18 | Frijoles | 8.46 | Site UXO | 59.26 |
| 8 | Gaillard Cut or northern plug | 0.39 | 0.17 | Frijoles | 8.46 | Site UXO | 59.26 |
| 9 | Pacific new locks intermediate plug | 0.30 | 0.13 | Frijoles | 8.46 | N/A | |
| 10 | Pacific new locks southern plug | 0.63 | | Velasquez<br>Farfan | 1.76<br>2.82 | Site UXO | 59.26 |
| 11 | Pacific new locks southern approach channel | 2.51 | | Tortolita<br>Tortolita South | 5.84<br>7.35 | Site UXO | 59.26 |
| 12 | Pacific entrance navigation channel | 6.51 | | Tortolita South | 7.35 | N/A | |
| | **TOTAL** | **50.12** | **11.44** | | **64.85** | | **135.29** |

Notes:

1. Northwest breakwater disposal site could be extended to accommodate the total amount of Atlantic entrance widening and deepening to 225 m and 15.5 m MLW.

**Table No. 11. Proposed disposal site alternatives for Post Panamax navigation channel and new approaches for scenario Gatun Lake at 9.14 m PLD**

# 7 PROPOSED EXCAVATION, DREDGING, AND DRILLING AND BLASTING EQUIPMENT FOR POST PANAMAXPOST PANAMAX NAVIGATION CHANNEL WORK

## 7.1 Dredge Effectiveness in Canal Waters According to Geological Conditions

- There are several types of dredges such as backhoes, cutter suction dredges, hopper dredges, floating clamshells, bucket dippers or draglines, bucket wheel suction, and others. However, only certain dredges including dipper dredges, cutter suction dredges, and hopper dredges have proven to be effective for work in Canal waters.
- The following table shows the effectiveness of the different dredges for each type of dredging material. The rows highlighted include those dredges recommended for the dredging of the Canal navigation channel. Appendix No. 10 includes pictures of the dredges proposed for the Canal navigation channel expansion program.

**Dredgers Effectiveness for Different Type of Material**

| Dredge | Depth in meters | Sediment and Sand | Gravel | Clay and Mud | Soft Rock <15 mpa | Medium Rock 15-50 mpa | Hard Rock +50 mpa |
|---|---|---|---|---|---|---|---|
| Hopper dredge - medium (5-10k $m^3$) | 60 | ● | + | - | | | |
| CSD - Medium (1 to 2k kW cutter) | 20 | +/- | +/- | +/- | - | | |
| CSD-Rock cutte-Medium (2 to 3k kW cutter) | 25 | + | ● | ● | + | +/- | |
| CSD-Rock cutte-Medium (3 to +5k kW cutter) | 30 | + | ● | ● | ● | + | |
| Backhoe | 18 | | - | - | - | | |
| Dipper dredge & Drilling and Blasting | 18 | | - | - | + | +/- | +/- |
| Dipper dredge & D/B (Pacific entrance) | 20+ | | - | - | + | +/- | - |

Effectiveness (production and cost):

| | |
|---|---|
| Very Good | ● |
| Good | + |
| Moderate | +/- |
| Low | - |

**Table No. 12. Recommended dredges for different types of material**

## 7.2 Atlantic Entrance Navigation Channel

### 7.2.1 Dredging

- Cutter suction dredges such as the ACP's MINDI have been used before to dredge the Atlantic entrance navigation channel. Drilling and blasting were very seldom required in the past, and it is foreseen that none would be necessary for deepening and widening the Post Panamax channel in the Atlantic entrance. Following is a table showing a summary of MINDI's productivity in this area.

**ACP CSD "MINDI" PRODUCTION IN THE ATLANTIC ENTRANCE FROM OCT. '94 TO FEB. '96**

| | Production | Bank cubic meter per hour | Bank cubic meter per day | Bank cubic meter per week |
|---|---|---|---|---|
| Atlantic Entrance Reach | Least | 408 | 5,100 | 35,700 |
| | Average | 868 | 10,850 | **75,950** |
| | Greatest | 1,523 | 19,038 | 133,263 |
| Gatun Approach Reach | Least | 426 | 5,325 | 37,275 |
| | Average | 780 | 9,750 | **68,250** |
| | Greatest | 1,288 | 16,100 | 112,700 |

**Table No. 13. Summary of cutter suction MINDI production dredging the Atlantic entrance navigation channel.**

- The productivity of external contractor, dredging company Jan der Nul, for recently completed Atlantic entrance widening to 198 m and deepening to 14.2 MLW was as follows:

**CONTRACTOR JAN DER NUL PRODUCTIVITY IN ATLANTIC ENTRANCE WIDENING TO 198 m AND 14.2 m MLW (Oct 2004 through April 2005)**

| Dredge | Station -1K+036 to 10K+250 ($m^3$ per day) | Station 10K+250 to 10K+750 ($m^3$ per day) | Average ($m^3$ per day) | Average ($m^3$ per wk) |
|---|---|---|---|---|
| Hopper dredge FRANCESCO DE GIORGIO | 14,389 | 17,307 | 14,513 | **101,590** |
| Cutter suction dredge JFJ | 24,802 | | 24,802 | **173,614** |

**Table No. 14. Summary of dredges production in dredging the Atlantic entrance navigation channel.**

- The Atlantic entrance expansion involves only the Atlantic entrance reach, that is, the northern area of station 7K+000, where the productivity of the MINDI or a similar CSD would be around 76,000 bank cubic meters per week. However, a medium rock cutter dredge with a 2,000 to 3,000-kilowatt cutter could dredge up to 103,000 bank cubic meters per week, or a 35% productivity increase compared to a regular cutter suction dredge such as the MINDI with a 671-kilowatt cutter. If a cutter suction dredge with a cutter of 6,000 kilowatts such as the JFJ, Jan der Nul dredge, is assigned to dredge Atlantic entrance, then a productivity of 170,000 cubic meters could be reached in this area.
- Since most of the material found at the Atlantic entrance bottom channel is sediment, the ACP is proposing the use of a hopper dredge to widen and deepen the Atlantic entrance navigation channel with an estimated productivity of

110,500 bank cubic meters per week under a full 3W-7D schedule[12]. This hopper dredge would be sufficient to perform Atlantic entrance dredging at a competitive price. However, depending on the attractiveness of the price proposal, the ACP could also hire a cutter suction dredge similar to the JFJ with a higher production.

## 7.3 Atlantic New Locks Northern and Southern Approach Channels

### 7.3.1 Excavation

- The ACP is proposing the use of conventional land-based excavation equipment such as excavators and trucks to perform the required excavation work in the Atlantic new lock approach channels. Estimated productivity is around 34,600 bank cubic meters per week, or an average 150,000 bank cubic meters per month, which could increase during the dry season, and decrease during the raining season.
- The work schedule would depend on external contractor resources, and the ACP's required completion date.
- Such productivity rate is based on Canal experience in the Gaillard Cut Widening Program to 192 m (630 ft) performed by external contractors.

### 7.3.2 Dredging

- A medium rock cutter suction dredge with a 2,000 to 3,000-kilowatt cutter is proposed to dredge the Gatun formation and Atlantic muck found in the Atlantic new locks approach channel at an estimated productivity of 60,000 bank cubic meters per week under a full 3W-7D schedule.
- As of today, the Canal is planning to acquire a new rock-cutter dredge with a 2,100 cutter to replace the MINDI, built in 1943, with 61 years of service. This new rock cutter dredge could have a 35% productivity increase relative to the MINDI, and would be well suited to dredge the Atlantic northern new locks approach channel.
- It was reported that the MINDI productivity could be as low as 30,000 cubic meters per week in areas with RH-2 to RH-3 Gatun formation . The 671-kilowatt cutter of the MINDI is capable of removing the Atlantic muck, but lacks capacity to effectively dredge the hardness of the Gatun formation. However, the CSD Mindi could be used as backup for the rock cutter-suction dredge.
- Support equipment required for the cutter-suction dredge includes pipes, pontoons, an anchor barge, a submersible barge, and a push boat for underwater discharge; and tractors and pipes to discharge material on land.

[12] 3W-7D stands for three 8-hour shifts each 7 days a week.

## 7.4 Gatun Lake Navigation Channel

### 7.4.1 Underwater Drilling and Blasting

- The ACP is proposing the use of drill-boats THOR or BARU[13] to perform underwater drilling and blasting operations. The BARU is the ACP's new drill-boat, which would be capable to drill 16 holes without moving the drill-boat, boosting its efficiency to 25% compared to the THOR.
- As part of the lake deepening program to 10.4 m PLD, the resulting productivity from April through June 2004 in Gatun Lake was 19,400 bank cubic meters per week as shown in the following table.

**DRILLBOAT THOR PRODUCTIVITY IN GATUN LAKE**

| Area | Dates | Apr-04 22-29 Apr | May-04 03-17 May | Jun-04 08 Jun |
|---|---|---|---|---|
| MAMEI | Days | 3 | 7 | 1 |
| | Volume ($m^3$) | 17,832 | 20,156 | 580 |
| SAN PABLO | Dates | | 19-30 May | 01-04 Jun |
| | Days | | 6 | 4 |
| | Volume ($m^3$) | | 15,051 | 4,649 |
| **Average productivity per day =** | | | **2,775 $m^3$** | |
| **Average productivity per week =** | | | **19,423 $m^3$** | |

**Table No. 15. Drillboat THOR production in Gatun Lake for 10.4 m PLD deepening program**

- The 19,400 bank cubic meters per week produced by the THOR were used to plan deepening and widening work in Gatun Lake under a full 3W-7D schedule. Assuming a 25% of productivity increase, BARU's productivity should be 24,250 bank cubic meters per week in Gatun Lake.
- Support equipment required for drill-boats includes working boats, and magazine boats to carry explosives.

### 7.4.2 Dredging

- The ACP is proposing the use of a medium rock cutter dredge to widen and deepen most Gatun Lake navigation channels. It is estimated that a rock cutter dredge with a 2,100-kilowatt cutter could dredge 67,500, (35% more than the MINDI) and 37,500 cubic meters per week for gravel, and medium to hard material, respectively, in Gatun Lake under a full 3W-7D schedule.

[13] As of today, drill-boat BARU is being built at the ACP Industrial Division and is scheduled for completion in January 2005.

- Since the medium rock cutter dredge might not be available during the first years of the Canal expansion program, it is assumed that the ACP cutter suction dredge MINDI would dredge in Gatun Lake during this time at a rate of 50,000 bank cubic meters per week.
- The MINDI has dredged Gatun Lake effectively, excluding Gamboa Reach, with an average productivity of 50,000 bank cubic meters per week. Following is a table that briefly summarizes MINDI's dredging productivity in this area.

**CSD MINDI PRODUCTIVITY IN BANK CUBIC METERS PER WEEK AT GATUN LAKE**

| Area \ Year | 1984 | 1980 & 1984 | 1980 to 1984 | 1983 | 2001 to 2002 | 2003 to 2004 | 2005 |
|---|---|---|---|---|---|---|---|
| Peña Blanca | 38,669 | | | | | | |
| Bohio | 36,910 | | | | | | |
| Buena Vista | 29,616 | | | | | | 43,460 |
| Tabernilla | 49,470 | | | | | | 57,850 |
| San Pablo | | 30,839 | | | | 63,000 | |
| Mamei Curve | | | 33,890 | | | 40,100 | |
| Juan Grande | | | | | | 48,100 | |
| Gamboa | | | | 29,161 | 31,600 | | |
| **Average from 1980 to 1984** | | | | | | **35,508** | |
| **Average from 1980 to 1985 excluding Gamboa** | | | | | | **36,566** | |
| **Average from 2003 to 2005 - Deepening to 10.4 m PLD** | | | | | | **50,502** | |

**Table No. 16. MINDI's productivity in Gatun Lake**

- Support equipment required for the cutter-suction dredge includes pipes, pontoons; an anchor barge, a submersible barge, and a push boat for underwater discharge; and tractors and pipes to discharge material on land.

## 7.5 Gaillard Cut Navigation Channel

### 7.5.1 Excavation

- The ACP is proposing the use of conventional land-based excavation equipment such as excavators and trucks to perform required excavation work in Gaillard Cut at a weekly average production of 34,600 bank cubic meters per week, or average 150,000 bank cubic meters per month. This productivity rate is based on Canal experience in the Gaillard Cut Widening Program (GCWP)[14] to 192 m (630 ft) performed by external contractors.

[14] ACP performed Gaillard Cut Widening Program to 192 m (630 ft) in 1992 through 2001.

- These productivity figures could be higher during the dry season, and lower during the rainy season. Setting of the working schedule would depend on external contractor resources and the ACP's required completion date.

### 7.5.2 Underwater Drilling and Blasting

- The ACP is proposing the use of drill-boats THOR and BARU to perform underwater drilling and blasting operations.
- The THOR's productivity for Gaillard Cut deepening to 9.14 m PLD should be about 23,500 bank cubic meters per week under a full 3W-7D schedule based on on-going Gatun Lake deepening program to 10.4 m PLD as shown in Table No. 18. Drill-boat BARU productivity should have a higher margin (25%) than the THOR estimated at 29,500 bank cubic meters per week.
- An average pattern of 30.5 m x 15.8 m (100 ft x 52 ft) is often used by drill-boat THOR to perform drilling. Each pattern would have 3.8 m (12.5 ft) of spacing, and 4 m (13ft) 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 needs and according to channel bottom geologic conditions. For instance, the pattern spacing and burden should be smaller for hard material.

**DRILLBOAT THOR PRODUCTIVITY IN BANK CUBIC METERS PER WEEK AT GAILLARD CUT FOR DEEPENING PROGRAM TO 10.4 m PLD**

| Area \ Year | FY 2003 | FY 2004 | FY 2005 | AVERAGE |
|---|---|---|---|---|
| Bas Obispo | | 29,329 | 25,700 | 27,515 |
| Cascadas | | | | |
| Empire | | 33,053 | 15,795 | 24,424 |
| Cunette | | | | |
| Culebra | 26,093 | 23,760 | 19,079 | 22,978 |
| Cucaracha | 30,651 | 4,963 | 13,105 | 16,240 |
| Paraiso | 31,674 | 18,022 | | 24,848 |
| Pedro Miguel | | | | |
| **AVERAGE** | **29,473** | **21,826** | **18,420** | **23,239** |

**Table No. 17. Drill-boat THOR productivity in Gaillard Cut for Deepening program to 10.4 m PLD**

### 7.5.3 Dredging

- About 50% of Gaillard Cut sub-bottom material hardness is up to RH3, and the remainder 50% greater than RH3. Therefore, a 2,000 to 3,000 kilowatt cutter suction dredge is proposed to dredge material not harder than RH3 without drilling and blasting; and ACP dipper dredge RMC to deepen the remainder sub-bottom material after drilling and blasting operations.

- Dredging average productivity during the Gaillard Cut Widening Program from January 1994 through June 2001 was about 32,167 cubic meters per week for a maximum hauling distance of 20 km in the case of the RMC, and 3 km pumping distance for the MINDI.
- For the ongoing deepening program to 10.4 m (34 ft) PLD and straightening program, the RMC performance is 25,240 bank cubic meters per week, and 31,260 bank cubic meters per week for the straightening program. Following is a table summarizing RMC performance in Gaillard Cut's ongoing dredging programs.

| DIPPER DREDGE RMC PERFORMANCE IN GAILLARD CUT ($m^3$ per wk) | | |
|---|---|---|
| **AREA** | **Deepening to 10.4 m PLD** | **Straightening program** |
| **Gamboa** | | 32,703 |
| **Chagres X** | 35,514 | |
| **Bas Obispo** | 25,048 | 29,833 |
| **Cunette (dredging maintenance)** | 32,469 | |
| **Empire** | 21,986 | |
| **Cucaracha & new tie up station** | 11,542 | |
| **Cucaracha** | 26,692 | |
| **Culebra** | | |
| **Paraiso** | 23,444 | |
| **AVERAGE** | **25,242** | **31,268** |

**Table No. 18. Dipper dredge production in Gaillard Cut Deepening Program 10.4 m PLD, and Straightening Program in 2004**

- A production of 28,000 cubic meters per week under a full 3W-7D schedule is expected for the Canal expansion dredging work based on dipper dredge RMC's performance as part of on-going dredging programs.
- Performance of the cutter suction dredge MINDI has been around 34,700 m3 per week in the Gaillard Cut deepening program to 10.4 m PLD as shown in the following table:

**CSD MINDI PRODUCTIVITY IN $m^3$ x wk AT GAILLARD CUT**

| Area \ Year | 2001 to 2002 | 2004 | 2005 |
|---|---|---|---|
| Gamboa | 31,580 | | |
| Bas Obispo | | | |
| Cascadas | | 21,650 | |
| Cunnete | | 20,280 | |
| Empire | | 28,545 | |
| Cucaracha | | 43,587 | |
| Culebra | | 61,137 | |
| Paraiso | | 36,057 | |
| **Average** | | **34,691** | |

**Table No. 19. Cutter suction dredge MINDI performance in Gaillard Cut during on-going deepening program to 10.4 m PLD**

- The ACP is proposing the use of a 2,000 to 3,000-kilowatt cutter suction dredge, for Gaillard Cut deepening to 9.14 m PLD to remove all material with hardness no harder than RH3. Assuming no need for drilling and blasting, its productivity would be around 37,500 cubic meters per week under a full 3W-7D schedule.
- Support equipment such as tugboats, push-boats, dump scows, survey launches, and passenger boats would be required to assist the dipper dredge and cutter suction dredge, and transfer the dredging material to designated underwater disposal sites in the case of dipper dredge.
- Since some of the disposal sites available along Gaillard Cut banks are located in areas farther than 2.5 kilometers from cutter suction dredge operations, a booster pump would be required to assist the dredge discharging operation on land, unless dump scows be used to transfer dredging material to Gatun Lake designated disposal sites.

## 7.6 Pacific New Locks Northern Channel

- As mentioned previously, this report covers required work on the Gaillard Cut northern approach channel (approximately 1 km), the northern plug, and the intermediate plug. Work on the northern channel, which is located between the Gaillard Cut plug and the intermediate plug, is reviewed in a separate report for new Post Panamax locks construction.

### 7.6.1 Excavation

- The ACP is proposing the use of conventional land-based excavation equipment such as excavators and trucks to perform the required excavation work in the Pacific new locks northern channel at a weekly average production of 34,600 bank cubic meters, or 150,000 bank cubic meters average per month. This

productivity rate is based on Canal experience in the GCWP to 192 m (630 ft) performed by external contractors.

- This productivity could be higher during the dry season, and lower during the rainy season, and establishment of the working schedule would depend on the external contractor's resources and the ACP required completion date.

### 7.6.2 Land-based Drilling and Blasting

- The ACP is proposing the use of land-based drilling and blasting equipment available at the Canal such as RBD, Rangers, Tamrocks, and P&H drills, among others. Based on Canal past experience, the approximate productivity rate for land-based drilling and blasting is 54,000 bank cubic meters per week under a 2-shifts, 5-days per week schedule.

### 7.6.3 Land-based Dredging

- Land-based dredging would be required to dredge the topsoil, 20% of total dredging material, in the Pacific new locks northern access north of Gaillard Cut plug. The topsoil removal would allow a backhoe dredge to excavate efficiently the next 50% of dredging material.
- It is estimated that an excavator would achieve a production of 25,000 cubic meters per week.

### 7.6.4 Underwater Drilling and Blasting

- The ACP is proposing the use of the new drill-boat BARU to perform underwater drilling and blasting operations. BARU's productivity in the new Pacific northern access channel would be about 30,000 bank cubic meters per week under a full 3W-7D schedule, which represents 30% increase relative to THOR production in Gaillard Cut.

### 7.6.5 Dredging

- The dredging operation would be accomplish in three phases:
  - The first phase would consist on the use of land-based dredging equipment to excavate 20% of dredging material, as explained in section 7.6.3.
  - The second phase would consist on the use of a backhoe to remove 50% of dredging material for a productivity rate of 20,000 cubic meters per week in a 3W-6D schedule[15].

[15] 3 shifts of 8 hours each at 6 days per week

- The dipper dredge RMC, with a greater reach than a backhoe, would excavate the remaining 30% of dredging material at a productivity rate of 28,000 cubic meters per week.

## 7.7 Pacific New Locks Southern Approach Channel

### 7.7.1 Drilling and Blasting

- For the southern plug, the ACP is proposing the use of land-based drilling and blasting equipment available at the Canal such as RBD, Rangers, Tamrocks, and P&H drills during low tides. Estimated productivity of land-based drilling and blasting is as low as 30,000 bank cubic meters per week due to Pacific entrance tidal variations.
- For the southern approach channel, the ACP is proposing the use of land-based drilling and blasting equipment available at the Canal such as RBD, Rangers, Tamrocks, and P&H drills mounted in barges. The average productivity rate for this semi-aquatic equipment could be around 20,000 bank cubic meters per week.
- The southern plug, and especially the southern approach channel, is subject to Pacific entrance tidal variations.

### 7.7.2 Dredging

- For the southern plug, the ACP is proposing the use of a backhoe at a rate of 20,000 bank cubic meters per week with a full 3W-6D schedule. The backhoe would remove mostly previously blasted basalt.
- For the southern approach channel, the ACP is proposing the use of a medium rock cutter dredge at a rate of 37,500 cubic meters per week in a full 3W-7D schedule to remove La Boca formation with no prior drilling and blasting. For basalt, the ACP would use same hydraulic backhoe from the southern plug with a productivity of 20,000 bank cubic meters per week in 3W-6D. The basalt would be blasted before subsequent dredging by the backhoe.

## 7.8 Pacific Entrance Navigation Channel

### 7.8.1 Underwater Drilling and Blasting

- The ACP is proposing the use of the new drill-boat BARU to drill and blast about 30% of the Pacific entrance navigation area. BARU's productivity at the Pacific entrance is estimated at about 30,000 bank cubic meters per week under a full 3W-7D schedule, which represents a 30% productivity increase compared to the THOR in Gaillard Cut.

### 7.8.2 Dredging

- Performance of dipper dredge RMC at the Pacific entrance, was about 16,500 cubic meters per week in hard material, while cutter suction MINDI has dredged

soft material at an average rate of 69,000 cubic meters per week. Following is a table that summarizes the performance of ACP dredges at the Pacific entrance:

**ACP DREDGES PERFORMANCE IN PACIFIC ENTRANCE NAVIGATION CHANNEL**

| DREDGE | Production ($m^3$ x week) | | |
|---|---|---|---|
| | Least | Average | Largest |
| Dipper dredge RMC in 1989 through 1994, and 1998 | 3,600 | 16,500 | 23,700 |
| Cutter suction dredge MINDI in 1991 and 1994 | 27,000 | 69,000 | 210,200 |

**Table No. 20. ACP dredges performance at the Pacific entrance.**

- For the Canal expansion program, ACP dredges would be working mostly in Canal inland waters, while external services would be contracted to perform dredging activities in open waters. External dredging company Boskalis is currently executing the Pacific entrance deepening program to 14.2 m MLWS since January 2005 using a hopper dredge to remove soft material, and a drill-boat and backhoe for harder material. Completion of this deepening is expected by June 2006. Following is a table showing Boskalis hopper dredge production in the Pacific entrance:

**CONTRACTOR BOSKALIS HOPPER DREDGE "BARENT ZANEN" PRODUCTIVITY IN PACIFIC ENTRANCE DEEPENING PROJECT TO 14.2 M**

| Dredging volume | Jan to Feb 2005 | Jun-05 | Average |
|---|---|---|---|
| Cubic meters per week | 180,320 | 141,050 | 160,685 |
| Cubic meters per day | 25,760 | 20,150 | 22,955 |
| Cubic meters per hour | 1,170 | 972 | 1,071 |

**Table No. 21. Contractor dredging equipment performance in deepening the Pacific entrance**

- Although the hopper dredge has proven to be effective at the Pacific entrance, it is foreseen that more medium to hard material would be found at a deeper elevation. Therefore, the ACP is proposing the use of a medium rock cutter dredge to dredge soft material, and medium to hard material at a rate of 60,000, and 37,500 bank cubic meters per week, respectively, under a full 3W-7D schedule. No drilling and blasting would be required for soft or medium to hard material. A rock cutter dredge with a 2,000 to 3,000 kilowatt cutter could dredge medium to hard material with no previous drilling and blasting.
- As for the very hard material, the ACP would use a hydraulic backhoe at a rate of 20,000 bank cubic meters per week in a 3W-6D schedule. Previous drilling and blasting would be required for backhoe effective performance.

## 7.9 Back-up Equipment

- Canal navigation channels represent enormous challenges because of their complex geological conditions and traffic restrictions, especially in Gaillard Cut; therefore, not all dredges would be capable of dredging Canal navigation channels. These factors narrow market supply on dredges that could be available to perform Canal Post Panamax navigation channel work.
- The ACP's existing cutter suction dredge could serve as back up for the rock cutter suction dredge, especially in Gatun Lake. Unfortunately, due to its limited capacity to dredge medium to hard material, the MINDI would not be able to assist dipper dredge RMC, the hydraulic backhoe or the rock cutter suction dredge at the Pacific area.
- The use of the MINDI as a back up would lower equipment impact on Post-Panamax dredging works from high to low, that is, from 6 to 3 months of delay.
- As opposed to dredges, and drillboats, it is foreseen that land-based equipment availability would not have major impact on Post Panamax channel work due to the ample market supply.
- Following is a table showing some equipment alternatives for dredging work:

**EQUIPMENT IMPACT ON POST-PANAMAX CHANNEL WORK PERFORMANCE**

| Equipment | Impact on dredging program | Alternative solution |
|---|---|---|
| Medium size hopper dredge (5-10k $m^3$) | Low | Easy acquisition; market ample availbility |
| Rock cutter dredge (2 to 3k kW cutter) | High | CSD MINDI could serve as backup |
| Land dredge | Moderate | Acquisition of another backhoe or mechanical dredge |
| Dipper dredge RMC | High | Acquisition of backhoe and land dredge |
| Hydraulic backhoe | Moderate | Another backhoe dredge |
| Drillboats | Moderate | Availability of 2 drillboats at ACP |
| Drilling and blasting in shallow waters (<3m) | Moderate | Methodology design pending |
| Land-based drilling and blasting | Moderate | Several units available at ACP |

**Table No. 22. Equipment impact and solutions on Post Panamax navigation channel work.**

### 7.10 Summary of Proposed Equipment for Post Panamax Channel Work

- Following is a table summarizing proposed equipment to perform improvement work on existing Canal navigation channels and construction of new locks approach channels:

**PROPOSED EQUIPMENT PRODUCTIVITY ESTIMATE BY MATERIAL TYPE**

| Excavation, dredging, and drilling and blasting equipment | Sediment, clay, mud, and sand | Gravel and clay | Soft rock < 15 Mpa | Medium hard rock 15 to 50 Mpa | Hard rock > 50 Mpa |
|---|---|---|---|---|---|
| Conventional on-land equipment | | | | 34,600 | |
| Land-based drilling and blasting equipment | | | 54,000 | | |
| Drill-boat THOR | | | | 19,400 to 23,500 | |
| Drill-boat BARU | | | | 24,250 to 30,000 | |
| Land-based hydraulic dredge excavator | | | | 25,000 | |
| Drilling and blasting in shallow waters < 3 m | | | | 20,000 | |
| Hopper dredge | 110,500 | | | | |
| Cutter suction dredge (1 to 2K cutter) | | | 50,000 | | |
| Cutter suction dredge (2 to 3K cutter) | | 67,500 | 60,000 | 37,500 | |
| Dipper dredge RMC | | | | 28,000 to 30,000 | |
| Hydraulic backhoe dredge | | | | | 20,000 |

Notes:
1. In addition to geologic conditions, factors such as working condtions, and required channel deepening affect equipment productivity.

**Table No. 23. Proposed equipment for Post Panamax channel work according to soil geologic condition and equipment effectiveness**

# 8 DRILLING AND BLASTING AND DREDGING VOLUME ESTIMATES BY EQUIPMENT TYPE

### 8.1 Dry Excavation Volume

- As shown on Table No. 5, the amount of excavation material for the Canal expansion dredging program is 11.44 million cubic meters. Conventional land-based excavation equipment would execute dry excavation activities in Post Panamax channel.

### 8.2 Drilling and Blasting Volume Estimate by Equipment Type

- According to the parameters explained on percentage estimates, and type of material that could be found in the area for subsequent dredging, the amount of dry and underwater drilling and blasting volumes are shown in the following table.

**TYPE OF DRILLING AND BLASTING VOLUME in million cubic meters: DRY AND WET**

| Volume by Drilling and Blasting Type | Sediment, clay, mud, and sand | Gravel and clay | Soft rock < 15 Mpa | Medium hard rock 15 to 50 Mpa | Hard rock > 50 Mpa | Total Volume |
|---|---|---|---|---|---|---|
| **9.14 m PLD SCENARIO** | | | | | | |
| Aquatic (Drill-boats) | | | | 4.33 | 6.01 | 10.34 |
| Subaquatic in shallow waters <3m (land drills mounted on barge) | | | | 0.71 | 0.71 | 1.42 |
| Dry (land drills) | | | | 2.18 | 2.91 | 5.09 |
| **Total Volumen** | **0.00** | **0.00** | **0.00** | **7.22** | **9.63** | **16.85** |

**Table No. 24. Volume estimates by drilling and blasting type.**

## 8.3 Dredging Volume Estimate by Equipment Type

- According to the type of material found in the different areas, the estimated dredging volume that the proposed dredges would excavate for both scenarios is as follows:

**DREDGING VOLUME in million cubic meters BY DREDGING EQUIPMENT TYPE**

| Type of dredgers | Sediment, clay, mud, and sand | Gravel and clay | Soft rock < 15 Mpa | Medium hard rock 15 to 50 Mpa | Hard rock > 50 Mpa | Total Volume |
|---|---|---|---|---|---|---|
| **9.14 m PLD SCENARIO** | | | | | | |
| Hopper dredge - Medium size (5-10k $m^3$) | 6.95 | | | | | 6.95 |
| CSD - 1 to 2k kW cutter | | 6.00 | | | | 6.00 |
| CSD 2 to 3k kW cortador | | 8.43 | 11.21 | 7.18 | | 26.82 |
| CSD 3 to +5k kW cutter | | | | | | |
| Land dredge | | | | 0.28 | 0.28 | 0.56 |
| Backhoe dredge (Northern new locks access) | | | | 0.93 | 0.93 | 1.86 |
| Dipper dredge | | | | 0.65 | 3.66 | 4.31 |
| Backhoe dredge (Pacific entrance) | | | | | 3.84 | 3.84 |
| **TOTAL VOLUME** | **6.95** | **14.43** | **11.21** | **9.04** | **8.71** | **50.34** |

**Table No. 25. Volume estimate by dredging equipment type for Post Panamax navigation channel work**

## 8.4 Volume Estimates for ACP Equipment Resources and External Contractors

- Because dry excavation programs have been executed successfully by external contractors at competitive prices, it is foreseen that Post Panamax navigation channel excavation would be performed again by external contractors.
- As pointed out earlier, ACP drill-boats would be in charge of Post Panamax underwater drilling and blasting work. ACP land drills could also perform most of the land-based drilling and blasting and provide blasting resources, but some of this work could be contracted if required.

- As for dredging, it is foreseen that ACP and external contractors would perform dredging work 50% each as shown in the following table:

**DREDGING VOLUME ESTIMATES in million cubic meters THAT COULD BE PERFORMED BY ACP AND EXTERNAL CONTRACTORS**

| Area | 9.14 m PLD | |
|---|---|---|
| | ACP | External contractors |
| Atlantic Entrance Navigation Channel | | |
| Atlantic Northern Approach Channel | | 6.95 |
| Atlantic Northern Plug | | 6.55 |
| Atlantic New locks | | 0.61 |
| Atlantic Southern Plug | 0.79 | |
| Gatun Lake | 16.03 | |
| Gaillard Cut | 6.03 | |
| Pacific Northern Approach Channel north of Gaillard Cut Plug | 2.26 | 0.56 |
| Pacific Gaillard Cut or Northern Plug | | |
| Pacific Northern Approach Channel between Gaillard Cut Plug and Intermediate Plug | | |
| Pacific Intermediate Plug | 0.39 | |
| Pacific New locks | | |
| Pacific Southern Plug | | 0.63 |
| Pacific Southern Approach Channel | | 2.51 |
| Pacific Entrance Navigation Channel | | 6.51 |
| **TOTAL VOLUME** | **25.5** | **24.32** |

**Table No. 26. Dredging volume estimates that could be performed by the ACP and external dredging companies**

- Following is a table that summarizes ACP internal and external resources in percentage terms that would be used to excavate and dredge Post Panamax channels.

**EXPECTED DISTRIBUTION OF CANAL EXPANSION DREDGING WORKS**

| Operation type | ACP | Recursos Externos |
|---|---|---|
| Dredging | 50% | 50% |
| Drilling and blasting | 100% | 0% |
| Dry excavation | 0% | 100% |

**Table No. 27. Resources percentage estimate to perform Canal expansion dredging activities**

# 9 PARAMETERS USED FOR UNIT COST ESTIMATES FOR EXCAVATION, DREDGING, AND DRILLING AND BLASTING

## 9.1 Productivity Estimate for Proposed Excavation, Dredging, and Ddrilling and Blasting Equipment

- As previously explained, proposed equipment for Post Panamax channel work productivity would vary according to material type as shown on Table No. 23. Such productivity also includes equipment maintenance, overhaul, emergency repairs, dredging maintenance, and crew relief.

## 9.2 Drilling and Blasting and Dredging Equipment Cost Estimate

- Dredging equipment cost estimates were based on ACP equipment costs during fiscal years 2001 through 2003. Also, external contracted dredge cost was based on ACP equipment costs plus 10% profit, and dredging contracts with external resources.
- The following costs were considered to estimate dredging and drilling and blasting equipment cost:
  - Equipment depreciation
  - Capital cost of facilities
  - Maintenance and overhaul
  - Labor
  - Fuel
  - Supply and materials
  - Miscellaneous
  - Division overhead
  - Profit for contracted services
- The following parameters were used to determine equipment cost:
  - Capital financial interest rate of 5% for external contractor's equipment, and ACP acquisition of new equipment; and 14% for ACP existing equipment.
  - A factor of 1.47 ($1.25 per gallon in 2004 to $0.85 per gallon in 2003) was used to update fuel cost.
  - Except for land-based dredge excavator, labor wages are based on ACP wage policies up to step 3 for each man-category wage. Labor wages for land-based dredge excavator were based on CAPAC16 wage policy.

[16] CAPAC stands for Cámara Panameña de la Construcción, which is the organization that establishes the minimum construction safety requirements and minimum construction labor wages.

- The following labor burden parameters were used based on ACP records during the last months of year 2003, and first months of year 2004:
    - Overhead of 11%, except for aquatic hydraulic backhoe, which is 12%
    - Employee benefits of 38.67% for direct labor, which includes 12.45% of social security, 1.50% of education insurance, 13.65% of vacation, and 11.07% of benefits
    - Employee differential of 5% due shift work
    - Overtime:
        - 25% for cutter suction dredge of 2 to 3K kilowatts cutter, and support equipment
        - 25% for cutter suction dredge MINDI and support equipment
        - 16% for dipper dredge RMC and support equipment
        - 15% for aquatic hydraulic backhoe and support equipment
        - 25% for drill-boats THOR and BARU and support equipment
        - 5% for survey launch support
- Except for hydraulic excavators, equipment overhaul and maintenance costs were based on ACP historical records during fiscal years 2001 through 2003. If the equipment were new, then overhaul and maintenance cost was assumed to be 50% lower than that of existing equipment.
- Hydraulic excavator and land-based support equipment overhaul and maintenance cost were based on industry standard book ("blue book").
- A profit of 10% was included to those contracted services.
- Cost estimates include cost of all support equipment such as tugboats, working boats, launches, survey launches, and others.
- Once the annual cost was determined, the yearly effective operating hours based on equipment efficiency were estimated to obtain each equipment hourly cost.

## 9.3 Unit Cost Estimate

### 9.3.1 Excavation Work Unit Cost

- Historical cost information from the GCWP was used to estimate the dry excavation costs for the Gaillard Cut deepening, Pacific northern channel access, and plugs. It is known that costs for ongoing Gaillard Cut straightening program are very similar and even lower than those paid for GCWP.
- Because of the shortage of capacity of disposal sites on the east side, it is estimated that the hauling distance on the east side would be 5 km, as opposed to the 3 km estimated for the west side.

### 9.3.2 Drilling and Blasting Unit Cost

#### 9.3.2.1 Land-based Drilling and Blasting

- Land-based drilling and blasting operational costs from GCWP were used to estimate the total cost of fracturing hard material for its later removal.
- The estimated cost for land-based drilling and blasting includes the operation of land-based drill rigs P&H, DM-45, 2 TAMROCKS D55 SP, and 2 Rangers 700, as well as support equipment including one D-5M tractor, one D-6 tractor, a CAT 924 payloader, a CAT 934 payloader, 2 diesel refueling vehicles, 1 lubricating vehicle, 2 water pumps, 2 4x4 vehicles, one diesel storage tank, 2 portable explosive magazines, and one compressor.
- The estimated cost also includes labor, equipment maintenance, and 12 % of over-head costs, fuel, explosives, and accessories.

#### 9.3.2.2 Unit Cost for Drilling and Blasting in Shallow Waters (< 3 m)

- Land-based drilling and blasting would be performed only at low tide when equipment would be accessible at the Pacific southern plug.
- For the Pacific new locks southern approach, land-based drill rigs such as TAMROCKS could be mounted on barges to access the area. Water in this area is expected to be less than 3 meters deep so neither the drill-boat THOR nor the BARU would be able to access the area for adequate underwater drilling and blasting.

#### 9.3.2.3 Underwater Drilling and Blasting

- ACP drill-boats are expected to perform all required under water blasting work. Unit cost would be subject to drill-boat production, and it is expected to be less for ACP new drill-boat BARU.

### 9.3.3 Dredging Unit Cost

- The hopper dredge unit cost was based on external consultant reports[17], which state that hopper-dredging work has been performed in areas at the nearby Coco Solo port facilities with 10 km offshore disposal. This cost was confirmed with the work performed by external contractor Jan der Nul in deepening Atlantic entrance navigation channel to 14.2 m depth.

[17] Great Lake Dredge & Dock Company, "Independent Technical Review of Navigation Studies", Final report, April 2004.

- Cutter suction dredge unit cost at Gaillard Cut includes a land-based booster pump to dispose dredging material to an upland disposal site.
- Cutter suction dredge unit costs at the Pacific entrance include hauling of dredging material to open water disposal site via dump scows. Distance of Pacific new locks southern approach channel to designated open water disposal sites is estimated at 13 to 15 km.
- As for backhoe hydraulic dredges, it was assumed that the ACP would charter one for projected Gaillard Cut widening to 218 m, which would also be used to assist dipper dredge RMC to complete some of the dredging work on the Pacific northern channel and Pacific plugs.

# 10 INDIRECT COST PERCENTAGE ESTIMATES

- For recent excavation and dredging projects, the ACP has been estimating 11.5% and 12% for excavation and dredging work, respectively to cover associated indirect costs.
- To corroborate these 11.5% and 12% indirect cost percentage estimate, actual costs from GCWP to 192 m were used as a basis to sustain potential indirect costs for Canal expansion excavation and dredging work.
- Following is a table showing indirect costs and contingencies that were identified during previous ACP excavation and dredging work:

| Indirect costs | Estimate of total costs | Cost estimate | |
|---|---|---|---|
| | | 10.4 m PLD | 9.14 m PLD |
| Navigational aids | $/km[1] | 7.98 | 8.98 |
| Environmental mitigation | 2.5% to 3.0% | 3.01 | 4.59 |
| Engineering design | 3.00% | 8.67 | 13.23 |
| Administration of projects | 3.10% | 10.59 | 15.97 |
| Preparation of disposal sites | $0.40/m3 | 9.20 | 12.17 |
| Preparation of disposal sites with UXO[2] | $45,000/ha | 2.00 | 2.00 |
| Hydrographic and topographic support | 2% | 6.83 | 10.30 |
| **TOTAL** | | **48.28** | **67.24** |

Notes:

1. Navigation aids approximate cost depends on navigation channel location and condition: $3,600 per km in the lake; $55,600 per km in the Cut; $131,550 per km in new channel access.

2. Unexploded ordinance is known as UXO and constitutes explosive devices used by US Army to conduct several weapon system testing exercises and training activities while in Panama.

**Table No. 28. Estimates for excavation and dredging works indirect costs.**

- As shown on Table No. 28, navigational aids, preparation of disposal sites with and without UXO, are expressed in terms of $ per kilometer, $ per hectare or $ per cubic meter rather than percentage estimate of total costs.

# 11 ACP SUPPORT COST ESTIMATE TO EXTERNAL CONTRACTORS

- It is foreseen that external contractors would perform about 50% of Canal expansion dredging work, and would require ACP support and inspection to execute these activities in Canal waters.
- Following is expected support that external contractors would require:
  - Relocation of navigational aids
  - Launches for transportation of ACP and contractor personnel
  - ACP tugs to assist external contractor equipment
  - ACP marine traffic controllers for navigation coordination
  - ACP pilots, project coordinators, and inspectors on board contractors' equipment
  - ACP contract specialists, and contracting officers for contract administration
  - ACP survey services to audit dredged material
- ACP support cost estimate was based on the works performed by ACP resources to support Atlantic and Pacific entrance deepening program to 14.2 m MLW in 2005 and 2006.

# 12 DREDGING AND DRILLING AND BLASTING EQUIPMENT REQUIREMENTS IN DREDGE-MONTHS

- Depending on the dredging volume, and drilling and blasting volume, as well as equipment performance regarding productivity, the following number of dredges, drill-boats, and land-based drill rigs would be required to perform improvements on Canal existing navigation channels, and construction of new locks approach channels.

**NUMBER OF EQUIPMENT REQUIRED TO PERFORM POST-PANAMAX CHANNEL WORKS**

| Type of equipment | 9.14 m PLD scenario | |
|---|---|---|
| | Dredger-months or driller-months | No. of dredgers or drill-boats required |
| Medium size hopper dredge (5-10k $m^3$) | 18.1 | 1 |
| Cutter suction dredge ( 1 to 2k kw cutter) | 56.7 | 1 |
| Rock cutter dredge (2 to 3k kW cutter) | 121.0 | 3 |
| Land dredger | 5.6 | 1 |
| Dipper dredge RMC | 41.5 | 1 |
| Backhoe dredge Lake and Access | 33.7 | 1 |
| Backhoe dredge Pacific entrance | 48.0 | 1 |
| Drill-boats | 73.9 | 2 |
| Drill rigs for shallow waters | 20.1 | 1 |
| Land based drill rigs | 25.1 | 3 to 4 |

**Table No. 29. Dredge-month estimate to perform pst-Panamax navigation channel work.**

- ACP resources include dipper dredge RMC, new rock cutter suction dredge available in 2008, drill-boat THOR, drill-boat BARU available in 2005, land-based drill rigs, support equipment, and cutter suction dredge MINDI, which would serve as back up equipment.
- External contractors would provide dry excavation services, and probably certain land-based drilling and blasting services, hopper dredges, land-based hydraulic excavators, hydraulic backhoe dredges, and rock cutter suction dredges.

# 13 PLANNING OF POST PANAMAX CHANNEL WORK EXECUTION PROGRAM

- A Gantt chart was developed to plan the execution program for Post Panamax channel work. It was assumed that one hopper dredge, three rock cutter suction dredges, cutter suction dredge MINDI, the dipper dredge RMC, two hydraulic backhoe dredge, both drillboats THOR and BARU, land-based drilling and blasting equipment, and conventional excavation equipment would be available to perform channel work under the scenario of 9.14 m PLD.
- The Gantt chart assumes the contracting of external services for excavation work, and 50% dredging, specifically, two rock cutter dredges, a hopper dredge, and two

hydraulic backhoe dredges. The ACP would lease one of these backhoe dredges, which will be operated by its personnel.

- The new ACP rock cutter suction dredge is assumed to be available by August 2008.
- As previously explained, all equipment productivity accounts for preventive maintenance, emergency repairs, dredging maintenance, and crew relief. However, to compensate for major overhaul time, it was assumed that all floating equipment, including, hopper dredges, rock cutter suction dredges, dipper dredges, and drill-boats, would remain operative at least 42 weeks out of 52 weeks per year.
- Meanwhile, the hydraulic backhoe dredge's full availability was estimated at 48 weeks per year due to its hydraulic nature, and its rapidly replaceable parts. The backhoe dredge would be working 6 days per week as opposed to other floating equipment scheduled to work 7 days per week.
- As for land-based equipment including land excavator dredges, it was assumed that such equipment would be working through the whole year since replacements are available, and their nature is not as critical as that of floating equipment.

# 14 LABOR REQUIRED TO EXECUTE POST PANAMAX NAVIGATION CHANNEL EXPANSION PROGRAM

- Labor on board ACP and external contractor dredges and drill-boats, and the number of people working in current Cut excavation and dredging work, and the Canal entrances deepening program were used as baseline to estimate the amount of labor required for Canal expansion dredging and excavation work. Following is a table showing the estimated number of workers for each equipment or activity. For more information, refer to Appendix No. 11.

**NUMBER OF PEOPLE WORKING DIRECTLY IN PROPOSED DREDGING AND EXCAVATION EQUIPMENT**

| Equipment | On board | On land | Support | Adm. | ACP support | TOTAL |
|---|---|---|---|---|---|---|
| **ACP dredges** | | | | | | |
| **CSD MINDI** | 92 | 5 | 27 | | | **124** |
| **Drill boat THOR** | 91 | | 16 | | | **107** |
| **Drill boat BARU** | 75 | | 8 | | | **83** |
| **Backhoe dredge** | 14 | | 77 | | | **91** |
| **Dipper dredge RMC** | 71 | | 77 | | | **148** |
| **Land-based dredging** | | 44 | 4 | | | **48** |
| **Land-based drillers** | | 56 | 5 | | | **61** |
| **Drilling in shallow waters** | | 20 | | | | **20** |
| **TOTAL** | | | | | | **682** |
| **Contractors equipment** | | | | | | |
| **Dry excavation** | | 50 | | | | **50** |
| **Hopper dredge** | 33 | | 12 | 9 | 38 | **92** |
| **Cutter suction dredge** | 44 | 18 | 21 | 14 | 64 | **161** |
| **Backhoe dredge** | 14 | | 12 | 9 | 46 | **81** |
| **TOTAL** | | | | | | **384** |
| **ACP support** | | | | | | |
| **ACP Workshops** | | 146 | | | | **146** |
| **ACP Dredging Division** | | | | 67 | | **67** |
| **Canal expansion management team** | | | | 15 | | **15** |
| **TOTAL** | | | | | | **228** |

**Table No. 30. Approximate number of people working on each equipment involved in Canal expansion program.**

- The persons that would work in these excavation and dredging work include dredge captains, mates, deckhands, chief engineers, dredge engineers, marine machinery mechanics, oilers, electricians, launch operators and seamen, survey technicians, cooks, etc.
- According to the planning of resources along Canal navigation channel reflected on the Gantt chart, the number of workers that would be required in an annual basis to execute channel improvements, and construction is as follows:

| Personnel / Fiscal Year | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|---|---|---|
| **Foreign personnel** | 0 | 67 | 93 | 237 | 200 | 133 | 165 | 215 |
| **Panamanian personnel contracted out by foreign dredgers** | 150 | 180 | 240 | 244 | 86 | 56 | 204 | 130 |
| **Personnel in ACP dredges** | 336 | 460 | 521 | 614 | 586 | 355 | 538 | 507 |
| **ACP support personnel** | 228 | 292 | 338 | 504 | 440 | 376 | 338 | 228 |
| **TOTAL** | **714** | **999** | **1,192** | **1,599** | **1,312** | **920** | **1,245** | **1,080** |

**Table No. 31. Number of people involved in excavation and dredging works by year.**

# 15 POST PANAMAX NAVIGATION CHANNEL EXPANSION PROGRAM BASE COST

- Base cost estimate includes indirect cost of 11.5% for excavation works, and 12% for dredging and drilling and blasting activities.
- Also fuel adjustment was effected to dredging and drilling and blasting direct costs to compensate the higher fuel prices. In 2004, the fuel cost was $1.25 per gallon but its price has risen to about $2.00 per gallon in 2005. The probabilistic cost analysis evaluated the probability that fuel prices be higher than expected $2.00 per gallon
- Following is a table summarizing total base cost including indirect costs, and ACP support to external contractors for improvements to Canal navigation channels. Total base cost is $640.99 million for the 9.14 m PLD scenarios:

**POST-PANAMAX NAVIGATION CHANNEL WORKS TOTAL BASE COST in million $**

| **9.14 m PLD Scenario** | | | |
|---|---|---|---|
| Dry excavation | $51.49 | $5.92 | **$57.41** |
| Drilling and blasting | $106.60 | $12.79 | **$119.39** |
| Dredging | $368.16 | $44.18 | **$412.34** |
| **Cost** | **$526.25** | **$62.89** | **$589.14** |
| **ACP support to external contractors** | | | **$25.63** |
| **Fuel cost adjusment** | | | **$26.22** |
| **TOTAL BASE COST for 9.14 m PLD** | | | **$640.99** |

Notes:

1. Indirect costs account for 11.5% of total excavation costs, and 12% for dredging and drilling and blasting costs.

**Table No. 32. Dredging and excavation program base cost for Canal Post Panamax navigation channels.**

# 16 PROBABILISTIC CONTINGENCY COST ESTIMATE

- The common process to estimate contingency for excavation and dredging activities as a percentage based on historical records estimate did not address the occurrence probability of major risks involved in the execution of a major project.
- A group of ACP personnel was formed in the year 2005 to perform a stochastic or probabilistic cost analysis to determine the probability of occurrence and impacts of potential risks that might increase or delay the proposed Canal Expansion Program. This probabilistic model measure the variability of key variables and the uncertainties related to a specific project to produce a range of potential results versus a static analysis which produces a single point result.
- Using Monte Carlo simulation technique, ACP simulated the risks and related impacts through the generation of probabilistic distribution of variables such as dredging quantities, prices, diesel price fluctuations, and dredgers productivities in the case of Post-Panamax dredging program. This exercise resulted in a probability distribution of the total cost addressing the probability of occurrence and consequences of potential risks, and therefore, producing an "acceptable" or more realistic level of contingency or cost risk versus using a standard static single percentage of contingency of 8.5% for dry excavation and 3% for dredging activities.
- The $80^{th}$ percentile of the distribution of project total cost simulated by the risk model was selected as a good estimate confidence level for the cost estimate. In other words, there is 80% of probability that total cost of a project is equal or less than the value at the $80^{th}$ percentile. In the case of dredging program for 9.14 m PLD scenario, the model calculated after 3,000 iterations a total cost of $758.1 million at the $80^{th}$ percentile.
- As shown in Table No. 32, dredging project base cost is $640.99 million which includes the known and quantifiable costs. However, it does not contemplate any risk events or contingency. The total cost of $758.10 million does include unquantifiable risks, and takes into account all schedule and cost overrun risks simultaneously. This total cost represents about 18.4%.
- For more details in probabilistic contingency estimate, refer to Appendix No. 12.
- Following is Table No. 33 that shows the breakdown of Post-Panamax dredging program cost:

**TOTAL COST INCLUDING RISK-BASED CONTINGENCY in million**

| Component | 9.14 m PLD scenario |
|---|---|
| Original base cost | $640.99 |
| Contingency | $117.11 |
| Contingency in percentage | 18.4% |
| **Base cost at 80th percentile** | **$758.10** |

Note: There is 80% of probability that Post-Panamax dredging cost would equal or less that $734.69 million or $484.05

**Table No. 33. Dredging and excavation program total cost for Canal Post Panamax navigation channels.**

# 17 APPROXIMATE CASH FLOW FOR POST PANAMAX NAVIGATION CHANNEL WORK

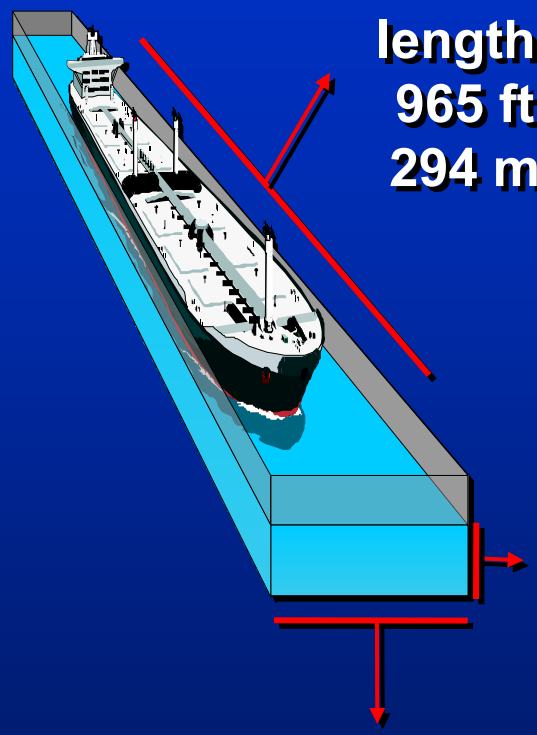
- Following is a table summarizing approximate required cash flow.

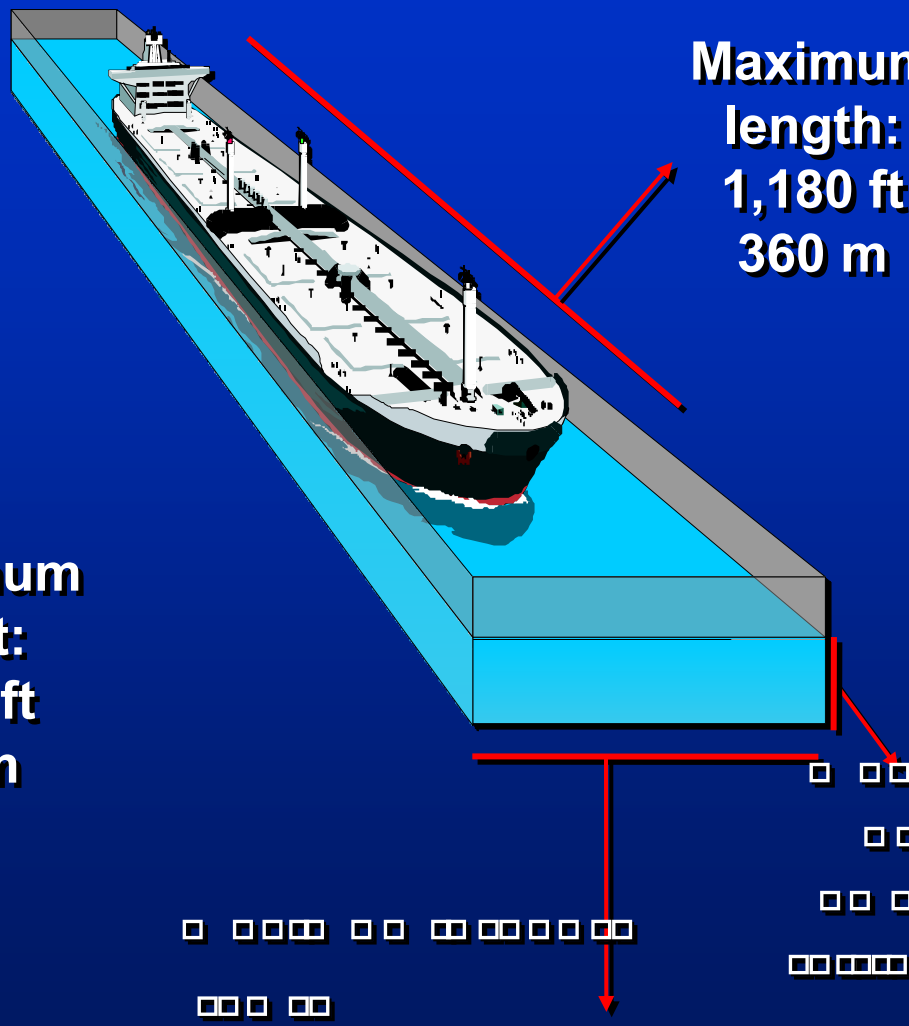
**APPROXIMATE CASH FLOW REQUIRED FOR POST-PANAMAX NAVIGATION CHANNEL WORKS**

| Sources | *FY 2007* | *FY 2008* | *FY 2009* | *FY 2010* | *FY 2011* | *FY 2012* | *FY 2013* | *FY 2014* | *TOTAL* |
|---|---|---|---|---|---|---|---|---|---|
| **9.14 m PLD Scenario** | **$24.11** | **$96.29** | **$107.60** | **$167.53** | **$153.38** | **$108.28** | **$66.97** | **$33.94** | **$758.10** |

**Table No. 34. Required cash flow estimate to modify existing Canal navigation channels, and to construct new channel access for Post Panamax new locks.**

# [illegible]


Maximum
length:
965 ft
294 m
Maximum
draft:
39.5 ft
12 m


Maximum
length:
1,180 ft
360 m

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

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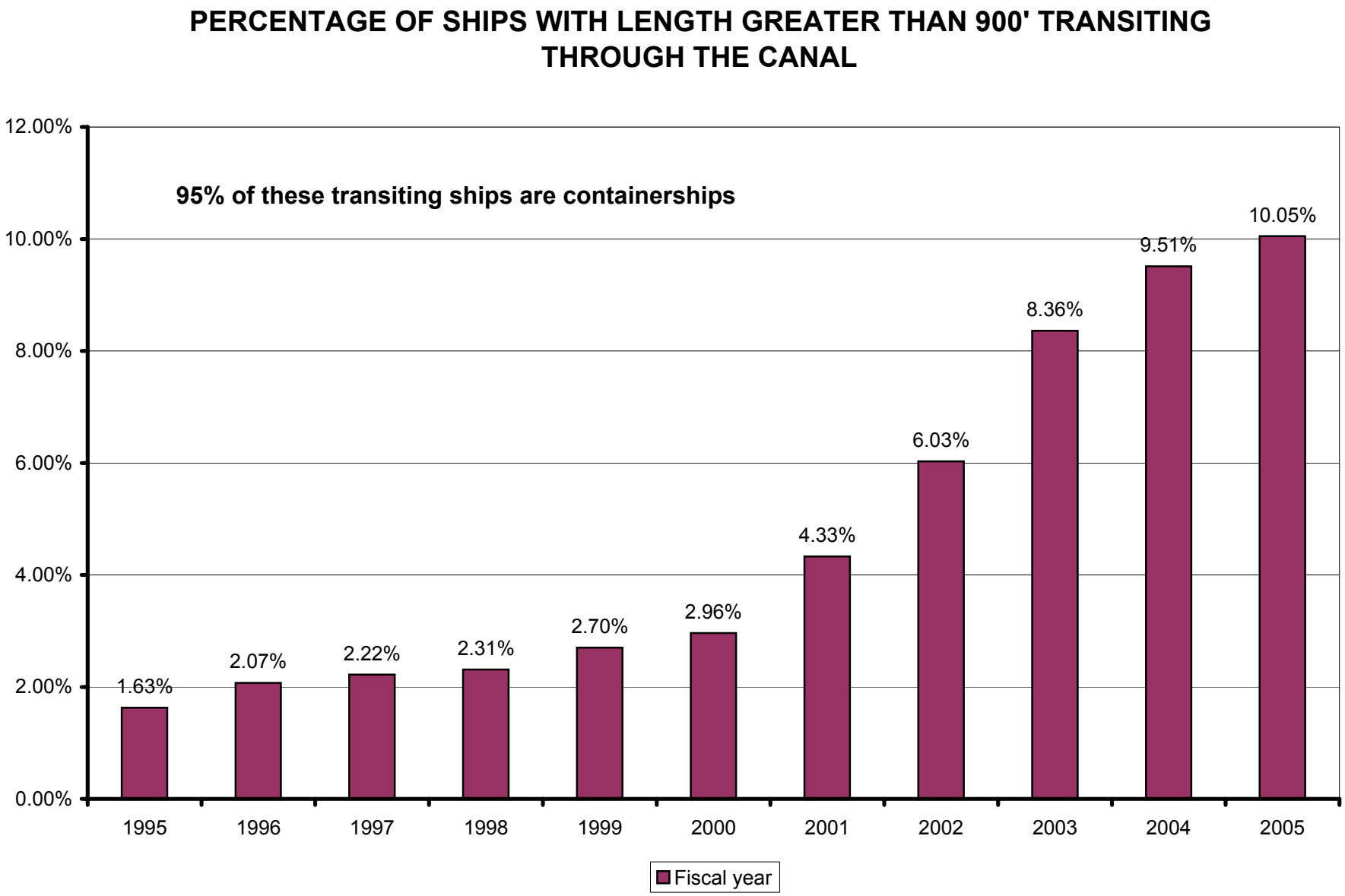
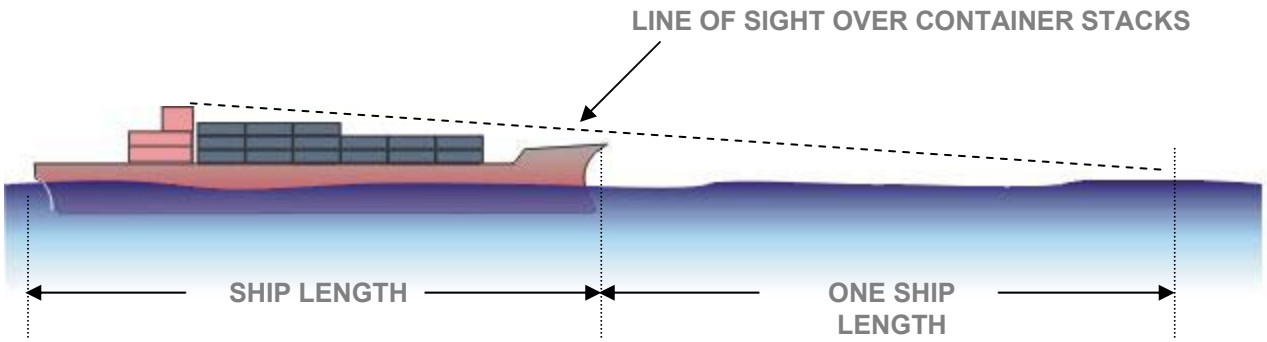
[illegible]

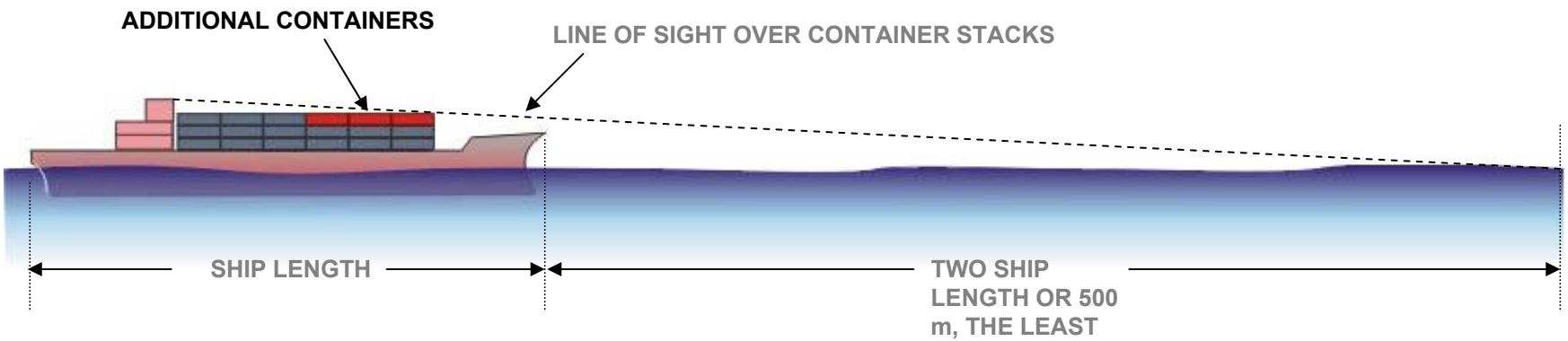
[illegible]


PERCENTAGE OF SHIPS WITH LENGTH GREATER THAN 900' TRANSITING THROUGH THE CANAL
95% of these transiting ships are containerships
12.00%
10.00%
8.00%
6.00%
4.00%
2.00%
0.00%
1.63%
2.07%
2.22%
2.31%
2.70%
2.96%
4.33%
6.03%
8.36%
9.51%
10.05%
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
Fiscal year

# LINE OF SIGHT REQUIREMENTS AS PER SOLAS, CHAPTER V, REGULATION 22

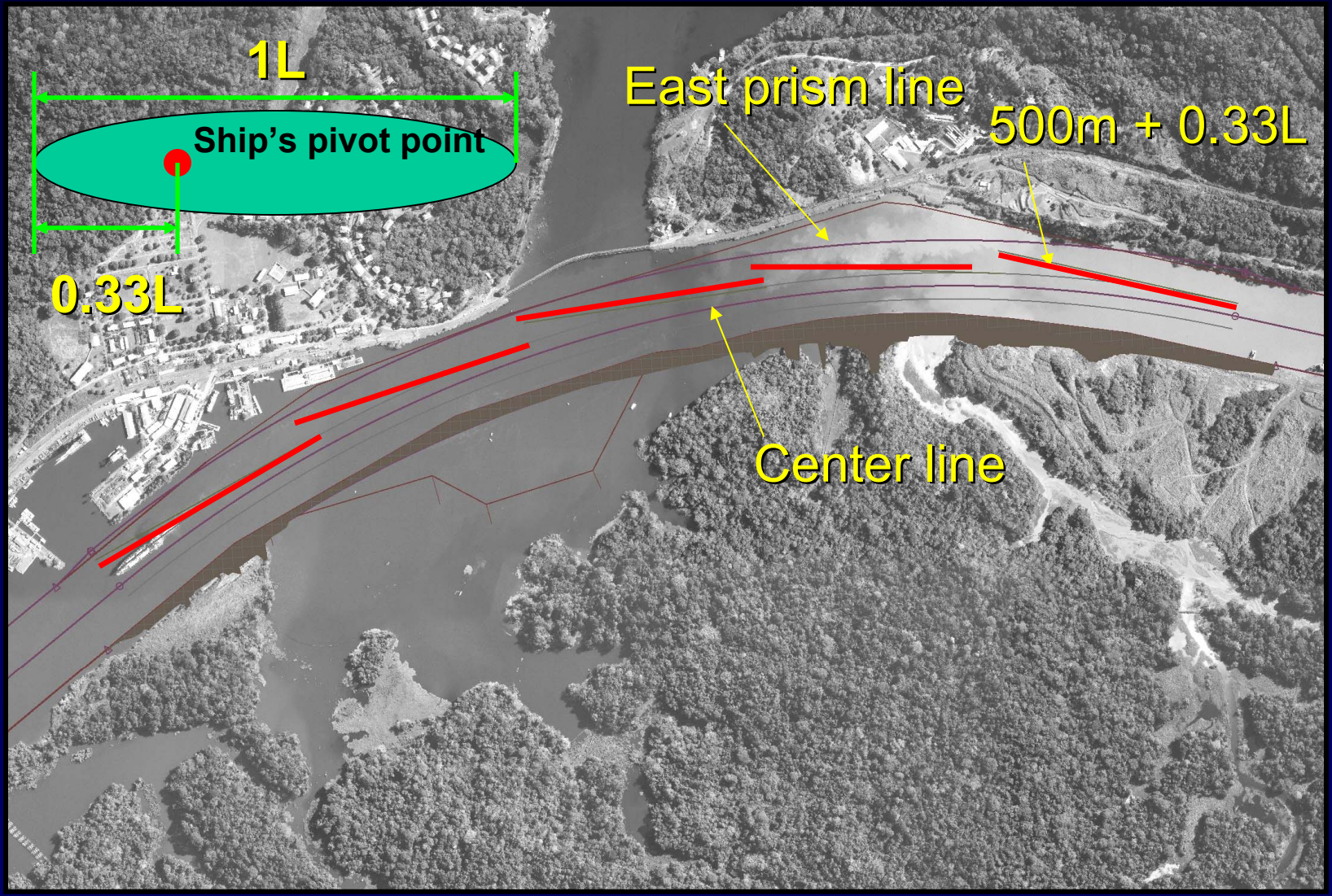



Autoridad del Canal de Panamá

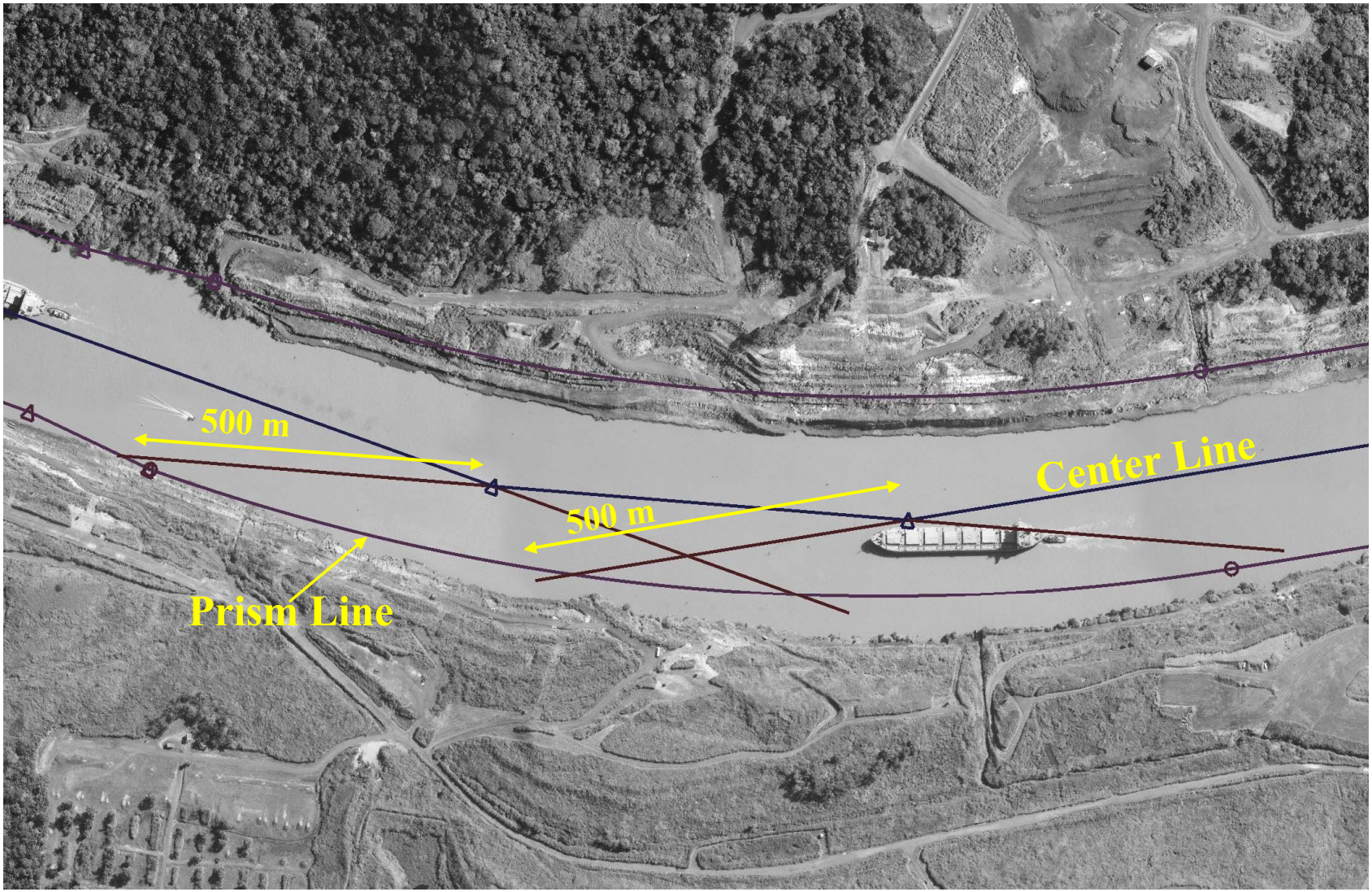



IMO SOLAS CONVENTION

# Line of visibility



# *Example of line of visibility requirement in La Pita bend*



# Navigation channel characteristics

| Scenario in Gaillard Cut | Ancho (metros) | Panamax | Post Panamax |
|---|---|---|---|
| Existing condition | Straight section = 192 m<br>Bend = 205-222 m | 2-way day time & combined beam < 58 m & ship length < 245 m | N/A |
| Straightening | Straight section = 192 m<br>Bend = 205-230 m | 2-way selected meetings daytime ship length < 275 m | 1-way daytime & breadth < 40 m |
| Widening to 218 | Straight section = 218 m<br>Bend = 218-230 m | 2-way: daytime & length < 275 m | 1- way daytime & beam< 46.3 m<br>2-way datime & combined beam < 70 m in Gamboa y Pacific area, & < 75m in Atlantic area |
| Panamax maximum width | Straight section = 225 m<br>Bend = 260 m | 2-way no restricition & daytime | 2-way daytime in Cut & combined beam < 65 m |
| Post Panamax maximum width | Straight section = 280 m<br>Bend = 366 m | 2-way no restriction | 2-way daytime |

Turning radius = 7.25 ship length & visibility line = 500m
Panamax: 32.3 m X 295 m X 12 m
Post Panamax: 46.3 m X 365 m X 13.7 m

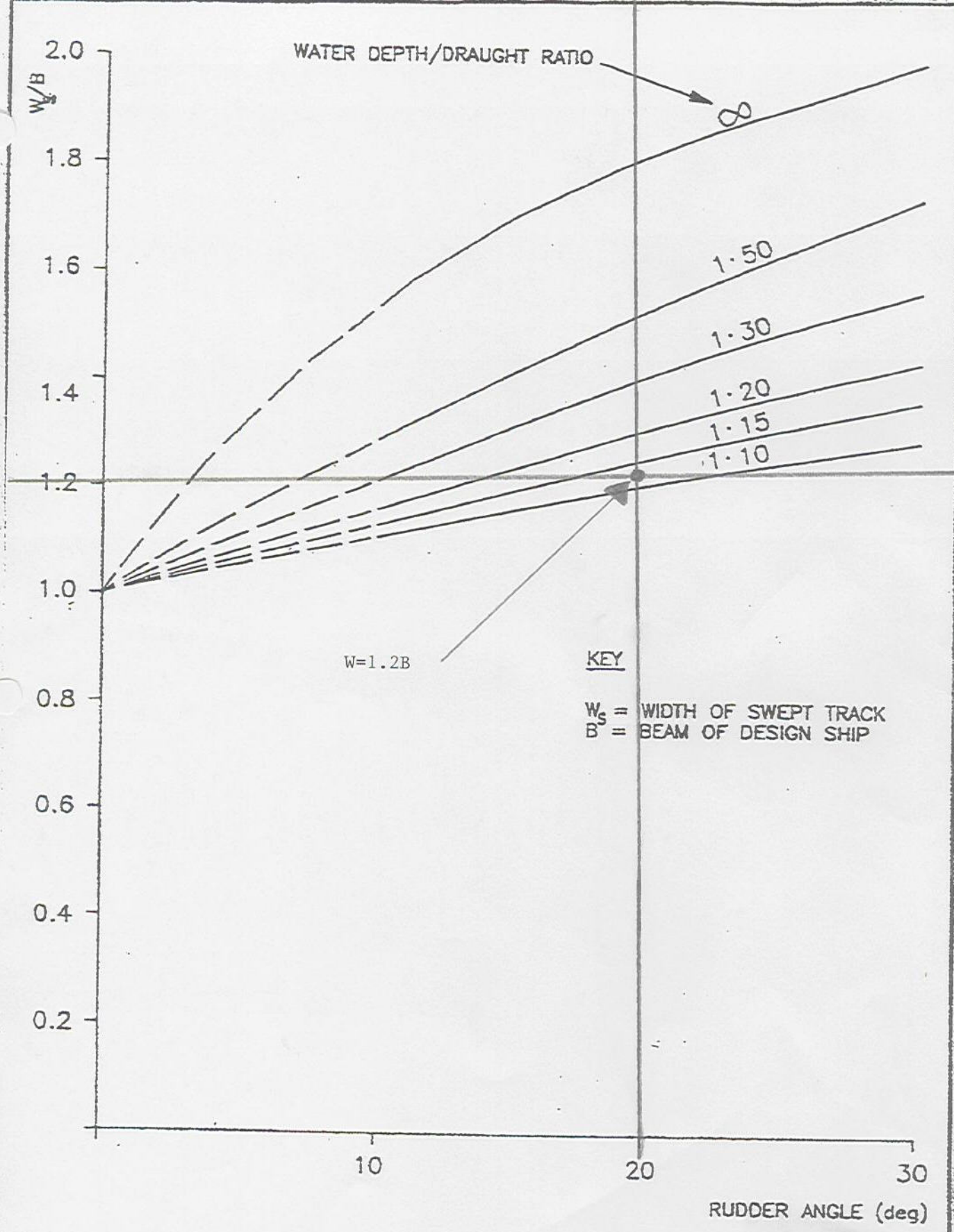



*Figure 5.9 - Width of Swept Track in a Turn as a Function of Rudder Angle and Water Depth (Based on Single Screw/Single Rudder Container Ship)*

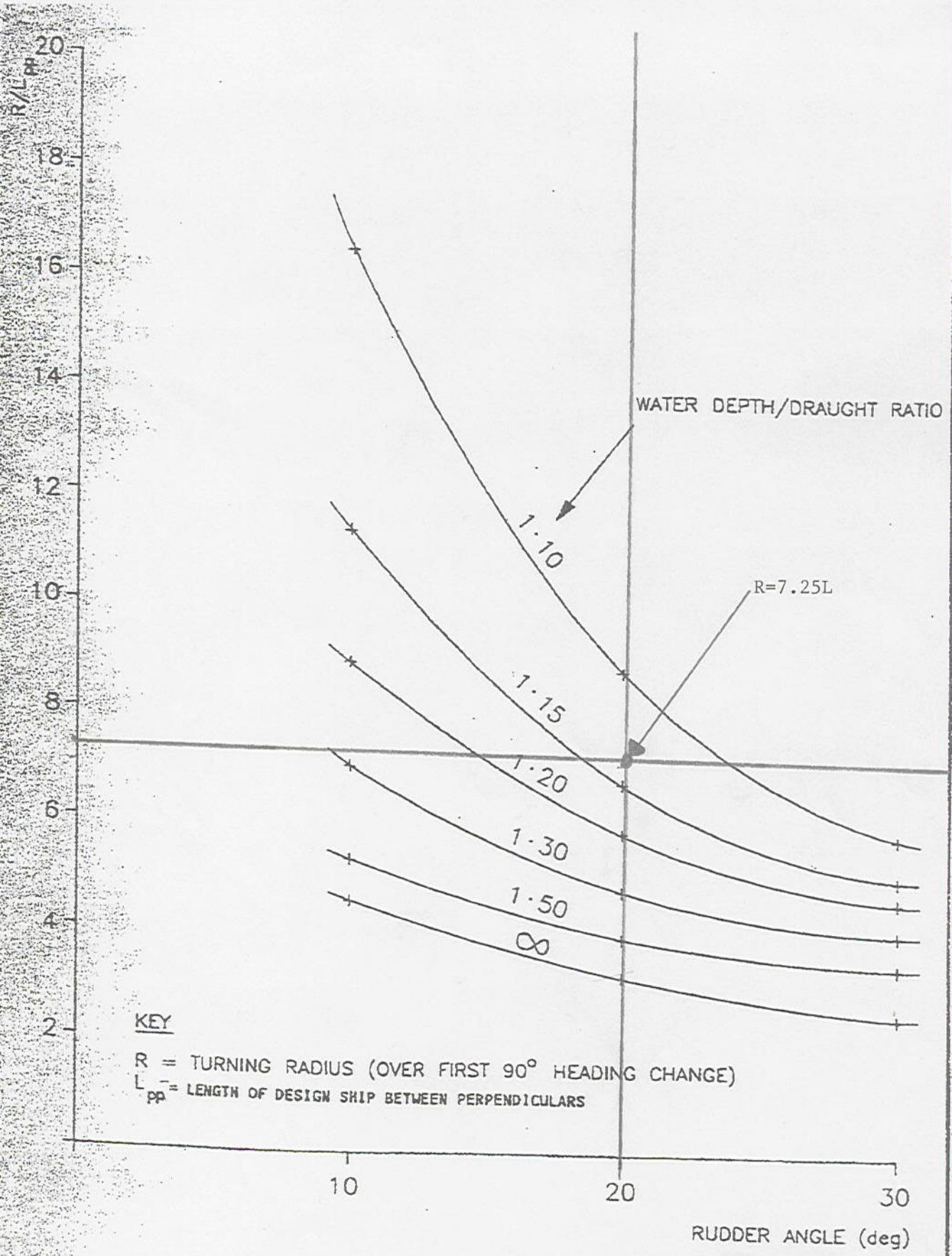



*Figure 5.8 - Turning Radius as a Function of Rudder Angle and Water Depth (Based on Single Screw/Single Rudder Container Ship)*

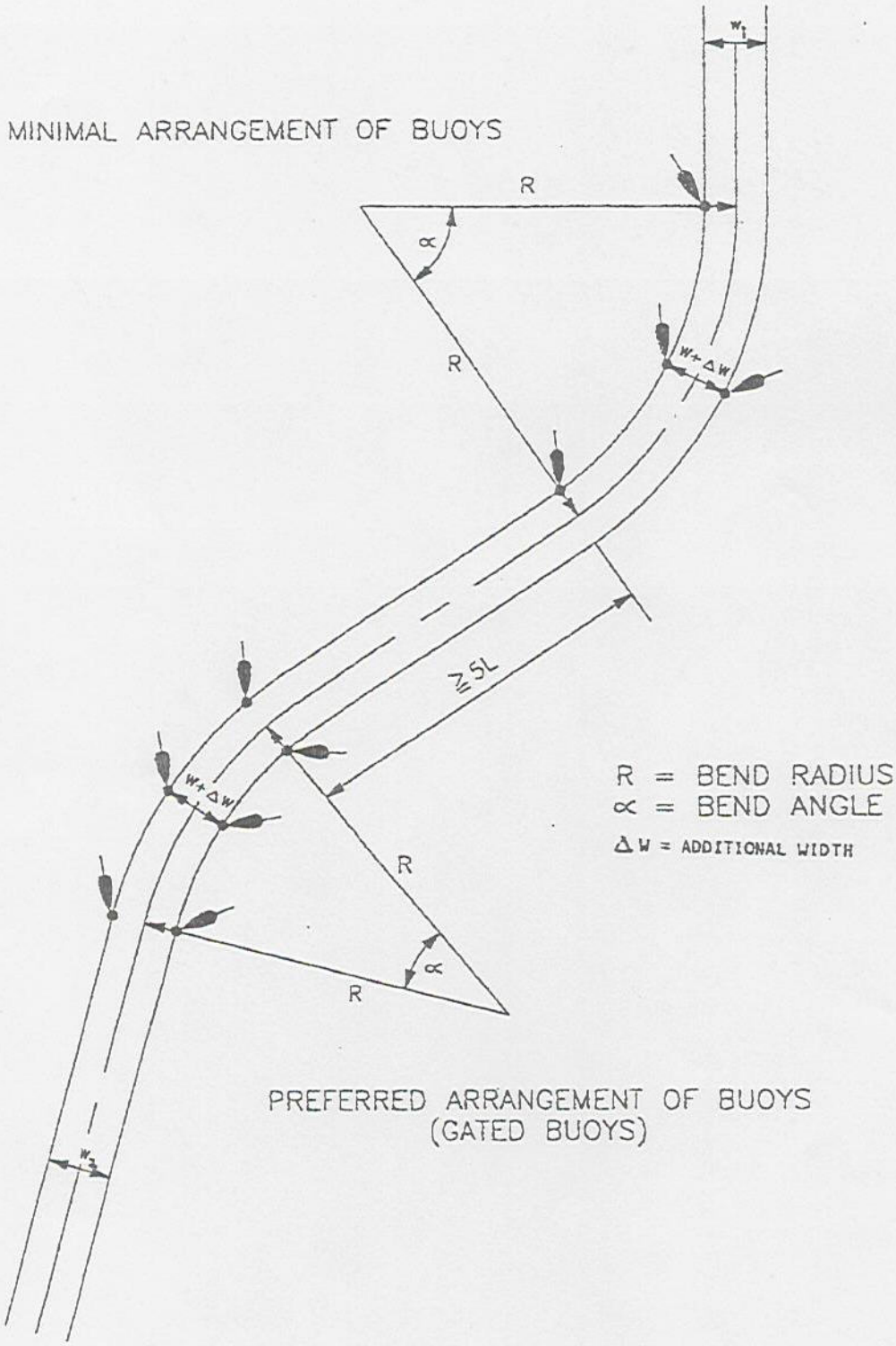



*Figure 5.1 - Suggested Bend Markings & Definitions*

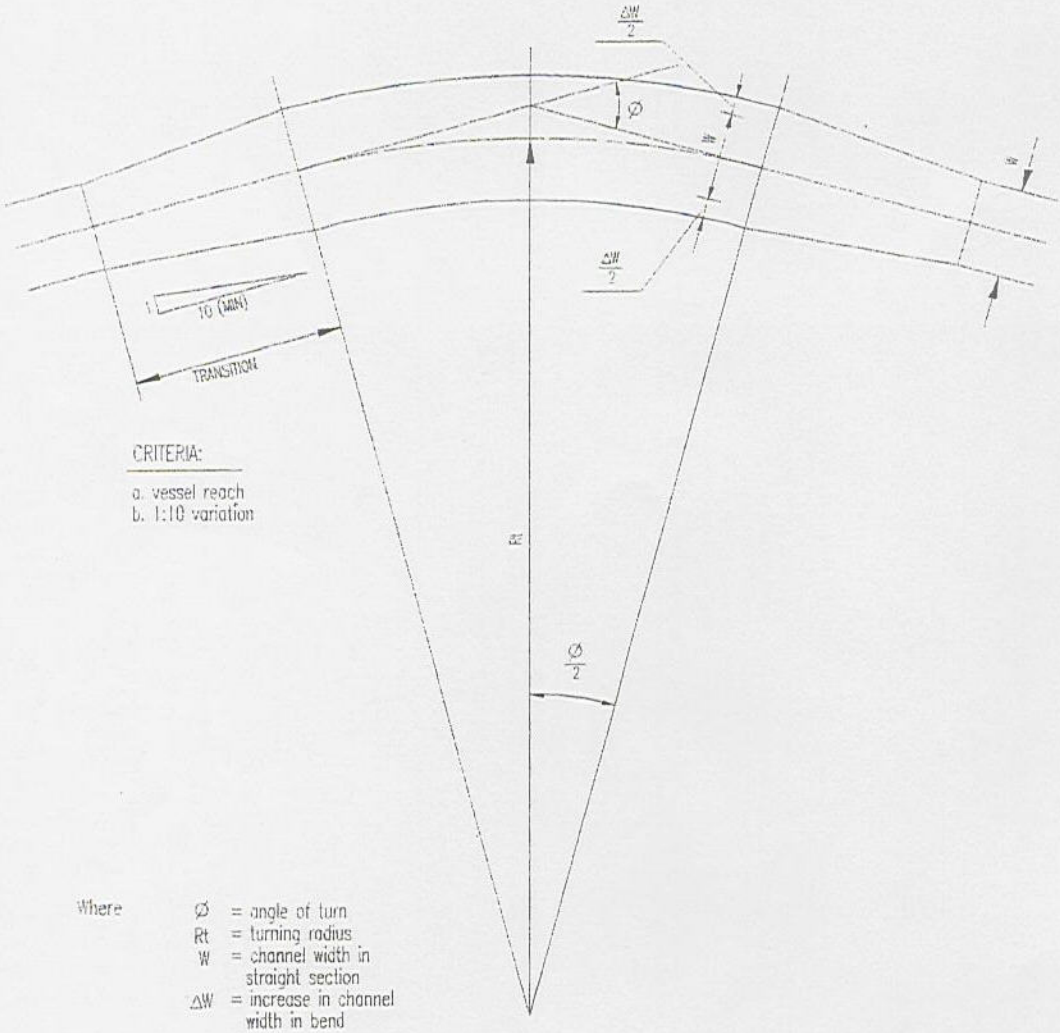
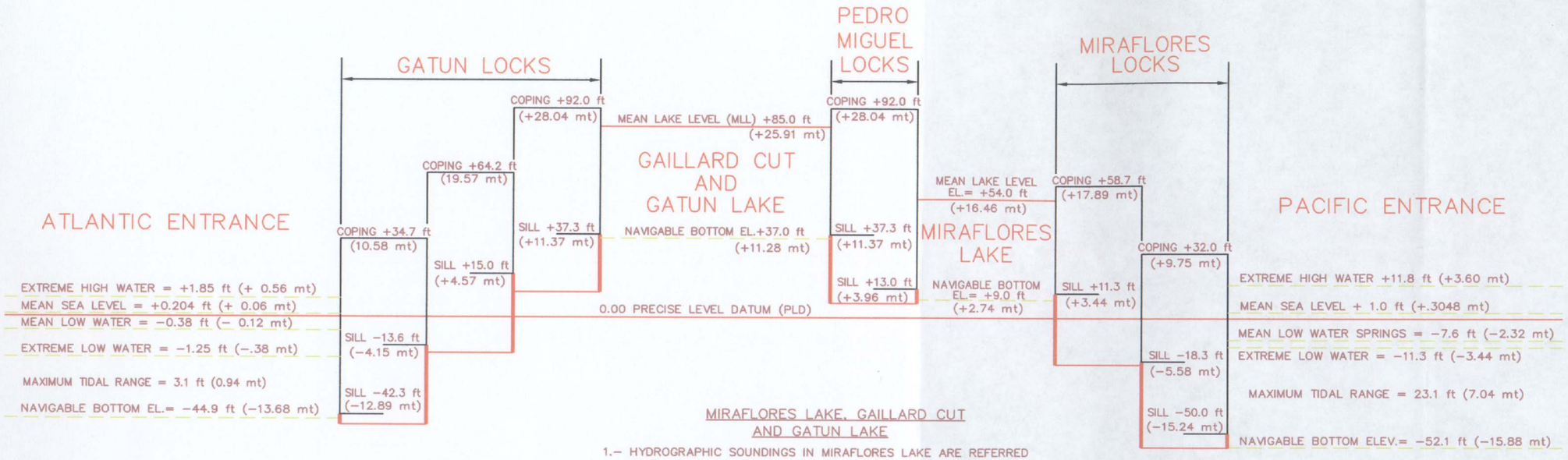



Figure 7: Typical Parallel Widened Curve




## ATLANTIC ENTRANCE

1.– THE DATUM FOR TIDAL ELEVATIONS AND HYDROGRAPHIC CHARTS AT ATLANTIC ENTRANCE IS "MEAN LOW WATER" WHICH IS −0.38 ft (−0.12 mt) PLD

2.– "MEAN LOW WATER" IS THE AVERAGE OF ALL LOW TIDE

## MIRAFLORES LAKE, GAILLARD CUT AND GATUN LAKE

1.– HYDROGRAPHIC SOUNDINGS IN MIRAFLORES LAKE ARE REFERRED TO "MEAN LAKE LEVEL" WHICH IS +54.0 ft (+16.46 mt) PLD

2.– HYDROGRAPHIC SOUNDINGS IN GAILLARD CUT AND GATUN LAKE ARE REFERRED TO "MEAN LAKE LEVEL" WHICH IS +85.0 ft (+25.91 mt) PLD

3.– MAXIMUM NAVIGABLE DEPTH IS CONTROLLED BY DEPTH OF WATER OVER SILL AT SOUTH END OF PEDRO MIGUEL LOCKS

## PACIFIC ENTRANCE

1.– THE DATUM FOR TIDAL ELEVATIONS AND HYDROGRAPHIC CHARTS AT PACIFIC ENTRANCE IS "MEAN LOW WATER SPRINGS" WHICH IS −7.6 ft (−2.32 mt) PLD

2.– "MEAN LOW WATER SPRINGS" IS THE AVERAGE OF LOW WATERS AT TIME OF SPRING TIDE

## NOTE:

1.– TIDAL DATA IS BASED ON HYDROGRAPHIC RECORDS FROM 1902 TO 1972

2.– CLEAR NAVIGABLE DEPTH WILL BE MAINTAINED TO NAVIGABLE BOTTOM ELEVATIONS BY MAINTENANCE DREDGING

3.– ALL ELEVATIONS ARE REFERRED TO PRECISE LEVEL DATUM (PLD)

JOB SAFETY DEPENDS ON YOU

NOTE:
THIS DRAWING SUPERSEDES DWG. No. 6120–30A AND DWG. No.6120–30B

| REV. | DATE: | DESCRIPTION | BY / CHKD | REC'MD | APP'VD |
|---|---|---|---|---|---|
| MC / AC | 7/99 / 7–05 96 | NAVIGABLE BOTTOMS NOTES POSSITIONS | RC / RC | J.R | R.S.F |

PANAMA CANAL COMMISSION

ENGINEERING AND INDUSTRIAL SERVICES
ENGINEERING DIVISION
BALBOA HEIGHTS, REPUBLIC OF PANAMA

# THE PANAMA CANAL CLEARANCE DIAGRAM

SCALE: NOT TO SCALE
DATE: JULY 26, 1999

DRAWN: M. R. CARRIZO
CARTOGRAPHIC SECTION

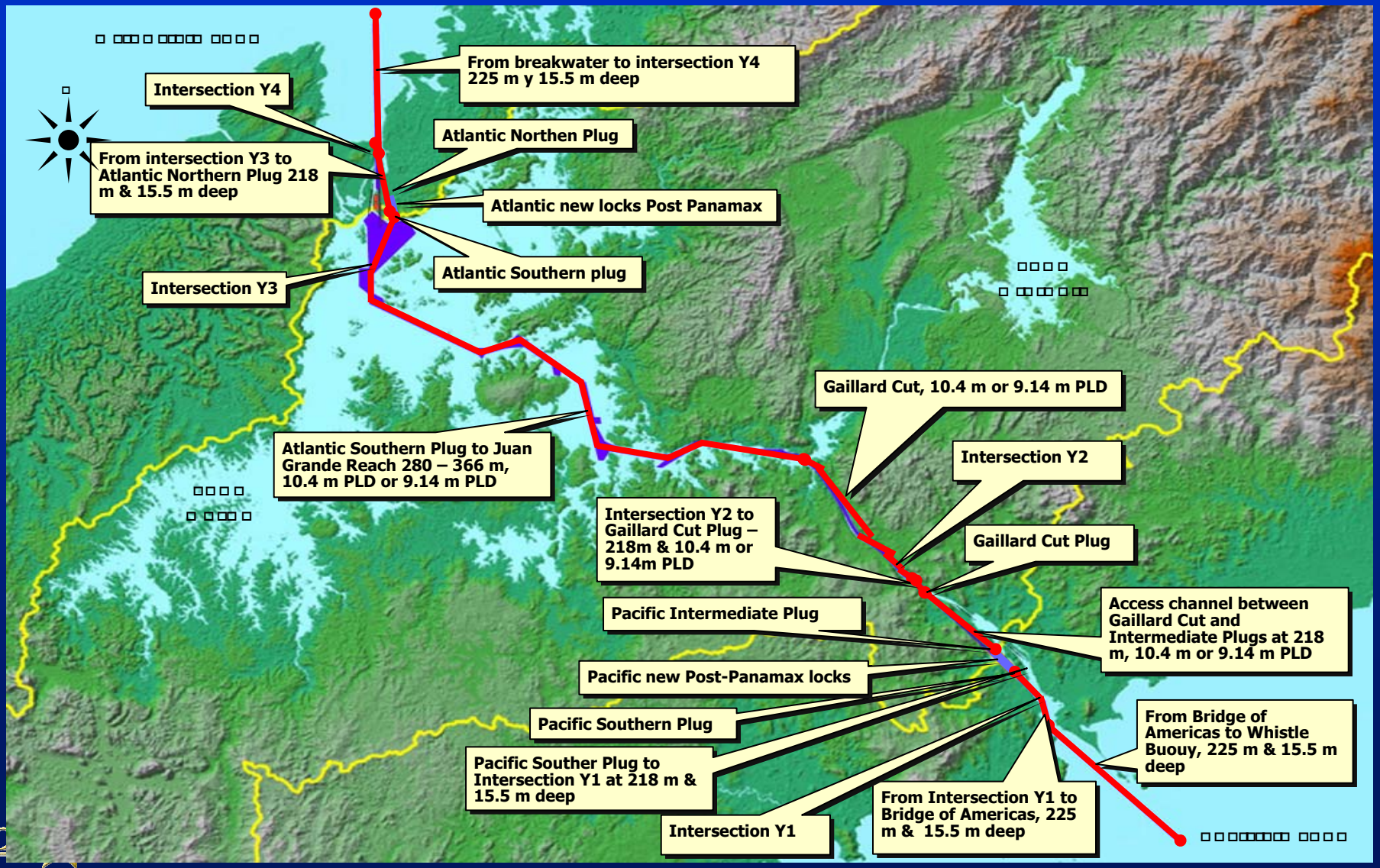
CHECKED: R. CASTILLO
SUPERVISOR, CARTOGRAPHIC SECTION

SUBMITTED:
MANAGER, SURVEYS BRANCH

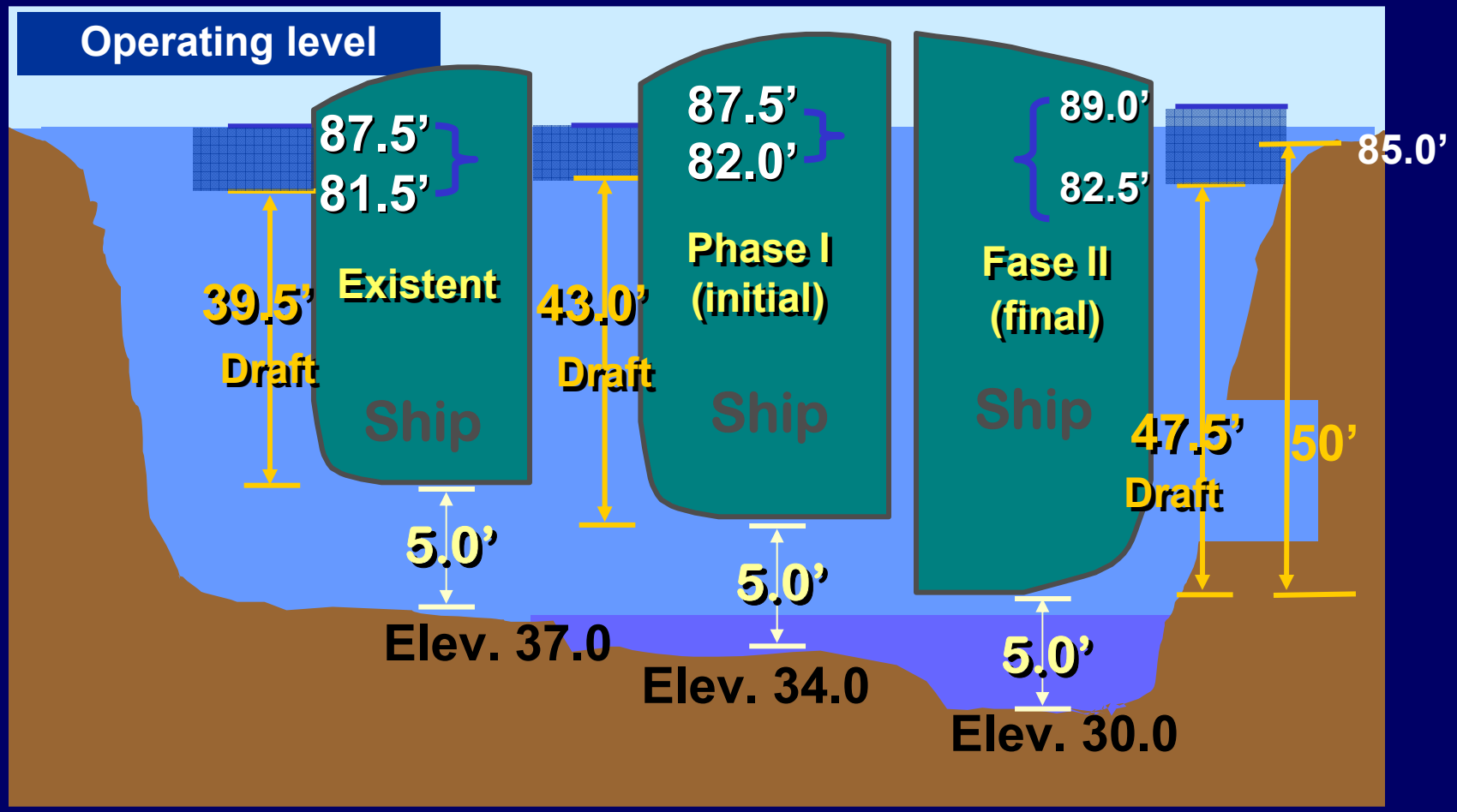
APPROVED:
MANAGER, ENGINEERING DIVISION

M 6120– 30 C

# Areas of expansion and construction of Canal navigation channels

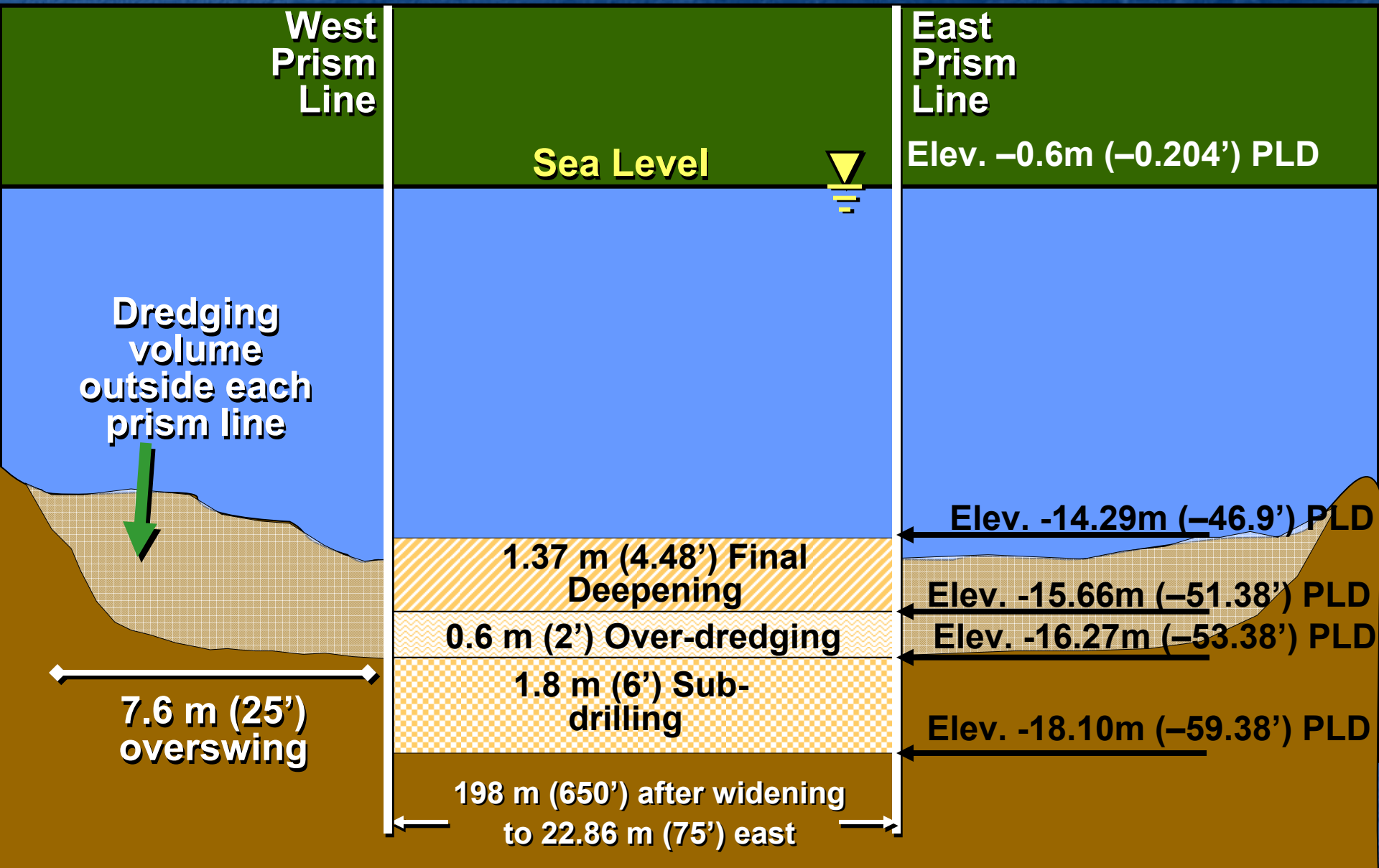


# Navigation channel deepening phases in Gatun Lake



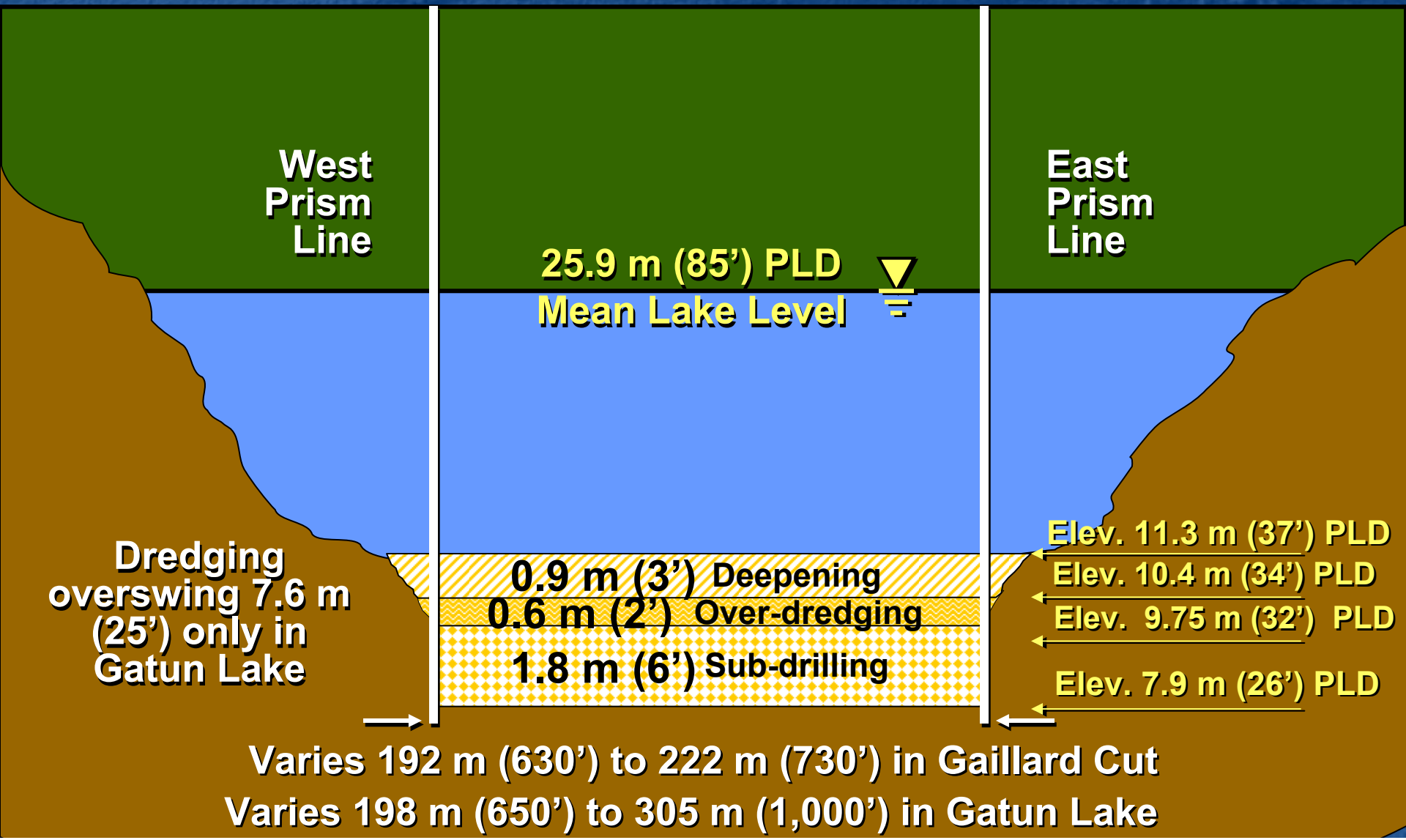
# Atlantic Entrance Deepening for 15.54 m (51') deep

(not to scale)



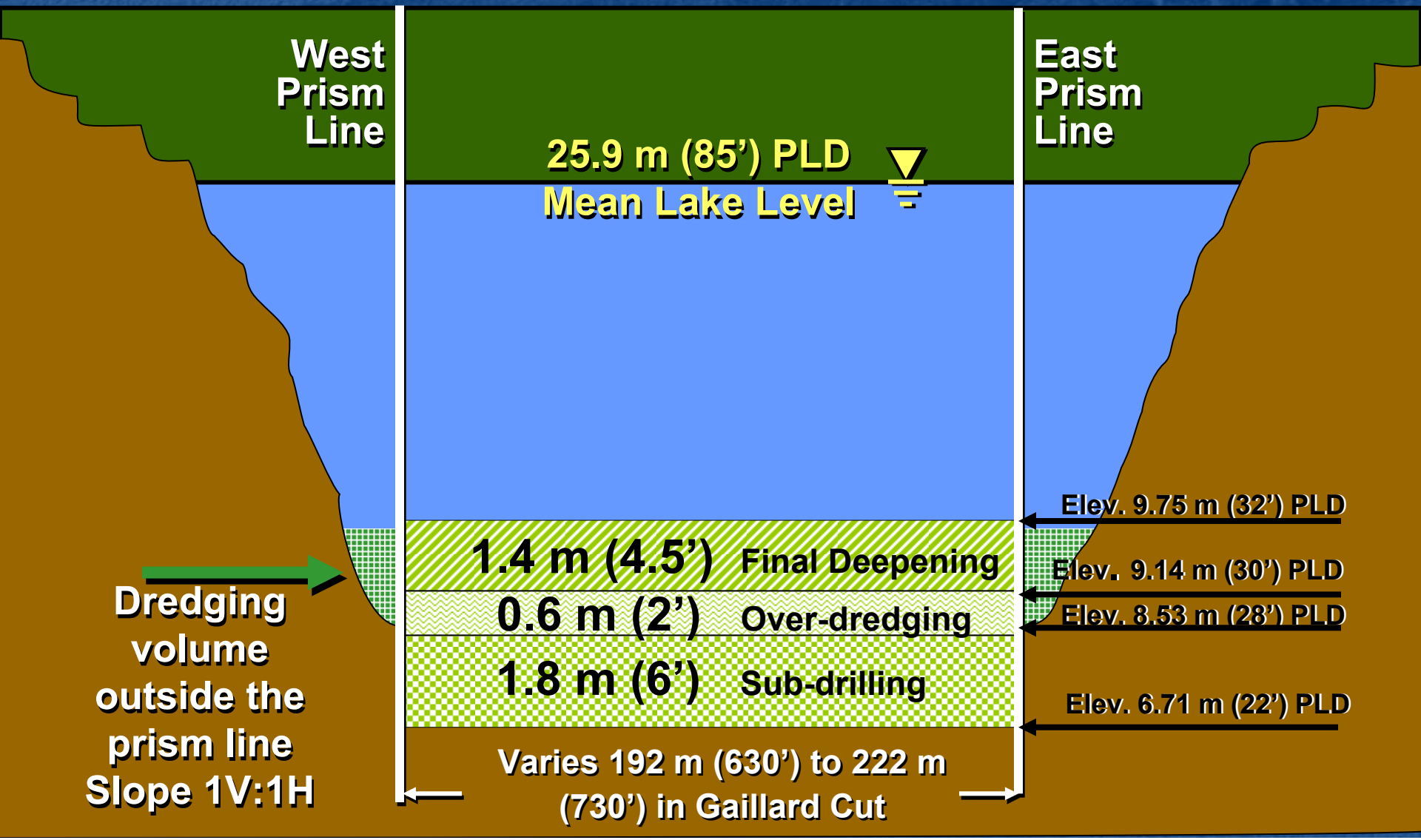
# Gatun Lake and Gaillard Cut Deepening to 10.4 m PLD

(not to scale)



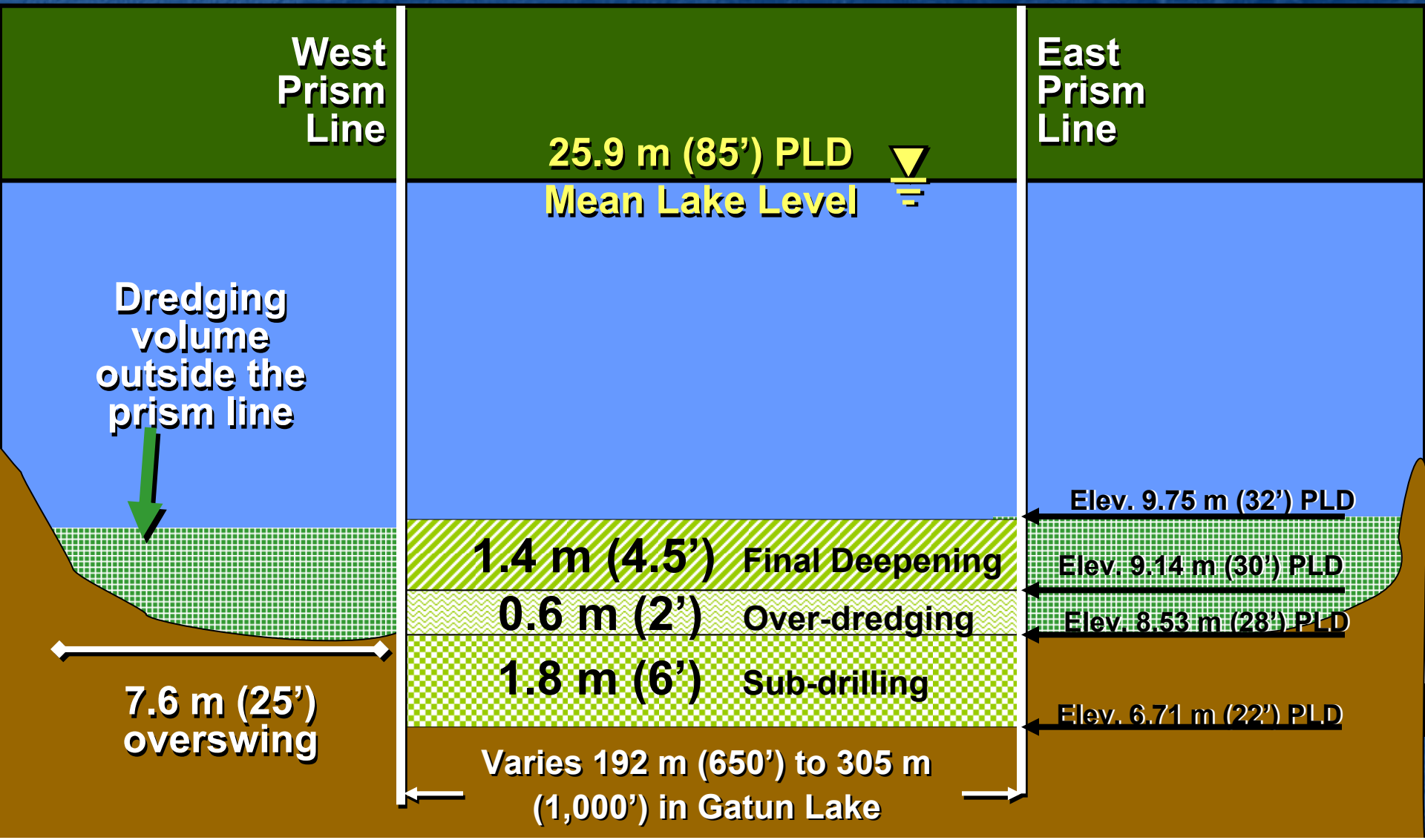
# Gaillard Cut Deepening to 9.14 m (30’) PLD

(not to scale)



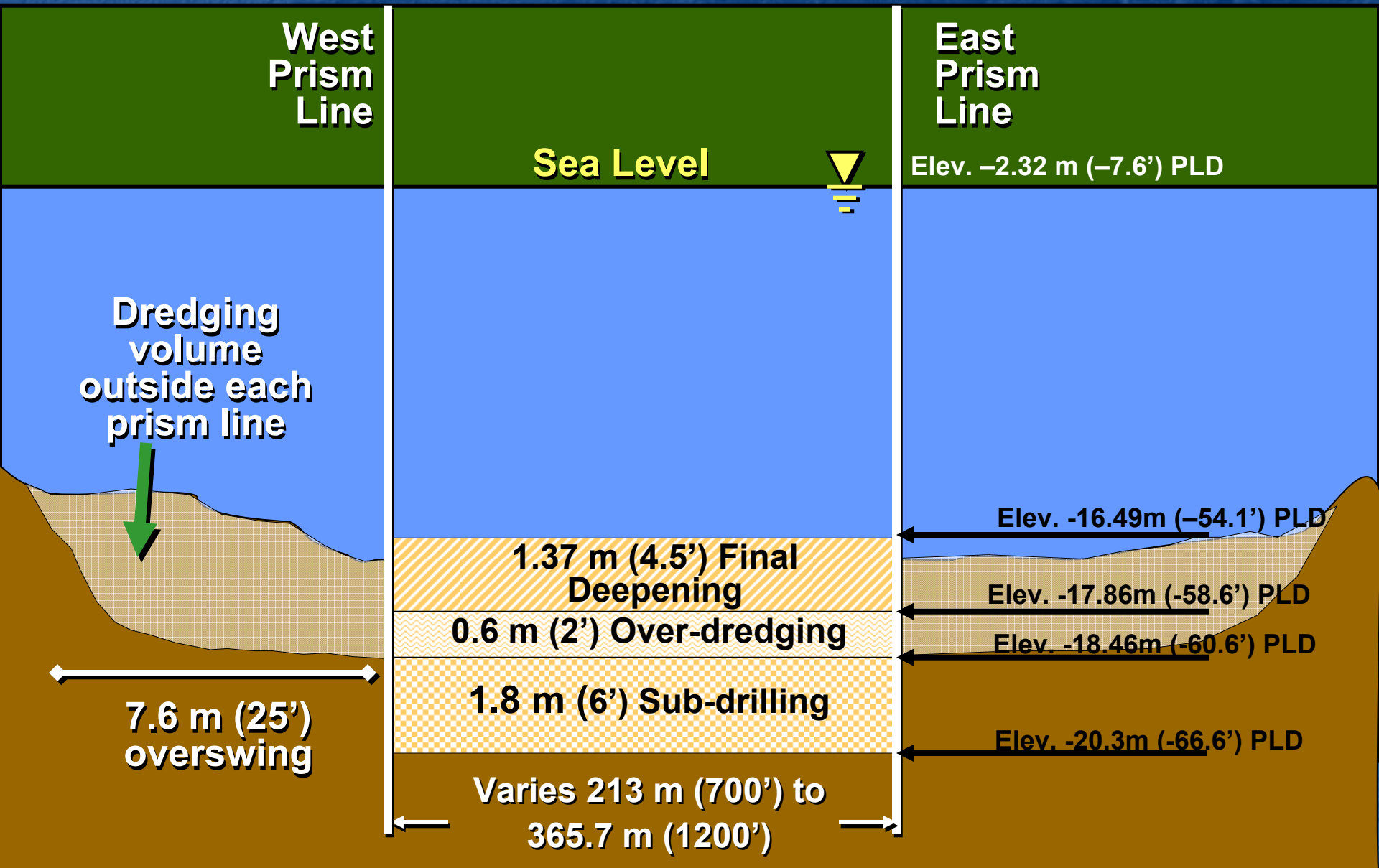
# Gatun Lake Deepening to 9.14 m (30') PLD

(not to scale)

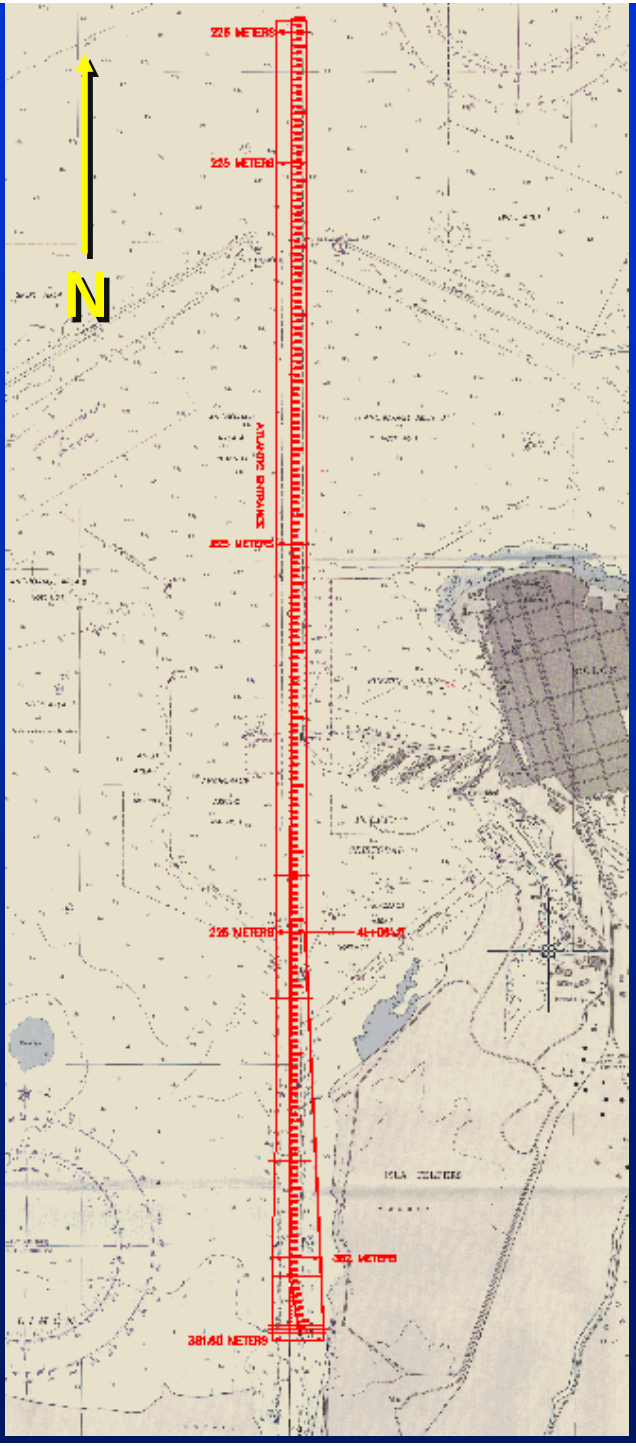


# Pacific Entrance Deepening for 15.5 m (51') deep

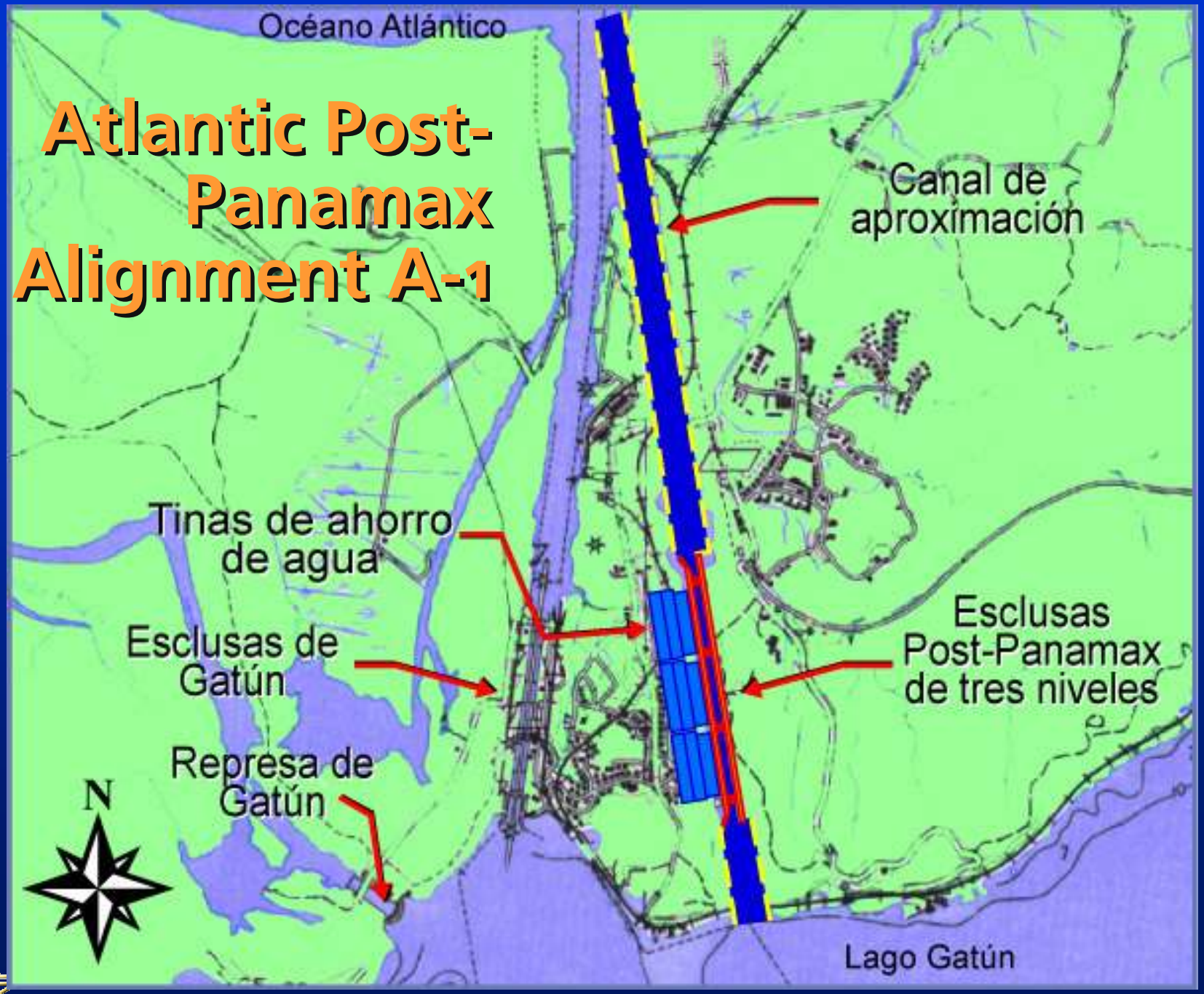
(not to scale)



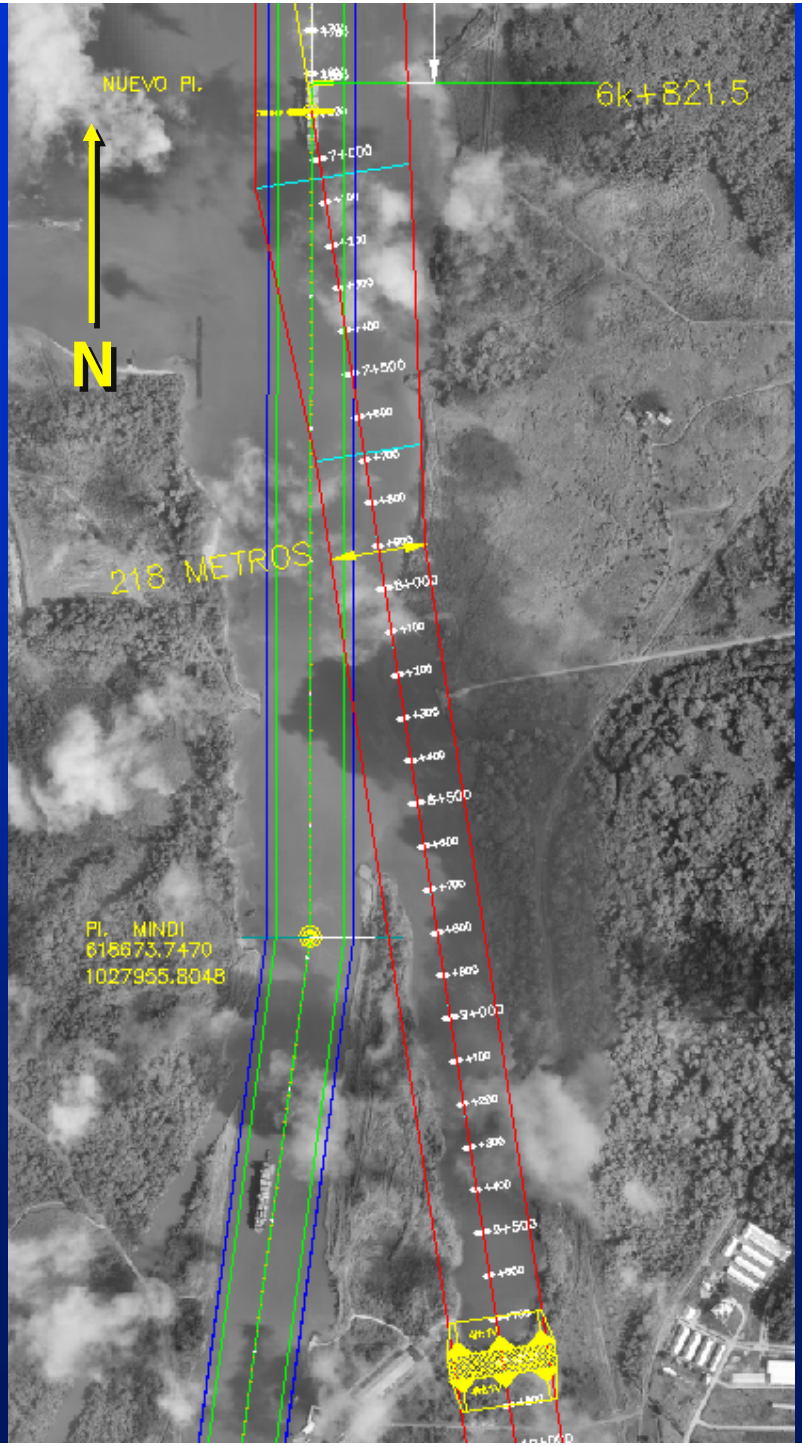
# Atlantic Entrance Navigation Channel



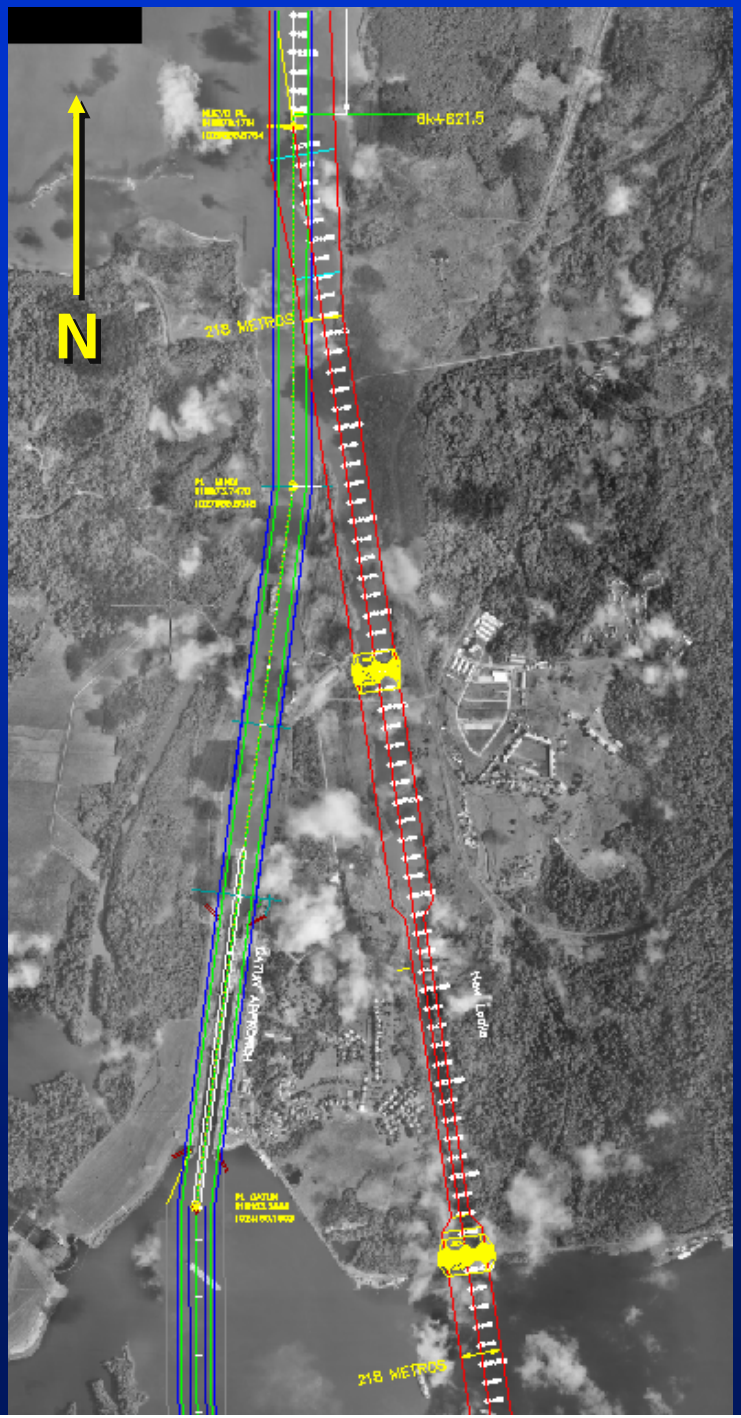
# Atlantic Post-Panamax Alignment A-1



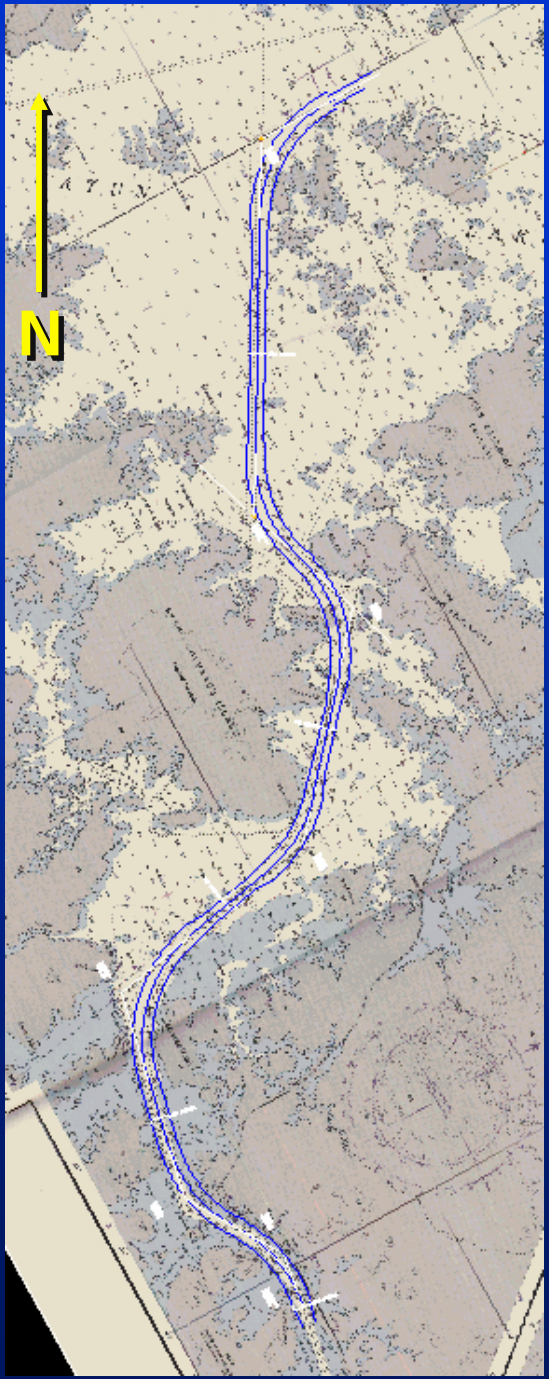
# Atlantic Northern Post-Panamax Approach Channel



# Atlantic Northern and Southern Plug

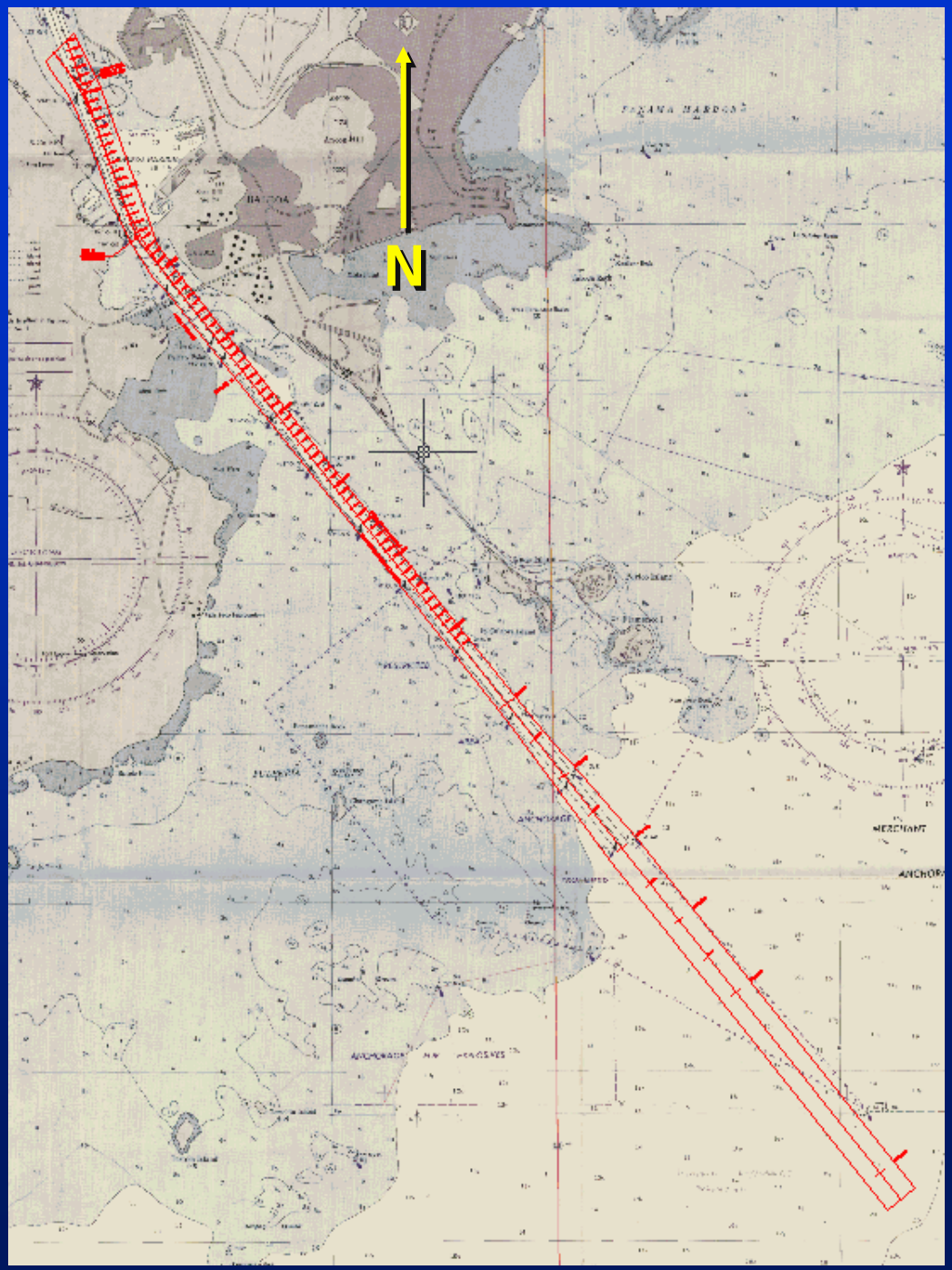


# Gatun Lake Navigation Channel from Gatun Reach to Juan Grande Reach

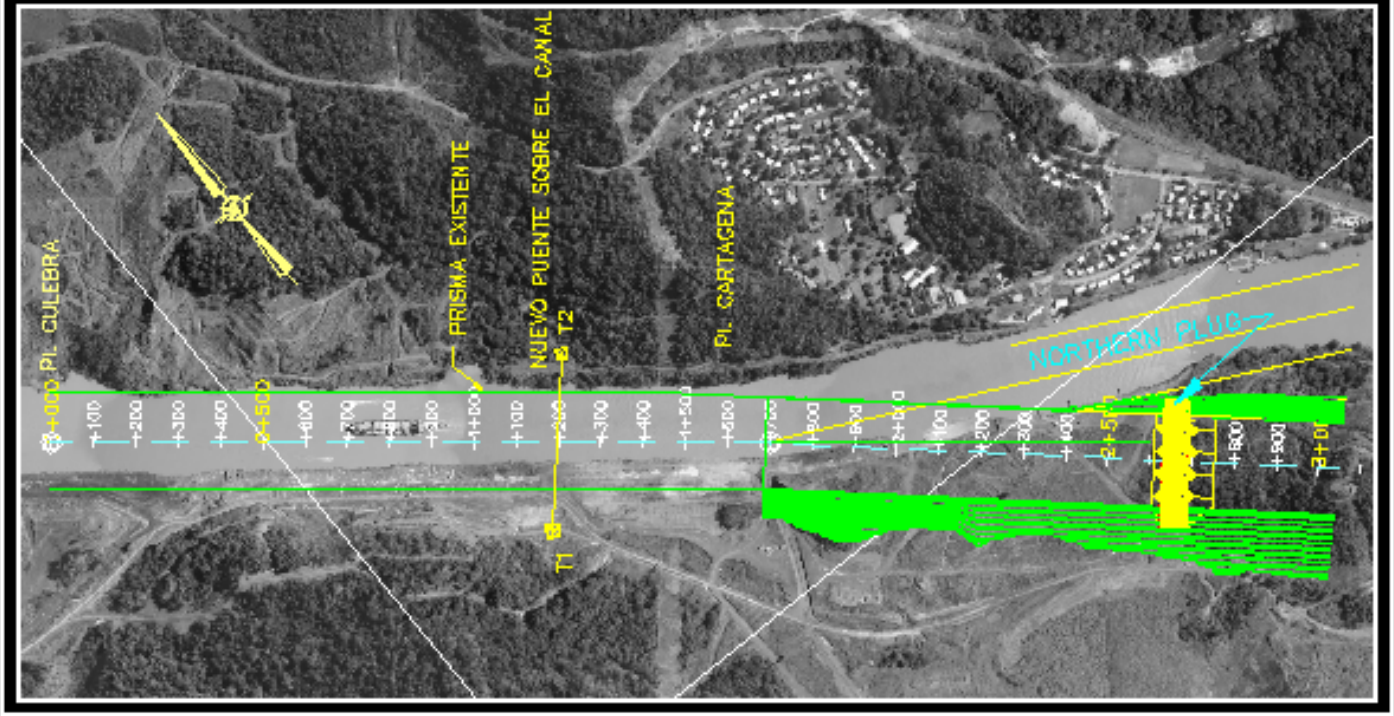


# Gaillard Cut, and Gamboa and Chagres Crossing Reach

# Pacific Entrance Navigation Channel

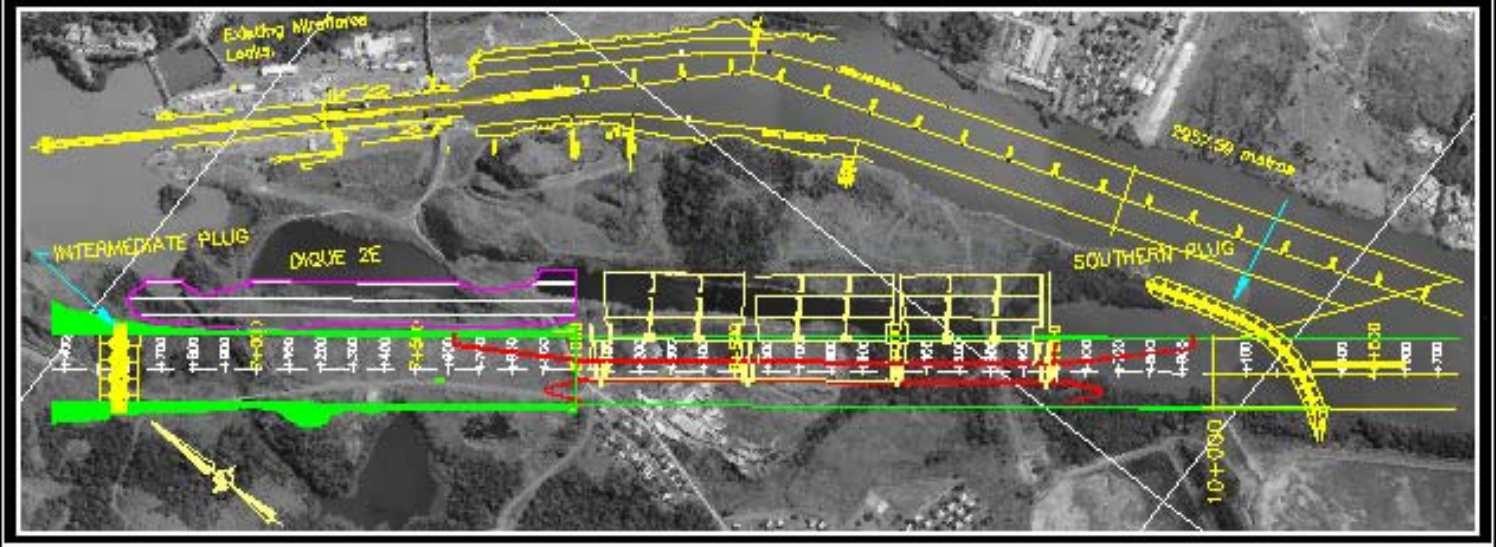


# Pacific Northern Post-Panamax Access North of Gaillard Cut Plug

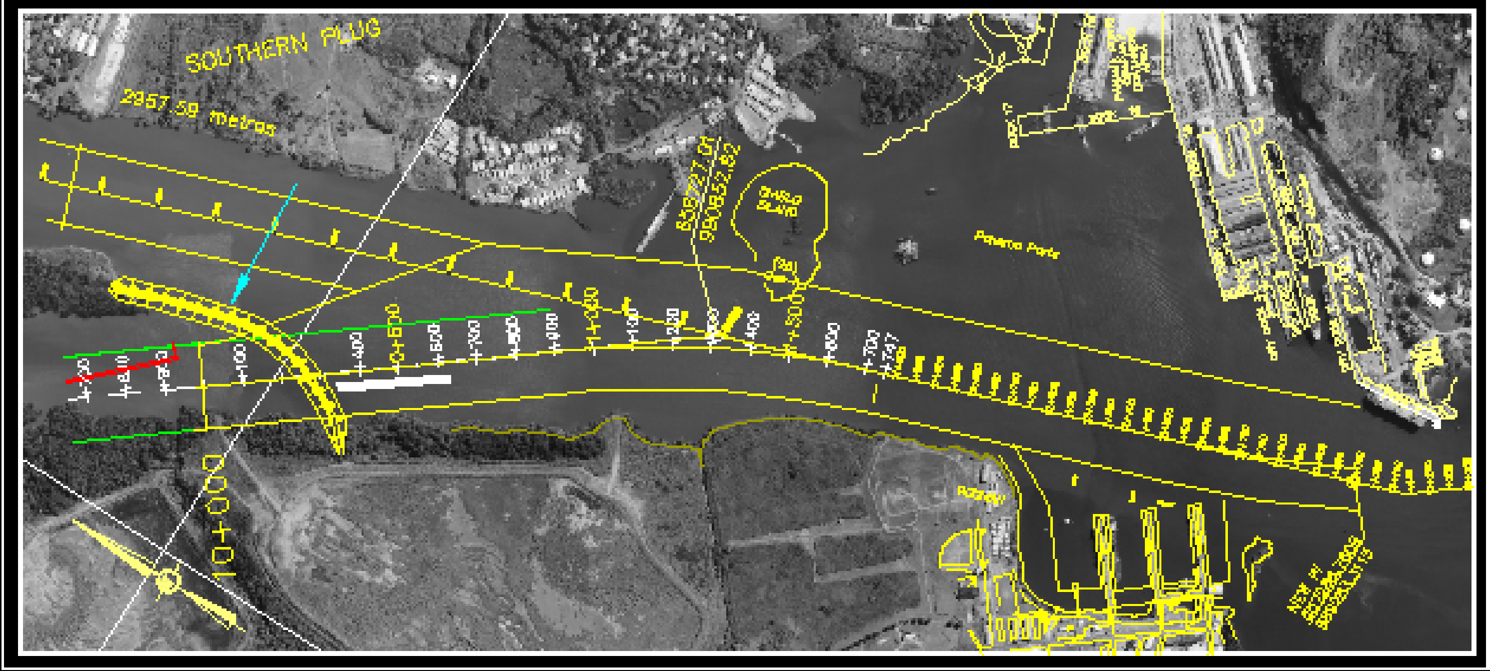


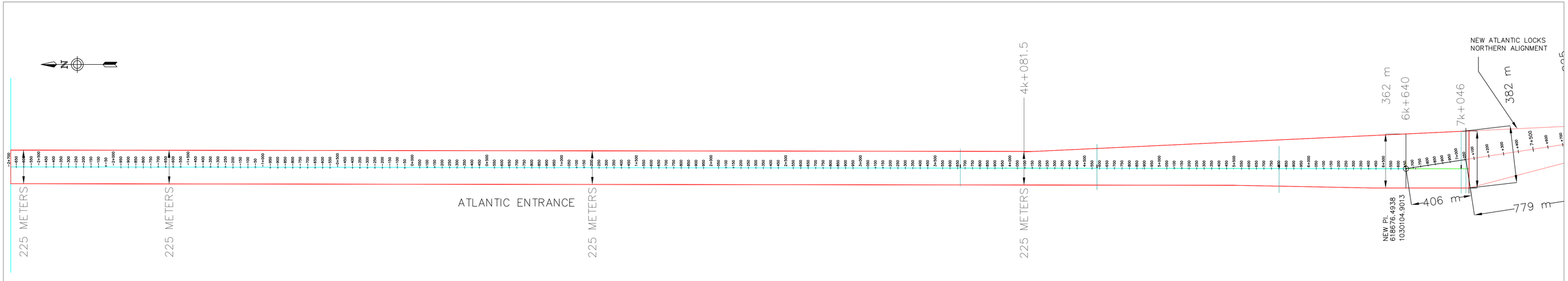
# Pacific Northern Post-Panamax Access Channel between Gaillard Cut and Intermediate Plug

# Pacific Post-Panamax Intermediate and Southern Plugs



# Pacific Southern Post-panamax Approach Cannel






LEGEND

EXISTING PRISM LINE

PROPOSED PRISM LINE

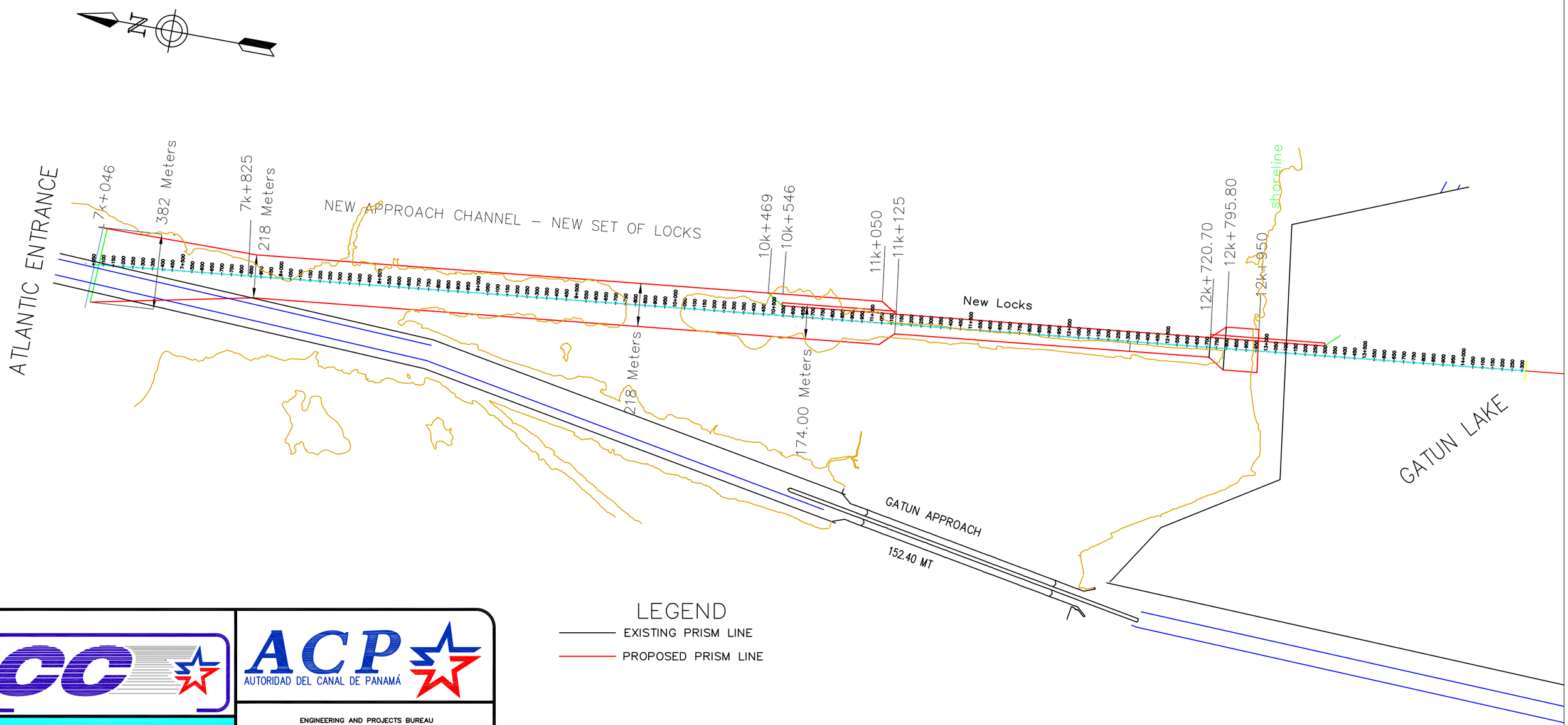
REGIONAL VIEW

ACP
AUTORIDAD DEL CANAL DE PANAMÁ

ENGINEERING AND PROJECTS BUREAU

ATLANTIC ENTRANCE
LAYOUT – 225 m WIDTH

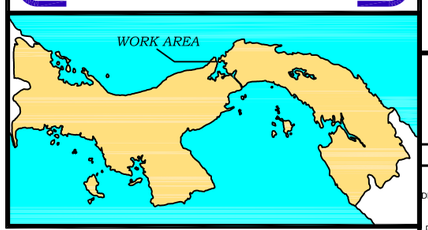
| | | | |
|---|---|---|---|
| SCALE: AS SHOWN | | DATE: APRIL 7, 2004 | |
| DESIGNED | Y. CHIN / R. RIVERA | SOMETIDO: GERENTE | RECIBIDO: GEOTÉCNICA / REVISADO: |
| DRAWING | R. RIVERA | | |
| REVISADO | Y. CHIN / R. RIVERA | APROBADO: GERENTE DE LA DIVISIÓN DE INGENIERÍA | |




LEGEND

EXISTING PRISM LINE

PROPOSED PRISM LINE



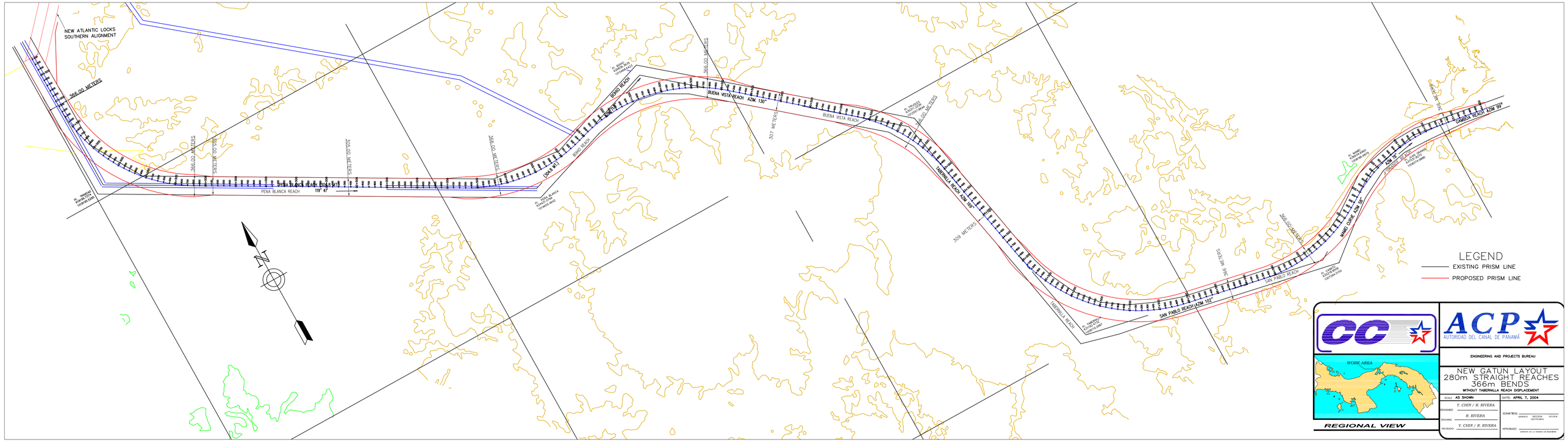

REGIONAL VIEW

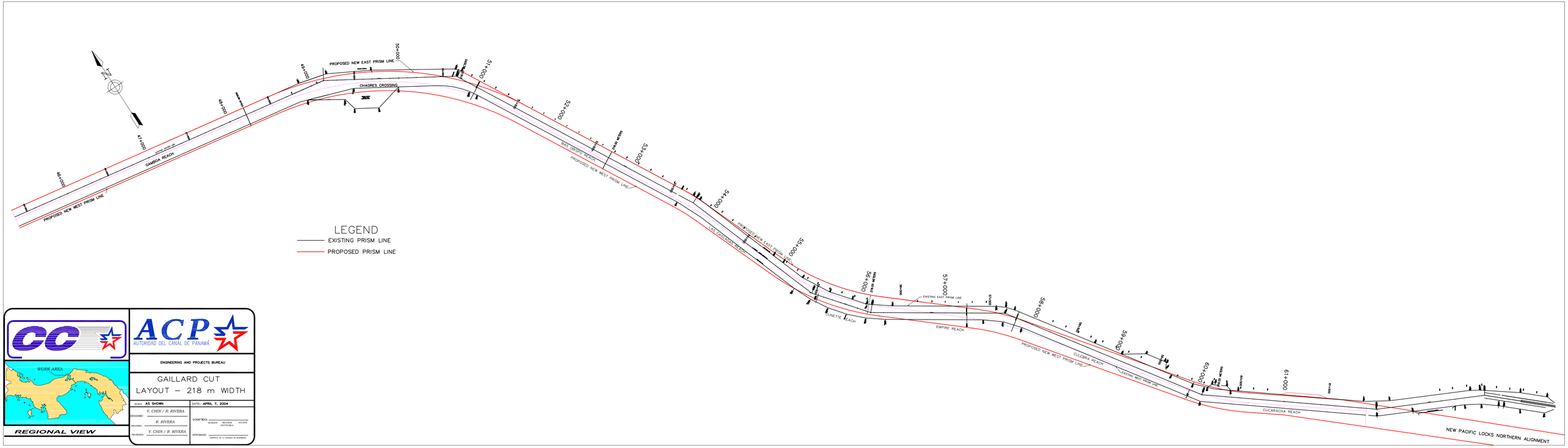
ACP
AUTORIDAD DEL CANAL DE PANAMÁ

ENGINEERING AND PROJECTS BUREAU

ATLANTIC NEW LOCKS
APPROACH CHANNEL
LAYOUT – 218m WIDTH

| | |
|---|---|
| SCALE AS SHOWN | DATE: APRIL 7, 2004 |
| DESIGNED Y. CHIN / R. RIVERA | SOMETIDO: GERENTE / SECCION GEOTECNICA / SECCION |
| DRAWING R. RIVERA | |
| REVISADO: Y. CHIN / R. RIVERA | APROBADO GERENTE DE LA DIVISION DE INGENIERIA |


NEW ATLANTIC LOCKS SOUTHERN ALIGNMENT
366.00 METERS
PENA BLANCA REACH
119° 47'
(904.9 M)
BONO REACH
BUENA VISTA REACH AZM. 130°
BUENA VISTA REACH
307 METERS
309 METERS
TABERNILLA REACH AZM. 189°
TABERNILLA REACH
SAN PABLO REACH AZM. 102°
SAN PABLO REACH
MAMO CURVE AZM. 58°
CAMBOA REACH AZM. 99°
N
LEGEND
EXISTING PRISM LINE
PROPOSED PRISM LINE
WORK AREA
REGIONAL VIEW
ACP
AUTORIDAD DEL CANAL DE PANAMÁ
ENGINEERING AND PROJECTS BUREAU
NEW GATUN LAYOUT
280m STRAIGHT REACHES
366m BENDS
WITHOUT TABERNILLA REACH DISPLACEMENT
SCALE: AS SHOWN
DATE: APRIL 7, 2004
DESIGNED: Y. CHIN / R. RIVERA
DRAWING: R. RIVERA
REVIEWED: Y. CHIN / R. RIVERA
SOMETIDO
APROBADO
GERENTE DE LA DIVISION DE INGENIERIA







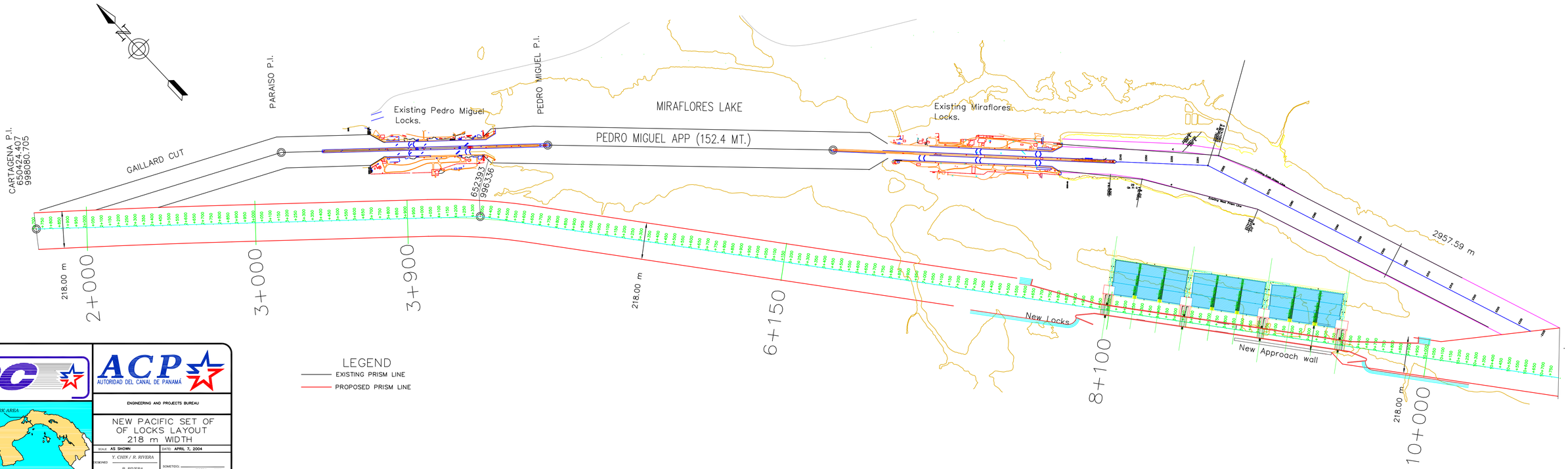
REGIONAL VIEW

ACP
AUTORIDAD DEL CANAL DE PANAMÁ

ENGINEERING AND PROJECTS BUREAU

GAILLARD CUT
LAYOUT – 218 m WIDTH

| | |
|---|---|
| SCALE: AS SHOWN | DATE: APRIL 7, 2004 |
| DESIGNED: Y. CHIN / R. RIVERA | SOMETIDO: GERENTE / SECCIÓN GEOTÉCNICA / SECCIÓN |
| DRAWING: R. RIVERA | |
| REVISADO: Y. CHIN / R. RIVERA | APROBADO: GERENTE DE LA DIVISIÓN DE INGENIERÍA |




LEGEND

EXISTING PRISM LINE

PROPOSED PRISM LINE

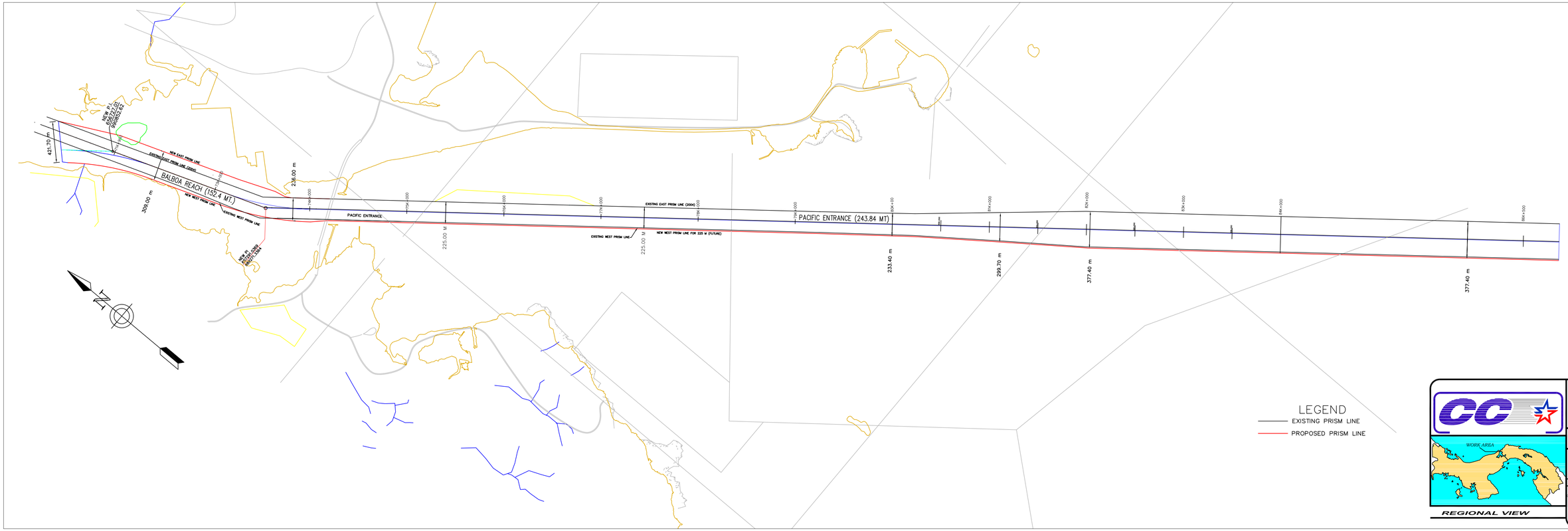
REGIONAL VIEW

ACP
AUTORIDAD DEL CANAL DE PANAMÁ

ENGINEERING AND PROJECTS BUREAU

NEW PACIFIC SET OF
OF LOCKS LAYOUT
218 m WIDTH

| | | | |
|---|---|---|---|
| SCALE: AS SHOWN | | DATE: APRIL 7, 2004 | |
| DESIGNED | Y. CHIN / R. RIVERA | SOMETIDO: GERENTE / SECCIÓN ARQUITECTÓNICA / SECCIÓN | |
| DRAWING | R. RIVERA | | |
| REVISADO | Y. CHIN / R. RIVERA | APROBADO: GERENTE DE LA DIVISIÓN DE INGENIERÍA | |




LEGEND

EXISTING PRISM LINE

PROPOSED PRISM LINE

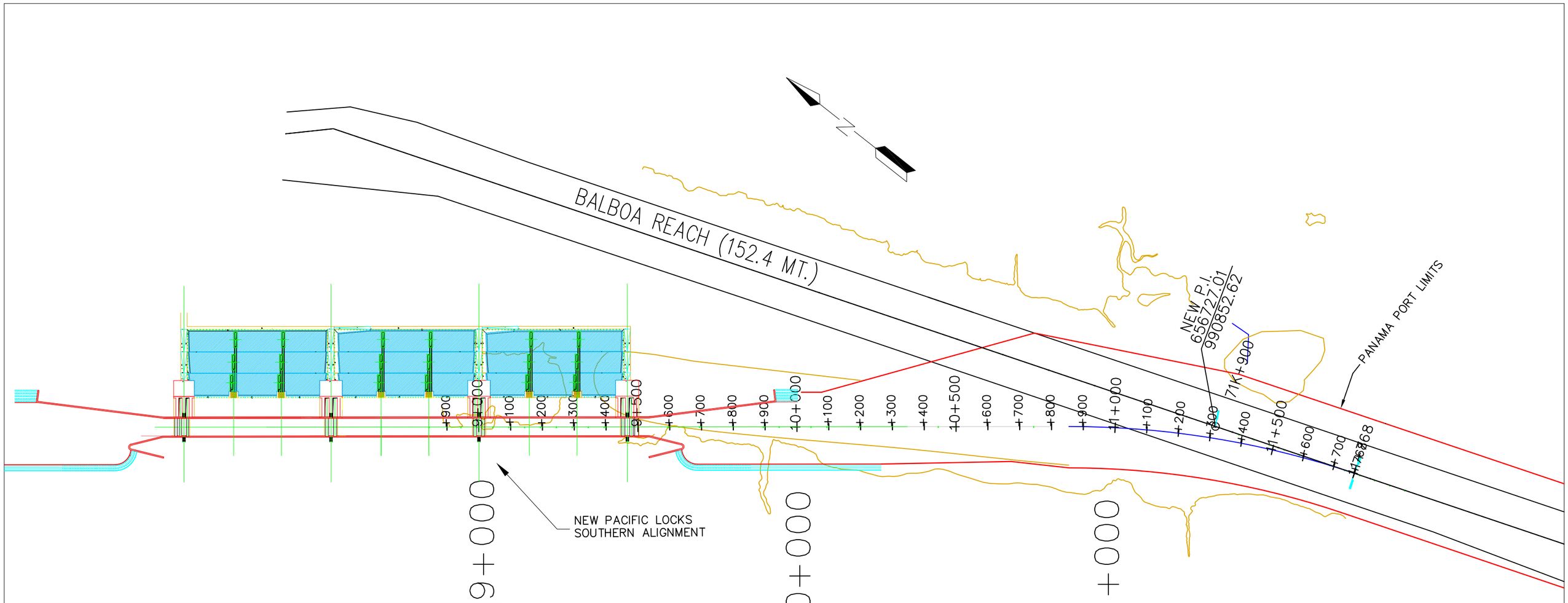


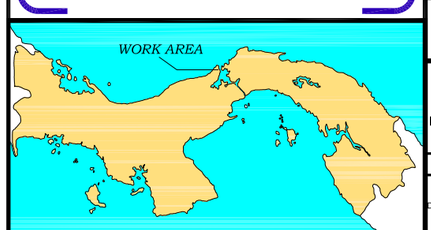

ACP
AUTORIDAD DEL CANAL DE PANAMÁ

ENGINEERING AND PROJECTS BUREAU

PACIFIC ENTRANCE
LAYOUT – 225 m WIDTH

| | | | |
|---|---|---|---|
| SCALE: AS SHOWN | | DATE: APRIL 7, 2004 | |
| DESIGNED: Y. CHIN / R. RIVERA | | SOMETIDO: GERENTE / SECCIÓN GEOTÉCNICA | SECCIÓN |
| DRAWING: R. RIVERA | | | |
| REVISADO: Y. CHIN / R. RIVERA | | APROBADO: GERENTE DE LA DIVISIÓN DE INGENIERÍA | |




REGIONAL VIEW

ACP
AUTORIDAD DEL CANAL DE PANAMÁ

ENGINEERING AND PROJECTS BUREAU

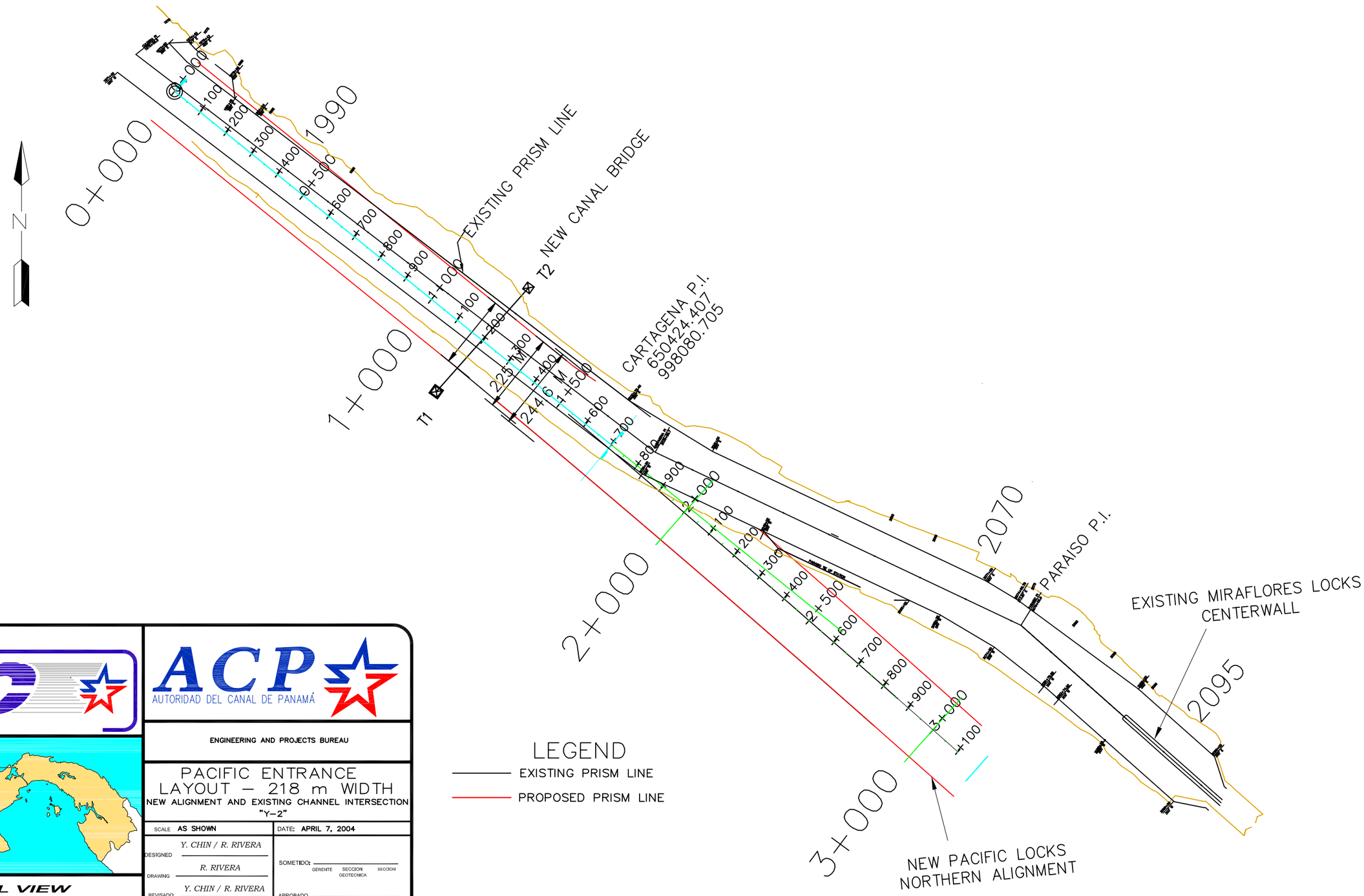
PACIFIC ENTRANCE
LAYOUT – 218 m WIDTH
NEW ALIGNMENT AND EXISTING CHANNEL INTERSECTION
"Y–1"

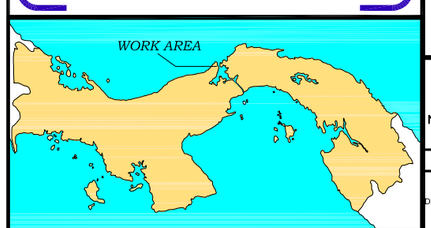
| | |
|---|---|
| SCALE AS SHOWN | DATE: APRIL 7, 2004 |
| DESIGNED Y. CHIN / R. RIVERA | SOMETIDO: GERENTE / SECCION GEOTECNICA / SECCION |
| DRAWING R. RIVERA | |
| REVISADO: Y. CHIN / R. RIVERA | APROBADO GERENTE DE LA DIVISION DE INGENIERIA |

LEGEND

EXISTING PRISM LINE

PROPOSED PRISM LINE



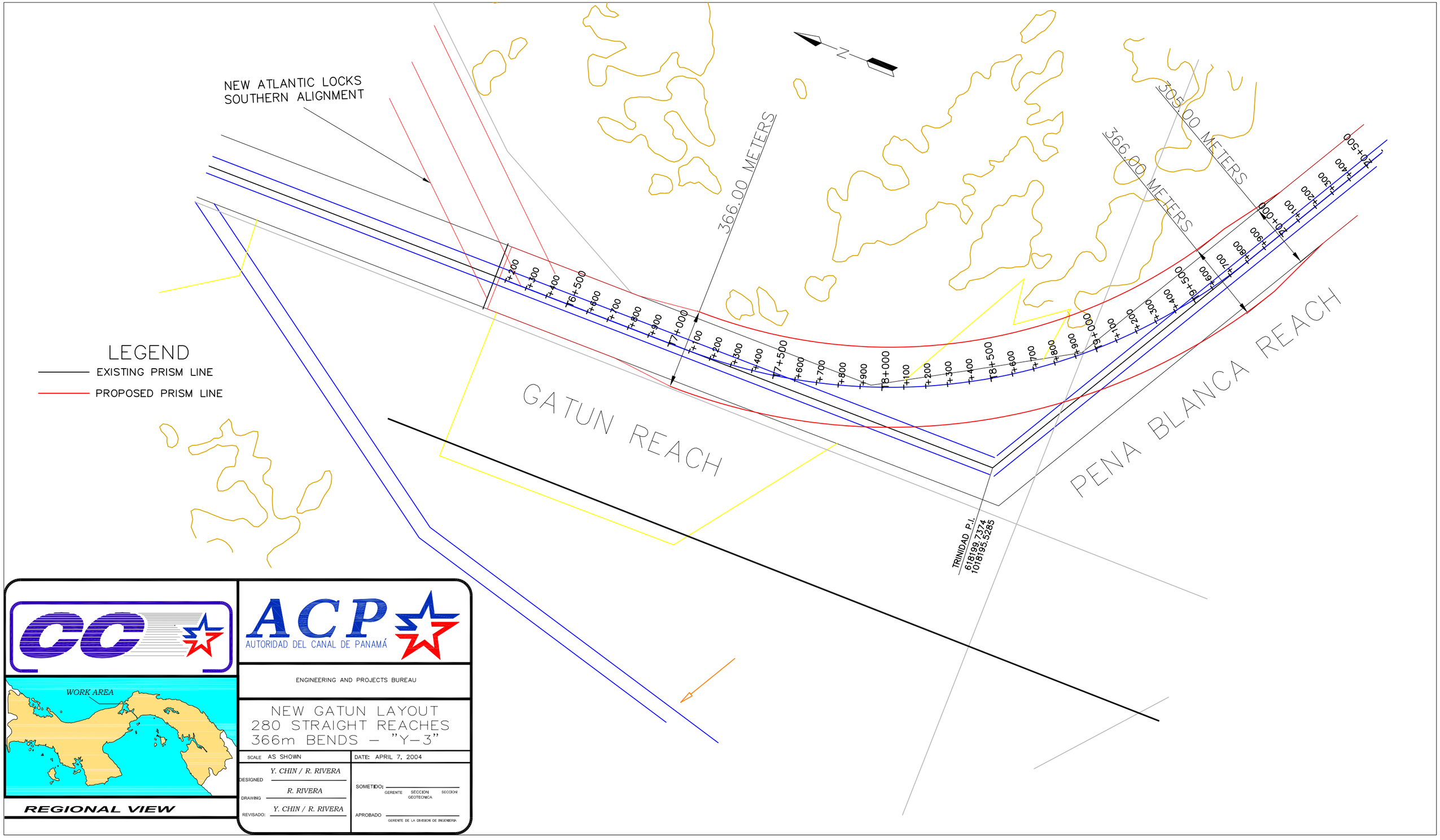

REGIONAL VIEW

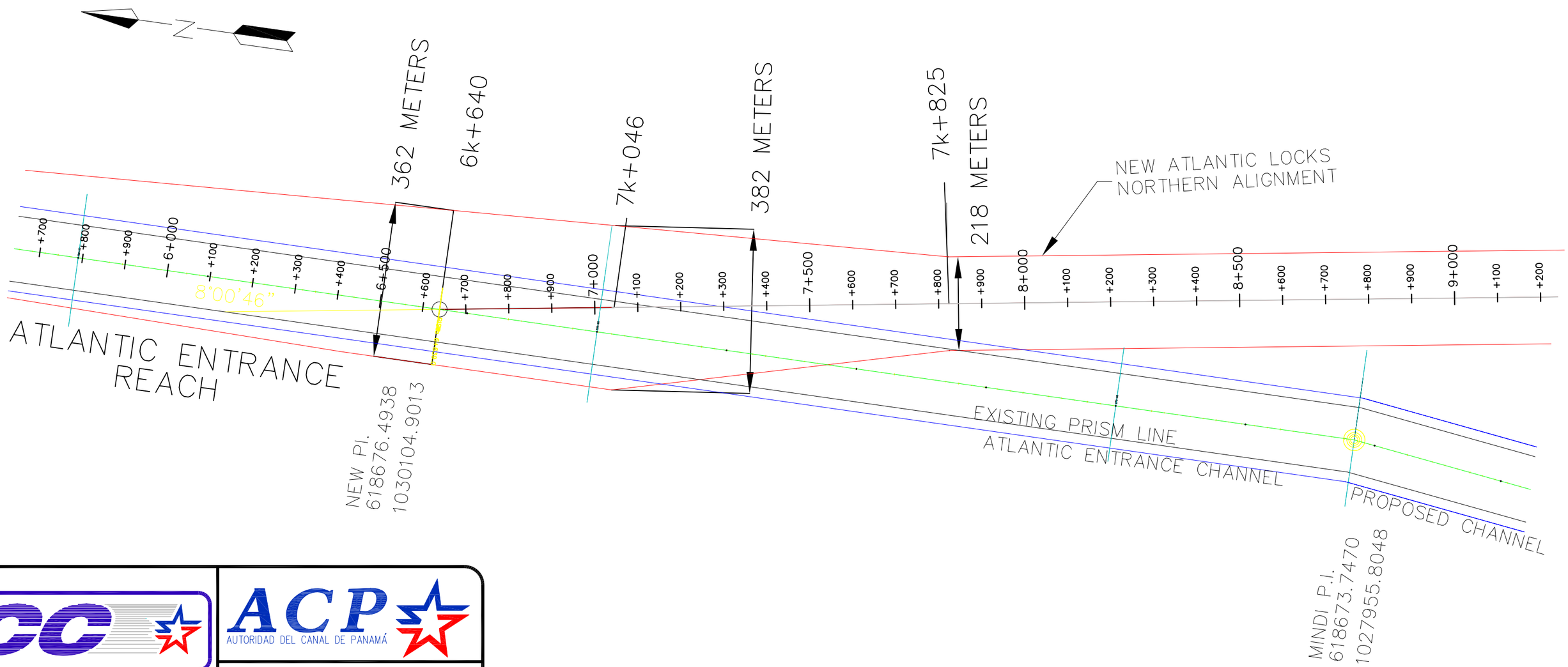
ACP
AUTORIDAD DEL CANAL DE PANAMÁ

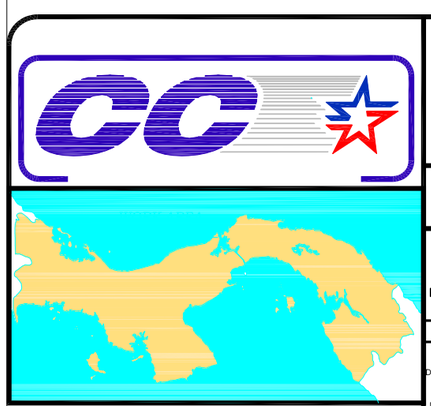
ENGINEERING AND PROJECTS BUREAU

PACIFIC ENTRANCE
LAYOUT – 218 m WIDTH
NEW ALIGNMENT AND EXISTING CHANNEL INTERSECTION
"Y–2"

| | |
|---|---|
| SCALE AS SHOWN | DATE: APRIL 7, 2004 |
| DESIGNED Y. CHIN / R. RIVERA | SOMETIDO: GERENTE SECCION GEOTECNICA SECCION |
| DRAWING R. RIVERA | |
| REVISADO: Y. CHIN / R. RIVERA | APROBADO GERENTE DE LA DIVISION DE INGENIERIA |


NEW ATLANTIC LOCKS
SOUTHERN ALIGNMENT
N
366.00 METERS
305.00 METERS
366.00 METERS
T6+500
T7+000
T7+500
T8+000
T8+500
T9+000
T9+500
T10+000
T10+500
GATUN REACH
PENA BLANCA REACH
TRINIDAD P.I.
618199.7374
1018195.5285
LEGEND
EXISTING PRISM LINE
PROPOSED PRISM LINE
WORK AREA
REGIONAL VIEW
ACP
AUTORIDAD DEL CANAL DE PANAMÁ
ENGINEERING AND PROJECTS BUREAU
NEW GATUN LAYOUT
280 STRAIGHT REACHES
366m BENDS – "Y-3"
SCALE AS SHOWN
DATE: APRIL 7, 2004
DESIGNED Y. CHIN / R. RIVERA
DRAWING R. RIVERA
REVISADO: Y. CHIN / R. RIVERA
SOMETIDO:
GERENTE SECCION GEOTECNICA
SECCION
APROBADO
GERENTE DE LA DIVISION DE INGENIERIA




ACP
AUTORIDAD DEL CANAL DE PANAMÁ

ENGINEERING AND PROJECTS BUREAU

ATLANTIC ENTRANCE
LAYOUT – 218 m WIDTH
NEW ALIGNMENT AND EXISTING CHANNEL INTERSECTION
"Y–4"

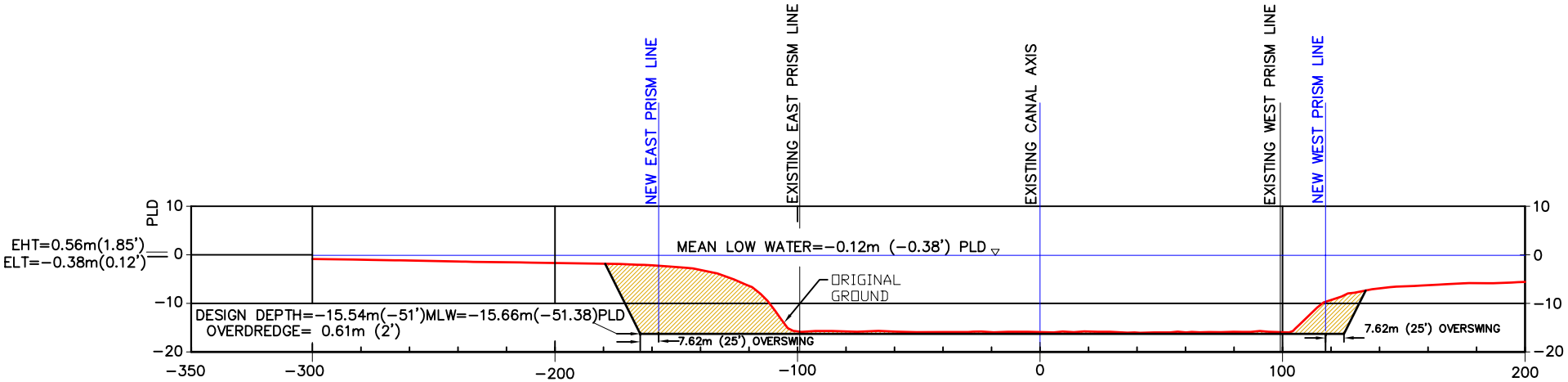
| | |
|---|---|
| SCALE AS SHOWN | DATE: APRIL 7, 2004 |
| DESIGNED Y. CHIN / R. RIVERA | SOMETIDO: GERENTE SECCION GEOTECNICA SECCION |
| DRAWING R. RIVERA | |
| REVISADO: Y. CHIN / R. RIVERA | APROBADO GERENTE DE LA DIVISION DE INGENIERIA |

LEGEND

EXISTING PRISM LINE

PROPOSED PRISM LINE

# TYPICAL X–SECTION
## ATLANTIC ENTRANCE – WIDTH 225M – DRAFT 13.7m (45')
## PANAMA CANAL AUTHORITY




# STATION No. 5+080

SCALE 2V/1H
UNITS ARE IN METERS

NOTES

PRECISE LEVEL DATUM (PLD) IS THE LEVEL SURFACE TO WHICH ALL HEIGHTS OR ELEVATIONS ARE REFERRED

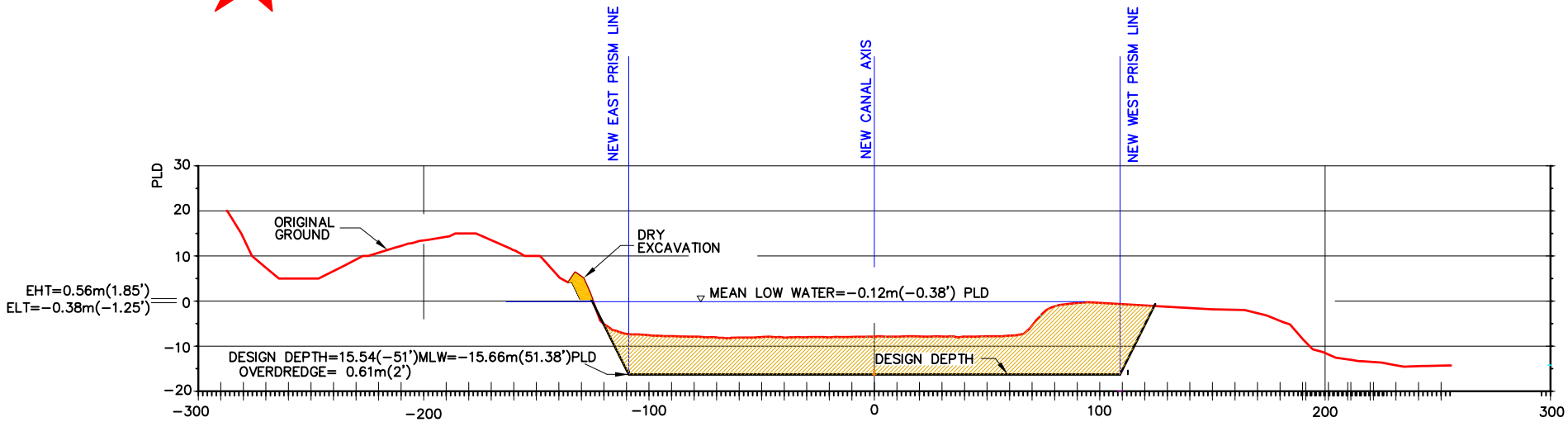
ATLANTIC MEAN LOW WATER (MLW)= –0.12m (–0.38') PLD

EHT= EXTREME HIGH TIDE

ELT= EXTREME LOW TIDE

ACP
AUTORIDAD DEL CANAL DE PANAMÁ

# TYPICAL X-SECTION – WIDTH 218m – DRAFT 13.7m (45')
## ATLANTIC ENTRANCE – NEW APPROACH CHANNEL FOR THE NEW SET OF LOCKS
## PANAMA CANAL AUTHORITY




# STATION No. 8+660

NOTES

PRECISE LEVEL DATUM (PLD) IS THE LEVEL SURFACE TO WHICH ALL HEIGHTS OR ELEVATIONS ARE REFERRED

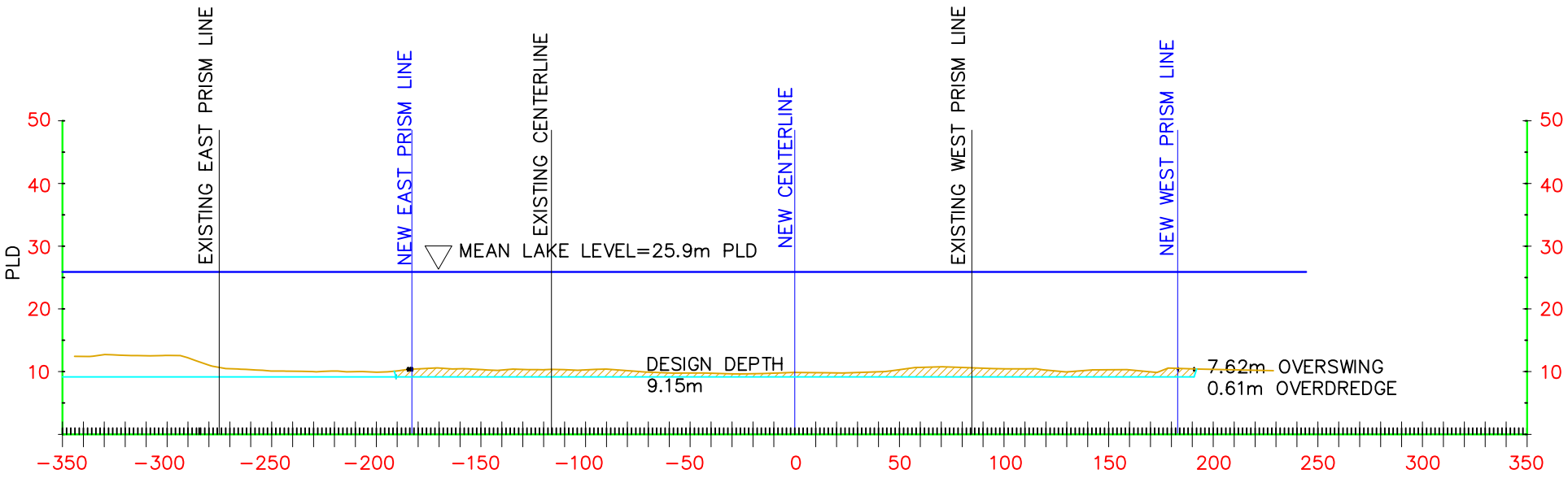
ATLANTIC MEAN LOW WATER (MLW)= −0.12m (−0.38') PLD

EHT= EXTREME HIGH TIDE

ELT= EXTREME LOW TIDE

SCALE 2V/1H
UNITS ARE IN METERS

# TYPICAL X–SECTION
# GATUN LAKE – 280m STRAIGHT & 366m BENDS
# CHANNEL BOTTOM 9.15m PLD (30' PLD)

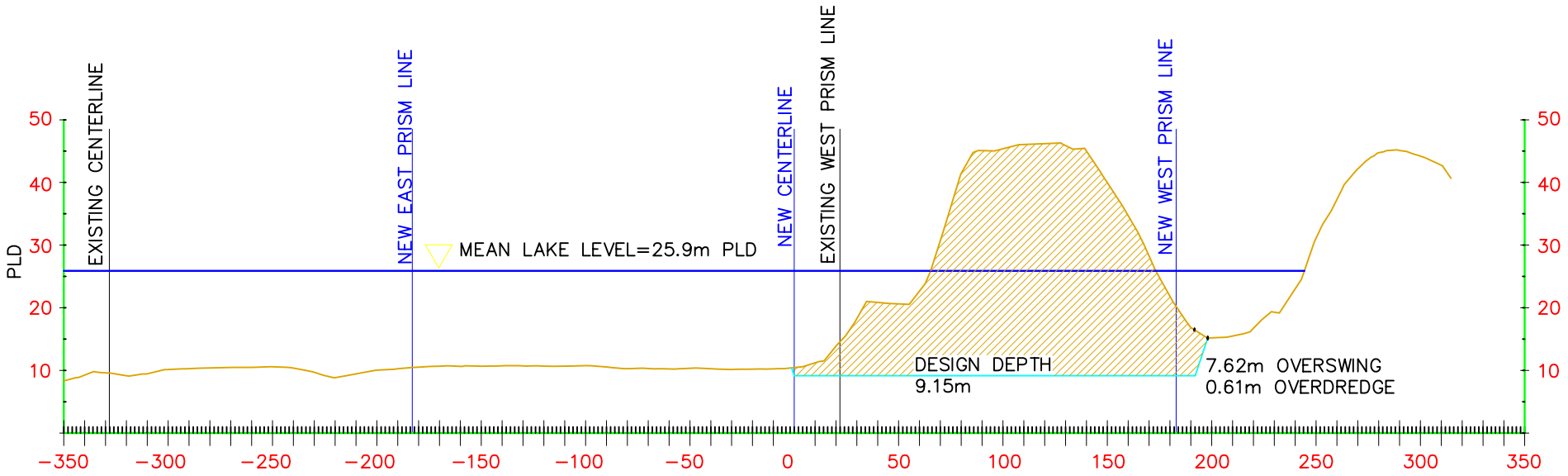



# STATION No. 22K+000

NOTES
PRECISE LEVEL DATUM (PLD) IS THE LEVEL SURFACE TO WHICH ALL HEIGHTS OR ELEVATIONS ARE REFERRED
MEAN LAKE LEVEL (MLL)= 25.9m PLD

SCALE 3V/1H
UNITS ARE IN METERS

# TYPICAL X–SECTION
# GATUN LAKE – 280m STRAIGHT & 366m BENDS
# CHANNEL BOTTOM 9.15m PLD (30'PLD)



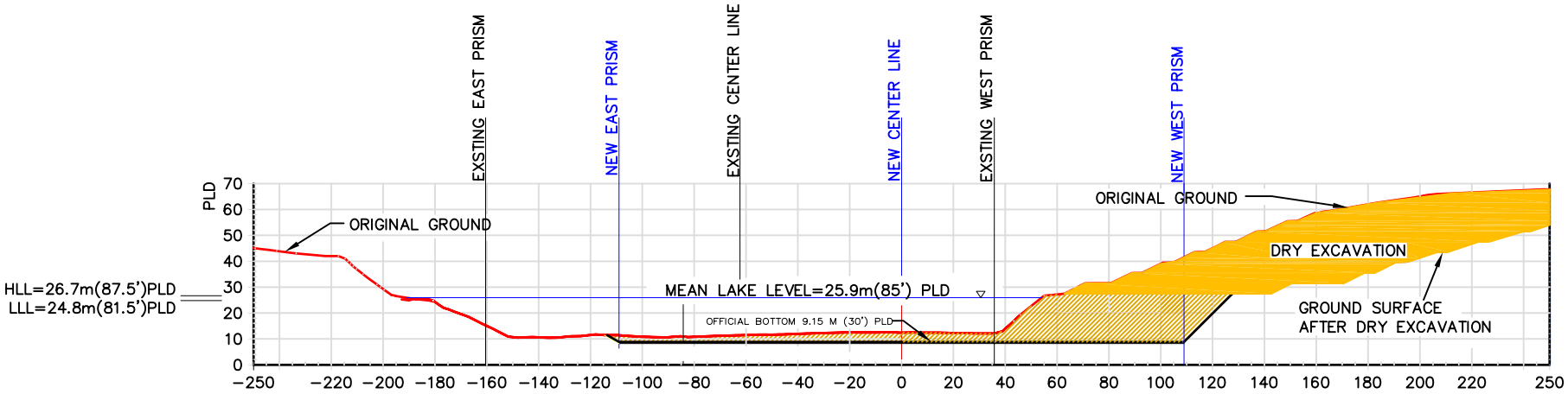

# STATION No. 27K+800

NOTES
PRECISE LEVEL DATUM (PLD) IS THE LEVEL SURFACE TO WHICH ALL HEIGHTS OR ELEVATIONS ARE REFERRED
MEAN LAKE LEVEL (MLL)= 25.9m PLD

SCALE 3V/1H
UNITS ARE IN METERS

# GAILLARD CUT

## TYPICAL X-SECTION – WIDTH 218 m
## 9.15 m PLD (30' PLD) GAILLARD CUT
## PANAMA CANAL AUTHORITY




SCALE 1V/1H
UNITS ARE IN METERS

## NOTES

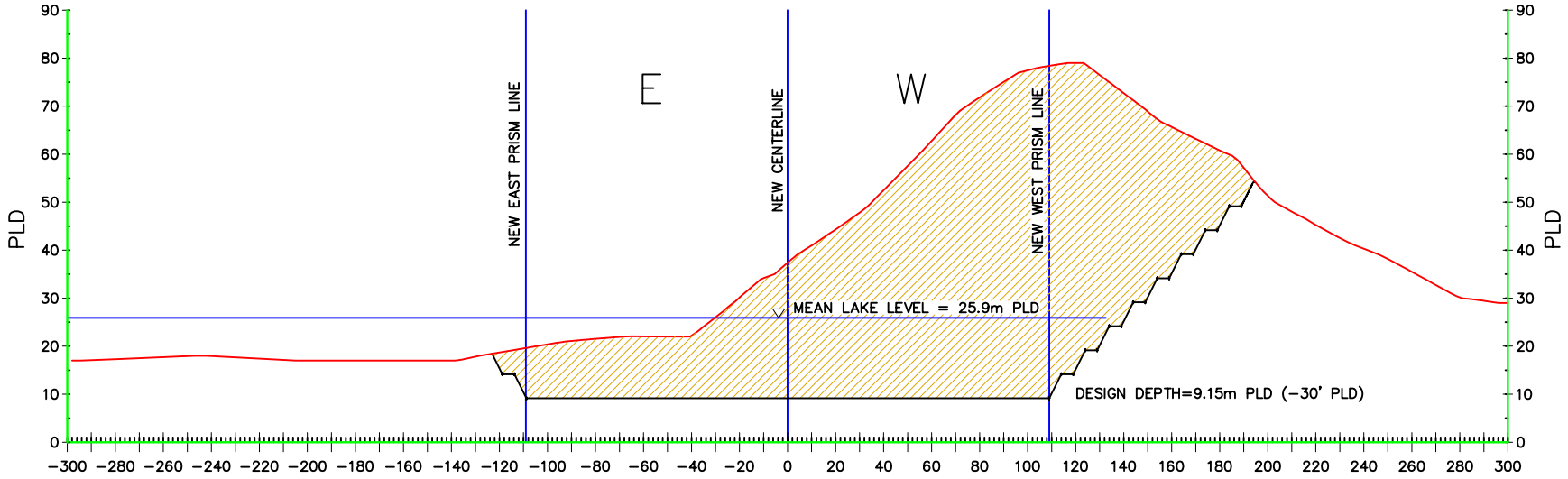
PRECISE LEVEL DATUM (PLD) IS THE LEVEL SURFACE TO WHICH ALL HEIGHTS OR ELEVATIONS ARE REFERRED

GATUN MEAN LAKE LEVEL (MLL)= 25.91m (85') PLD

HLL= HIGH LAKE LEVEL

LLL= LOW LAKE LEVEL

# TYPICAL X–SECTION
# PACIFIC NEW LOCKS – NORTH APPROACH
# CHANNEL BOTTOM 9.15m PLD (30' PLD)




## STATION No. 4K+600

NOTES
PRECISE LEVEL DATUM (PLD) IS THE LEVEL SURFACE TO WHICH ALL HEIGHTS OR ELEVATIONS ARE REFERRED
MEAN LAKE LEVEL (MLL)= 25.9m PLD

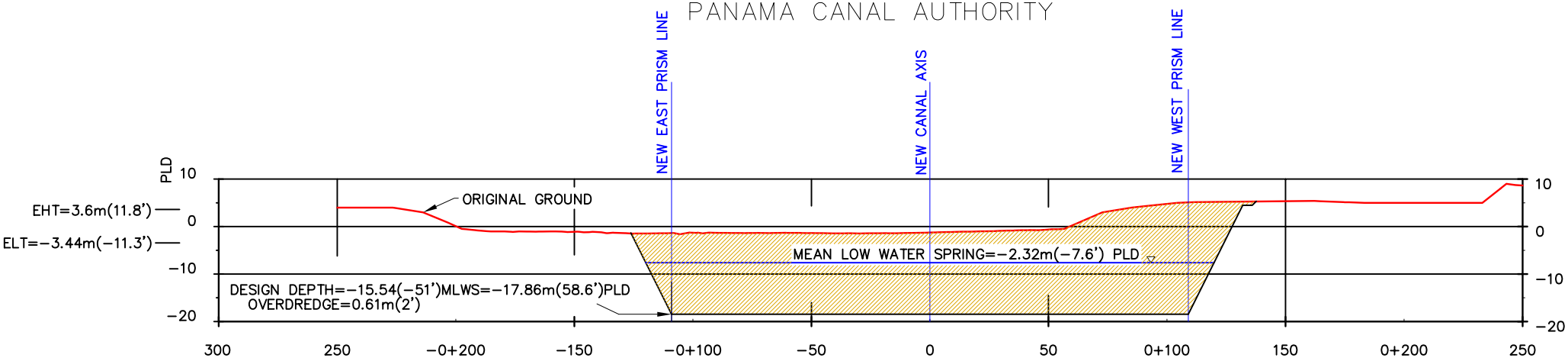
| LINE | SURFACE | OFFSET |
|---|---|---|
| W218m | | |

Scaled 2.0000 Times Ver.
Scaled 1.0000 Times Hor.

TYPICAL X-SECTION

PACIFIC ENTRANCE – SOUTH THE NEW LOCKS – WIDTH 218M – DRAFT 13.7m (45')

PANAMA CANAL AUTHORITY




# STATION No. 9K+800

SCALE 2V/1H
UNITS ARE IN METERS

NOTES

PRECISE LEVEL DATUM (PLD) IS THE LEVEL SURFACE TO WHICH ALL HEIGHTS OR ELEVATIONS ARE REFERRED

PACIFIC MEAN LOW WATER SPRING (MLWS)= −2.32m (−7.6') PLD

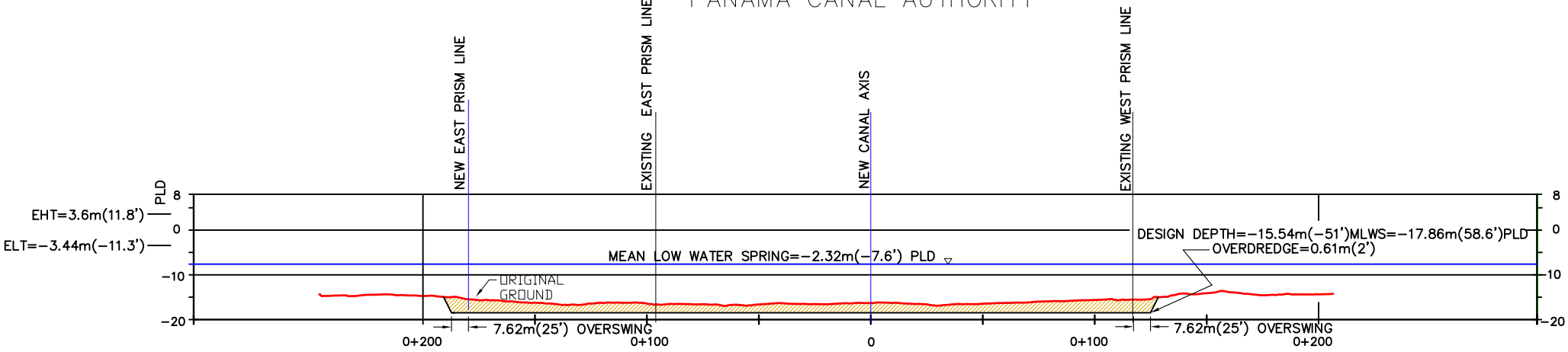
EHT= EXTREME HIGH TIDE

ELT= EXTREME LOW TIDE

TYPICAL X-SECTION

PACIFIC ENTRANCE –NORTH THE BRIDGE – WIDTH 225M – DRAFT 13.7m (45')

PANAMA CANAL AUTHORITY




# STATION No. 73K+000

NOTES

PRECISE LEVEL DATUM (PLD) IS THE LEVEL SURFACE TO WHICH ALL HEIGHTS OR ELEVATIONS ARE REFERRED

PACIFIC MEAN LOW WATER SPRING (MLWS)= –2.32m (–7.6') PLD

EHT= EXTREME HIGH TIDE

ELT= EXTREME LOW TIDE

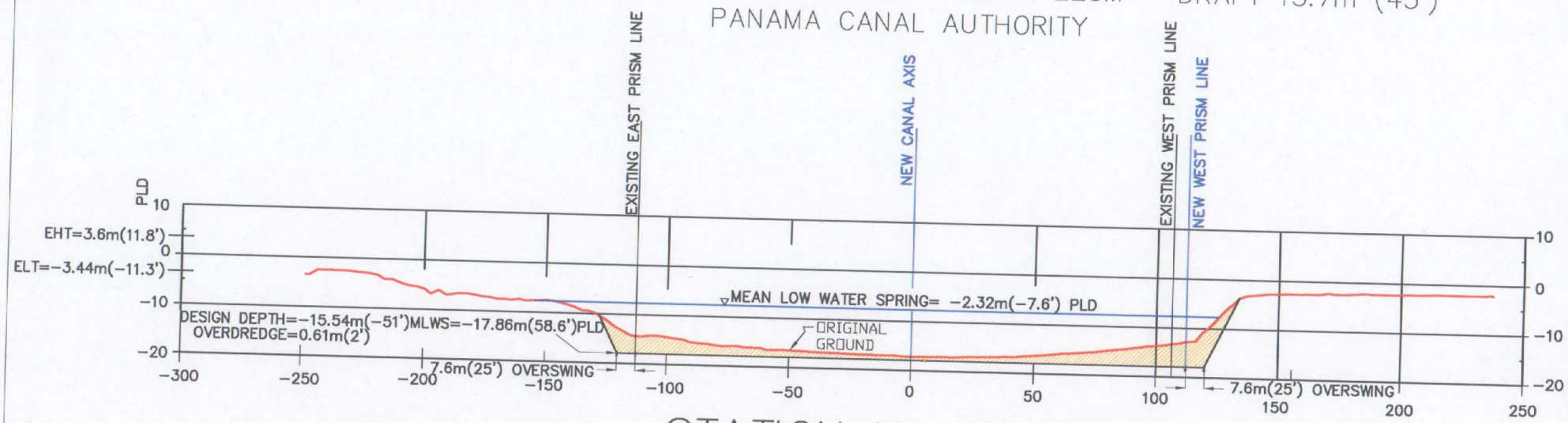
SCALE 2V/1H

UNITS ARE IN METERS

TYPICAL X-SECTION

PACIFIC ENTRANCE – SOUTH THE BRIDGE – WIDTH 225M – DRAFT 13.7m (45')

PANAMA CANAL AUTHORITY




STATION No. 74+760

NOTES

PRECISE LEVEL DATUM (PLD) IS THE LEVEL SURFACE TO WHICH ALL HEIGHTS OR ELEVATIONS ARE REFERRED

PACIFIC MEAN LOW WATER SPRING (MLWS)= -2.32m (-7.6') PLD

EHT= EXTREME HIGH TIDE

ELT= EXTREME LOW TIDE

SCALE 2V/1H

UNITS ARE IN METERS

## ANDESITE

The majority of the andesites occur as flows, dikes or sills frequently associated with the Las Cascadas formation and are mostly early Miocene in age. The andesites are hard, strong, igneous, dark gray, tough, occasionally porphyritic, dense, fine-grained, and usually extrusive.

(Andesites are composed of acid plagioclases, especially andesine, and mafic minerals such as hornblende, biotite, and pyroxene. Quartz is generally present.)

BASALT

The majority of the basalts in Gaillard Cut are of late Miocene age. These basalts, which are sometimes referred to as andesitic basalts, occur as sills, dikes, plugs, and flows. Most are fine- to medium-grained, closely to moderately jointed, columnar jointing occurs locally. It is a dark, tough to brittle, basic, igneous rock, hard, high in iron, magnesia, and calcium and low in silica. Joints are frequently filled with calcite, chlorite, zeolite, and occasionally quartz. The flows are usually amygdaloidal and vesicular in the upper parts. The basalts are occasionally porphyritic and sometimes diabasic.

(These basalts are mafic igneous rocks composed chiefly of calcic plagioclase, usually labradorite, and clinopyroxine in a fine-grained to glassy matrix. Nepheline, olivine, hypersthene or rarely quartz may be present.)

## 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. □sat = 1434 kg/m³
7. □dry = 848 kg/m³
8. Consistency: OC-1 to OC-3 – Very soft to medium high consistency.

## BAS OBISPO FORMATION

The Bas Obispo formation, of Oligocene age and pyroclastic origin, occurs in Gaillard Cut in Bas Obispo reach, Mandinga Flair and Gamboa. It consists of hard, sub-angular to angular fragments of basalt and andesite ranging in size up to large boulders in a hard, well-indurated, sandy, andesitic matrix, all somewhat hydro thermally altered. It shows locally crude bedding and is massively jointed with some faults and shear zones. There are some minor scattered flows and intrusions of andesite and basalt. It is hard, RH-4-5, volcanic, non-marine, and is well cemented with calcite. It requires heavy blasting and will stand on steep slopes.

(It is a basic material with plagioclases, mafic minerals and secondary calcite cementation.)

## BOHIO FORMATION

The Bohio formation occurs in the central part of the Canal area, its thickness is estimated at about 1000; consists of a series of sandstones and conglomerates, which are medium to hard, massively jointed, and massively but crudely bedded.
The conglomerates consist of angular to rounded pebbles, cobbles and occasional boulders up to six feet in diameter, embedded in a dark-gray, coarse-grained, angular sandstone matrix. Tuff beds are found at scattered localities. Basalt intrusions ranging from a few feet to over 200 feet in width are common in the Bohio formation and are most numerous in the vicinity of Darien and Gamboa, it is overlain by the Caimito formation, and is the strongest of the sedimentary formations that would be encountered in the construction of a canal on the selected alignment.

Defined by French Writers; Hill, Mac Donald, W.P. Woodring and T. Thompson 1890 – 1947

## CAIMITO FORMATION

The Caimito Formation, upper Oligocene in age, consists of a series of tuffs, tuff-breccias, siltstones, sandstones, conglomerates and limestones, which are medium hard, thinly to thickly bedded, and closely to moderately jointed. On the basis of lithology the formation is divisible into basal, middle, and upper phases. The basal phase is a tuffaceous sandstone conglomerate of local distribution containing abundant basalt pebbles, cobbles and boulders. This material weathers deeply and fresh outcrops are seldom encountered. The middle phase consists of slightly fossiliferous, tuffaceous sandstones and limestones, and is also local in extent. The upper phase is a widely distributed series of tuffs, tuff-breccias, and tuffaceous sandstones with occasional sandy limestone beds.

## CUCARACHA FORMATION

The Cucaracha formation is middle-early Miocene in age, the same age as the Las Cascadas formation, and it is considered to be a facies change of the formation. Stratigraphically, it lies between the Culebra and the Pedro Miguel formations. The formation crops out in Gaillard Cut in Culebra and Cucaracha reaches. It is a terrestrial deposit of volcanic debris from intense, explosive activity. The formation consists of weak, dark green to reddish, slightly indurated, andesitic materials that are predominantly weak clay shales. These clay shales are locally bentonitic and interbedded with fine, tuffaceous sandstones, pebble conglomerates, and thinly bedded, lenticular black, carbonaceous clay shales. There is a hard, strong, light grey ash flow, 10 to 30 feet thick, about 200 feet below the top of the formation that marks the middle portion of the formation. All of the formation except the ash flow has been altered, and hydrates and slakes on exposure to air. It is cut by basalt dikes and is generally fine-grained, noncalcareous, and nearly impervious. It contains fossil plant remains and occasional mammalian fossils. The maximum known thickness is 625'. The clay shales comprise about 60% of the formation; they are not true shales but are compact, soft to medium-hard, RH-1-3, variably waxy or soapy, massively bedded, altered tuffs in which the original, unstable, glassy particles of volcanic ash have broken down into clay minerals. The clay shales are slightly to highly bentonitic with numerous, irregular, unoriented, smoothly

polished, slickensided, minute fractures caused by volumetric changes as a result of the alteration and in some areas are due to faulting.

(This formation contains about 60% clay minerals, devitrified volcanic glass shards, some siderite nodules and it is andesitic.)

## CULEBRA FORMATION

The Culebra formation is of lower early Miocene age and it underlies the Cucaracha formation. It crops out in Gaillard Cut in Culebra Reach. It is a series of medium-hard, variably silty and sandy, dark, well-laminated, soft, tuffaceous siltstones, marls, and carbonaceous clays with some pebbly, sandy, tuffaceous layers and a few beds of lignitic shale. The formation contains abundant plant debris. It represents a period of continuous marine deposition, interbedded with gradual facies changes and marine microfossils, and deltaic or near shore deposition with rapid facies changes. The formation is about 350 feet thick, contains calcareous cementation, altered to clay minerals, and is stronger than the Cucaracha. The formation lies unconformably on the Eocene Gatuncillo formation. Holes drilled in the formation became too hot to load for blasting because of the oxidation of finely divided pyrite in the materials. It commonly emits a gaseous odor from the core borings.

(The formation is similar to the La Boca formation in mineral content. It is calcareous and frequently contains finely divided pyrite in the carbonaceous materials.)

## DACITE

Dacite is a quartz-rich extrusive (volcanic) rock, fine-grained, that contains abundant sodic plagioclase. Dacite is a minor constituent of many arc volcanoes. Contains the same general composition as Andesite, but has a less calcic feldspar content.

## 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.

## GATUNCILLO FORMATION

The Gatuncillo formation is a fossiliferous, sedimentary formation that is middle to late Eocene in age. It underlies the Bas Obispo-Bohio-Panama complex and lies unconformably and laps onto the preTertiary basement complex. The formation crops out in Gaillard Cut at Lirio East and occurs in the lower part of core borings in Lirio West and Northwest Culebra.

The formation consists of intercalations of soft, thinly bedded, uniformly fine-grained, calcareous, yellowish gray or buff colored shale and impure bentonitic beds in a thick sequence of soft, gray-green, massively bedded siltstone with prominent lenses of a pure, hard, crystalline limestone.

(The mineral content of the formation is similar to the La Boca formation but has less carbonaceous debris.)

## 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. 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.

(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.)

## LAS CASCADAS FORMATION

The formation is of middle early Miocene age. It crops out in Las Cascadas and Empire reaches, and east and west of Gaillard Cut. It underlies the La Boca formation, and is considered to be a facies change and the same age as the Cucaracha formation. It consists of dark gray to light green agglomerates and agglomeratic tuffs with andesitic and basaltic, small, angular to sub-angular pebbles and cobbles up to 8 inches in diameter in a fine-grained, tuffaceous matrix. It is massively to roughly be dded, and interbedded with yellow-green, gray-green or red, well-bedded tuffs, andesite flows and flow breccias, and ash flows. It is intruded by basalt dikes. The formation is variably hard to medium soft, variably hydrothermally altered to clay minerals, and cemented with secondary calcite. It is moderately to massively jointed with calcite joint fillings.

(The Las Cascadas is slightly more acidic than the Pedro Miguel formation and contains large amounts of devitrified volcanic glass shards deposited as tuffaceous ash. It is cemented with secondary calcite.)

## PANAMA FORMATION

This formation consists primarily of agglomerates and tuffs, which extend from the Miraflores Lake to the Panama City and to the northeast through the continental divide and to the east in the area of the Pacific coast.

The Panama formation also includes tuffaceous sandstones, tuffaceous siltstones, lenses of stream deposits and lenses of marine limestones.

The agglomerate consists of sub-angular to sub-rounded blocks of andesite, highly disseminated in a fine-grained tuffaceous matrix.

The stream deposits are made of tuffaceous sandstone, which exhibit crude bedding, they contain rounded to sub-rounded and sub-angular boulders, cobbles and pebbles.

The age assigned to this formation is from lower to upper Oligocene.

The hardness of the formation varies between RH-1 and RH-3, soft to medium hard rock.

## PEDRO MIGUEL FORMATION

The Pedro Miguel formation of upper early Miocene age is equivalent in age to the La Boca formation with which it interfingers. It is pyroclastic and is generally a coarse-textured, hard to medium hard, RH-3-4, dense, dark gray, massively to moderately jointed, fine- to coarse-grained material with small angular fragments up to large boulders of basalt in a sandy tuffaceous matrix, well-cemented with secondary calcite and some zeolite. It locally shows well-developed bedding,

sorting, and frequent fossils indicating a partly water and partly terrestrial deposition. It is interbedded with hard, black, fine-grained, indurated tuffs with usually massive jointing and occasional basalt flows. The formation is blue-gray when fresh, oxidizing to grayish-brown. The average depth of weathering is 20 feet to 30 feet. It requires heavy blasting. This formation overlies the Cucaracha formation.

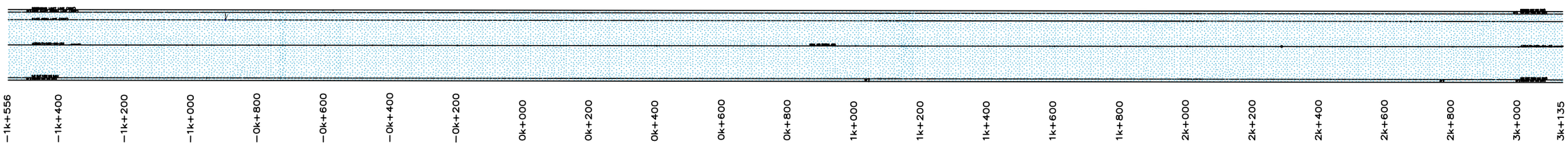
The Pedro Miguel occurs in various areas of Gaillard Cut from Empire Reach to the Pacific entrance to the Canal.

(The formation is composed of andesitic basalt fragments in a tuffaceous matrix with secondary calcite and occasionally zeolite cementation.)

## RECENT SEDIMENTS:

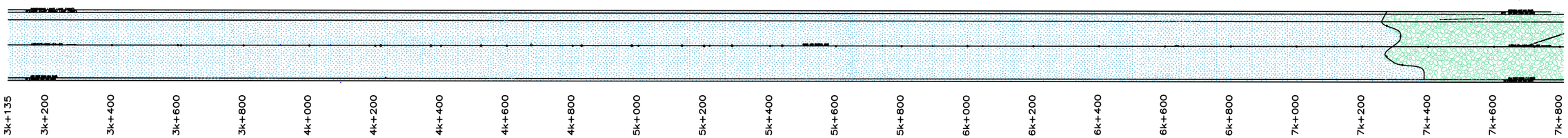
Consists of undifferentiated sediments of the Holocene (10000 years). They are composed mainly of alluvial and or fill material. Beach sediments consists of yellow quartz, sub-angular, 40 to 50 mm in length, and volcanic, igneous fragments, mainly of dacite, basalt and tuff, in which predominates sizes of 5 to 20 mm, these fragments are sub-angular, reworked by water of a beach and/or river, predominating the smaller volcanic fragments. Its color varies from translucid, dark yellowish, light and dark gray and dark greenish gray.

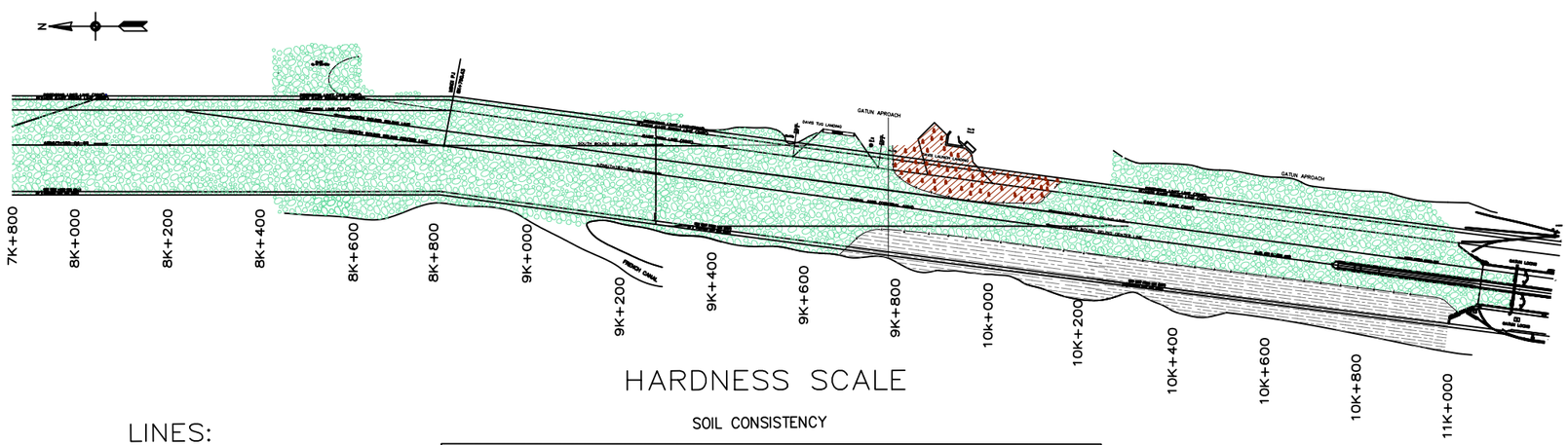
# ATLANTIC ENTRANCE PROJECT




## NOTES:

- PROYECTION: UNIVERSAL TRANSVERSAL MERCATOR
- HORIZONTAL DATUM: 1927 NORTH AMERICAN DATUM
- STATIONS IN METERS
- THE GEOLOGICAL INTERPRETATION WAS BASED ON FOLLOWING INFORMATION:
  - Existing Drill within the canal.
  - Dredging reports and logs for the affected areas.
  - Information ditacted by Dredge Capt. (Jay Gibson) based on past experience.




## LEGEND:

- FILL OC-1 TO RH-5
  HETEROGENEOUS FILL ( SOFT OVERBURDEN AND BOULDERS
- ATLANTIC MUCK OC-1 TO OC-2
  VERY SOFT TO MEDIUM SOFT CONCISTENCY OVERBURDEN
- GATUN FORMATION
  RH-1 to RH-2 SOFT TO MEDIUM SOFT ROCK
- GATUN FORMATION
  RH-2 TO RH-3 MEDIUM SOFT TO MEDIUM HARD ROCK

## HARDNESS SCALE

SOIL CONSISTENCY

| SYMBOL | SOIL CONSISTENCY | UNCONFINED COMPRESSIVE STRENGTH MPa |
|---|---|---|
| OC-1 | VERY SOFT AND SOFT | 0.00 – 0.025 |
| OC-2 | MEDIUM SOFT | 0.025 – 0.050 |
| OC-3 | MEDIUM HARD | 0.050 – 0.100 |
| OC-4 | HARD | 0.100 – 0.200 |
| OC-5 | VERY HARD | 0.200 – 0.400 |
| OC-5 to RH-1 VERY HARD CONSISTENCY OVERBURDEN TO SOFT ROCK | | 0.400 – 1.000 |

ROCK HARDNESS

| SYMBOL | ROCK HARDNESS | UNCONFINED COMPRESSIVE STRENGTH MPa |
|---|---|---|
| RH-1 | SOFT | 1– 25 |
| RH-2 | MEDIUM SOFT | 25 – 50 |
| RH-3 | MEDIUM HARD | 50 – 100 |
| RH-4 | HARD | 100 – 200 |
| RH-5 | VERY HARD | >200 |

## LINES:

- INFERRED CONTACT LINE
- CANAL AXIS (CENTRAL AXIS)
- BEARING LINE
- PRISM LINE
- SHORE LINE
- DREDGING LIMIT LINE

PANAMA CANAL AUTHORITY

DEPARTMENT OF ENGINEERING AND PROYECT
ENGENIEERING DIVISION
BALBOA HEIGHTS, REPUBLIC OF PANAMA

## CANAL EXPANSION PROJECT
## ATLANTIC ENTRANCE
### PLAN VIEW WITH GEOLOGY

FROM STA. 1KM+556 TO STA. 11K+000

SCALE: 1:5000

DATE: APRIL 05, 2004

GEOLOGY: I. DIAZ

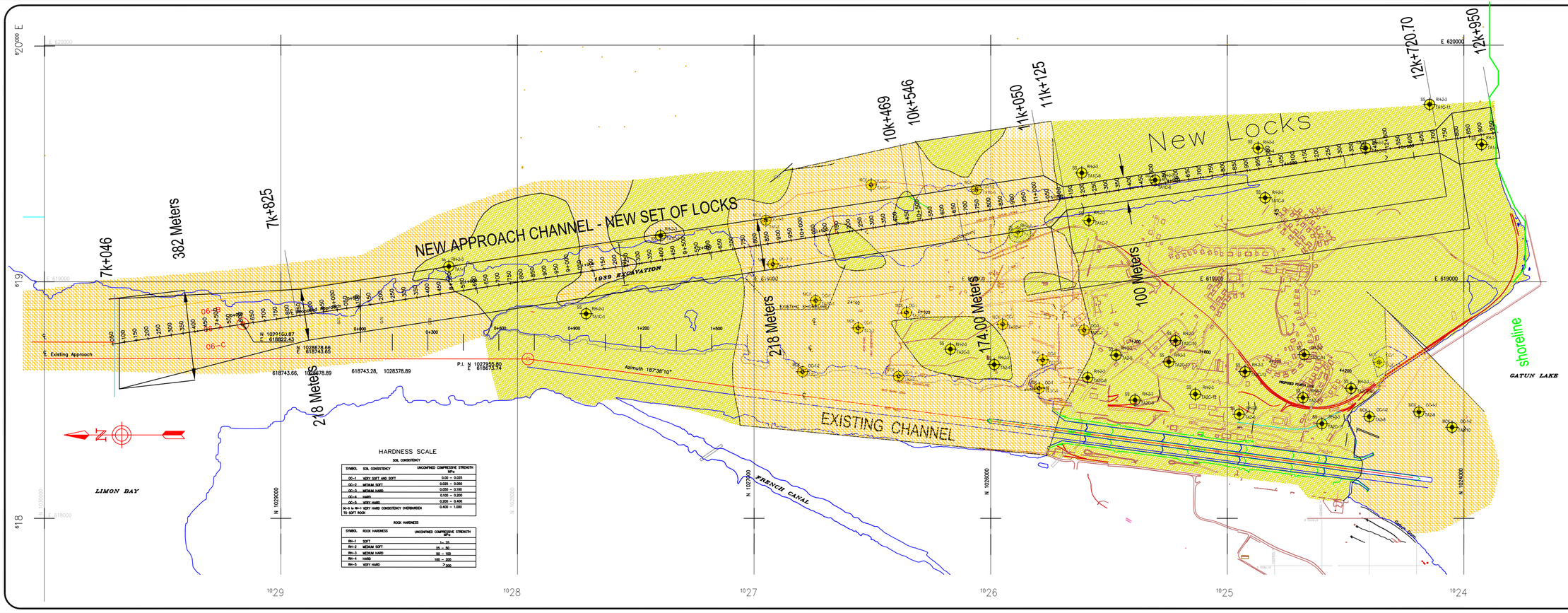
DRAWNS BY: M. CARRIZO/A. LU (IPIT) I. DIAZ (IPIG)

SUBMITTED BY: M. DE PUY, CHIEF, GEOTECHNICAL BRANCH

APROVED BY: LUIS D. ALFARO, CHIEF, ENGINEERING DIVISION

1:5000 — 400 200 0 400 METERS

6123–118




## Formation Simbology

**Tg** — **Gatún**
Formación Gatún, Mioceno medio, Arenisco, lutita, toba y conglomerado
*(Gatun Formation, middle Miocene, andstone, siltstone, tuff and conglomerate)*

**Qa** — **Atlantic Muck**
Sedimentos Holocenos, no diferenciados, principalmente aluvión o relleno
*(Undivided Holocen sediments, principally alluvium or fill)*

**Contractor Drill Holes** — TA2C-9

**ACP DRILL HOLES** — TA2-10

**Geologic Sections** — A, A'

**Geologic Contact**

**Geologic Fault**

### HARDNESS SCALE

SOIL CONSISTENCY

| SYMBOL | SOIL CONSISTENCY | UNCONFINED COMPRESSIVE STRENGTH MPa |
|---|---|---|
| DC-1 | VERY SOFT AND SOFT | 0.00 – 0.025 |
| DC-2 | MEDIUM SOFT | 0.025 – 0.050 |
| DC-3 | MEDIUM HARD | 0.050 – 0.100 |
| DC-4 | HARD | 0.100 – 0.200 |
| DC-5 | VERY HARD | 0.200 – 0.400 |
| DC-6 | VERY HARD CONSISTENCY OVERBURDEN TO SOFT ROCK | 0.400 – 1.000 |

ROCK HARDNESS

| SYMBOL | ROCK HARDNESS | UNCONFINED COMPRESSIVE STRENGTH MPa |
|---|---|---|
| RH-1 | SOFT | 1 – 25 |
| RH-2 | MEDIUM SOFT | 25 – 50 |
| RH-3 | MEDIUM HARD | 50 – 100 |
| RH-4 | HARD | 100 – 200 |
| RH-5 | VERY HARD | > 200 |

Capacidad del Canal

WORK AREA

REGIONAL VIEW

AUTORIDAD DEL CANAL DE PANAMÁ

ENGINEERING AND PROJECTS BUREAU

GEOLOGIC MAP

ATLANTIC SIDE

SCALE: 1:10,000 — DATE: APRIL 7, 2004

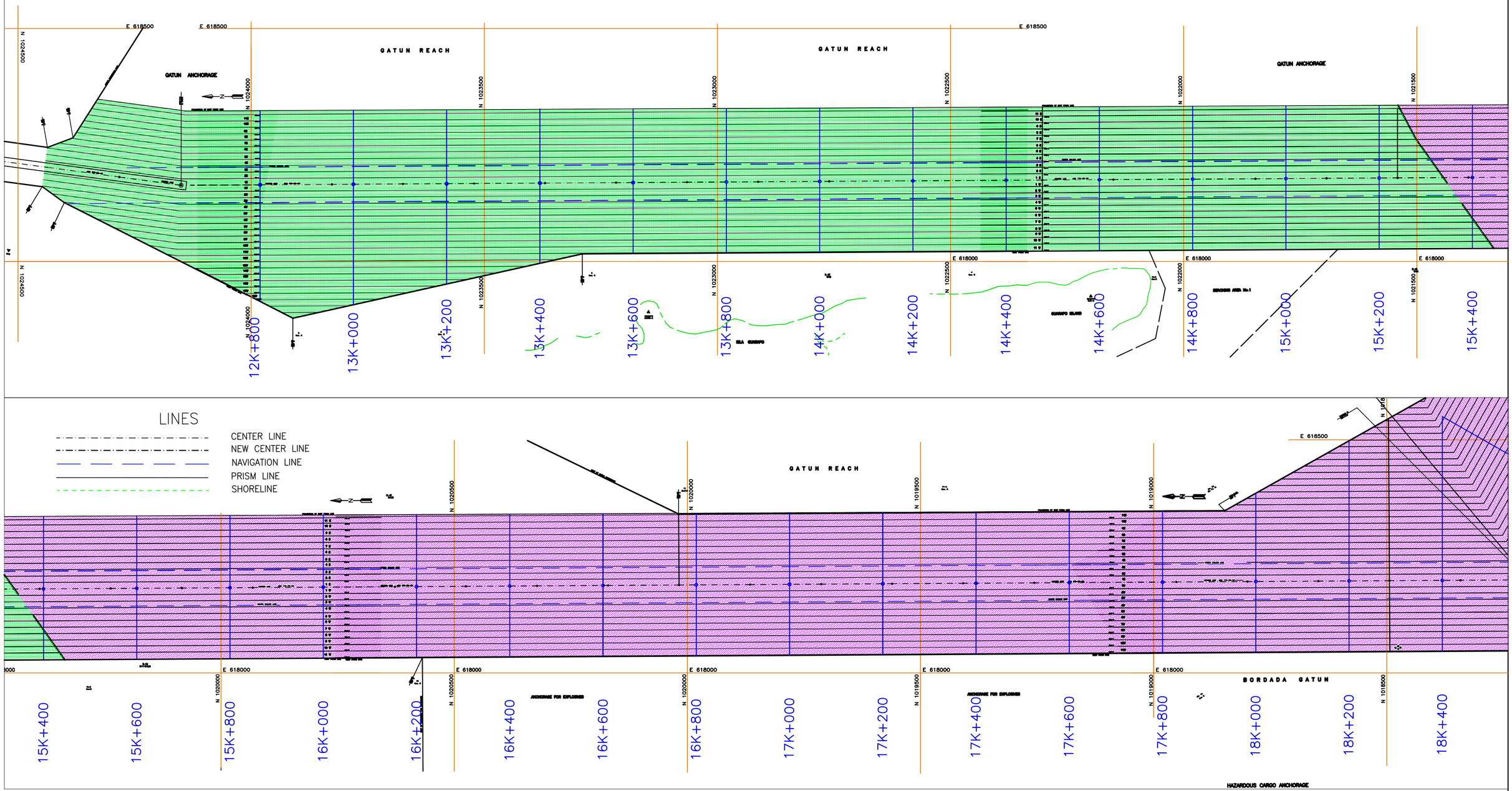
GEOLOGISTS: D. IRVING P. FRANCESCHI

DRAWING: R. HAWKINS R.

REVISADO: R. PENILLA M. DEPUTY

SOMETIDO: GERENTE — DIVISIÓN GEOTÉCNICA — SECCIÓN

APROBADO: GERENTE DE LA DIVISIÓN DE INGENIERÍA




## LINES

- CENTER LINE
- NEW CENTER LINE
- NAVIGATION LINE
- PRISM LINE
- SHORELINE

## HARDNESS SCALE

SOIL CONSISTENCY

| SYMBOL | SOIL CONSISTENCY | UNCONFINED COMPRESSIVE STRENGTH MPa |
|---|---|---|
| OC–1 | VERY LOW TO LOW | 0.00 – 0.025 |
| OC–2 | MEDIUM LOW | 0.025 – 0.050 |
| OC–3 | MEDIUM HIGH | 0.050 – 0.100 |
| OC–4 | HIGH | 0.100 – 0.200 |
| OC–5 | VERY HIGH | 0.200 – 0.400 |
| OC–5 a RH–1 | VERY HIGH CONSISTENCY TO SOFT ROCK | 0.400 – 1.000 |

ROCK HARDNESS

| SYMBOL | ROCK HARDNESS | UNCONFINED COMPRESSIVE STRENGTH MPa |
|---|---|---|
| RH–1 | SOFT | 1 – 25 |
| RH–2 | MEDIUM–SOFT | 25 – 50 |
| RH–3 | MEDIUM–HARD | 50 – 100 |
| RH–4 | HARD | 100 – 200 |
| RH–5 | VERY HARD | > 200 |

## GEOLOGICAL FORMATIONS

- ANDESITE
- BOHIO
- BASALT
- CAIMITO
- BAS OBISPO
- GATUN
- FAULT
- INFERRED FAULT

BORING NAME

LBW-5

RH-4 ⊕ AGG

ROCK HARDNESS (See Hardness Scale)

ROCK TYPE (See Lithology Table)

## LEGEND

### LITHOLOGY TABLE

AF = ASH FLOW
AGG = AGGLOMERATE
AGG,T = TUFFACEOUS AGGLOMERATE
ANDE = ANDESITE
BAS = BASALT
BBRE = BASALT BRECCIA
CL= CLAY
CLSH = CLAYSHALE
CONG = CONGLOMERATE
FG = FAULT GOUGE
FILL = FILL
FZ = FAULT ZONE
GVL = RIVER GRAVEL
W = WEATHERED ROCK
RS or RD = RIVER SEDIMENT
LS = LIMESTONE
LS = LIGNITIC SHALE
MCK = MUCK
NR = NO RECOVERY
OB = OVERBURDEN
SD = SAND
SH = SHALE
SLDB = SLIDE DEBRIS
SS = SANDSTONE
ST = SILTSTONE
T = TUFF
TAGG = AGGLOMERATIC TUFF

Panamá 1903-2003 Centenario de la República

ACP PANAMA CANAL AUTHORITY

ENGINEERING AND PROJECTS DEPARTMENT
ENGINEERING DIVISION
BALBOA HEIGHTS, REPUBLIC OF PANAMA

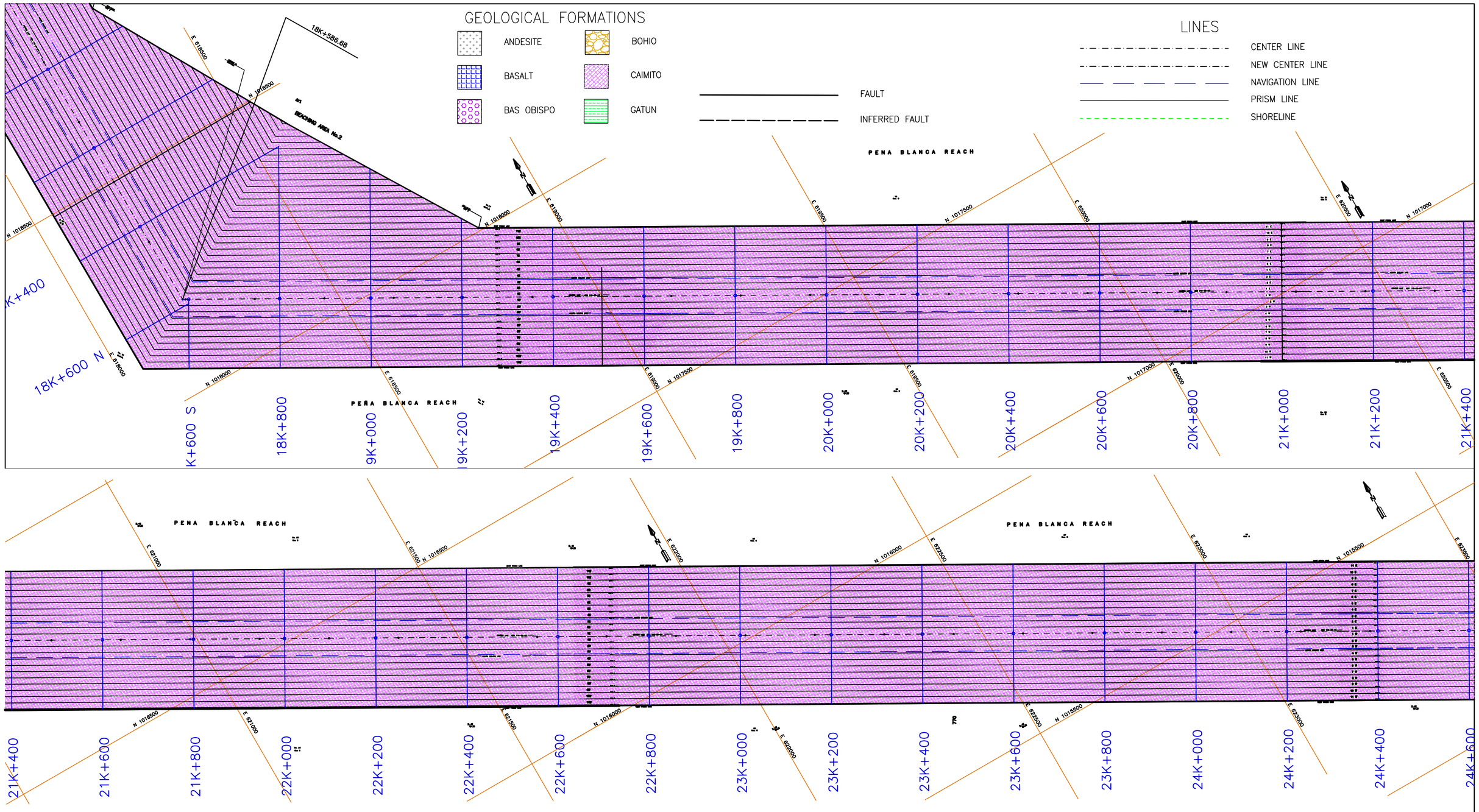
# CANAL EXPANSION PROJECT
# GATUN LAKE
## PLAN VIEW WITH GEOLOGY
### GATUN LOCKS to STA 18K+400

SCALE: 1:3000 | DATE: MARCH 2004

GEOLOGIST: J. RAMESCH
DRAWN BY: SURVEYS BRANCH J. RAMESCH (IPIG)

CHECKED BY: M. DE PUY, MANAGER, GEOTECHNICAL ENG.
APPROVED BY: LUIS D. ALFARO, MANAGER, ENGINEERING DIVISION

6123–116 SHEET 1 of 6




## HARDNESS SCALE

SOIL CONSISTENCY

| SYMBOL | SOIL CONSISTENCY | UNCONFINED COMPRESSIVE STRENGTH MPa |
|---|---|---|
| OC–1 | VERY LOW TO LOW | 0.00 – 0.025 |
| OC–2 | MEDIUM LOW | 0.025 – 0.050 |
| OC–3 | MEDIUM HIGH | 0.050 – 0.100 |
| OC–4 | HIGH | 0.100 – 0.200 |
| OC–5 | VERY HIGH | 0.200 – 0.400 |
| OC–5 a RH–1 | VERY HIGH CONSISTENCY TO SOFT ROCK | 0.400 – 1.000 |

ROCK HARDNESS

| SYMBOL | ROCK HARDNESS | UNCONFINED COMPRESSIVE STRENGTH MPa |
|---|---|---|
| RH–1 | SOFT | 1 – 25 |
| RH–2 | MEDIUM–SOFT | 25 – 50 |
| RH–3 | MEDIUM–HARD | 50 – 100 |
| RH–4 | HARD | 100 – 200 |
| RH–5 | VERY HARD | > 200 |

## LEGEND

### LITHOLOGY TABLE

AF = ASH FLOW
AGG = AGGLOMERATE
AGG,T = TUFFACEOUS AGGLOMERATE
ANDE = ANDESITE
BAS = BASALT
BBRE = BASALT BRECCIA
CL= CLAY
CLSH = CLAYSHALE
CONG = CONGLOMERATE
FG = FAULT GOUGE
FILL = FILL
FZ = FAULT ZONE
GVL = RIVER GRAVEL
W = WEATHERED ROCK
RS or RD = RIVER SEDIMENT
LS = LIMESTONE
LS = LIGNITIC SHALE
MCK = MUCK
NR = NO RECOVERY
OB = OVERBURDEN
SD = SAND
SH = SHALE
SLDB = SLIDE DEBRIS
SS = SANDSTONE
ST = SILTSTONE
T = TUFF
TAGG = AGGLOMERATIC TUFF

Panamá 1903-2003 Centenario de la República

BORING NAME

LBW-5

RH-4 ⊕ AGG

ROCK HARDNESS (See Hardness Scale)

ROCK TYPE (See Lithology Table)

6123–116

SHEET 2 of 6

ACP PANAMA CANAL AUTHORITY

ENGINEERING AND PROJECTS DEPARTMENT
ENGINEERING DIVISION
BALBOA HEIGHTS, REPUBLIC OF PANAMA

# CANAL EXPANSION PROJECT
# GATUN LAKE
## PLAN VIEW WITH GEOLOGY
### STA 18K+400 to STA 24K+600

SCALE: 1:3000

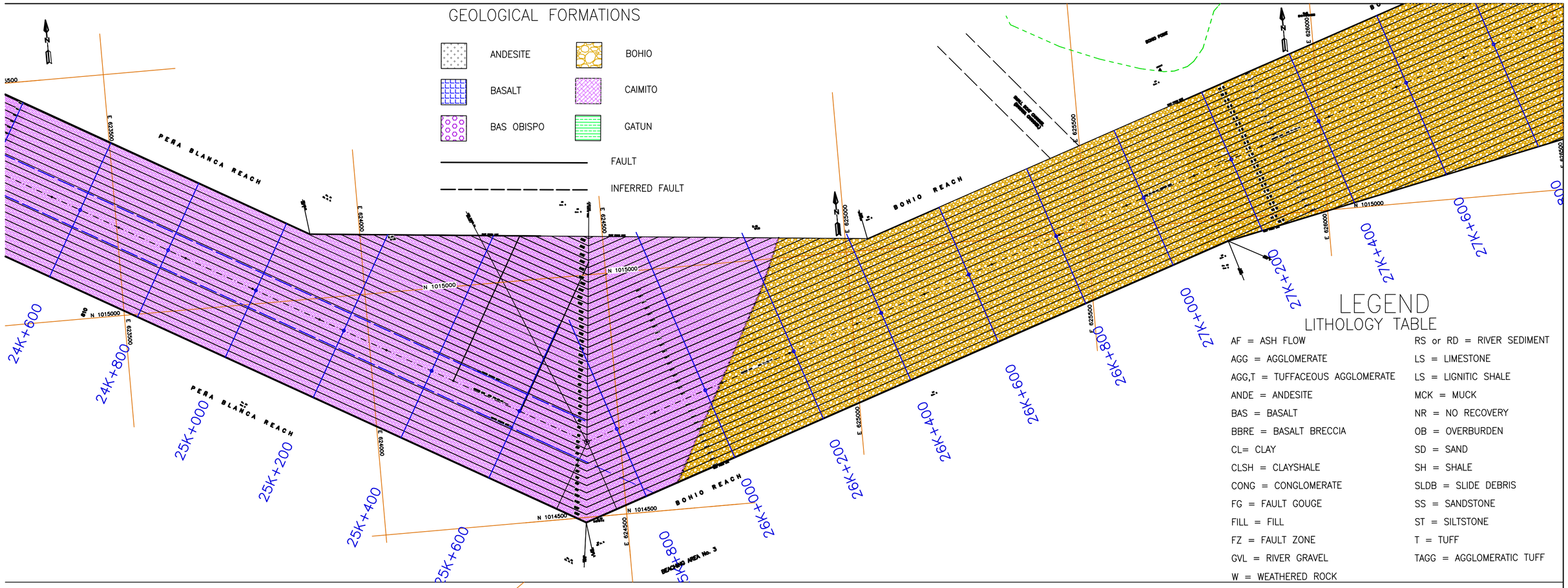
DATE: MARCH 2004

GEOLOGIST: J. RAMESCH

DRAWN BY: SURVEYS BRANCH J. RAMESCH (IPIG)

CHECKED BY: M. DE PUY, MANAGER, GEOTECHNICAL ENG.

APPROVED BY: LUIS D. ALFARO, MANAGER, ENGINEERING DIVISION




## HARDNESS SCALE

SOIL CONSISTENCY

| SYMBOL | SOIL CONSISTENCY | UNCONFINED COMPRESSIVE STRENGTH MPa |
|---|---|---|
| OC–1 | VERY LOW TO LOW | 0.00 – 0.025 |
| OC–2 | MEDIUM LOW | 0.025 – 0.050 |
| OC–3 | MEDIUM HIGH | 0.050 – 0.100 |
| OC–4 | HIGH | 0.100 – 0.200 |
| OC–5 | VERY HIGH | 0.200 – 0.400 |
| OC–5 a RH–1 | VERY HIGH CONSISTENCY TO SOFT ROCK | 0.400 – 1.000 |

ROCK HARDNESS

| SYMBOL | ROCK HARDNESS | UNCONFINED COMPRESSIVE STRENGTH MPa |
|---|---|---|
| RH–1 | SOFT | 1 – 25 |
| RH–2 | MEDIUM–SOFT | 25 – 50 |
| RH–3 | MEDIUM–HARD | 50 – 100 |
| RH–4 | HARD | 100 – 200 |
| RH–5 | VERY HARD | > 200 |

Panamá 1903-2003 Centenario de la República

6123–116 SHEET 3 of 6

PANAMA CANAL AUTHORITY

ENGINEERING AND PROJECTS DEPARTMENT
ENGINEERING DIVISION
BALBOA HEIGHTS, REPUBLIC OF PANAMA

# CANAL EXPANSION PROJECT
# GATUN LAKE
## PLAN VIEW WITH GEOLOGY
### STA 24K+600 to STA 30K+800

SCALE: 1:3000

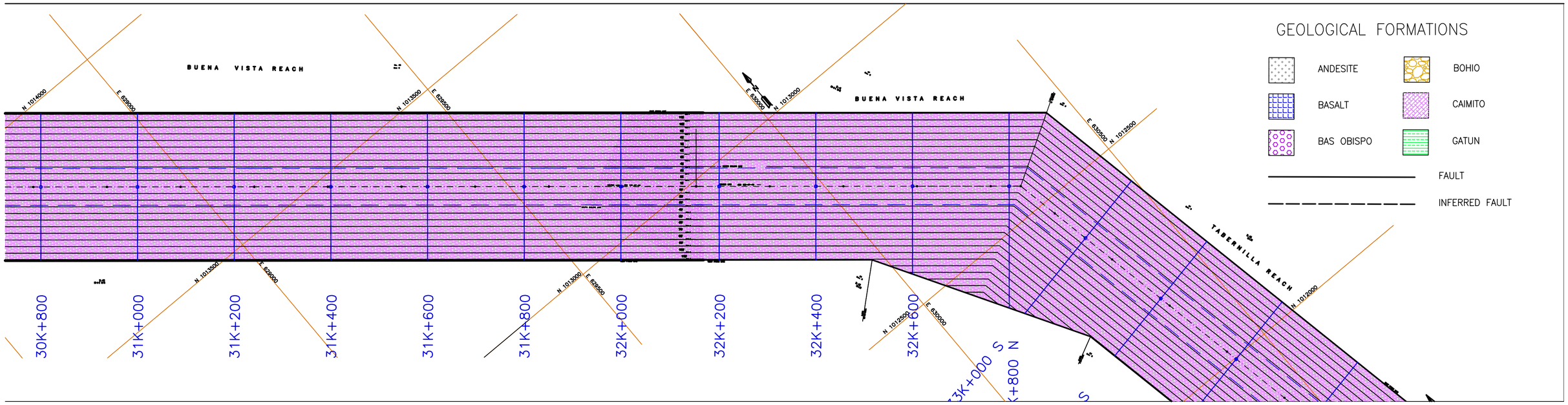
DATE: MARCH 2004

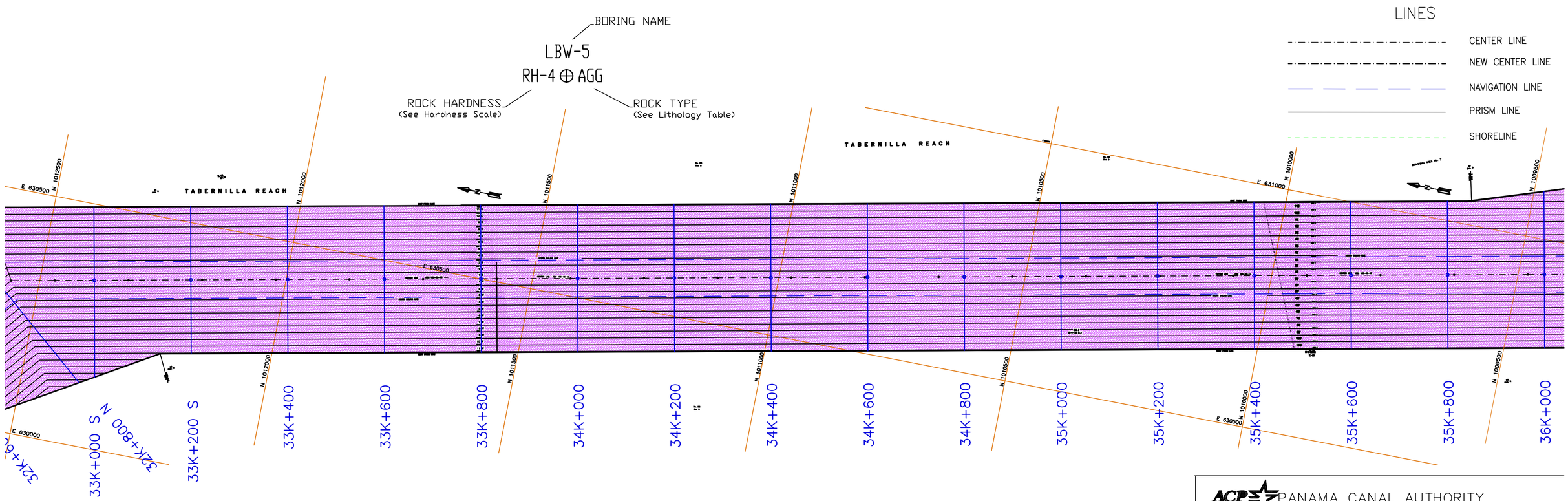
GEOLOGIST: J. RAMESCH

DRAWN BY: SURVEYS BRANCH J. RAMESCH (IPIG)

CHECKED BY: M. DE PUY, MANAGER, GEOTECHNICAL ENG.

APPROVED BY: LUIS D. ALFARO, MANAGER, ENGINEERING DIVISION




## HARDNESS SCALE

SOIL CONSISTENCY

| SYMBOL | SOIL CONSISTENCY | UNCONFINED COMPRESSIVE STRENGTH MPa |
|---|---|---|
| OC–1 | VERY LOW TO LOW | 0.00 – 0.025 |
| OC–2 | MEDIUM LOW | 0.025 – 0.050 |
| OC–3 | MEDIUM HIGH | 0.050 – 0.100 |
| OC–4 | HIGH | 0.100 – 0.200 |
| OC–5 | VERY HIGH | 0.200 – 0.400 |
| OC–5 a RH–1 | VERY HIGH CONSISTENCY TO SOFT ROCK | 0.400 – 1.000 |

ROCK HARDNESS

| SYMBOL | ROCK HARDNESS | UNCONFINED COMPRESSIVE STRENGTH MPa |
|---|---|---|
| RH–1 | SOFT | 1 – 25 |
| RH–2 | MEDIUM–SOFT | 25 – 50 |
| RH–3 | MEDIUM–HARD | 50 – 100 |
| RH–4 | HARD | 100 – 200 |
| RH–5 | VERY HARD | > 200 |

## LEGEND

### LITHOLOGY TABLE

AF = ASH FLOW
AGG = AGGLOMERATE
AGG,T = TUFFACEOUS AGGLOMERATE
ANDE = ANDESITE
BAS = BASALT
BBRE = BASALT BRECCIA
CL= CLAY
CLSH = CLAYSHALE
CONG = CONGLOMERATE
FG = FAULT GOUGE
FILL = FILL
FZ = FAULT ZONE
GVL = RIVER GRAVEL
W = WEATHERED ROCK
RS or RD = RIVER SEDIMENT
LS = LIMESTONE
LS = LIGNITIC SHALE
MCK = MUCK
NR = NO RECOVERY
OB = OVERBURDEN
SD = SAND
SH = SHALE
SLDB = SLIDE DEBRIS
SS = SANDSTONE
ST = SILTSTONE
T = TUFF
TAGG = AGGLOMERATIC TUFF

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ACP PANAMA CANAL AUTHORITY

ENGINEERING AND PROJECTS DEPARTMENT
ENGINEERING DIVISION
BALBOA HEIGHTS, REPUBLIC OF PANAMA

# CANAL EXPANSION PROJECT
# GATUN LAKE
## PLAN VIEW WITH GEOLOGY
### STA 30K+800 to STA 36K+000

SCALE: 1:3000
DATE: MARCH 2004

GEOLOGIST: J. RAMESCH
DRAWN BY: SURVEYS BRANCH J. RAMESCH (IPIG)

CHECKED BY: M. DE PUY, MANAGER, GEOTECHNICAL ENG.
APPROVED BY: LUIS D. ALFARO, MANAGER, ENGINEERING DIVISION

## GEOLOGICAL FORMATIONS

- ANDESITE
- BOHIO
- BASALT
- CAIMITO
- BAS OBISPO
- GATUN
- FAULT
- INFERRED FAULT

## LINES

- CENTER LINE
- NEW CENTER LINE
- NAVIGATION LINE
- PRISM LINE
- SHORELINE

## HARDNESS SCALE

SOIL CONSISTENCY

| SYMBOL | SOIL CONSISTENCY | UNCONFINED COMPRESSIVE STRENGTH MPa |
|---|---|---|
| OC–1 | VERY LOW TO LOW | 0.00 – 0.025 |
| OC–2 | MEDIUM LOW | 0.025 – 0.050 |
| OC–3 | MEDIUM HIGH | 0.050 – 0.100 |
| OC–4 | HIGH | 0.100 – 0.200 |
| OC–5 | VERY HIGH | 0.200 – 0.400 |
| OC–5 a RH–1 | VERY HIGH CONSISTENCY TO SOFT ROCK | 0.400 – 1.000 |

ROCK HARDNESS

| SYMBOL | ROCK HARDNESS | UNCONFINED COMPRESSIVE STRENGTH MPa |
|---|---|---|
| RH–1 | SOFT | 1 – 25 |
| RH–2 | MEDIUM–SOFT | 25 – 50 |
| RH–3 | MEDIUM–HARD | 50 – 100 |
| RH–4 | HARD | 100 – 200 |
| RH–5 | VERY HARD | > 200 |

BORING NAME

LBW-5

RH-4 ⊕ AGG

ROCK HARDNESS (See Hardness Scale)

ROCK TYPE (See Lithology Table)

## LEGEND

LITHOLOGY TABLE

| | |
|---|---|
| AF = ASH FLOW | RS or RD = RIVER SEDIMENT |
| AGG = AGGLOMERATE | LS = LIMESTONE |
| AGG,T = TUFFACEOUS AGGLOMERATE | LS = LIGNITIC SHALE |
| ANDE = ANDESITE | MCK = MUCK |
| BAS = BASALT | NR = NO RECOVERY |
| BBRE = BASALT BRECCIA | OB = OVERBURDEN |
| CL= CLAY | SD = SAND |
| CLSH = CLAYSHALE | SH = SHALE |
| CONG = CONGLOMERATE | SLDB = SLIDE DEBRIS |
| FG = FAULT GOUGE | SS = SANDSTONE |
| FILL = FILL | ST = SILTSTONE |
| FZ = FAULT ZONE | T = TUFF |
| GVL = RIVER GRAVEL | TAGG = AGGLOMERATIC TUFF |
| W = WEATHERED ROCK | |

Panamá 1903-2003 Centenario de la República

PANAMA CANAL AUTHORITY

ENGINEERING AND PROJECTS DEPARTMENT
ENGINEERING DIVISION
BALBOA HEIGHTS, REPUBLIC OF PANAMA

# CANAL EXPANSION PROJECT
# GATUN LAKE
## PLAN VIEW WITH GEOLOGY
### STA 63K+000 to STA 42K+400

SCALE: 1:3000

DATE: MARCH 2004

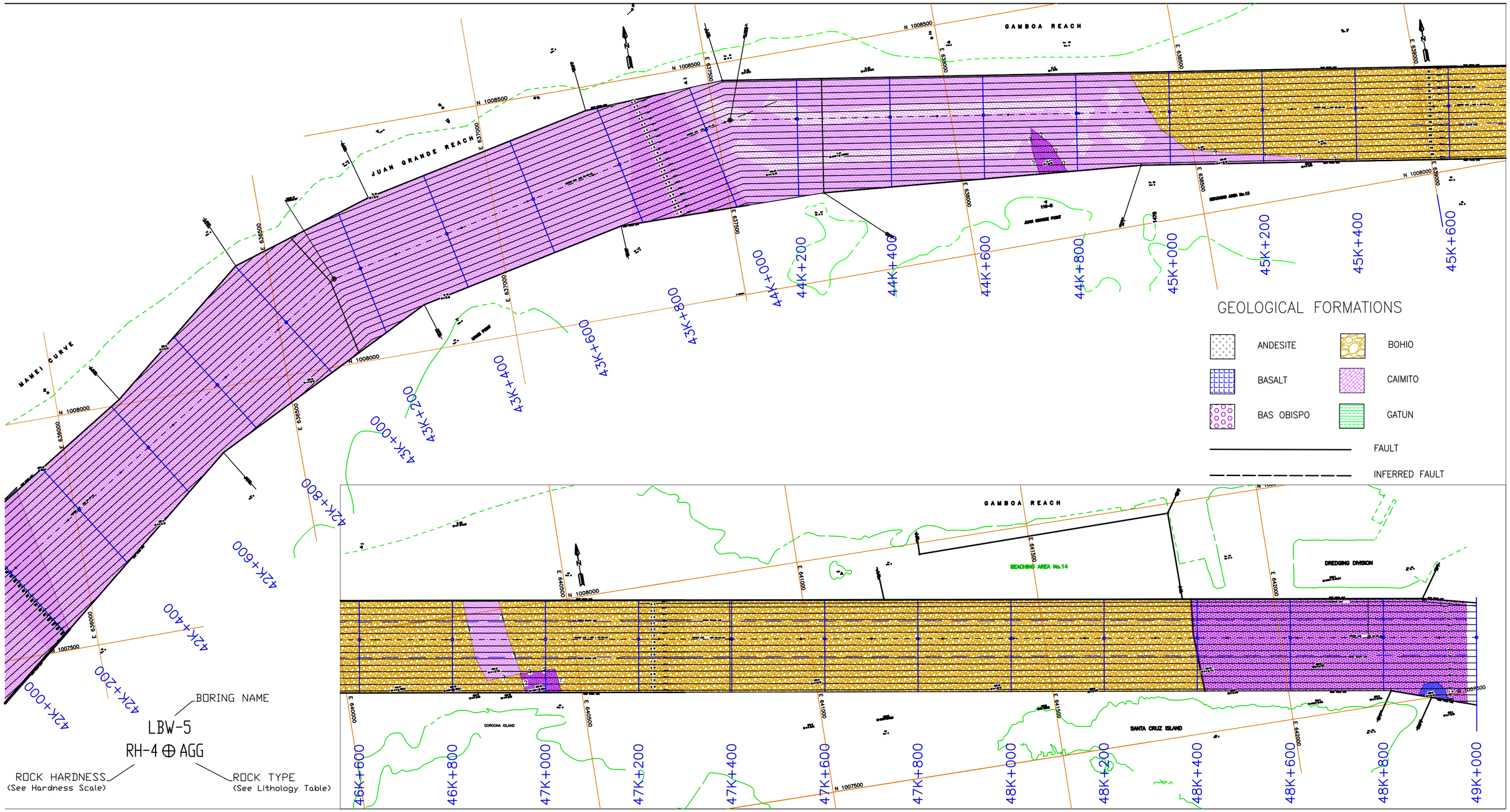
GEOLOGIST: J. RAMESCH

DRAWN BY: SURVEYS BRANCH J. RAMESCH (IPIG)

CHECKED BY: M. DE PUY, MANAGER, GEOTECHNICAL ENG.

APPROVED BY: LUIS D. ALFARO, MANAGER, ENGINEERING DIVISION

6123–116 SHEET 5 of 6




## HARDNESS SCALE

SOIL CONSISTENCY

| SYMBOL | SOIL CONSISTENCY | UNCONFINED COMPRESSIVE STRENGTH MPa |
|---|---|---|
| OC–1 | VERY LOW TO LOW | 0.00 – 0.025 |
| OC–2 | MEDIUM LOW | 0.025 – 0.050 |
| OC–3 | MEDIUM HIGH | 0.050 – 0.100 |
| OC–4 | HIGH | 0.100 – 0.200 |
| OC–5 | VERY HIGH | 0.200 – 0.400 |
| OC–5 a RH–1 | VERY HIGH CONSISTENCY TO SOFT ROCK | 0.400 – 1.000 |

ROCK HARDNESS

| SYMBOL | ROCK HARDNESS | UNCONFINED COMPRESSIVE STRENGTH MPa |
|---|---|---|
| RH–1 | SOFT | 1 – 25 |
| RH–2 | MEDIUM–SOFT | 25 – 50 |
| RH–3 | MEDIUM–HARD | 50 – 100 |
| RH–4 | HARD | 100 – 200 |
| RH–5 | VERY HARD | > 200 |

## LEGEND

### LITHOLOGY TABLE

AF = ASH FLOW
AGG = AGGLOMERATE
AGG,T = TUFFACEOUS AGGLOMERATE
ANDE = ANDESITE
BAS = BASALT
BBRE = BASALT BRECCIA
CL= CLAY
CLSH = CLAYSHALE
CONG = CONGLOMERATE
FG = FAULT GOUGE
FILL = FILL
FZ = FAULT ZONE
GVL = RIVER GRAVEL
W = WEATHERED ROCK
RS or RD = RIVER SEDIMENT
LS = LIMESTONE
LS = LIGNITIC SHALE
MCK = MUCK
NR = NO RECOVERY
OB = OVERBURDEN
SD = SAND
SH = SHALE
SLDB = SLIDE DEBRIS
SS = SANDSTONE
ST = SILTSTONE
T = TUFF
TAGG = AGGLOMERATIC TUFF

### LINES

CENTER LINE
NEW CENTER LINE
NAVIGATION LINE
PRISM LINE
SHORELINE

Panamá 1903-2003 Centenario de la República

6123–116

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ACP PANAMA CANAL AUTHORITY

ENGINEERING AND PROJECTS DEPARTMENT
ENGINEERING DIVISION
BALBOA HEIGHTS, REPUBLIC OF PANAMA

# CANAL EXPANSION PROJECT
# GATUN LAKE
## PLAN VIEW WITH GEOLOGY
### STA 42K+400 to STA 49K+000

SCALE: 1:3000

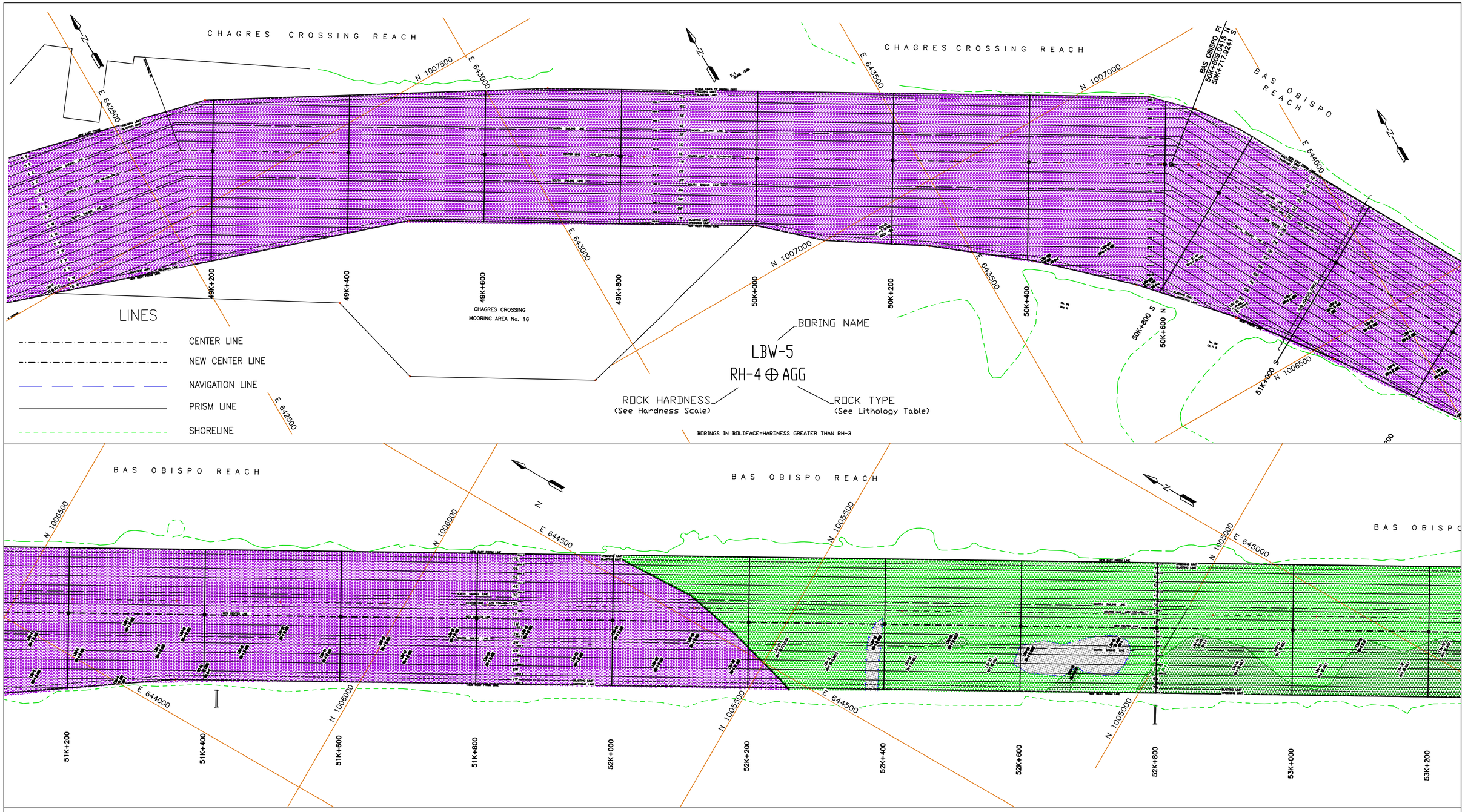
DATE: MARCH 2004

GEOLOGIST: J. RAMESCH

DRAWN BY: SURVEYS BRANCH J. RAMESCH (IPIG)

CHECKED BY: M. DE PUY, MANAGER, GEOTECHNICAL ENG.

APPROVED BY: LUIS D. ALFARO, MANAGER, ENGINEERING DIVISION




## HARDNESS SCALE

### SOIL CONSISTENCY

| SYMBOL | SOIL CONSISTENCY | UNCONFINED COMPRESSIVE STRENGTH MPa |
|---|---|---|
| OC-1 | VERY LOW TO LOW | 0.00 – 0.025 |
| OC-2 | MEDIUM LOW | 0.025 – 0.050 |
| OC-3 | MEDIUM HIGH | 0.050 – 0.100 |
| OC-4 | HIGH | 0.100 – 0.200 |
| OC-5 | VERY HIGH | 0.200 – 0.400 |
| OC-5 a RH-1 | VERY HIGH CONSISTENCY TO SOFT ROCK | 0.400 – 1.000 |

### ROCK HARDNESS

| SYMBOL | ROCK HARDNESS | UNCONFINED COMPRESSIVE STRENGTH MPa |
|---|---|---|
| RH-1 | SOFT | 1 – 25 |
| RH-2 | MEDIUM-SOFT | 25 – 50 |
| RH-3 | MEDIUM-HARD | 50 – 100 |
| RH-4 | HARD | 100 – 200 |
| RH-5 | VERY HARD | > 200 |

## LEGEND

### LITHOLOGY TABLE

AF = ASH FLOW
AGG = AGGLOMERATE
AGG,T = TUFFACEOUS AGGLOMERATE
ANDE = ANDESITE
BAS = BASALT
BBRE = BASALT BRECCIA
CL= CLAY
CLSH = CLAYSHALE
CONG = CONGLOMERATE
FG = FAULT GOUGE
FILL = FILL
FZ = FAULT ZONE
GVL = RIVER GRAVEL
W = WEATHERED ROCK
RS or RD = RIVER SEDIMENT
LS = LIMESTONE
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SD = SAND
SH = SHALE
SLDB = SLIDE DEBRIS
SS = SANDSTONE
ST = SILTSTONE
T = TUFF
TAGG = AGGLOMERATIC TUFF

### GEOLOGICAL FORMATIONS

ANDESITE
CULEBRA
BASALT
LA BOCA
BAS OBISPO
>RH-3
<RH-3
LAS CASCADAS
CUCARACHA
PEDRO MIGUEL
FAULT
INFERRED FAULT

6123-117 SHEET 1 of 4

PANAMA CANAL AUTHORITY

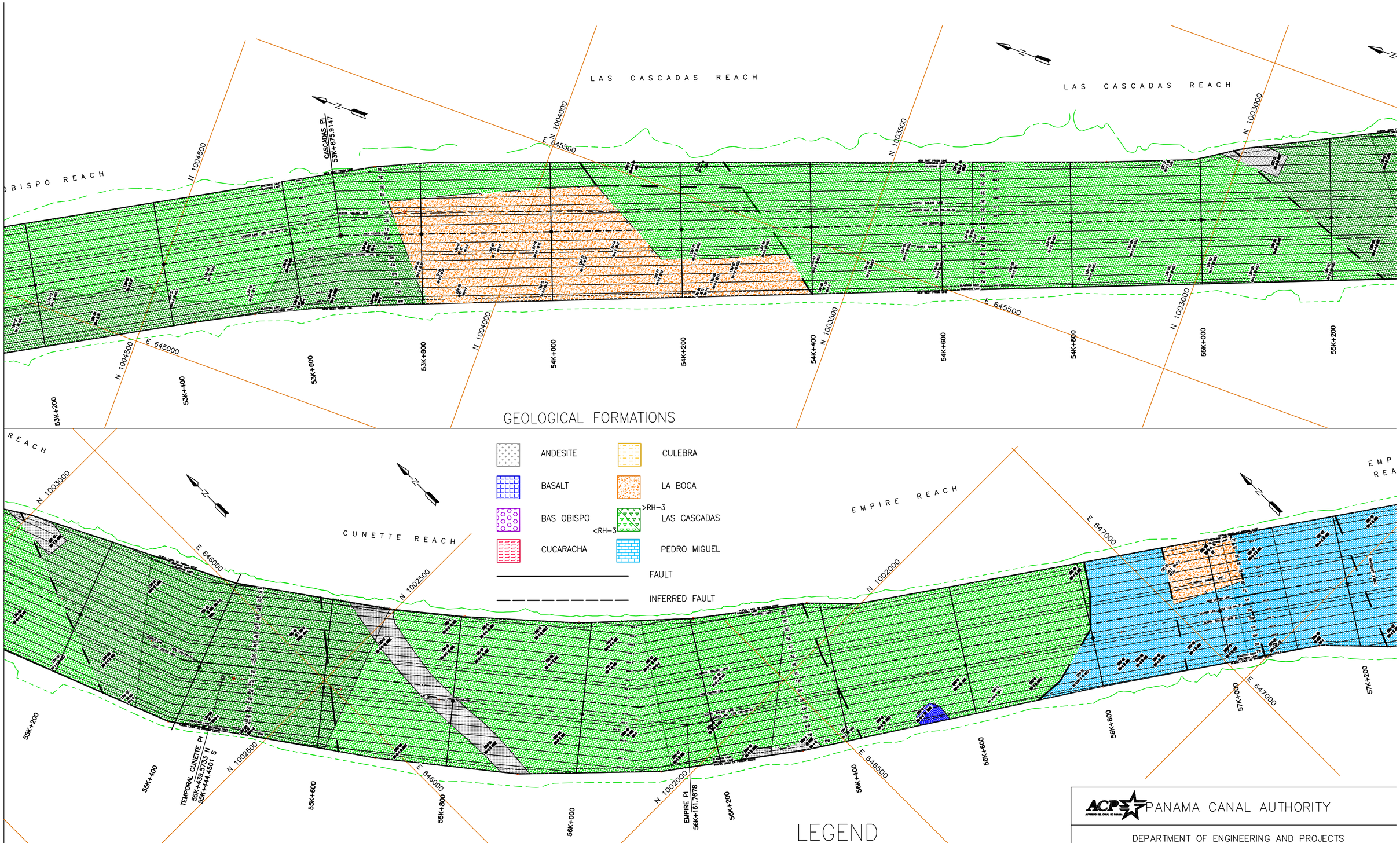
DEPARTMENT OF ENGINEERING AND PROJECTS
ENGINEERING DIVISION
BALBOA HEIGHTS, REPUBLIC OF PANAMA

# CANAL EXPANSION PROJECT
# GAILLARD CUT
## PLAN VIEW WITH GEOLOGY
### CHAGRES CROSSING – STA 53K+200

SCALE: 1:2000
DATE: MARCH 2004

GEOLOGIST: J. RAMESCH
DRAWN BY: SURVEYS BRANCH J. RAMESCH (IPIG)

CHECKED BY: M. DE PUY, MANAGER, GEOTECHNICAL ENG.
APPROVED BY: LUIS D. ALFARO, MANAGER, ENGINEERING DIVISION




# LEGEND

## HARDNESS SCALE

### SOIL CONSISTENCY

| SYMBOL | SOIL CONSISTENCY | UNCONFINED COMPRESSIVE STRENGTH MPa |
|---|---|---|
| OC-1 | VERY LOW TO LOW | 0.00 – 0.025 |
| OC-2 | MEDIUM LOW | 0.025 – 0.050 |
| OC-3 | MEDIUM HIGH | 0.050 – 0.100 |
| OC-4 | HIGH | 0.100 – 0.200 |
| OC-5 | VERY HIGH | 0.200 – 0.400 |
| OC-5 a RH-1 | VERY HIGH CONSISTENCY TO SOFT ROCK | 0.400 – 1.000 |

### ROCK HARDNESS

| SYMBOL | ROCK HARDNESS | UNCONFINED COMPRESSIVE STRENGTH MPa |
|---|---|---|
| RH-1 | SOFT | 1 – 25 |
| RH-2 | MEDIUM-SOFT | 25 – 50 |
| RH-3 | MEDIUM-HARD | 50 – 100 |
| RH-4 | HARD | 100 – 200 |
| RH-5 | VERY HARD | > 200 |

BORING NAME

LBW-5

RH-4 ⊕ AGG

ROCK HARDNESS (See Hardness Scale)

ROCK TYPE (See Lithology Table)

BORINGS IN BOLDFACE=HARDNESS GREATER THAN RH-3

## LINES

- CENTER LINE
- NEW CENTER LINE
- NAVIGATION LINE
- PRISM LINE
- SHORELINE

## LITHOLOGY TABLE

AF = ASH FLOW
AGG = AGGLOMERATE
AGG,T = TUFFACEOUS AGGLOMERATE
ANDE = ANDESITE
BAS = BASALT
BBRE = BASALT BRECCIA
CL= CLAY
CLSH = CLAYSHALE
CONG = CONGLOMERATE
FG = FAULT GOUGE
FILL = FILL
FZ = FAULT ZONE
GVL = RIVER GRAVEL
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LS = LIMESTONE
LS = LIGNITIC SHALE
MCK = MUCK
NR = NO RECOVERY
OB = OVERBURDEN
SD = SAND
SH = SHALE
SLDB = SLIDE DEBRIS
SS = SANDSTONE
ST = SILTSTONE
T = TUFF
TAGG = AGGLOMERATIC TUFF

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ACP PANAMA CANAL AUTHORITY

DEPARTMENT OF ENGINEERING AND PROJECTS
ENGINEERING DIVISION
BALBOA HEIGHTS, REPUBLIC OF PANAMA

# CANAL EXPANSION PROJECT
# GAILLARD CUT
## PLAN VIEW WITH GEOLOGY
### STA 53K+200 to 57K+200

SCALE: 1:2000

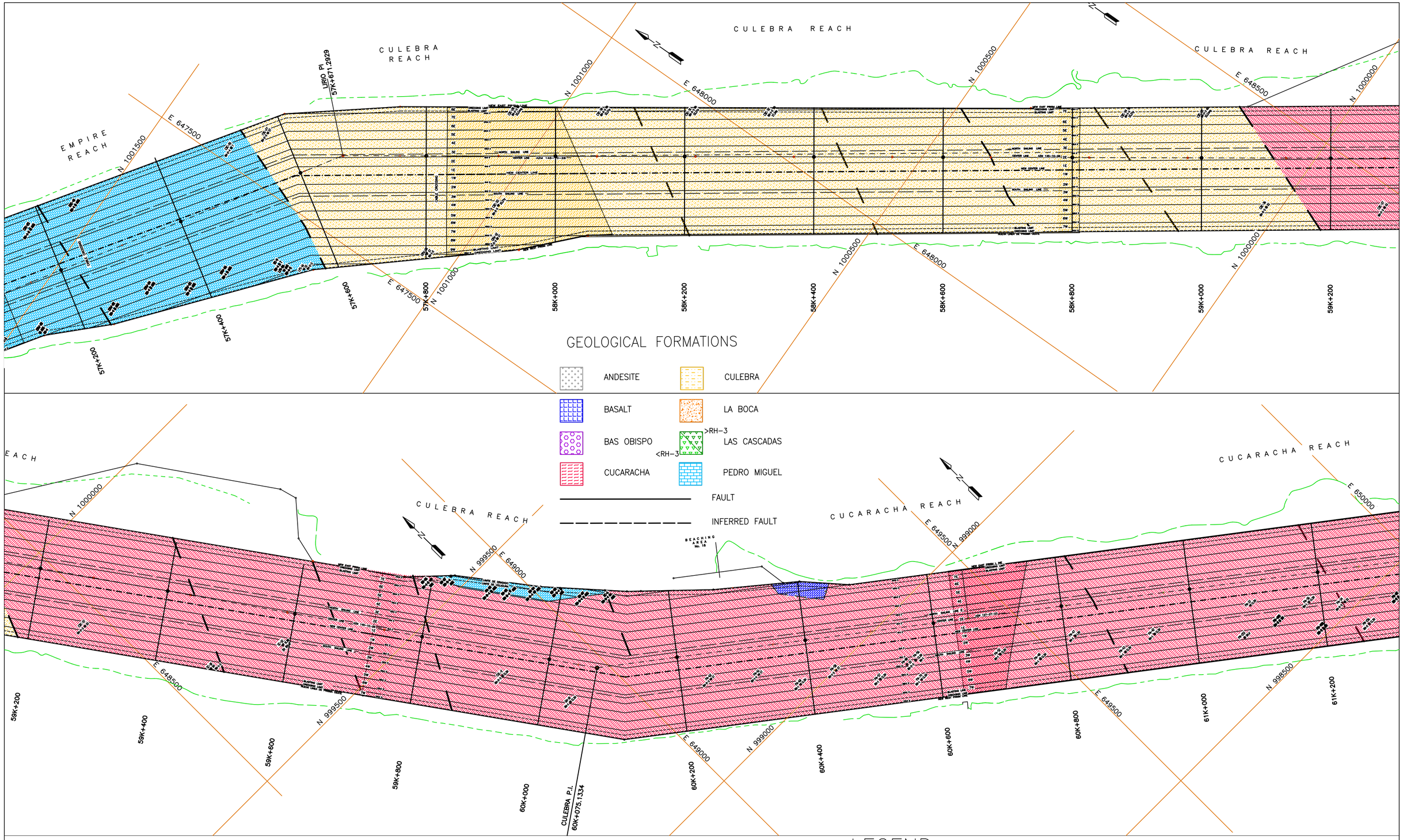
DATE: MARCH 2004

GEOLOGIST: J. RAMESCH

DRAWN BY: SURVEYS BRANCH J. RAMESCH (IPIG)

CHECKED BY: M. DE PUY, MANAGER, GEOTECHNICAL ENG.

APPROVED BY: LUIS D. ALFARO, MANAGER, ENGINEERING DIVISION




## GEOLOGICAL FORMATIONS

- ANDESITE
- CULEBRA
- BASALT
- LA BOCA
- BAS OBISPO
- LAS CASCADAS (>RH-3, <RH-3)
- CUCARACHA
- PEDRO MIGUEL
- FAULT
- INFERRED FAULT

## HARDNESS SCALE

### SOIL CONSISTENCY

| SYMBOL | SOIL CONSISTENCY | UNCONFINED COMPRESSIVE STRENGTH MPa |
|---|---|---|
| OC-1 | VERY LOW TO LOW | 0.00 – 0.025 |
| OC-2 | MEDIUM LOW | 0.025 – 0.050 |
| OC-3 | MEDIUM HIGH | 0.050 – 0.100 |
| OC-4 | HIGH | 0.100 – 0.200 |
| OC-5 | VERY HIGH | 0.200 – 0.400 |
| OC-5 a RH-1 | VERY HIGH CONSISTENCY TO SOFT ROCK | 0.400 – 1.000 |

### ROCK HARDNESS

| SYMBOL | ROCK HARDNESS | UNCONFINED COMPRESSIVE STRENGTH MPa |
|---|---|---|
| RH-1 | SOFT | 1 – 25 |
| RH-2 | MEDIUM-SOFT | 25 – 50 |
| RH-3 | MEDIUM-HARD | 50 – 100 |
| RH-4 | HARD | 100 – 200 |
| RH-5 | VERY HARD | > 200 |

BORING NAME

LBW-5

RH-4 ⊕ AGG

ROCK HARDNESS (See Hardness Scale) — ROCK TYPE (See Lithology Table)

BORINGS IN BOLDFACE=HARDNESS GREATER THAN RH-3

## LINES

- CENTER LINE
- NEW CENTER LINE
- NAVIGATION LINE
- PRISM LINE
- SHORELINE

## LEGEND

### LITHOLOGY TABLE

AF = ASH FLOW
AGG = AGGLOMERATE
AGG,T = TUFFACEOUS AGGLOMERATE
ANDE = ANDESITE
BAS = BASALT
BBRE = BASALT BRECCIA
CL= CLAY
CLSH = CLAYSHALE
CONG = CONGLOMERATE
FG = FAULT GOUGE
FILL = FILL
FZ = FAULT ZONE
GVL = RIVER GRAVEL
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NR = NO RECOVERY
OB = OVERBURDEN
SD = SAND
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SLDB = SLIDE DEBRIS
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Panamá 1903-2003 Centenario de la República

ACP PANAMA CANAL AUTHORITY

DEPARTMENT OF ENGINEERING AND PROJECTS
ENGINEERING DIVISION
BALBOA HEIGHTS, REPUBLIC OF PANAMA

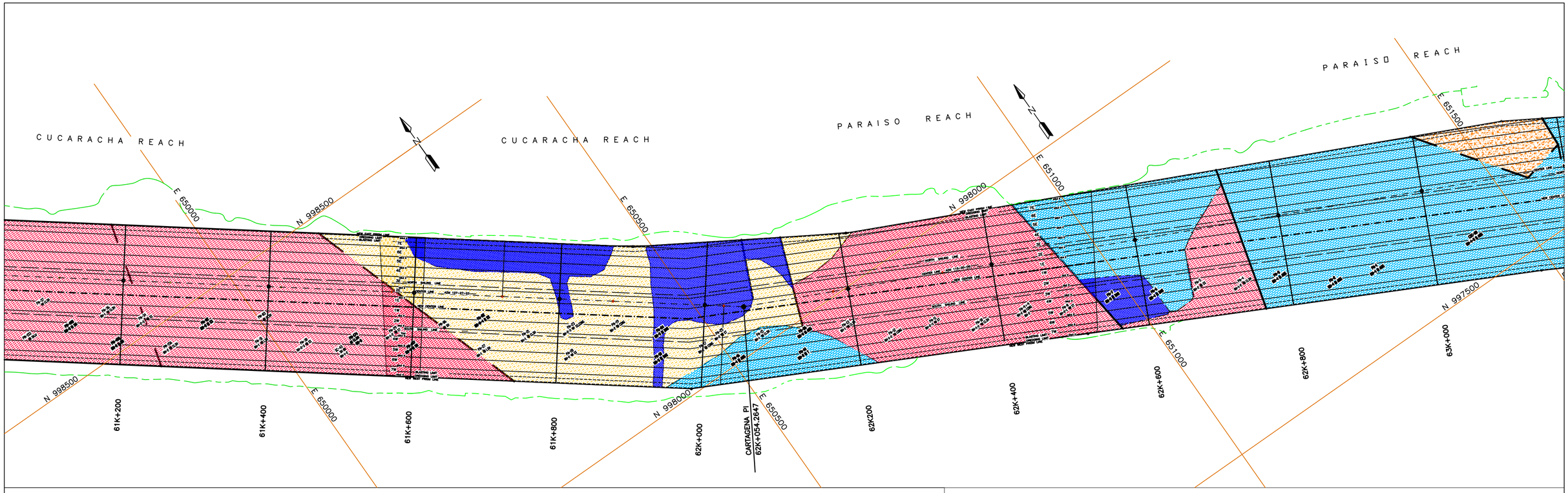
# CANAL EXPANSION PROJECT
# GAILLARD CUT
## PLAN VIEW WITH GEOLOGY
### 57K+200 to 61K+200

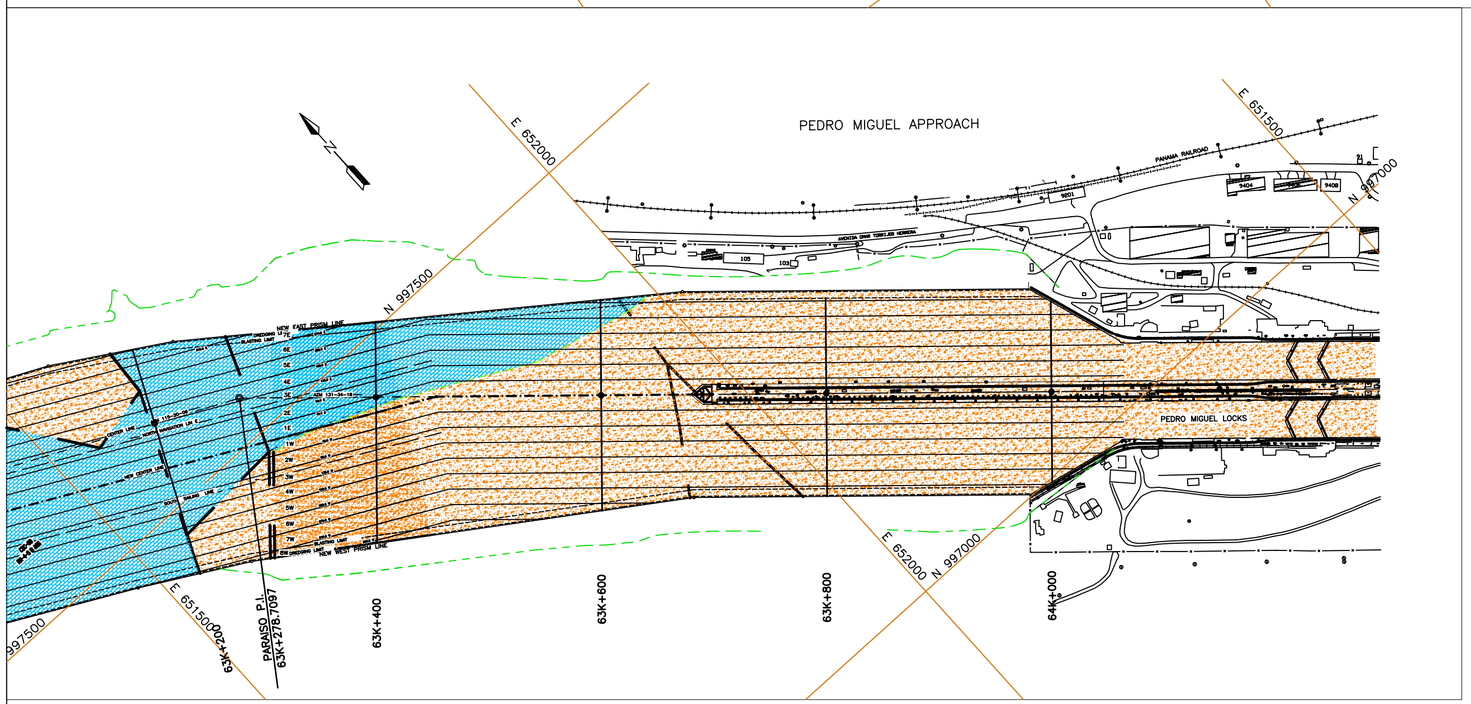
SCALE: 1:2000
DATE: MARCH 2004

GEOLOGIST: J. RAMESCH
DRAWN BY: SURVEYS BRANCH J. RAMESCH (IPIG)

CHECKED BY: M. DE PUY, MANAGER, GEOTECHNICAL ENG.
APPROVED BY: LUIS D. ALFARO, MANAGER, ENGINEERING DIVISION

6123-117 SHEET 3 of 4




# LEGEND

## LITHOLOGY TABLE

| | |
|---|---|
| AF = ASH FLOW | RS or RD = RIVER SEDIMENT |
| AGG = AGGLOMERATE | LS = LIMESTONE |
| AGG,T = TUFFACEOUS AGGLOMERATE | LS = LIGNITIC SHALE |
| ANDE = ANDESITE | MCK = MUCK |
| BAS = BASALT | NR = NO RECOVERY |
| BBRE = BASALT BRECCIA | OB = OVERBURDEN |
| CL= CLAY | SD = SAND |
| CLSH = CLAYSHALE | SH = SHALE |
| CONG = CONGLOMERATE | SLDB = SLIDE DEBRIS |
| FG = FAULT GOUGE | SS = SANDSTONE |
| FILL = FILL | ST = SILTSTONE |
| FZ = FAULT ZONE | T = TUFF |
| GVL = RIVER GRAVEL | TAGG = AGGLOMERATIC TUFF |
| W = WEATHERED ROCK | |

Panamá 1903-2003 Centenario de la República

## HARDNESS SCALE

SOIL CONSISTENCY

| SYMBOL | SOIL CONSISTENCY | UNCONFINED COMPRESSIVE STRENGTH MPa |
|---|---|---|
| OC-1 | VERY LOW TO LOW | 0.00 – 0.025 |
| OC-2 | MEDIUM LOW | 0.025 – 0.050 |
| OC-3 | MEDIUM HIGH | 0.050 – 0.100 |
| OC-4 | HIGH | 0.100 – 0.200 |
| OC-5 | VERY HIGH | 0.200 – 0.400 |
| OC-5 a RH-1 | VERY HIGH CONSISTENCY TO SOFT ROCK | 0.400 – 1.000 |

ROCK HARDNESS

| SYMBOL | ROCK HARDNESS | UNCONFINED COMPRESSIVE STRENGTH MPa |
|---|---|---|
| RH-1 | SOFT | 1 – 25 |
| RH-2 | MEDIUM-SOFT | 25 – 50 |
| RH-3 | MEDIUM-HARD | 50 – 100 |
| RH-4 | HARD | 100 – 200 |
| RH-5 | VERY HARD | > 200 |

## LINES

- CENTER LINE
- NEW CENTER LINE
- NAVIGATION LINE
- PRISM LINE
- SHORELINE

BORING NAME

LBW-5

RH-4 ⊕ AGG

ROCK HARDNESS (See Hardness Scale)

ROCK TYPE (See Lithology Table)

BORINGS IN BOLDFACE=HARDNESS GREATER THAN RH-3

## GEOLOGICAL FORMATIONS

- ANDESITE
- CULEBRA
- BASALT
- LA BOCA
- BAS OBISPO
- >RH-3 / <RH-3 LAS CASCADAS
- CUCARACHA
- PEDRO MIGUEL
- FAULT
- INFERRED FAULT

6123-117 SHEET 4 of 4

ACP PANAMA CANAL AUTHORITY

DEPARTMENT OF ENGINEERING AND PROJECTS
ENGINEERING DIVISION
BALBOA HEIGHTS, REPUBLIC OF PANAMA

# CANAL EXPANSION PROJECT
# GAILLARD CUT
## PLAN VIEW WITH GEOLOGY
### 61K+200 to PEDRO MIGUEL APPROACH

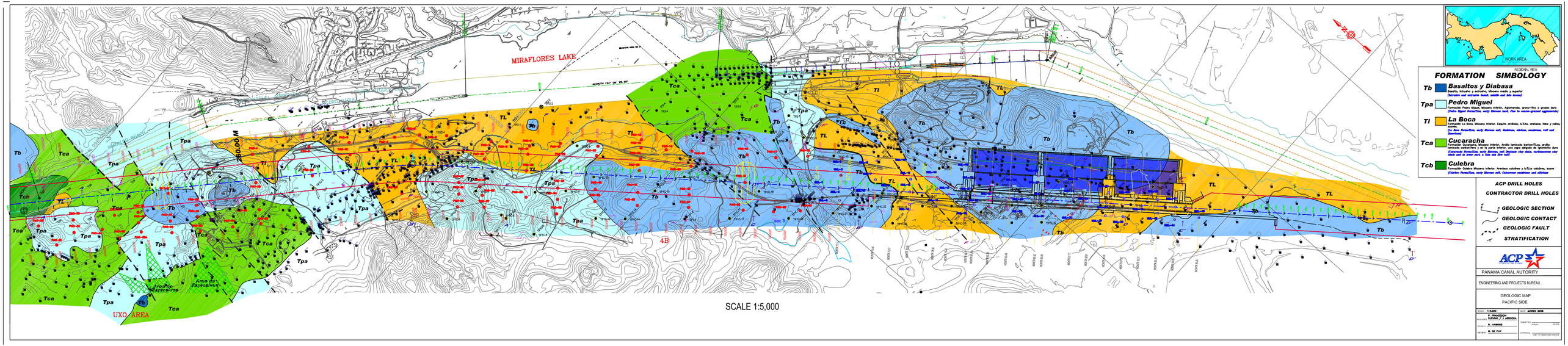
SCALE: 1:2000 | DATE: MARCH 2004

GEOLOGIST: J. RAMESCH

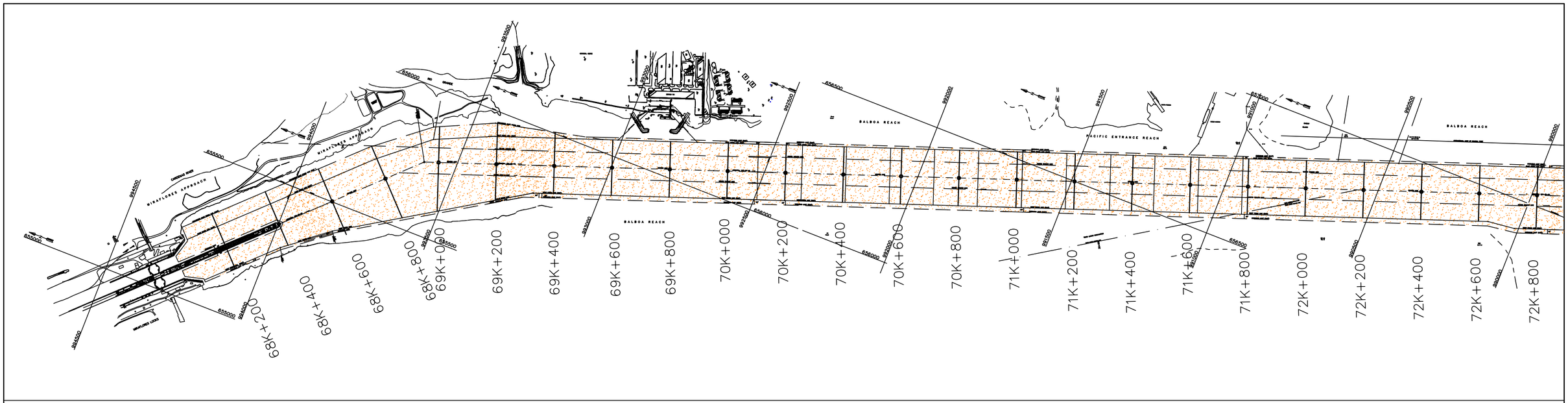
DRAWN BY: SURVEYS BRANCH J. RAMESCH (IPIG)

CHECKED BY: M. DE PUY, MANAGER, GEOTECHNICAL ENG.

APPROVED BY: LUIS D. ALFARO, MANAGER, ENGINEERING DIVISION


MIRAFLORES LAKE
UXO AREA
Area de Explosivos
Almacen de Explosivos
4B
SEC 3
Tb
Tpa
Tl
TL
Tca
Tch
WORK AREA
REGIONAL VIEW
FORMATION SIMBOLOGY
Tb Basaltos y Diabasa
Basalto, intrusivo y extrusivo, Mioceno medio y superior
(Intrusive and extrusive basalt, middle and late Miocene)
Tpa Pedro Miguel
Formación Pedro Miguel, Mioceno Inferior, Aglomerado, grano-fino a grueso duro.
(Pedro Miguel Formation, early Miocene hard, fine to coarse-grained agglomerate)
Tl La Boca
Formación La Boca, Mioceno Inferior. Depósito arcillosos, lutitas, areniscas, toba y yeso.
Formation
(La Boca Formation, early Miocene soft, Shales, siltstone, sandstone, tuff and limestone)
Tca Cucaracha
Formación Cucaracha, Mioceno Inferior. Arcilla laminada beige/TL/Lu, arcilla laminada azul/verde/TL/Lu y en la parte inferior, una capa delgada de lignitofita dura
(Cucaracha Formation, early Miocene, soft Laminate clay shale, carbonaceous clay shale and in lower part, a thin soft lint layer)
Tcb Culebra
Formación Culebra Mioceno Inferior. Arenisca calcárea y lutita calcárea, suave
(Culebra Formation, early Miocene soft, Calcareous sandstone and siltstone)
ACP DRILL HOLES
CONTRACTOR DRILL HOLES
GEOLOGIC SECTION
GEOLOGIC CONTACT
GEOLOGIC FAULT
STRATIFICATION
ACP
PANAMA CANAL AUTORITY
ENGINEERING AND PROJECTS BUREAU
GEOLOGIC MAP
PACIFIC SIDE
SCALE: 1:5,000
DATE: MARZO 2006
EXPLORER: P. FRANCESCHI / CURVINE / J. ARROCHA
DRAWER: R. HAMONG
REVIEW: M. DE PUY
SUBMITTED:
APPROVAL:

SCALE 1:5,000




## LINES

- CENTER LINE
- NEW CENTER LINE
- NAVIGATION LINE
- PRISM LINE
- SHORELINE

## GEOLOGICAL FORMATIONS

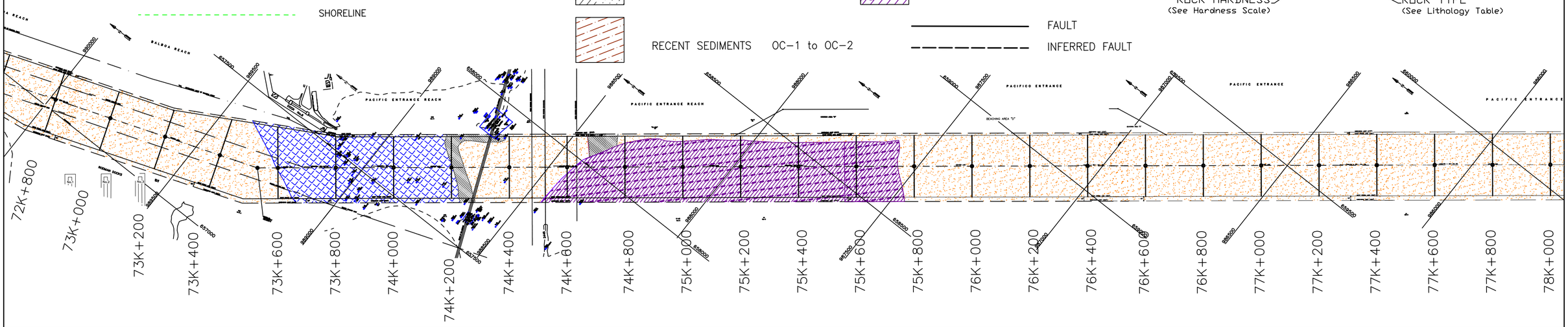
- BASALT RH-4 to RH-5
- DACITE RH-4 to RH-5
- RECENT SEDIMENTS OC-1 to OC-2
- LA BOCA FM { RH-2 to RH-3 / RH-3 to RH-5
- PANAMA FM { RH-2 to RH-3 / RH-3 to RH-5
- FAULT
- INFERRED FAULT

BORING NAME

LBW-5

RH-4 ⊕ AGG

ROCK HARDNESS (See Hardness Scale) — ROCK TYPE (See Lithology Table)




## HARDNESS SCALE

### SOIL CONSISTENCY

| SYMBOL | SOIL CONSISTENCY | UNCONFINED COMPRESSIVE STRENGTH MPa |
|---|---|---|
| OC-1 | VERY LOW TO LOW | 0.00 – 0.025 |
| OC-2 | MEDIUM LOW | 0.025 – 0.050 |
| OC-3 | MEDIUM HIGH | 0.050 – 0.100 |
| OC-4 | HIGH | 0.100 – 0.200 |
| OC-5 | VERY HIGH | 0.200 – 0.400 |
| OC-5 a RH-1 | VERY HIGH CONSISTENCY TO SOFT ROCK | 0.400 – 1.000 |

### ROCK HARDNESS

| SYMBOL | ROCK HARDNESS | UNCONFINED COMPRESSIVE STRENGTH MPa |
|---|---|---|
| RH-1 | SOFT | 1 – 25 |
| RH-2 | MEDIUM-SOFT | 25 – 50 |
| RH-3 | MEDIUM-HARD | 50 – 100 |
| RH-4 | HARD | 100 – 200 |
| RH-5 | VERY HARD | > 200 |

## LEGEND

### LITHOLOGY TABLE

AF = ASH FLOW
AGG = AGGLOMERATE
AGG,T = TUFFACEOUS AGGLOMERATE
ANDE = ANDESITE
BAS = BASALT
BBRE = BASALT BRECCIA
CL= CLAY
CLSH = CLAYSHALE
CONG = CONGLOMERATE
FG = FAULT GOUGE
FILL = FILL
FZ = FAULT ZONE
GVL = RIVER GRAVEL
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MCK = MUCK
NR = NO RECOVERY
OB = OVERBURDEN
SD = SAND
SH = SHALE
SLDB = SLIDE DEBRIS
SS = SANDSTONE
ST = SILTSTONE
T = TUFF
TAGG = AGGLOMERATIC TUFF

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ACP PANAMA CANAL AUTHORITY

ENGINEERING AND PROJECTS DEPARTMENT
ENGINEERING DIVISION
BALBOA HEIGHTS, REPUBLIC OF PANAMA

# CANAL EXPANSION PROJECT
# PACIFIC ENTRANCE
## PLAN VIEW WITH GEOLOGY
### MIRAFLORES LOCKS to STA 78K+000

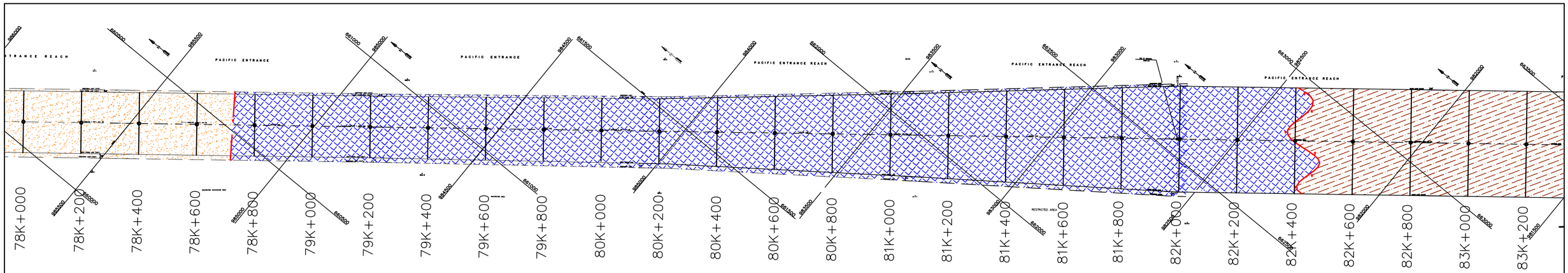
SCALE: 1:5000 — DATE: JUNE 2002

GEOLOGIST: J. RAMESCH

DRAWN BY: SURVEYS BRANCH J. RAMESCH (IPIG)

CHECKED BY: M. DE PUY, MANAGER, GEOTECHNICAL ENG.

APPROVED BY: LUIS D. ALFARO, MANAGER, ENGINEERING DIVISION




## LINES

- CENTER LINE
- NEW CENTER LINE
- NAVIGATION LINE
- PRISM LINE
- SHORELINE

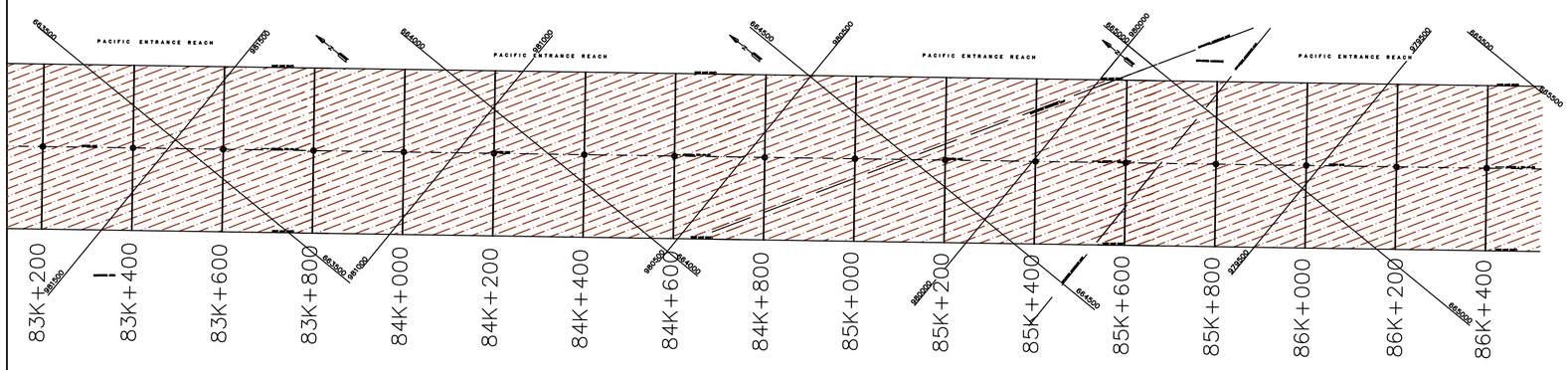
BORING NAME

LBW-5

RH-4 ⊕ AGG

ROCK HARDNESS (See Hardness Scale)

ROCK TYPE (See Lithology Table)




## GEOLOGICAL FORMATIONS

- LA BOCA FM { RH-2 to RH-3 / RH-3 to RH-5
- PANAMA FM { RH-2 to RH-3 / RH-3 to RH-5
- BASALT RH-4 to RH-5
- DACITE RH-4 to RH-5
- RECENT SEDIMENTS OC-1 to OC-2
- FAULT
- INFERRED FAULT

## HARDNESS SCALE

### SOIL CONSISTENCY

| SYMBOL | SOIL CONSISTENCY | UNCONFINED COMPRESSIVE STRENGTH MPa |
|---|---|---|
| OC-1 | VERY LOW TO LOW | 0.00 – 0.025 |
| OC-2 | MEDIUM LOW | 0.025 – 0.050 |
| OC-3 | MEDIUM HIGH | 0.050 – 0.100 |
| OC-4 | HIGH | 0.100 – 0.200 |
| OC-5 | VERY HIGH | 0.200 – 0.400 |
| OC-5 a RH-1 | VERY HIGH CONSISTENCY TO SOFT ROCK | 0.400 – 1.000 |

### ROCK HARDNESS

| SYMBOL | ROCK HARDNESS | UNCONFINED COMPRESSIVE STRENGTH MPa |
|---|---|---|
| RH-1 | SOFT | 1 – 25 |
| RH-2 | MEDIUM-SOFT | 25 – 50 |
| RH-3 | MEDIUM-HARD | 50 – 100 |
| RH-4 | HARD | 100 – 200 |
| RH-5 | VERY HARD | > 200 |

## LEGEND

### LITHOLOGY TABLE

AF = ASH FLOW
AGG = AGGLOMERATE
AGG,T = TUFFACEOUS AGGLOMERATE
ANDE = ANDESITE
BAS = BASALT
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CONG = CONGLOMERATE
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FILL = FILL
FZ = FAULT ZONE
GVL = RIVER GRAVEL
W = WEATHERED ROCK
RS or RD = RIVER SEDIMENT
LS = LIMESTONE
LS = LIGNITIC SHALE
MCK = MUCK
NR = NO RECOVERY
OB = OVERBURDEN
SD = SAND
SH = SHALE
SLDB = SLIDE DEBRIS
SS = SANDSTONE
ST = SILTSTONE
T = TUFF
TAGG = AGGLOMERATIC TUFF

Panamá 1903-2003 Centenario de la República

6123-119

SHEET 2 of 2

ACP PANAMA CANAL AUTHORITY

ENGINEERING AND PROJECTS DEPARTMENT
ENGINEERING DIVISION
BALBOA HEIGHTS, REPUBLIC OF PANAMA

# CANAL EXPANSION PROJECT
# PACIFIC ENTRANCE
## PLAN VIEW WITH GEOLOGY
### STA 77K+000 to STA 86K+400

SCALE: 1:5000

DATE: JUNE 2002

GEOLOGIST: J. RAMESCH

DRAWN BY: SURVEYS BRANCH J. RAMESCH (IPIG)

CHECKED BY: M. DE PUY, MANAGER, GEOTECHNICAL ENG.

APPROVED BY: LUIS D. ALFARO, MANAGER, ENGINEERING DIVISION

# ATLANTIC ENTRANCE DEPENING AND NEW LOCKS DISPOSAL SITES

Panamá 1903-2003 Centenario de la República

Capacidad del Canal

ANCLAJE ATLANTICO
ROMPEOLA OESTE
ROMPEOLA ESTE
ENTRADA ATLANTICA (152.40 MT)
ANCLAJE EXPLOSIVOS
ANCLAJE AREA "A"
ANCLAJE AREA "D"
ANCLAJE AREA "B"
DRAGADO LIMITE
ANCLAJE AREA "C"
CRISTOBAL HARBOR BEACHING AREA
AREA "F"
FAN DUMPING
BAHIA DE LIMON
ISLA TELFERS
GATUN LAKE
ISLA MARGARITA
COCO SOLO
BAHIA DE MANZANILLO
COLON
ZONA LIBRE DE COLON
CRISTOBAL
FOLK RIVER
3er Juego de Esclusas Alternativa A-1
3er Juego de Esclusas Alternativa A-2
2.0 Kms.
2.7 Kms.
1.6 Kms.

## DESIGNATED DISPOSAL SITES AT THE ATLANTIC ENTRANCE

- Marine Sites
- Terrestrial Sites
- New terrestrial sites

(1) West Breakwater (1,253,314 $m^2$)
(2) East Breakwater (872,087 $m^2$)
(3) Davis (321,976 m )
(4) South Limon Bay (1,664,774 $m^2$)
(5) 1939 Third Set Locks (232,115 $m^2$)
(6) French Canal Excavation (135,805 $m^2$)
(7) Telfers Island (2,106,425 $m^2$)
(8) Davis (58,398 $m^2$)
(9) Sherman (6,739,069 $m^2$)
(10) Mt. Hope (774,058 $m^2$)
(11) Mindi (438,824 $m^2$)

# ATLANTIC ENTRANCE

Panamá 1903-2003 Centenario de la República

Capacidad del Canal

ANCLAJE ATLANTICO

(1) V=8.2 Mm3

(2) V=0.4 Mm3

(3) V=0.79 Mm3
V=9.4 Mm3

(4) V=4.32 Mm3

2.37 Kms.

4.47 Kms.

2.7 Kms.

0.8 Kms.

ROMPEOLA ESTE

ANCLAJE EXPLOSIVOS

ANCLAJE AREA "A"

ANCLAJE AREA "B"

ANCLAJE AREA "C"

ANCLAJE AREA "D"

AREA "F"

CRISTOBAL HARBOR BEACHING AREA

ISLA MARGARITA

COCO SOLO

BAHIA DE MANZANILLO

COLON

ZONA LIBRE DE COLON

CRISTOBAL

FOLK RIVER

BAHIA DE LIMON

ISLA TELFERS

GATUN LAKE

New locks approach channel final grade design elevation -15.66 m PLD

Proposed new locks location

Existing ground elevation +20m PLD

## PROPOSED DISPOSAL SITES

Aquatic

On Land

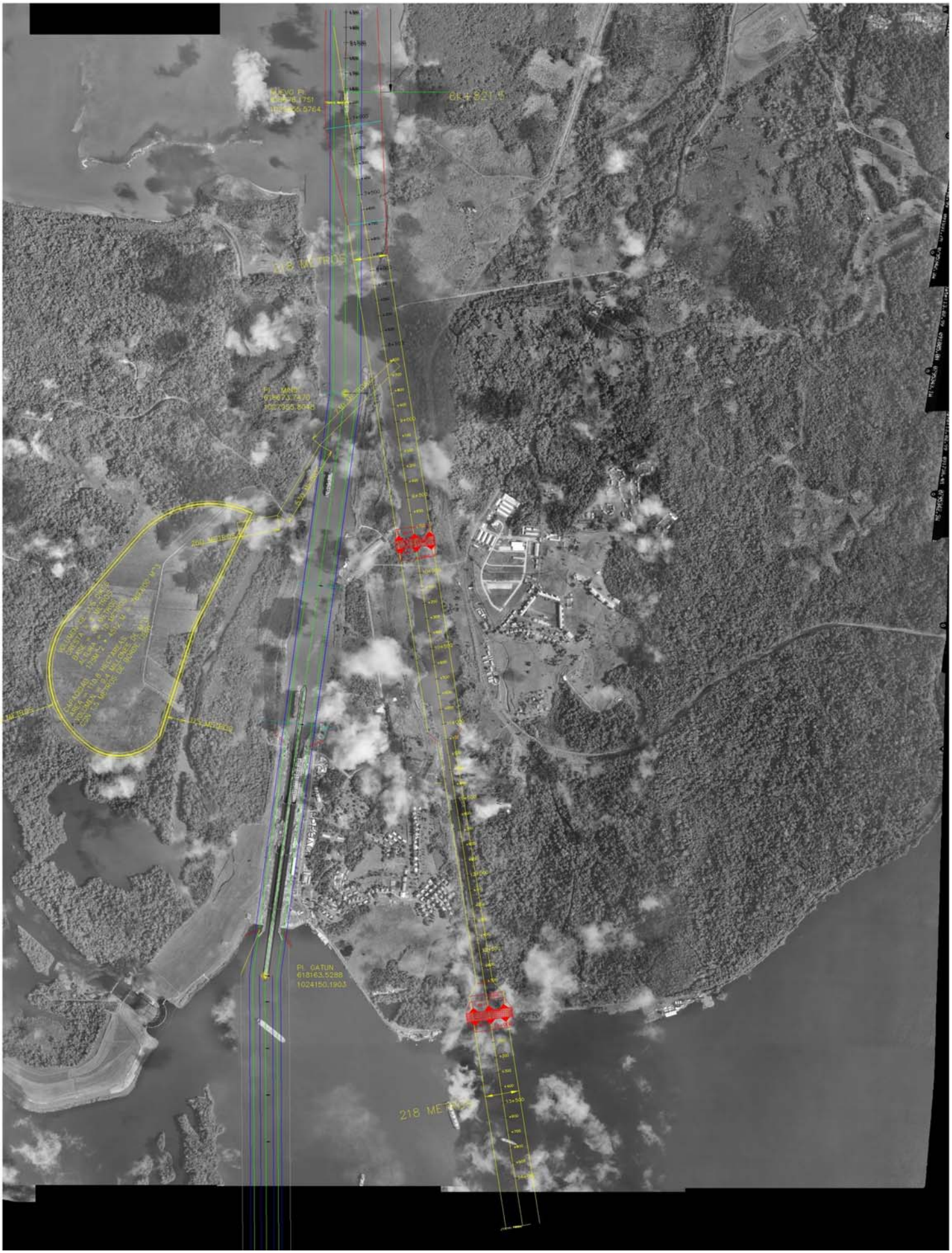
(1) West Breakwater

(2) South Limon Bay

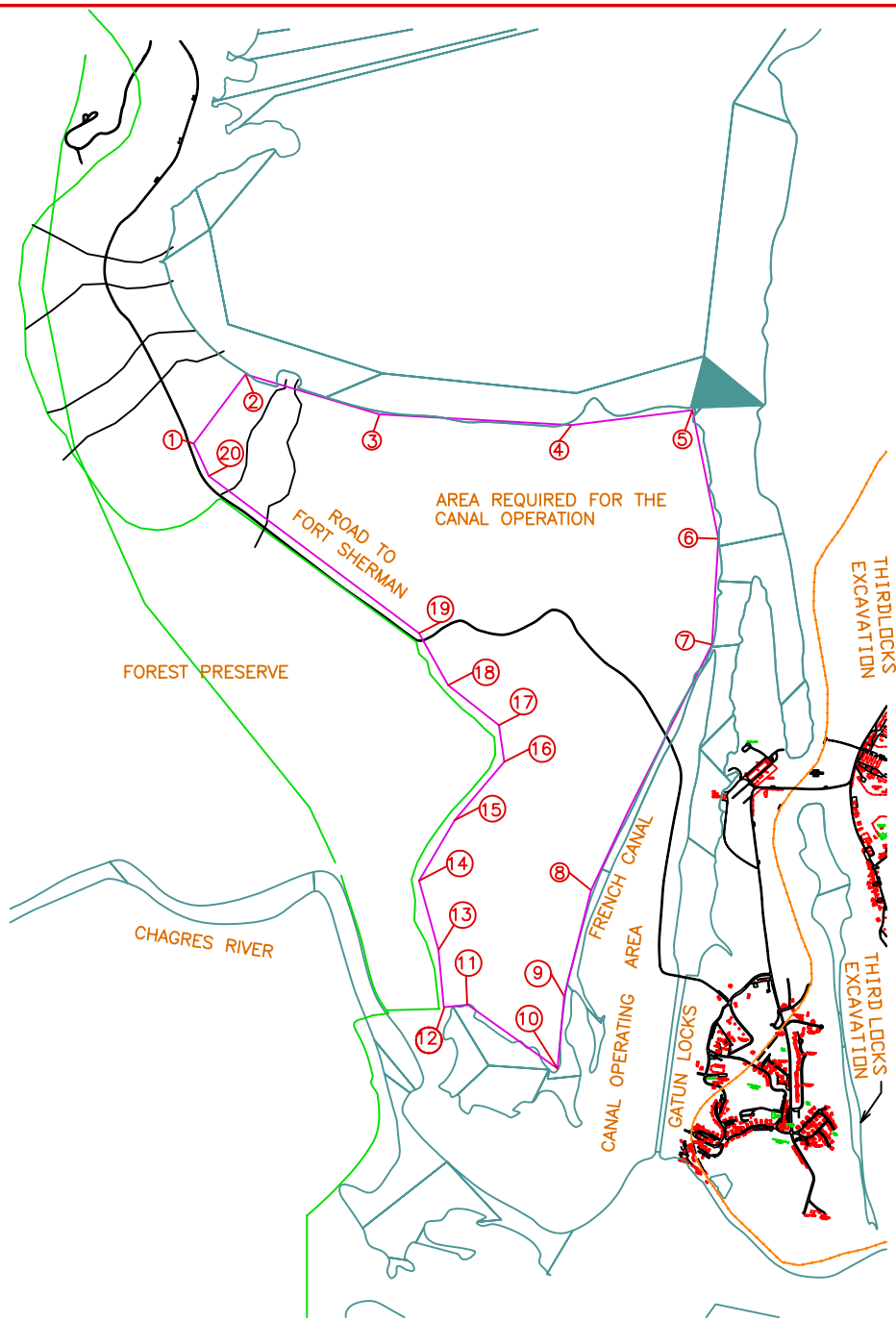
(3) Sherman

(4) Fan dumping

Y:\SHRE IPC FILES\IMFORMATION FOR DREDGING COMPANIES\DISPOSAL SITES\ATLANTIC ENTRANCE Y2 .DWG


NUEVO P.
6K+821.5
PI MAD
618673.7470
1021990.8048
200 METROS
PI GATUN
618163.5288
1024150.1903
218 METROS

# Fort Sherman




| POINT | EASTING | NORTHING |
|---|---|---|
| 1 | 615261.646 | 1029016.781 |
| 2 | 615591.488 | 1029456.905 |
| 3 | 616443.582 | 1029202.458 |
| 4 | 617666.070 | 1029133.932 |
| 5 | 618435.743 | 1029229.527 |
| 6 | 618600.664 | 1028411.171 |
| 7 | 618559.434 | 1027737.231 |
| 8 | 617790.562 | 1026173.882 |
| 9 | 617618.769 | 1025499.942 |
| 10 | 617577.539 | 1025039.188 |
| 11 | 617002.822 | 1025446.75 |
| 12 | 616854.001 | 1025429.883 |
| 13 | 616819.643 | 1025794.361 |
| 14 | 616695.952 | 1026234.485 |
| 15 | 616922.718 | 1026619.594 |
| 16 | 617238.818 | 1026990.948 |
| 17 | 617204.459 | 1027224.764 |
| 18 | 616881.488 | 1027479.211 |
| 19 | 616695.952 | 1027809.304 |
| 20 | 615357.850 | 1028810.473 |
| 1 | 615261.646 | 1029016.781 |

TOTAL AREA = 665.12 HECT.

NEW AREA REQUIRED TO ASSURE ADEQUATE CHANNEL CONDITIONS FOR NAVIGATION

DATE: MAY 26, 1999

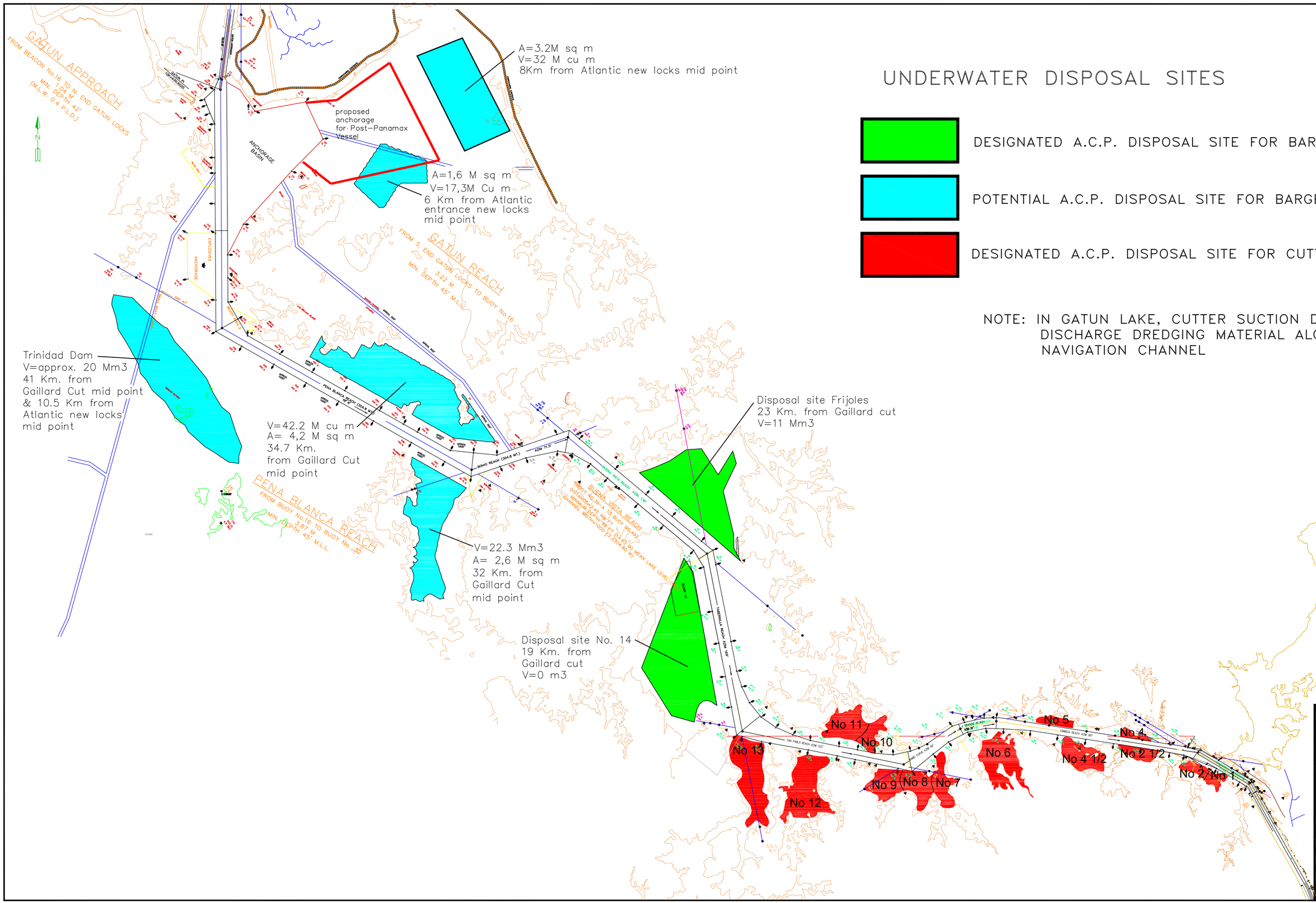
# UNDERWATER DISPOSAL SITES

DESIGNATED A.C.P. DISPOSAL SITE FOR BARGES DISPOSAL

POTENTIAL A.C.P. DISPOSAL SITE FOR BARGES DISPOSAL

DESIGNATED A.C.P. DISPOSAL SITE FOR CUTTER SUCTION DREDGES

NOTE: IN GATUN LAKE, CUTTER SUCTION DREDGES DISCHARGE DREDGING MATERIAL ALONG NAVIGATION CHANNEL



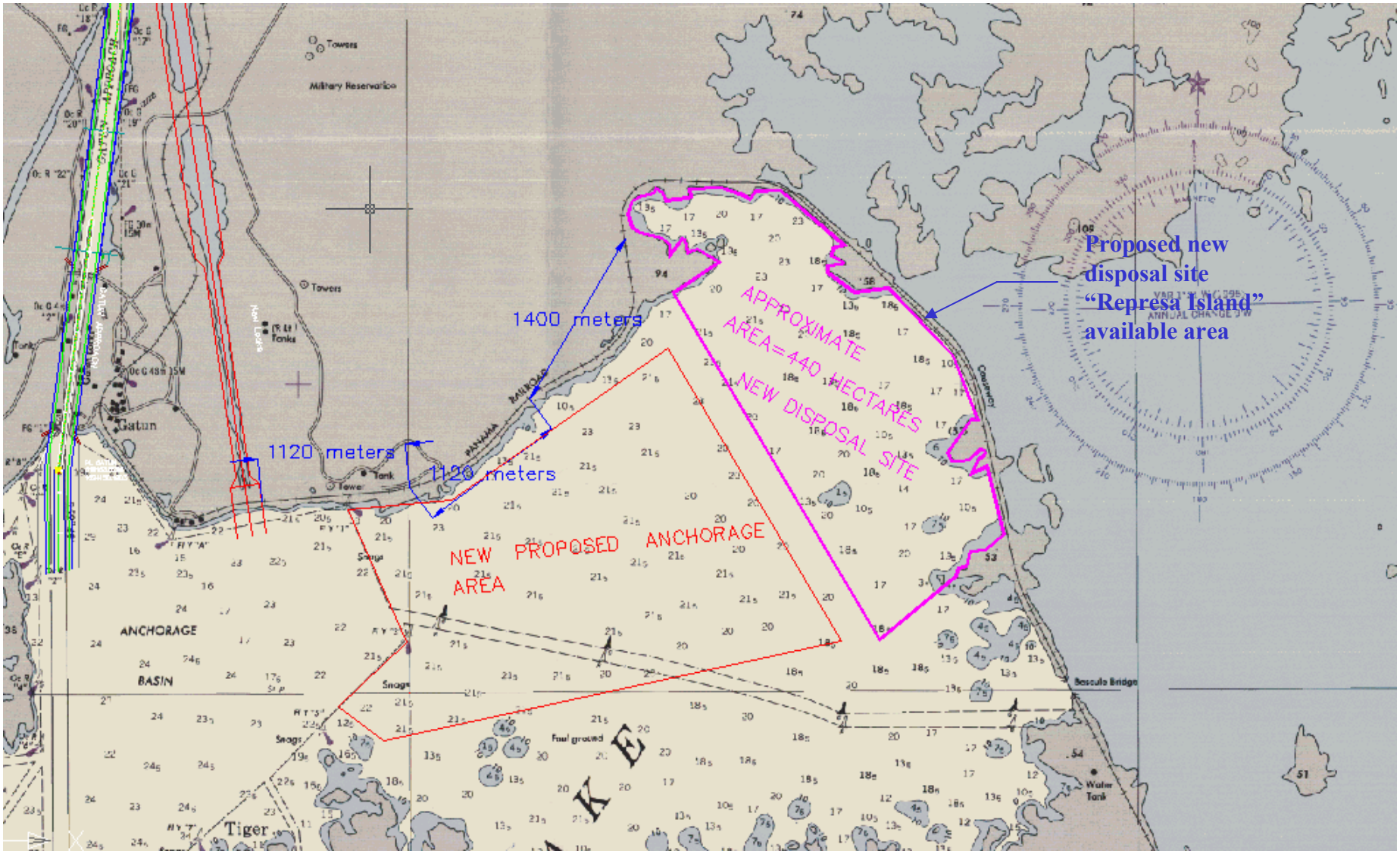

PANAMA CANAL AUTHORITY

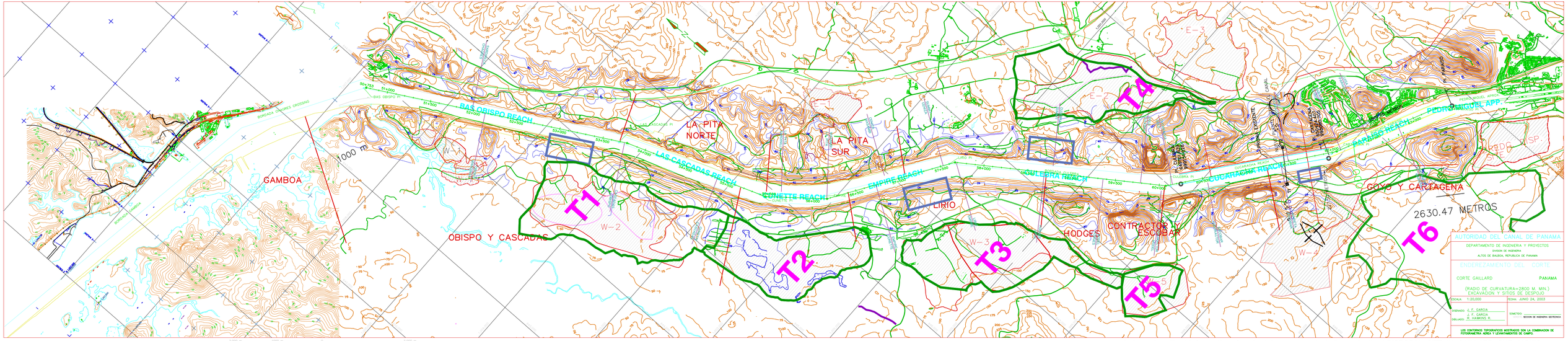
DEPARTMENT OF ENGINIEERING & PROJECTS
INGENIEERING DIVISION
BALBOA HIGHTS, REPUBLIC OF PANAMA

## GATUN LAKE DISPOSAL SITE

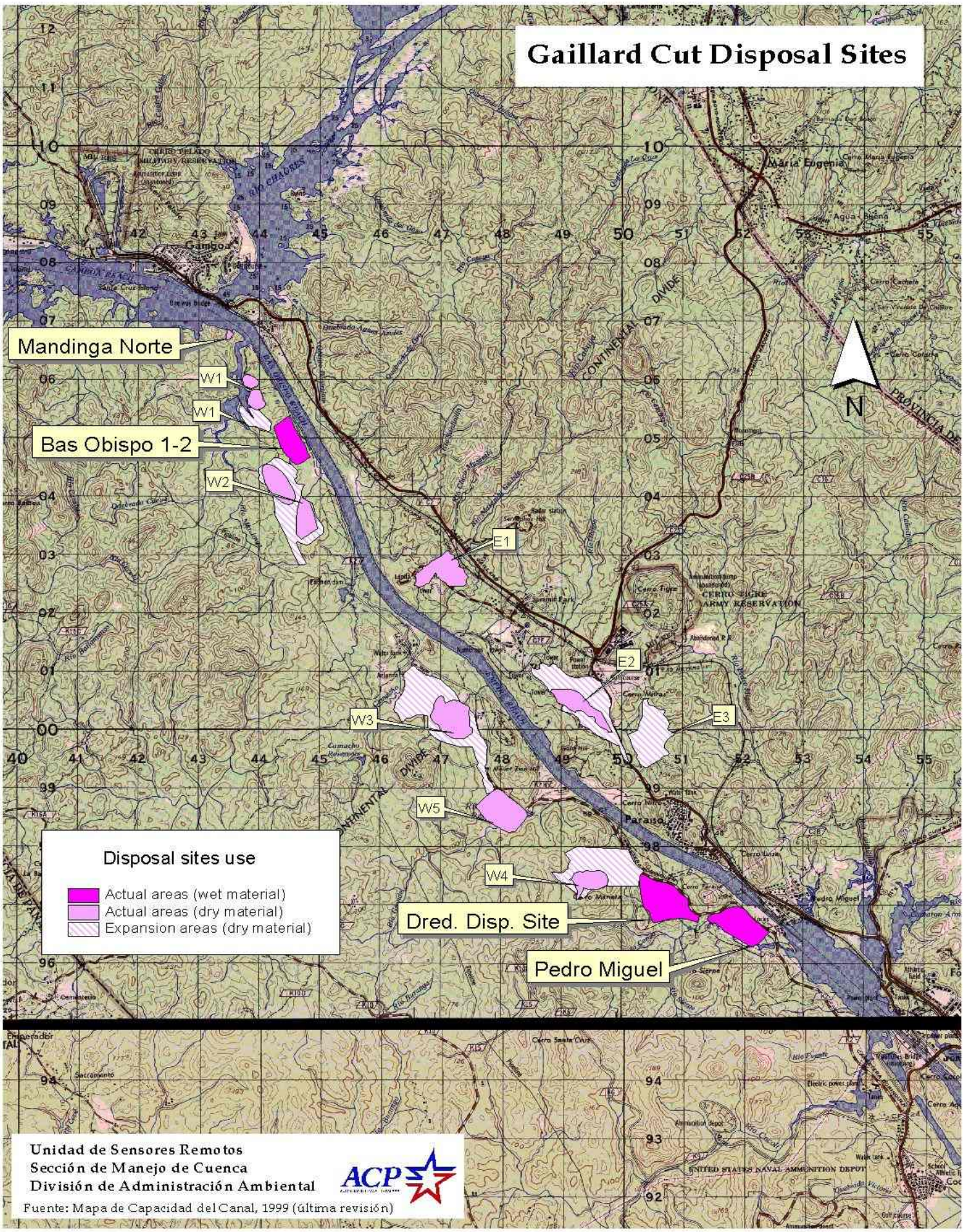
| | |
|---|---|
| SCALE: HOR. 1:50,000 MT | DATE: JANUARY 03, 2001 |
| SUBMITED BY: | CHEKED BY: TOPHOGRAFY MANAGER AND SURVEY |
| DRAWN BY: UNIDAD DE CARTOGRAFIA | |
| VERIFIED BY: UNIT SUPERVISOR | APPROVAL: CHIEF, INGENIERING DIVISION |
| VERIFIED BY: UNIT SUPERVISOR | |

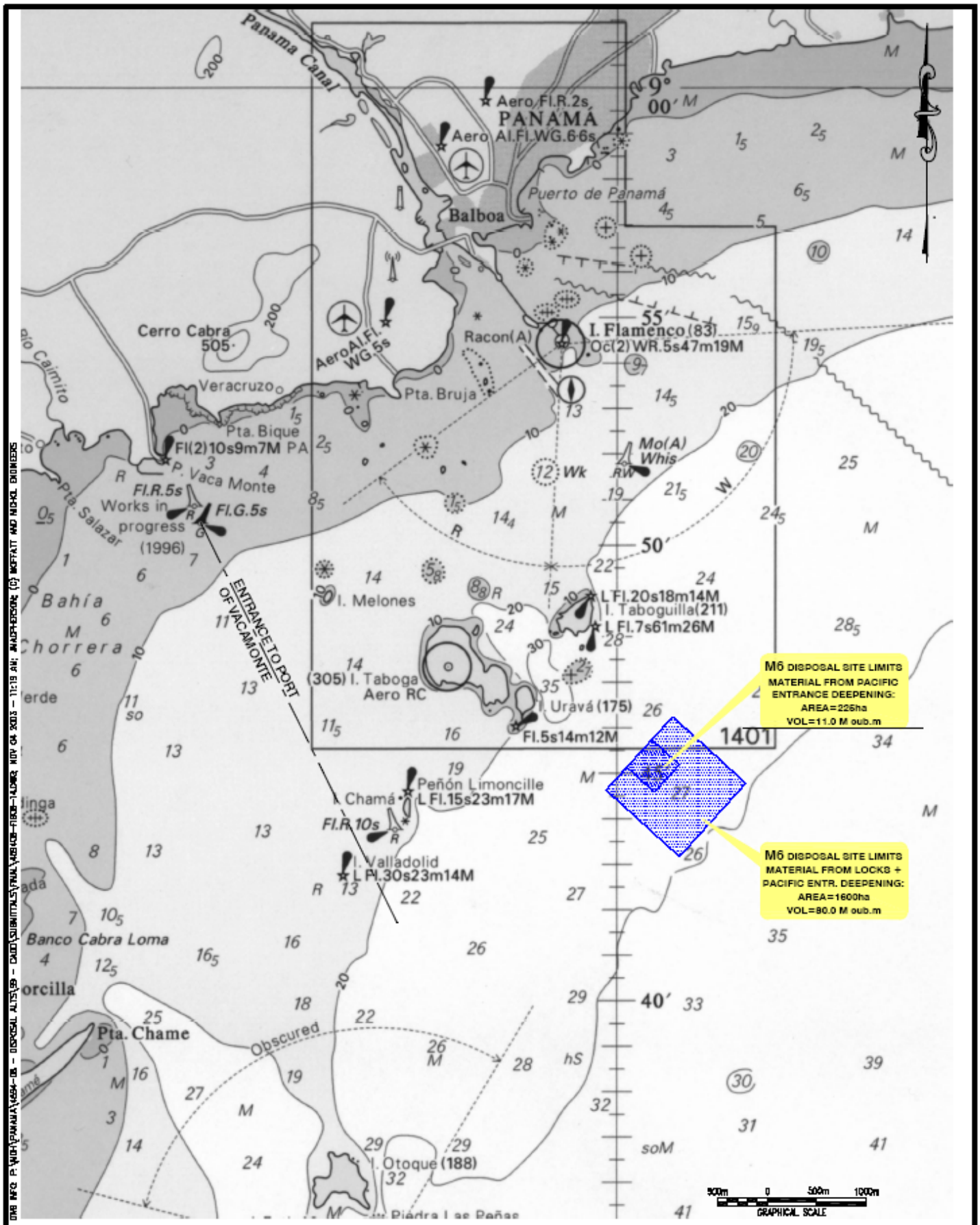
Y:\SHARED IPC FILES\INFORMATION FOR DREDGING COMPANIES\DISPOSAL SITES\DISPOSAL SITE IN GATUN LAKE-Y.DWG


Proposed new disposal site "Represa Island" available area
APPROXIMATE AREA=440 HECTARES NEW DISPOSAL SITE
NEW PROPOSED ANCHORAGE AREA
1400 meters
1120 meters
1120 meters
Military Reservoirs
Towers
Gatun
ANCHORAGE
BASIN
Tiger
Bascule Bridge
Water Tank
Fuel grouted
Snags
Tank
Tower
Fenks
PANAMA RAILROAD
Causeway
ANNUAL CHANGE 0'W




y:\share ipc files\information for dredging companies\disposal sites\DISPOSAL SITE IN GAILLARD CUT-Y.DWG


Gaillard Cut Disposal Sites
Mandinga Norte
W1
W1
Bas Obispo 1-2
W2
E1
E2
E3
W3
W5
W4
Dred. Disp. Site
Pedro Miguel
N
Disposal sites use
Actual areas (wet material)
Actual areas (dry material)
Expansion areas (dry material)
Unidad de Sensores Remotos
Sección de Manejo de Cuenca
División de Administración Ambiental
ACP
Fuente: Mapa de Capacidad del Canal, 1999 (última revisión)




MOFFATT & NICHOL ENGINEERS
LOUIS BERGER GROUP INC.

**Figure 8-14**
**Potential Location for Deep Water Disposal Site (M6)**

ACP AUTORIDAD DEL CANAL DE PANAMÁ

# PACIFIC ENTRANCE

Existing ground elevation from +20m to 40m PLD

New lock approach channel final grade design 8.84m PLD

Proposed new locks location

Existing ground Elevation +19m PLD

New locks approach channel final grade design Elevation -17.86m PLD

(1) V=0.66 Mm3

(2) V=0.55 Mm3

(3) V=2.99 Mm3

(4) V=4.3 Mm3

(5) V=1.02 Mm3

(6) V=7.59 Mm3

(7) V=9.56 Mm3

1.8 Km.

1.2 Km.

5.5 Km.

4.2 Km.

## PACIFIC ENTRANCE DISPOSAL SITES

Aquatic

On land

(1) Victoria
(2) Rosseau
(3) Velasquez
(4) Farfán
(5) Palo Seco
(6) Tortolita
(7) Tortolita Sur

Capacidad del Canal

Y:\SHARE IPC FILES\INFORMATION FOR DREDGING COMPANIES\DISPOSAL SITES\ DISPOSAL SITES IN PACIFIC ENTRANCE-Y2.DWG

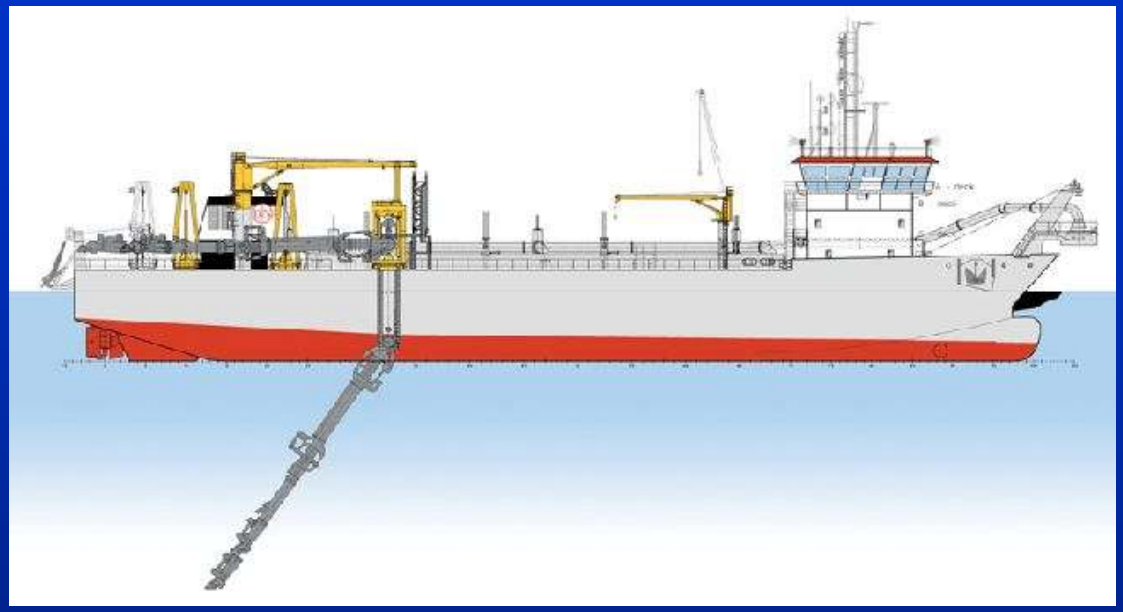
## Dredgers Efectiveness for Different Type of Material

| Equipment | Depth in meters | Sediment and Sand | Gravel | Clay and Mud | Soft Rock <15 mpa | Medium Rock 15-50 mpa | Hard Rock +50 mpa |
|---|---|---|---|---|---|---|---|
| Hopper dredge - Medium (5-10k $m^3$) | 60 | ● | ● | ● | | | |
| CSD - Medium (1 to 2k kW cutter) | 20 | ● | ● | ● | ● | | |
| CSD-Rock cutter - Medium (2 to 3k kW cutter) | 25 | ● | ● | ● | ● | ● | |
| CSD-Rock cutter - Large (3 to +5k kW cutter) | 30 | ● | ● | ● | ● | ● | |
| Backhoe | 18 | | ● | ● | ● | | |
| Dipper and Drilling/Blasting (D&B) | 18 | | ● | ● | ● | ● | ● |
| Backhoe and D&B (Pacific Entrance) | 20+ | | ● | ● | ● | ● | ● |

Effectiveness (production and cost):

- Very Good ●
- Good ●
- Moderate ●
- Low ●

# Hopper dredges



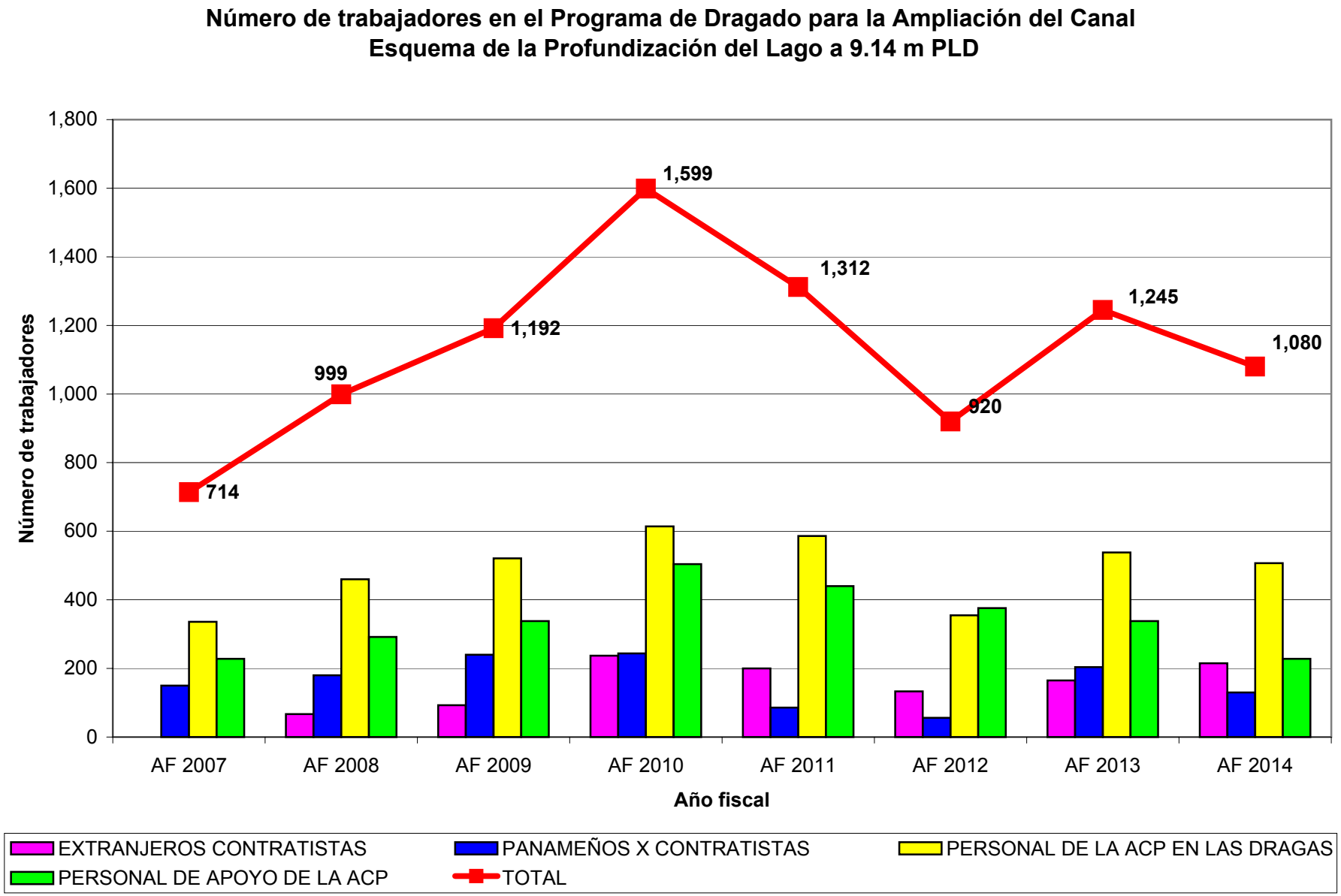
# Drilling and Blasting Boats

# Dipper and backhoe dredges

# Cutter suction dredges

# ESQUEMA PARA PROFUNDIZACIÓN DEL LAGO A 9.14 m PLD

| EQUIPO | CONTRATISTA | | | | | ACP | | | APOYO DE ACP | | | | | | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ABORDO | TIERRA | APOYO | ADMIN | SUB-TOTAL | ABORDO | | SUB-TOTAL | IPD | | IPIT | MR | GER | SUB-TOTA | |
| | | | | | | Permanente | Temporal | | Lancha, tug | Otros | | | | | |
| **ATLANTICO** | | | | | | | | | | | | | | | |
| Excavacion seca | | 50 | | | **50** | | | | | | | | | **0** | **50** |
| Tolva | 33 | | 12 | 9 | **54** | | | | 12 | 6 | 8 | 12 | | **38** | **92** |
| | | | | | | | | | | | | | | | |
| **CANAL DE ACCESO ATLANTICO** | | | | | | | | | | | | | | | |
| Cutter suction dredge No. 2 | 44 | 18 | 21 | 14 | **97** | | | | 12 | 14 | 8 | 30 | | **64** | **161** |
| | | | | | | | | | | | | | | | |
| **LAGO & CORTE** | | | | | | | | | | | | | | | |
| THOR | | | | | **0** | 40 | 51 | **91** | 16 | | | | | **16** | **107** |
| ACP cutter suction dredge | | | | | | 76 | 21 | **97** | 24 | | 3 | | | **27** | **124** |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| **CORTE & CANAL ACCESO CORTE** | | | | | | | | | | | | | | | |
| Excavacion seca | | 50 | | | **50** | | | | | | | | | **0** | **50** |
| PYV tierra | | | | | **0** | | 56 | **56** | | 3 | 2 | | | **5** | **61** |
| RMC | | | | | **0** | 51 | 20 | **71** | 60 | 5 | 12 | | | **77** | **148** |
| Baru | | | | | | 75 | | **75** | 8 | | | | | **8** | **83** |
| Retroexcavadora No. 2 x ACP | 14 | | | | **14** | | | | 60 | 5 | 12 | | | **77** | **91** |
| Excavadora terrestre | | 44 | 4 | | **48** | | | | | | | | | | **48** |
| | | | | | | | | | | | | | | | |
| **CANAL ACCESO SUR PACIFICO y ENTRADA DEL PACIFICO** | | | | | | | | | | | | | | | |
| Excavacion seca | | | | | | | | | | | | | | | |
| Cutter suction dredge No. 2 | 44 | 18 | 21 | 14 | **97** | | | | 12 | 14 | 8 | 30 | | **64** | **161** |
| Retroexcavadora No. 1 | 14 | | 12 | 9 | **35** | | | | 9 | 10 | 5 | 22 | | **46** | **81** |
| Barcaza de PYV | 28 | | 4 | 9 | **41** | | | | 9 | 6 | | 4 | | **19** | **60** |
| PYV en aguas pocas profundas | | | | | **0** | | 20 | **20** | | | 2 | | | **2** | **22** |
| | | | | | | | | | | | | | | | |
| **TALLER** | | | | | | | | | | | | | | | |
| Capataz general | | | | | | | | | | 1 | | | | **1** | **1** |
| Taller de tornería | | | | | | | | | | 23 | | | | **23** | **23** |
| Taller de soldadura | | | | | | | | | | 25 | | | | **25** | **25** |
| Taller de mecánica | | | | | | | | | | 20 | | | | **20** | **20** |
| Taller de carpintería | | | | | | | | | | 11 | | | | **11** | **11** |
| Capataz electricista | | | | | | | | | | 1 | | | | **1** | **1** |
| Taller de electricidad | | | | | | | | | | 17 | | | | **17** | **17** |
| Taller de señalización | | | | | | | | | | 28 | | | | **28** | **28** |
| Taller de pintura | | | | | | | | | | 20 | | | | **20** | **20** |
| | | | | | | | | | | | | | | | |
| **LOGÍSTICA DE IPD** | | | | | | | | | | | | | | | |
| Oficina del Gerente | | | | | | | | | | 30 | | | | **30** | **30** |
| Sección de Operaciones | | | | | | | | | | 9 | | | | **9** | **9** |
| Sección de Logística | | | | | | | | | | 28 | | | | **28** | **28** |
| | | | | | | | | | | | | | | | |
| **EQUIPO GERENCIAL PARA AMPLIACIÓN DEL CANAL** | | | | | | | | | | | | | 15 | **15** | **15** |
| | | | | | | | | | | | | | | | |
| **TOTAL** | 177 | 180 | 74 | 55 | **486** | 242 | 168 | **410** | 222 | 276 | 60 | 98 | 15 | **671** | **1,567** |


Número de trabajadores en el Programa de Dragado para la Ampliación del Canal
Esquema de la Profundización del Lago a 9.14 m PLD
Número de trabajadores
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
714
999
1,192
1,599
1,312
920
1,245
1,080
AF 2007
AF 2008
AF 2009
AF 2010
AF 2011
AF 2012
AF 2013
AF 2014
Año fiscal
EXTRANJEROS CONTRATISTAS
PANAMEÑOS X CONTRATISTAS
PERSONAL DE LA ACP EN LAS DRAGAS
PERSONAL DE APOYO DE LA ACP
TOTAL

**CANAL EXPANSION 30-REV17a.mpp**

% indirec & conting seco = 20% dragado, P&V = 15%

| | AF 2007 | AF 2008 | AF 2009 | AF 2010 | AF 2011 | AF 2012 | AF 2013 | AF 2014 |
|---|---|---|---|---|---|---|---|---|
| **1) ANCLAJE DEL ATLANTICO PARA 45' CALADO (DRAGA "ROCK CUTTER" DCSR#1** | | | | | | | | |
| **2) CAUCE DE NAVEGACION ENTRADA DEL ATLÁNTICO (225m-45' PLD)** | | | | | | | | |
| **DRAGADO ( DRAGA DE TOLVA#1 )** | 0 | 0 | 0 | 92 | 92 | 92 | 0 | 0 |
| **3) CANAL DE ACCESO NORTE-ATLÁNTICO 218m- (7K+100 @ 9K+700)** | | | | | | | | |
| **CONTRATO DE EXCAVACIÓN SECA** | 0 | 0 | 0 | 50 | 0 | 0 | 0 | 0 |
| **DRAGADO (CORTE SUCCION #3)** | 0 | 0 | 0 | 161 | 161 | 161 | 161 | 0 |
| **4) TAPON NORTE DE ESCLUSAS NUEVAS-ATLANTICO (9K+700 @ 9K+900)** | | | | | | | | |
| **CONTRATO DE EXCAVACION SECA** | 0 | 0 | 0 | 0 | 0 | 0 | 50 | 50 |
| **DRAGADO (CORTE SUCCION #3)** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 161 |
| **5) ESCLUSA (b=180 pies) SIN MURO DE APROXIMACIÓN-ATLÁNTICO (9K+900 @ 11K+000)** | | | | | | | | |
| **6) TAPON SUR DE ESCLUSAS NUEVAS-ATLANTICO (12K+820 @ 13K+020)** | | | | | | | | |
| **CONTRATO DE EXCAVACION SECA** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 50 |
| **DRAGADO (CORTE SUCCION #1)** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **7) ENSANCHE (280m-366m) Y PROFUNDIZACIÓN DEL LAGO LAGO GATÚN A 30' PLD** | | | | | | | | |
| **P Y V ACUÁTICA (BARCAZA THOR)** | 0 | 0 | 0 | 107 | 107 | 0 | 0 | 0 |
| **P Y V ACUÁTICA (BARCAZA BARÚ)** | 0 | 0 | 0 | 0 | 0 | 83 | 83 | 83 |
| **DRAGADO ( DRAGA MINDI)** | 124 | 124 | 124 | 124 | 124 | 0 | 0 | 0 |
| **DRAGADO (CORTE SUCCION #1)** | 0 | 0 | 0 | 0 | 124 | 124 | 124 | 124 |
| **DRAGA RETRO#B** | 0 | 0 | 0 | 0 | 91 | 91 | 0 | 0 |
| **8) PROFUNDIZACIÓN DEL CORTE GAILLARD A 30' PLD (INCLUYE GAMBOA)** | | | | | | | | |
| **P Y V ACUÁTICA (BARCAZA THOR)** | 107 | 107 | 0 | 0 | 0 | 0 | 0 | 0 |
| **P Y V ACUÁTICA (BARCAZA BARÚ)** | 0 | 0 | 0 | 0 | 83 | 0 | 0 | 0 |
| **DRAGA RMC** | 0 | 0 | 0 | 0 | 148 | 148 | 148 | 0 |
| **DRAGADO (CORTE SUCCION #1)** | 0 | 124 | 124 | 0 | 0 | 0 | 0 | 0 |

| | AF 2007 | AF 2008 | AF 2009 | AF 2010 | AF 2011 | AF 2012 | AF 2013 | AF 2014 |
|---|---|---|---|---|---|---|---|---|
| **9) PROFUNDIZACIÓN DEL CORTE GAILLARD A 218 m 30' PLD (INCLUYE GAMBOA)** | | | | | | | | |
| EJECUCIÓN DE EXCAVACIÓN SECA | 75 | 75 | 75 | 0 | 0 | 0 | 0 | 0 |
| P Y V ACUÁTICA (BARCAZA THOR) | 0 | 0 | 107 | 0 | 0 | 0 | 0 | 0 |
| DRAGADO ( DRAGA RMC) | 0 | 0 | 0 | 148 | 0 | 0 | 0 | 0 |
| DRAGADO (CORTE SUCCION #1) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **10) PROYECTO DE NUEVO MUELLE** | | | | | | | | |
| **11) PROYECTO DE AMPLIACIÓN @ 218M MENOS ENDEREZAMIENTO (O-16)** | | | | | | | | |
| **12) CANAL DE ACCESO AL NORTE DEL TAPON DEL CORTE GAILLARD (1k+700 @ 2k+630);ANCHO 218m -30' PLD** | | | | | | | | |
| FASE No 2 (IPIG) - EXC SECA | 75 | 75 | 75 | 0 | 0 | 0 | 0 | 0 |
| P Y V TERRESTRE | 0 | 0 | 61 | 61 | 0 | 0 | 0 | 0 |
| P Y V ACUÁTICA (BARCAZA BARÚ) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FASE No 5 - 20% VOL DRAGA TIERRA | 0 | 0 | 48 | 48 | 0 | 0 | 0 | 0 |
| FASE No 5-50% VOL DRAGA RETRO#B | 0 | 0 | 0 | 91 | 0 | 0 | 0 | 0 |
| FASE No 5 - 30% VOL DRAGA RMC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **13) FASE No9-TAPON DEL CORTE GAILLARD (2K+600 @ 2K+750)** | | | | | | | | |
| P Y V TERRESTRE | 0 | 0 | 0 | 0 | 0 | 0 | 61 | 0 |
| 10% EXCAVACIÓN SECA | 0 | 0 | 0 | 0 | 0 | 0 | 50 | 0 |
| 40% VOL DRAGA RETRO#B | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50% DRAGADO ( DRAGA RMC) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 148 |
| **14) CANAL DE APROXIMACIÓN NORTE A LA ESCLUSA DEL PACÍFICO(2K+740 @ 8K+000); ANCHO=218m** | | | | | | | | |
| **15) FASE No 10-TAPON INTERMEDIO AL NORTE DE ESCLUSAS NUEVAS-PACIFICO (6K+500 @ 6K+630)** | | | | | | | | |
| P Y V TERRESTRE | 0 | 0 | 0 | 0 | 0 | 0 | 61 | 61 |
| 10% EXCAVACIÓN SECA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 50 |
| 40% VOL DRAGA RETRO#B | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 91 |
| 50% DRAGADO ( DRAGA RMC) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **16) ESCLUSA SIN MURO DE APROXIMACIÓN-PACÍFICO(6K+840 @ 9K+200)** | | | | | | | | |

| | AF 2007 | AF 2008 | AF 2009 | AF 2010 | AF 2011 | AF 2012 | AF 2013 | AF 2014 |
|---|---|---|---|---|---|---|---|---|
| **17) TAPON SUR DE ESCLUSAS NUEVAS-PACIFICO(10K+060 @ 10K+200)** | | | | | | | | |
| **P Y V TERRESTRE** | 0 | 0 | 0 | 0 | 0 | 0 | 61 | 0 |
| **DRAGA DE RETROEXCAVADORA #2** | 0 | 0 | 0 | 0 | 0 | 0 | 84 | 84 |
| **18) CANAL DE ACCESO SUR-PACÍFICO;ANCHO=218m A 45' PLD(10K+200 @ 10K+800** | | | | | | | | |
| **P Y V - 1 BARCAZA 2 TAMROCKS** | 22 | 22 | 22 | 0 | 0 | 0 | 0 | 0 |
| **50% Vol.- RETROEXCAVADORA #2** | 0 | 0 | 0 | 84 | 84 | 84 | 0 | 0 |
| **50% Vol.- CORTE SUCCION #2** | 0 | 0 | 0 | 161 | 161 | 0 | 0 | 0 |
| **19) CAUCE DE NAVEGACION - ENTRADA PACÍFICO;ANCHO= 225m A 45' PLD** | | | | | | | | |
| **STA 70K+900 A 74K+400:** | | | | | | | | |
| **P Y V ACUÁTICA (BARCAZA BARÚ)** | 83 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **HIDROGRAFÍA** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **LICITACION- MOVILIZACIÓN-DRAGA RETROE** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **30% Vol. Duro-RETROEXCAVADORA#2** | 0 | 0 | 84 | 0 | 0 | 0 | 0 | 0 |
| **70% Vol. Media @ Suave - DCSR#2** | 0 | 0 | 161 | 161 | 0 | 0 | 0 | 0 |
| **STA 74K+400 A 85K+920:** | | | | | | | | |
| **P Y V ACUÁTICA (BARCAZA BARÚ)** | 0 | 83 | 83 | 83 | 0 | 0 | 0 | 0 |
| **30% Vol. Duro-RETROEXCAVADORA#2** | 0 | 0 | 0 | 0 | 0 | 0 | 84 | 0 |
| **HIDROGRAFÍA** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **LICITACION-ALQUILER Y MOVILIZACIÓN-DRA** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **70% Vol. Media @ Suave - DCSR#2** | 0 | 161 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total** | **486** | **771** | **964** | **1,371** | **1,175** | **783** | **967** | **902** |
| **POR CONTRATO** | | | | | | | | |
| **EXCAVACIÓN SECA** | 150 | 150 | 150 | 50 | 0 | 0 | 150 | 100 |
| **Panameños x contratistas** | 150 | 150 | 150 | 50 | 0 | 0 | 150 | 100 |
| **Apoyo x ACP** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Extranjeros** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **DRAGADO DESDE TIERRA** | 0 | 0 | 48 | 48 | 0 | 0 | 0 | 0 |
| **Panameños x contratistas** | 0 | 0 | 48 | 48 | 0 | 0 | 0 | 0 |

| | AF 2007 | AF 2008 | AF 2009 | AF 2010 | AF 2011 | AF 2012 | AF 2013 | AF 2014 |
|---|---|---|---|---|---|---|---|---|
| Apoyo x ACP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Extranjeros | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DRAGA TOLVA | 0 | 0 | 0 | 92 | 92 | 92 | 0 | 0 |
| Panameños x contratistas | 0 | 0 | 0 | 14 | 14 | 14 | 0 | 0 |
| Apoyo x ACP | 0 | 0 | 0 | 38 | 38 | 38 | 0 | 0 |
| Extranjeros | 0 | 0 | 0 | 40 | 40 | 40 | 0 | 0 |
| DRAGA CORTE SUCCIÓN | 0 | 161 | 161 | 483 | 322 | 161 | 161 | 161 |
| Panameños x contratistas | 0 | 30 | 30 | 120 | 60 | 30 | 30 | 30 |
| Apoyo x ACP | 0 | 64 | 64 | 192 | 128 | 64 | 64 | 0 |
| Extranjeros | 0 | 67 | 67 | 171 | 134 | 67 | 67 | 131 |
| DRAGA RETROEXCAVADORA HID. | 0 | 0 | 84 | 84 | 84 | 84 | 168 | 84 |
| Panameños x contratistas | 0 | 0 | 12 | 12 | 12 | 12 | 24 | 0 |
| Apoyo x ACP | 0 | 0 | 46 | 46 | 46 | 46 | 46 | 0 |
| Extranjeros | 0 | 0 | 26 | 26 | 26 | 26 | 98 | 84 |
| **SUBTOTAL POR CONTRATO** | **150** | **311** | **443** | **757** | **498** | **337** | **479** | **345** |
| Panameños x contratistas | 150 | 180 | 240 | 244 | 86 | 56 | 204 | 130 |
| Apoyo x ACP | 0 | 64 | 110 | 276 | 212 | 148 | 110 | 0 |
| Total Extranjeros | 0 | 67 | 93 | 237 | 200 | 133 | 165 | 215 |
| **POR ACP** | | | | | | | | |
| P Y V TERRESTRE | 22 | 22 | 83 | 61 | 0 | 0 | 183 | 61 |
| P Y V ACUÁTICA | 190 | 190 | 190 | 190 | 190 | 83 | 83 | 83 |
| DRAGA MINDI | 124 | 124 | 124 | 124 | 124 | 0 | 0 | 0 |
| DRAGA CORTE SUCCIÓN NUEVA | 0 | 124 | 124 | 0 | 124 | 124 | 124 | 124 |
| DRAGA RETROEXCAVADORA HID | 0 | 0 | 0 | 91 | 0 | 0 | 0 | 91 |
| DRAGA MECÁNICA RMC | 0 | 0 | 0 | 148 | 148 | 148 | 148 | 148 |
| **SUBTOTAL POR ACP (DIRECTO)** | **336** | **460** | **521** | **614** | **586** | **355** | **538** | **507** |
| **APOYO INDIRECTO DE ACP** | | | | | | | | |
| APOYO DEL TALLER DE ACP | 146 | 146 | 146 | 146 | 146 | 146 | 146 | 146 |
| APOYO DE LOGÍSTICA DE IPD (ACP) | 67 | 67 | 67 | 67 | 67 | 67 | 67 | 67 |
| EQUIPO GERENCIAL - AMPLIACIÓN | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| **SUBTOTAL POR APOYO INDIRECTO ACP** | **228** | **228** | **228** | **228** | **228** | **228** | **228** | **228** |
| **TOTAL** | **714** | **999** | **1,192** | **1,599** | **1,312** | **920** | **1,245** | **1,080** |

AF 2007 AF 2008 AF 2009 AF 2010 AF 2011 AF 2012 AF 2013 AF 2014

| | AF 2007 | AF 2008 | AF 2009 | AF 2010 | AF 2011 | AF 2012 | AF 2013 | AF 2014 |
|---|---|---|---|---|---|---|---|---|
| **EXTRANJEROS CONTRATISTAS** | 0 | 67 | 93 | 237 | 200 | 133 | 165 | 215 |
| **PANAMEÑOS X CONTRATISTAS** | 150 | 180 | 240 | 244 | 86 | 56 | 204 | 130 |
| **PERSONAL DE LA ACP EN LAS DRAGAS** | 336 | 460 | 521 | 614 | 586 | 355 | 538 | 507 |
| **PERSONAL DE APOYO DE LA ACP** | 228 | 292 | 338 | 504 | 440 | 376 | 338 | 228 |
| **TOTAL** | **714** | **999** | **1,192** | **1,599** | **1,312** | **920** | **1,245** | **1,080** |
| **PERSONAL ADICIONAL A LA ACP** | 319 | 406 | 498 | 579 | 394 | 275 | 467 | 351 |

**Extract from: "Development and implementation of a risk model and contingency estimation for the Panama Canal's 3rd Lane Locks Expansion Program", Final Report, March 2006**

Variable: Dredging

Dredging variations are based on the four dredging processes which affect productivity; costs and performance time. These are rock and soil pretreatment (drilling and blasting), dredging equipment, dredged material transportation and disposal site. Variations take into account dredges' productivity, dredging volume, and dredges' hourly costs. According to its dredging effectiveness in each area, a type of dredge was proposed to widen and deepen the Canal Post-panamax navigation channel. Dredge productivity would vary according to Canal channel complex and diverse geologic condition in addition to current Canal traffic, and transportation of dredging material. Dredging material volume variations are based on sedimentation rate, eventual bank slides, and a greater margin of over-dredge than estimated. It is not foreseen that Canal dredges cost would have significant cost variation other than normal general inflation cycles. Their unit cost would mainly depend on equipment performance through average productivity. However, cost for contracted external dredging resources would vary according to dredging market.

Variations on the extracted volume, equipment cost per hour, and equipment productivity were introduced by multiplying these items by the factors produced by the probability distributions shown below:

| | **Quantity** | | |
|---|---|---|---|
| **Type of equipment** | **Minimum** | **Probable** | **Maximum** |
| Tolva – Medium (5-10k $m^3$) | 1 | 1.1 | 1.15 |
| DCS – Medium (1 a 2k kW cutter) | 1 | 1.1 | 1.15 |
| DCS – Rock – Lake | 1 | 1.1 | 1.15 |
| DCS – Rock – Cut | 1 | 1.1 | 1.15 |
| DCS – Rock - Atl & Pac | 1 | 1.1 | 1.15 |
| DCS – Rock – Pac | 1 | 1.1 | 1.15 |
| Dredging - land | 1 | 1.1 | 1.15 |
| Dredge – Dipper (Backhoe) (Cut) | 1 | 1.1 | 1.15 |
| Dredge - Mechanical (Cut) | 1 | 1.1 | 1.15 |
| Dredge – Mechanical (Access Channel) | 1 | 1.1 | 1.15 |
| Dredge – Dipper (Backhoe) (Pacific) | 1 | 1.1 | 1.15 |
| Distribution | Triangular | | |

| | **Cost per hour** | | | **Productivity** | | |
|---|---|---|---|---|---|---|
| **TYPE OF EQUIPMENT** | **Minimum** | **Probable** | **Maximum** | **Minimum** | **Probable** | **Maximum** |
| DCS - Medium (1 a 2k kW cutter) | | | | 0.75 | 1.0 | 1.2 |
| DCS - Rock – Lake | | | | 0.75 | 1.0 | 1.3 |
| DCS - Rock – Cut | | | | 0.7 | 1.0 | 1.1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| DCS - Rock - Atl & Pac | 0.9 | 1.0 | 1.4 | 0.8 | 1.0 | 1.2 |
| DCS - Rock - Pac | 0.9 | 1.0 | 1.4 | 0.7 | 1.0 | 1.1 |
| Dredging – land | 1.0 | 1.0 | 1.1 | 0.7 | 1.0 | 1.1 |
| Dredge – Dipper (Backhoe) (Cut) | | | | 0.8 | 1.0 | 1.2 |
| Dredge - Mechanical (Cut) | | | | 0.75 | 1.0 | 1.1 |
| Dredge - Mechanical (Access Channel) | | | | 0.9 | 1.0 | 1.3 |
| Dredge – Dipper (Backhoe) (Pacific) | 0.9 | 1.0 | 1.3 | 0.7 | 1.0 | 1.1 |
| Distribution | Triangular | | | Triangular | | |

| Tolva – Medium (5-10k $m^3$) | **Cost / m3** |
|---|---|
| Minimum | 1.00 |
| Expected | 1.20 |
| Maximum | 1.30 |
| **Distribution** | Triangular |

Variable: Drilling and blasting

Rock and soil pretreatment variations include estimated quantities and drill-boat performance. Quantities variations depend mostly on channel navigation geologic condition (rock fragmentation), and dredge capability to remove material with or without prior channel bottom material blasting. Drilling and blasting productivity is subject to the type of drill-boat designated for each area along Canal navigation channel, traffic conditions, and channel area, and conditions. Drilling and blasting cost was introducing a variance in quantity and productivity through triangular distributions with the following parameters.

| **Drilling and Blasting Equipment** | **Quantity** | | | **Productivity** | | |
|---|---|---|---|---|---|---|
| | **Minimum** | **Probable** | **Maximum** | **Minimum** | **Probable** | **Maximum** |
| Wet excavation – Lake -THOR | 1.0 | 1.0 | 1.1 | 0.85 | 1 | 1.1 |
| Wet excavation – Lake - BARU | 1.0 | 1.0 | 1.1 | 0.85 | 1 | 1.1 |
| Wet excavation – Cut - THOR | 1.0 | 1.0 | 1.1 | 0.75 | 1 | 1.1 |
| Wet excavation - Cut - BARU | 1.0 | 1.0 | 1.1 | 0.75 | 1 | 1.1 |
| Wet excavation – North Access Channel & Pac BARU | 1.0 | 1.0 | 1.1 | 0.75 | 1 | 1.1 |
| Wet excavation – waters (<3m) | 1.0 | 1.0 | 1.1 | 0.9 | 1 | 1.1 |
| Dry excavation | 1.0 | 1.0 | 1.1 | 0.8 | 1 | 1.2 |
| Distribution | Triangular | | | Triangular | | |

Variable: Dry excavation

Contracting external resources to perform dry excavation phase have been a quite successful experience for ACP due local contractors effectiveness in excavating dry material at competitive prices as shown in Canal previous excavation projects such as Gaillard Cut widening to 192 m, and current Cut straightening, and widening to 218 m. Dry excavation variations are based in volume, and prices. Due to Gaillard Cut proposed deepening to 9.14 m PLD, it is most likely that some slides occur as reflected in the following table. The cost of dry excavation was varied by introducing factors affecting quantities and cost per cubic meter.

| Canal Área | Quantity | | | Unit cost | | |
|---|---|---|---|---|---|---|
| | Minimum | Probable | Maximum | Minimum | Probable | Maximum |
| Access Channel – Atlantic North @ 218m | 1 | 1 | 1.1 | 1 | 1 | 1.1 |
| Atlantic North Plug @ 2m PLD | 1 | 1 | 1.1 | 1 | 1 | 1.1 |
| Atlantic South Plug @ 27.4m PLD | 1 | 1 | 1.1 | 1 | 1 | 1.1 |
| Deepening Gaillard Cut @ 30' PLD | 1 | 2 | 3 | 1 | 1 | 1.1 |
| Access Channel – Pacific North - Cut @ 218m | 1 | 1 | 2 | 1 | 1 | 1.1 |
| Pacific North Plug – Cut @ 27.4m PLD | 1 | 1 | 1.2 | 1 | 1 | 1.1 |
| Pacific Intermediate Plug - Lock @ 27.4m PLD | 1 | 1 | 1.2 | 1 | 1 | 1.1 |
| Distribution | Triangular | | | Triangular | | |

Variable: Owner's costs

The owner's costs of the navigation channel works (dredging, dry excavation and drilling and blasting) were varied using a triangular distribution allowing this cost to go from the original estimate up to 15% more. Owner costs include navigation aids support, mitigation (reforestation), design, contract administration, disposal sites preparation, and survey support. In addition to owner's costs there is another item called ACP support to external contractors which includes aids to navigation (range towers, buoys, and lights), hydrographic survey, tugboats, launches, pilots, inspectors, coordinator, marine traffic control, contracting officer, contract specialist, and cranes.

| Navigation Channel | Indirect |
|---|---|
| Minimum | 1.00 |
| Expected | 1.00 |
| Maximum | 1.15 |
| **Distribution** | Triangular |

Variable: Disposal sites

Disposal sites depend on type of material, type of equipment, distance from the project area, capacity, and environmental evaluation. Two means of transportation of dredged material are considered: barges and pipeline, these will be limited by their size, transit and disposal site availability. In order to simulate possible problems with disposal sites for dredging material, such as limited capacity, the total cost of the dredging works was multiplied by a factor which varies from 1 to 1.02, increasing dredging cost up to 2% more. Such disposal site capacity limitation is mostly foreseen in Gaillard Cut deepening program at 9.14 m PLD. Designated area Frijoles would be near full capacity by the time this deepening program would be completed. Therefore, it is probable that Frijoles would not have enough remaining capacity to accommodate the total Cut dredging volume. Inland disposal sites require an assessment of capacity, foundation analysis, dike evaluation, rehabilitation and design. An alternative to Open Water and Inland Disposal Sites would be to use dredged material. This alternative will require deeper analysis and consideration.

| | |
|---|---|
| **Disposal sites design problems** | |

| | |
|---|---|
| Minimum | 1.000 |
| Expected | 1.010 |
| Maximum | 1.020 |
| **Distribution** | Triangular |

Component: Raise Gatun Lake

For the Raise Gatun Lake component, the cost estimate was computed as follows:

| |
|---|
| Cost of Raise Gatun lake |
| + Others |
| = Cost Estimate |

The cost of raising Gatun Lake is defined in terms of modifying Gates and locks for higher water levels, as well as modifying other ACP structures and facilities. Due to the early conceptual stage of the design of this component, it was applied the following variation to the cost of raising Gatun Lake.

| **Raise Lake** | |
|---|---|
| Maximum | 3 |
| Most likely | 2 |
| Minimun | 1 |
| Distribution | Triangular |

After defining the variations on the total cost estimate in real terms, it was necessary to evaluate the impact of general inflation on the cost estimate expressed in nominal terms (including inflation).

Variable: Inflation

Panama's long run inflation was varied from 0.6 to 3% annually. This variation reflects both the historically low inflation of the country and the increased inflation during the last year.

| **Inflation** | **(rounded)** |
|---|---|
| Maximum | 0.03 |
| Most likely | 0.02 |
| Minimum | 0.01 |
| Distribution | Pert |

## Basic Assumptions

All the assumptions used in the cost estimates and the financial model apply to the risk model. The following are the key assumptions of the model. All assumptions were considered thoroughly throughout the development of the model.

- The contracting method is design-bid-build.
- There are 6 contracts for the access channel works.
- There are 2 contracts for the locks. (1 Pacific, 1 Atlantic)
- ACP dredges would perform about 50% of total expansion dredging volume.
- Work schedule includes paid lost days due to rain, due to family affairs, miscellaneous leave and holidays.

- All unskilled labor is hired locally.
- Contractor's key personnel are foreign.
- A high contingency is applied to the Raise Gatun Lake project based on the low level of detail in the cost identified by Moffat & Nichols. It was therefore adjusted with criteria of the Engineering Department.
- The schedule is based on the cost estimate for the locks, access and navigational channels.
- New cutter suction dredge[1] of 2.1 Kw cutter head ready mid 2008.

[1] Mechanical and Hydraulic Dredging are the major types of dredging equipment. ACP is familiar with the equipment that could be used on the expansion program. There may be a risk of limited the availability on the market at the time of the program initiation, due to other mega projects around the world.