Technical Analysis of Disposal Sites for Work on Proposed New Panama Canal Post-Panamax Navigation Channel and Locks

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TECHNICAL ANALYSIS OF DISPOSAL SITES FOR WORK ON PROPOSED NEW PANAMA CANAL POST-PANAMAX NAVIGATION CHANNEL AND LOCKS

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 and construction of new Post-Panamax locks navigation approach channels, which involve deepening and widening work to guarantee the safe and expedite transit of Post-Panamax vessels through the Canal.

This report covers the technical analysis of disposal site options to accommodate dry and wet excavation material resulting from navigation channel improvement work. The ACP contracted the services of external consultants Moffatt & Nichol (M&N) and Louis Berger Group (LBG), to evaluate the different alternatives for the disposal of excavated and dredged material in Gaillard Cut and the Canal's Pacific entrance. Such studies were completed in March 2004, and may be reviewed by accessing the consultants' final reports delivered to the ACP.[1]

The management of dry and wet excavation material in the Canal represents the most critical issue of any excavation and dredging operation because of the environmental implications regarding disposal sites, the limited number of available sites, their limited capacity, the hauling distance, and the large volume of excavated and dredged material.

2 POST-PANAMAX NAVIGATION CHANNEL EXCAVATION AND DREDGING VOLUME ESTIMATES

- As part of the Canal Expansion Program, dredging and excavation work would be performed along existing Canal channels from the northern end of the Atlantic entrance to the southern end of the Pacific entrance. Similar work would also be required on the new Atlantic and Pacific lock alignments or approach channels. Refer to Appendix No. 1 for a sketch of areas of expansion and construction of Canal navigation channels, and Appendix No. 2 for Post-Panamax design ship dimensions.
- The design ship's main characteristics used to determine the proposed new Canal locks and improved navigation channels dimensions are as follows:
    - Length: 360 m
    - Beam: 46 m

[1] 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 of 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.

  - Draft: 13.1m to 13.7 m

- The deepening and widening of Canal existing channels, and the construction of approach channels for new locks would produce navigation channels with the following minimum dimensions:
  - Atlantic entrance = 225 m wide and a 13.7 m draft
  - Atlantic new locks northern approach channel = 218 m wide and a 13.7 m draft
  - Atlantic new locks southern approach channel = 218 m wide and 10.4 m PLD[2]
  - Gatun Lake = 280 m in straight reaches, 366 m in bends, and 10.4 m PLD
  - Gaillard Cut = 218 m and 10.4 m PLD
  - Pacific new locks northern approach channel = 218 m and 10.4 m PLD
  - Pacific new locks southern approach channel = 218 m and 13.7 m draft
  - Pacific entrance navigation channel = 225 m and 13.7 m draft
- Table No. 1 summarizes the excavation and dredging volumes that the deepening and widening would produce for each of the expansion areas described above.
- As shown in Table No. 1, the amounts of material dredged and excavated for navigation channel improvements and construction total 42.67 million bank cubic meters, and 11.66 million bank cubic meters, respectively. It was assumed that a preliminary bulking value for the hard and soft material could be around 25 to 30 percent; however, this bulking factor could then be reduced to approximately 15 to 20 percent as material is placed on a disposal site, is compacted and consolidates. However, at this early assessment stage, using a conservative 30 percent value is recommended to ensure that available capacity of on-land and marine disposal sites meets or exceeds the dredging and excavation material volume estimates.
- Assuming a bulking factor of 30 percent, the total amounts of dredging and excavation material would be 55.47 million loose cubic meters, and 15.16 million loose cubic meters, respectively
- These volumes do not include the excavation and dredging material resulting from the new Canal locks footprint and Pacific new locks northern access channel between the Gaillard Cut plug and the intermediate plug.

[2] All Canal elevations are referred to Precise Level Datum, which is close to Atlantic and Pacific entrance mean sea level.

EXCAVATION AND DREDGING VOLUME FOR CANAL EXPANSION PROGRAM							
Scenario: Locks 427 m x 55 m x 16.8 m							
	Areas	Stations	Width (m)	Dredging		Excavation	
				(M bank m^3)	(M loose m^3)	(M bank m^3)	(M loose m^3)
1	Atlantic entrance navigation channel	-2K+700 to 7K+100	225	6.95	**9.04**	0.00	**0.00**
2	Northern Approach Channel - Atlantic new locks	7K+100 to 9K+700	218	6.55	**8.52**	0.90	**1.17**
3	Northern plug of Atlantic new locks	9K+700 to 9K+900	250	0.61	**0.79**	0.16	**0.21**
4	Atlantic Post Panamax Locks Site	11K+000 to 12K+820	94			5.41	**7.03**
5	Atlantic new locks southern plug 10.4 m PLD	12K+820 to 13K+020	300	0.69	**0.90**	0.40	**0.52**
6	Gatun Lake widening to 280m & 366 m to 10.4 m PLD	16K+200 to 44K+000	280	7.40	**9.62**	0.00	**0.00**
7	Gaillard Cut widening to 218 m at 10.4 m PLD	44K+940 to 61K+920	218	4.08	**5.30**	7.22	**9.39**
8	Pacific new locks northern approach channel north of Gaillard Cut plug, 10.4 m PLD	1K+700 to 2K+540	218	2.43	**3.16**	2.13	**2.77**
9	Gaillard Cut or northern plug	2K+540 to 2K+700	256	0.51	**0.66**	0.63	**0.82**
10	Pacific new locks northern approach channel north of intermediate plug, 10.4 m PLD	2K+700 to 6K+680	218			39.75	**51.68**
11	Pacific new locks intermediate plug	6K+680 to 6K+840	275	0.55	**0.72**	0.00	**0.00**
12	Pacific Post Panamax Locks Site	6K+840 to 9K+200	94			9.12	**11.86**
13	Pacific new locks southern plug	9K+200 to 9K+400	400	0.80	**1.04**	0.07	**0.09**
14	Pacific new locks southern approach channel	9K+460 to 10K+800	218	5.60	**7.28**	0.15	**0.20**
15	Pacific entrance navigation channel	71K+900 to 86+500	225	6.50	**8.45**	0.00	**0.00**
TOTAL EXCAVATION & DREDGING VOLUME				42.67	55.47	65.94	85.74
Notes: A bulking factor of 30 percent was assumed to determine loose cubic meter.							
Stations numbering in red are just for reference.							

Table No.1. Excavation and Dredging Volumes for Canal Expansion Program

3 GEOLOGIC CHARACTERISTICS OF DREDGING AND EXCAVATION MATERIAL

- Except for Gaillard Cut and the new locks approach channels, where numerous core-drilling operations have been performed, geologic information for the Atlantic entrance, Gatun Lake, and the Pacific entrance is based on few core-drilling operations, dredging reports, and information provided by ACP dredge masters. Therefore, the geologic conditions of these Canal navigation channel areas are uncertain, especially at the Pacific entrance.
- For more information on Canal channel bottom material geologic properties, refer to Appendixes No. 3 and No. 4.

3.1 Atlantic entrance

- Atlantic muck, Gatun formation, and a very slim heterogeneous fill of soft overburden and boulders form the material found in the Atlantic entrance channel sub-bottom. The specific area to be dredged is located within station –2K+700 and station 7K+100. Therefore, the type of material that the dredge would remove would mostly be Gatun formation with RH-1 to RH-2[3], which is classified as soft to medium-soft rock.

3.2 Atlantic new locks northern approach channel

- The northern approach channel for the new locks on the Atlantic side is made up of Gatun formation and Atlantic muck.

3.3 Atlantic new locks southern approach channel

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

3.4 Gatun Lake

- Gatun Reach is made up of Gatun and Caimito formations. The Gatun formation consists of sandstone, siltstone, conglomerate and medium soft to medium hard tuff (RH-2 to RH-3). The Caimito formation consists of tuff, siltstone, sandstone, conglomerate and limestone, which are classified as medium-hard materials.
- Peña Blanca Reach is made up of Caimito formation.
- Bohio Reach is formed by Bohio formation, which is made up of sandstone and conglomerates classified as medium to hard material.
- Buena Vista Reach is made up of Bohio and Caimito formations.
- Tabernilla Reach is formed by Caimito formation. Some basalt is also found.

[3] RH is the abbreviation of rock hardness. The RH-5 is very hard rock and RH-1 very soft rock.

- San Pablo Reach is made up of Caimito formation.
- Mamei Reach is made up of Caimito formation.
- Juan Grande is formed by Caimito formation.
- Gamboa Reach is made up of Bas Obispo, Bohio and Caimito formations. Bas Obispo formation consists of hard fragments of basalt and andesite.
- Chagres Crossing Reach is made up of Bas Obispo formation.

3.5 Gaillard Cut

- Bas Obispo Reach is formed by Bas Obispo and Las Cascadas formations. Las Cascadas formation consists of agglomerate, agglomeratic tuff with andesitic and basaltic pebbles and cobbles. This formation is variably hard to medium soft.
- Las Cascadas Reach is formed by Bas Obispo, La Boca, and Las Cascadas formations. La Boca formation consists of sandstone, siltstone, limestone, and agglomerates.
- Cunette Reach is formed by Las Cascadas formation.
- Empire Reach is made up of Las Cascadas, Pedro Miguel, and La Boca formations. Pedro Miguel formation consists of hard to medium hard material with small fragments up to large boulders of basalt.
- Culebra Reach is formed by Culebra and Cucaracha formations along with some Pedro Miguel formation. Culebra formation consists of soft tuffaceous siltstone, and clay. Cucaracha formation consists of weak clay shales.
- Cucaracha Reach is made up of Cucaracha, Culebra, and Pedro Miguel formations. Hard material can be found in this reach.

3.6 Pacific new locks northern approach channel

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

3.7 Pacific new locks southern approach channel

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

3.8 Pacific entrance navigation channel

- The area located north of the Bridge of the Americas is formed by La Boca formation with RH-2 to RH-5, and basalt RH-4 to RH-5.
- The area located south of the Bridge of the Americas is formed by La Boca formation, some dacite RH-4 to RH-5, Panama formation RH-2 to RH-5, basalt RH-4 to RH-5, and sediments in the last 4 kilometers of the reach to the Pacific entrance.

4 PROPOSED DREDGES FOR NAVIGATION CHANNEL DEEPENING, WIDENING, AND CONSTRUCTION

- 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. 5 includes pictures of the dredges proposed for the Canal navigation channel expansion program.

Dredge Efectiveness per Different Type of Materials

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	●

Table No. 2. Dredge Effectiveness per Material Type

4.1 Atlantic entrance

- The Atlantic entrance channel would not require any drilling and blasting since the material is mostly sediment and sand; therefore, either a cutter-suction dredge or a hopper dredge could effectively dredge the Atlantic entrance channel.
- The ACP is proposing the use of a hopper dredge to deepen and widen the Atlantic entrance navigation channel because of its dredging volume production and cost-effectiveness for the type of material found in this area.

4.2 Atlantic new locks northern and southern approach channels

- A medium rock cutter suction dredge with a cutter of 2,000 to 3,000 kw is proposed to dredge the Gatun formation and Atlantic muck found in the Atlantic new locks approach channel.

- The ACP CSD[4] Mindi has a 671-kilowatt cutter, which is sufficient to remove the Atlantic muck, but lacks the capacity to dredge the Gatun formation effectively. Therefore, a medium size rock cutter-suction dredge is recommended for this area. However, the CSD Mindi could serve 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.

4.3 Gatun Lake

- A rock cutter-suction dredge with a 2,000 to 3,000 kilowatt cutter is proposed to dredge Gatun Lake. This rock cutter-suction dredge could surpass the productivity levels of a medium size cutter-suction dredge such as the CSD Mindi by at least 35%, and complete the work sooner. The CSD Mindi could serve as backup for the proposed rock cutter-suction dredge.
- Some underwater drilling and blasting might be required in certain areas of Gatun Lake such as Bohio Reach, Mamei Reach, Juan Grande Reach, Gamboa Reach, and Chagres Crossing Reach. The ACP drill-boat Thor is scheduled to perform the drilling and blasting in the 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.
- Support equipment required for the drill-boat includes push boats or workboats.

4.4 Gaillard Cut

- Almost fifty percent of the Gaillard Cut navigation channel area has rock hardness above RH-3, classified as medium-hard to very hard rock, and the remaining area is below RH-3, classified as soft to medium-hard rock. Therefore, substantial drilling and blasting would be required before excavation and dredging.
- Conventional equipment such as excavators, trucks, and drills would be used for dry drilling and blasting, and excavation activities.
- The ACP has proposed the use of drill-boats Thor and Baru[5] to perform underwater drilling and blasting operations.
- The ACP dipper dredge RMC (Rialto M. Christensen) has been proposed to perform dredging after-drilling and blasting operations. Support equipment such as tugboats, push-boats, dump scows, survey launches, and passenger boats would be required to move the dredge and transfer the dredging material to designated underwater disposal sites.

[4] CSD stands for cutter suction dredge
[5] As of today, drill-boat Baru is being built in ACP Industrial Division and scheduled to be completed in January 2005.

4.5 Pacific new locks northern approach channel

- The Pacific new locks northern approach channel is basically an extension of the Gaillard Cut; therefore, geologic conditions should be similar.
- Due to the similarity, the same dredging and excavation equipment described for the Gaillard Cut area would be used in this area, including conventional land-based equipment, the drill-boat Baru, and the dipper dredge RMC.

4.6 Pacific new locks southern approach channel

- Conventional land-based equipment would be used for dry excavation and drilling and blasting activities including excavators, trucks, and tractors to remove the material above sea level.
- The area below water level lacks sufficient draft to accommodate a drill-boat for drilling and blasting operations. The use of ACP Tamrocks, Rangers, or the electric P&H drills mounted on top of small barges has been proposed to drill and blast this area.
- For dredging activities, the use of a medium-size rock cutter-suction dredge has been proposed to remove La Boca formation without need for drilling and blasting activities, and some basalt after drilling and blasting activities.
- In addition to the medium-size rock cutter-suction dredge, a hydraulic backhoe would be required after drilling and blasting to remove about 50% of the material from the Pacific new locks southern approach channel, which is formed by basalt.
- Support equipment such as an anchor barge, a submersible barge, push-boats, pontoons, pipes, dump scows, tugboats, and survey and passenger launches would assist both dredges.

4.7 Pacific entrance navigation channel

- The drill-boat Baru is scheduled to perform drilling and blasting operations at the Pacific entrance channel with subsequent dredging performed by a medium-size rock cutter dredge for medium-hard rock to sediments, and a hydraulic backhoe for very hard rock.
- Support equipment such as an anchor barge, a submersible barge, push-boats, pontoons, pipes, dump scows, tugboats, and survey and passenger launches would assist dredge operations.

5 PROPOSED DISPOSAL SITES TO ACCOMMODATE CANAL NAVIGATION CHANNEL DREDGING AND EXCAVATION MATERIAL

- Following is a table showing ACP's recommendations for the disposal of material dredged and excavated as part of the proposed Canal Expansion Program to accommodate Post-Panamax vessels.

PROPOSED DISPOSAL SITES FOR CANAL NAVIGATION CHANNEL DREDGING AND EXCAVATION WORKS

Scenario: Locks 427 m x 55 m x 16.8 m

	Areas	Dredging (loose M m^3)	Excavation (loose M m^3)	Proposed dredging		Proposed excavation	
				Area	Capacity (M m3)	Area	Capacity (M m3)
1	Atlantic entrance navigation channel[1]	9.04	0.00	Northwest breakwater	8.2	N/A	
2	Northern Approach Channel - Atlantic new locks	8.52	1.17	Sherman	10	Represa Island disposal site	32.00
3	Northern plug of Atlantic new locks	0.79	0.21	Sherman	10	Represa Island disposal site	32.00
4	Atlantic Post Panamax Locks Site	0.00	7.03			Represa Island disposal site	32.00
5	Atlantic new locks southern plug 10.4 m PLD	0.90	0.52	Represa Island disposal site	32.00	Represa Island disposal site	32.00
6	Gatun Lake widening to 280m & 366 m to 10.4 m PLD	9.62	0.00	Gatun Lake		N/A	
7	Gaillard Cut widening to 218 m at 10.4 m PLD	5.30	9.39	Frijoles	11	Site E2 Site W2 Site W3 Site W5	21.70 23.83 17.09 4.22
8	Pacific new locks northern approach channel north of Gaillard Cut plug, 10.4 m PLD	3.16	2.77	Frijoles	11	Site UXO	77.04
9	Gaillard Cut or northern plug	0.66	0.82	Frijoles	11	Site UXO	77.04
10	Pacific new locks northern approach channel north of intermediate plug, 10.4 m PLD	0.00	51.68			Site UXO	77.04
11	Pacific new locks intermediate plug	0.72	0.00	Frijoles	11	N/A	
12	Pacific Post Panamax Locks Site	0.00	11.86			Site UXO T7 - Miraflores Lake T8 - 1939 Excavation Cocoli	77.04 4.50 3.00 7.00 to 10.00
13	Pacific new locks southern plug	1.04	0.09	Velasquez Farfan	2.29 3.66	Site UXO	77.04
14	Pacific new locks southern approach channel	7.28	0.20	Tortolita Tortolita South	7.59 9.56	Site UXO	77.04
15	Pacific entrance navigation channel	8.45	0.00	Tortolita South	9.56	N/A	
	TOTAL	**55.47**	**15.16**		**84.30**		**193.38**

Notes:

1. Northwest breakwater disposal site could be extended to accommodate the total amount of Atlantic entrance widening and deepening to 225 m and 13.7 m draft.

Table No. 3. Proposed disposal sites for Canal Expansion Program dredging and excavation material

5.1 Atlantic Area

5.1.1 Northwest breakwater disposal site

- The northwest breakwater disposal site is located off the west Cristobal breakwater. It has remaining capacity for 8.2 million cubic meters at –2 meters MLW[6], which is not sufficient to accommodate the 9.0 million loose cubic meters[7] of dredged material resulting from the widening and deepening of the Atlantic entrance to 225 m and 13.7 m draft. However, this site could be easily extended north, to accommodate all dredged material resulting from deepening and widening the Atlantic entrance channel. The underwater disposal site must also provide enough draft for hopper dredge safe navigation; therefore, an extension of the northwest breakwater disposal site would be required.
- The average dredging transportation distance from the northwest breakwater disposal site to the Atlantic entrance channel's mid point is about 4.5 kilometers.

5.1.2 Sherman disposal area

- This land site has a total 665 ha, but is not totally conditioned to receive dredging material, and contains some environmental sensitive areas, especially those located on the west side. Therefore, only part of this area could be used as a disposal site.
- The Sherman disposal site contains the following areas, which are suitable to accommodate dredging or excavation material:
    - Sherman north wild disposal area = 115,000 cubic meters
    - Sherman central wild disposal area = 646,000 cubic meters
    - Sherman south wild disposal area = 27,000 cubic meters
    - Former drop zone = 9.4 million cubic meters
- The areas designated as Sherman wild disposal areas were formerly known as Gatun Approach wild disposal areas, and have received dredging material previously. On the other hand, the former drop zone has never been used as disposal site, so this area does require the construction of a dike to contain the dredged material. Such dike configuration would be as follows, and would have an estimated cost of about $6 million:
    - Top width = 5 meters
    - Base width = 35 meters

[6] Atlantic sea mean low water.
[7] A 30% bulking factor was applied to estimated dredging material bank cubic meters.

- Height = 10 meters
- Dike volume required = 789,600 cubic meters
- Area = 110.8 ha
- Freeboard = 1.5 meters

- The Sherman disposal area would have a total capacity for 10 million cubic meters after dike construction, and could receive 8.5 million cubic meters of loose dredging material from the Atlantic new locks northern approach channel through the submerged pipes of the rock cutter-suction dredge proposed for dredging the new lock channels. Canal vessel transits would not be affected by using submerged discharge pipes.

5.1.3 Other options

- Telfers Island is a land site located east of the Atlantic entrance navigation channels, which was previously part of the Canal's patrimony and was used to receive dredging material. It has a dike around its perimeter and is suitable to contain around 3.7 million cubic meters of material. However, Telfers Island is under ARI[8] jurisdiction, and permission must be requested to fill the existing dike area. Filling Telfers Island would benefit ARI by providing a level landfill for future industrial or housing development.
- Other options to dispose Atlantic entrance dredging material are the Limon Bay water disposal site located west of Anchorage Area C, which has remaining capacity for 4.315 million cubic meters of material up to elevation –2m MLW; and the open-water disposal site located south of Limon Bay and north of Sherman, which has remaining capacity for 400,000 cubic meters of material. However, these sites should be reserved for future Atlantic entrance navigation channel maintenance, and are not recommended for dredging capital work.

5.2 Gatun Lake

5.2.1 Represa Island disposal site

- This proposed disposal area represents a potential site to accommodate material dredged from the new Atlantic southern locks plug as well as the excavated material from the new Atlantic locks. It is located northeast of Gatun Lake, adjacent to the Gatun anchorage expansion area, and its capacity goes beyond 32 million cubic meters (which would take 320 ha), since it measures 440 ha overall.
- Should the barge transportation option be selected for the transportation of material, the Represa Island site could be used as a regular underwater

[8] Autoridad de la Región Interoceánica (ARI) is the Panamanian agency in charge of administering and selling former Panama Canal areas formerly under USA government jurisdiction for housing and industrial development.

disposal site, or it could be transformed into a land reclamation project if land-based transportation such as trucks or railway is chosen over the barge transportation option.

- A rock cutter-suction dredge designated to dredge the new Atlantic locks southern plug could discharge material through pipes in the Represa Island disposal site. The discharge pumping distance would be approximately 4 km from the southern plug to the proposed disposal site.

5.2.2 Dump site No. 14

- Dumpsite No. 14 is located west of Tabernilla Reach. After completion of the Gaillard Cut Widening Program to 192 m in 2001, it ended up with remaining capacity for 1.4 million cubic meters of material at –9 m MLL[9]. This site is currently being used to accommodate material from the Gaillard Cut deepening project to 13.7 m PLD. Therefore, once completed the current deepening project site No. 14 might lack any remaining capacity for the Gaillard Cut widening project to 218 m.
- Transportation distance using dump scows from the Gaillard Cut mid point to site No. 14 is approximately 23 km.

5.2.3 Frijoles disposal site

- Frijoles disposal site is located east of Buena Vista Reach, and is also being currently used to accommodate dredged material from the Gaillard Cut deepening program to 1 m. Transportation distance using dump scows from the Gaillard Cut mid point to Frijoles is approximately 27 km.
- The Frijoles disposal site's current remaining capacity is 14 million cubic meters. After the Gaillard Cut Deepening Program to 13.7 m PLD, site capacity could be around 11 million cubic meters, which would be sufficient to hold 5.3 million loose cubic meters of dredged material from Gaillard Cut. If a decision were made to dredge 2 million loose cubic meters of this material using a land-based dredge excavator in Gaillard Cut, then the Frijoles disposal site would only have to accommodate 3.3 million loose cubic meters of material.

5.2.4 Disposal sites along Gatun Lake navigation channels

- The CSD Mindi usually performs dredging operations in Gatun Lake navigation channels, unless hard rock is found, in which case the dipper dredge RMC executes the dredging work. Dredging material pumped by the CSD is unloaded through pipes on top of the small islands found along Gatun Lake navigation channels. Usually this dredged material is deposited

[9] MLL refers to Gatun Lake's mean lake level – to avoid proliferation of aquatic plants and to provide enough under-keel clearance for barges and tugboat safe navigation.

above MLL, to avoid proliferation of aquatic vegetation, or deposited –9 m MLL.

5.2.5 Other potential disposal site options

- In addition to the Frijoles and No. 14 dumpsites to dispose of dredged material using barges from Gaillard Cut to Gatun Lake, the ACP Surveys Branch and the Canal Capacity Projects Division have identified several potential disposal sites as shown in a sketch attached in Appendix No. 6. These potential sites could also receive the material dredged by the cutter suction dredge, although it normally discharges material along lake islands.
- The remoteness of these potential sites from Gaillard Cut would definitely increase dipper dredge operating costs compared to the Frijoles disposal site, which is located 27 km from Gaillard Cut's mid point.

5.3 Gaillard Cut

5.3.1 Disposal site E1

- Site E1 is located behind La Pita on Gaillard Cut's east side, and has no capacity at all. It was used to deposit excavation material from the Gaillard Cut Widening Program to 192 m. No dredging material was accommodated on site E1.
- A redesign of Site E1 might increase available capacity for dry excavation material.

5.3.2 Disposal Site E2

- Site E2 is located next to Culebra Reach on Gaillard Cut's east side, and is currently used to deposit dry east bank excavated material from the Gaillard Cut Straightening Program. It is not suited to accommodate dredging material due to the site height and large pumping distance for a cutter suction dredge.
- According to consultants Moffatt & Nichol (M&N), hired by the ACP to study several disposal site options on the Pacific side and Gaillard Cut[10], the site area could be expanded to 105.6 ha for fill receipt. The new proposed Site E2 known as T2 in M&N's report would have volume capacity as follows:
    - Average depth of 10 m over entire site = 10.56 million cubic meters
    - Fill to uniform elevation = 21.70 million cubic meters
    - Maximum site capacity = 30.85 million cubic meters

[10] Moffatt & Nichol Engineers, Louis Berger Group, Golder Associates, "Pacific Side Excavation & Dredging Material Disposal Alternatives Evaluation", Final Report, 3 Volumes, March 2004.

- Capacity of site E2 would be sufficient to hold the 1.52 and 0.44 million loose cubic meters of dry and wet excavation material respectively from the east bank of the proposed Gaillard Cut Widening Program to 218 m.
- For more technical and environmental information on Site E2, please refer to M&N's final report, available at the Canal Capacity Projects Division.

5.3.3 Disposal site E3

- Site E3 is located behind Omar Torrijos Road, formerly known as Gaillard Highway. This site has not yet been used as a disposal site due to its remoteness from Gaillard Cut banks.

5.3.4 Disposal site W1

- Site W1 is located next to Mandinga River on the west bank of Gaillard Cut. Although it has been previously used to deposit dredging and excavation material, according to M&N studies, the site contains endemic species, offers an ample surface for the movement of mammal species, and is covered with secondary forest growth. There are reforestation parcels maintained by the Smithsonian Tropical Research Institute (STRI). Therefore, this site should be excluded from consideration as a disposal site due to its high ecological value, diversity of flora and fauna, and the potential for eco-tourism.

5.3.5 Bas Obispo disposal sites 1 and 2

- The Bas Obispo sites 1 and 2 are located on the west bank of Gaillard Cut, specifically adjacent to Bas Obispo Reach. These sites are intended to accommodate dredging material, but are close to M&N's boundary recommendations for disposal site exclusion due to environmental implications.
- Bas Obispo 1 offers a man-made dike to contain dredging material, which would deter any environmental impact especially to the Mandinga River ecosystem. On the other hand, unless a dike is built, Bas Obispo 2 should be excluded as a disposal site option due to its negative environmental implication.

5.3.6 Disposal site W2

- Site W2 is located on the west bank of Gaillard Cut, adjacent to Bas Obispo Reach and Cascadas Reach. It is used to deposit Gaillard Cut west bank dry excavation material.
- According to M&N's evaluation, the designated area of site W2 could be extended south adjacent to Camacho River. The new boundaries would offer 88.99 ha for fill receipt.

- Capacity estimates for the newly proposed Site W2, named T2 in M&N's report, are as follows:
    - Average depth of 10 over entire site = 8.89 million cubic meters
    - Fill to uniform elevation = 23.83 million cubic meters
    - Maximum site capacity = 32.35 million cubic meters
- For more technical and environmental information on Site W2, please refer to M&N's final report, available at the Canal Capacity Projects Division.

5.3.7 Disposal site W3

- Site W3 is located on the west side of Gaillard Cut, adjacent to Empire Reach and Culebra Reach. The site is also known as T3 in M&N's evaluation of Gaillard Cut disposal sites.
- According to M&N's evaluation, 60% of the site falls within a medium risk UXO area.
- The site, with an area of 115 ha, is suited to accommodate dry excavation material, with volume capacity estimates as follows:
    - Average depth of 10 m over entire site = 11.50 million cubic meters
    - Fill to uniform elevation = 17.09 million cubic meters
    - Maximum site capacity = 28.13 million cubic meters
- For more technical and environmental information on Site W3, please refer to M&N's final report, available at the Canal Capacity Projects Division.

5.3.8 Disposal site W4

- Site W4 should be discarded as potential disposal site because of its proximity to the new Centennial Bridge. It was used to accommodate excavation material from the Gaillard Cut Widening Program to 192 m.

5.3.9 Disposal site W5

- Site W5 is located on the west side of Gaillard Cut, adjacent to Culebra Reach and Cucaracha Reach. Most of the site has already been cleared of substantial growth; however, UXO[11] surveys and clearance could be required before depositing excavation material.

[11] Unexploded Ordnance materials are ammunition, ammunition components, chemical or biological warfare material or explosives that have been abandoned, expelled from demolition pits or burning pads, lost, discarded, buried or fired. US Army forces left UXO during several weapon system testing exercises and training activities in Panama.

- The site is intended to accommodate dry excavation material from the Gaillard Cut Widening Program to 218 m, and offers 29.76 ha for material receipt.
- The estimated fill capacity of Site W5, known as T5 in M&N's report, is as follows, depending on the fill scenario:
    - Average depth of 10 m over entire site = 2.98 million cubic meters
    - Fill to uniform elevation = 4.22 million cubic meters
    - Maximum site capacity = 7.28 million cubic meters
- For more technical and environmental information on Site W5, please refer to M&N final report, available at the Canal Capacity Projects Division.

5.3.10 Disposal site UXO

- The UXO site is located south of Site W5 and adjacent to the new Pacific locks proposed excavation site. Therefore, the site would be adequate to accommodate new locks excavation material on the Pacific side after proper UXO clearance.
- Due to its remoteness to the proposed Gaillard Cut Widening project to 218 m, the UXO site is not considered adequate to accommodate Gaillard Cut excavation material.
- Some 63 ha of the total 305 ha of the UXO site were cleared in the late 1990s by the firm EOD Technology to depths varying from 0.61 to 1.22 m. However, it is recommended that the area undergo surveys, risk assessment and surface clearance before any excavation material is deposited.
- Sources of information on survey and removal of UXO are:
    - U.S. Army Corps of Engineers, Engineering and Support Center, Huntsville (USAESCH)
    - Army Range Inventory Program by US Army Environmental Center
- For more technical and environmental information on the UXO site, please refer to M&N's final report, available at the Canal Capacity Projects Division.
- Estimated fill capacity of the UXO site, known as T6 in M&N's report, is as follows:
    - Average depth of 10 m over entire site = 30.54 million cubic meters
    - Fill to uniform elevation = 77.04 million cubic meters
    - Maximum site capacity = 115.24 million cubic meters

5.3.11 Dredging disposal site

- It is located within the UXO site and includes the area cleared by EOD Technology in the late 1990s.
- The site is actually used to accommodate material discharged by the CSD Mindi from dredging Paraiso Reach work. The land-based discharge pipes of the Mindi are located on the cleared area, although dredging material tends to flow to the UXO unclear area by means of gravity.
- If the UXO site is selected as disposal site for new locks excavation material, the ACP should consider adequate management for dredging and excavation material taken from dredging operations at Gaillard Cut, and new locks excavation work.

5.3.12 Pedro Miguel disposal site

- The Pedro Miguel disposal site is located west of Pedro Miguel locks, and is used to deposit dredged material from Pedro Miguel Reach.
- The site should be discarded as a disposal site option since it is in the way of the new Pacific locks proposed alignment.

5.4 Pacific Area

5.4.1 Cocoli Disposal Site

- The Cocoli disposal site is located west of the new Pacific Locks alignment in the valley of the Cocoli River between the proposed Cocoli diversion dam and the locks.
- The site is about 70 hectares and would be adequate to accommodate at least 7 to 10 million cubic meters from the Pacific Locks excavation.

5.4.2 T8 - 1939 Excavation

- This site is located just east of the new locks.
- Part of the disposal material from the locks excavation could be used to fill up the trenches that were excavated during the 1939 third lock excavation.
- This site was called T8 in the M&N report and has a capacity for approximately 3 million cubic meters.

5.4.3 T7 - Miraflores Lake West Bank

- This site is located between Miraflores Lake and the new access channel to the Post Panamax Locks.
- At a uniform depth of 10 m, its holding capacity is approximately 4.5 million cubic meters.

- This site was called T7 in the M&N report
- Part of the material disposed in this site will form the Barrier Dam Between the Miraflores Lake and the new access channel.

5.4.4 Victoria disposal site

- Terrestrial site Victoria is located on the west bank of the Pacific entrance, adjacent to the 1939 third locks excavation site. It has an area of 207,400 square meters, and remaining capacity for 661,505 cubic meters.
- The site should be reserved for future dredging maintenance of the Pacific entrance navigation channel.

5.4.5 Rosseau disposal site

- Land site Rosseau requires construction of a dike to contain dredged material. The volume capacity estimate is 552,598 million loose cubic meters. The approximate cost of dike construction is $1.0 million.
- The site should also be reserved for future dredging maintenance of the Pacific entrance navigation channel.

5.4.6 Velasquez disposal site

- Land site Velasquez is located on the west bank of the Pacific entrance, and south of sites Victoria and Rosseau. It has an area of 836,600 square meters, and remaining capacity for 2.29 million cubic meters. It could be used to accommodate the 1 million loose cubic meters from dredging work for the new Pacific locks southern plug.
- However, the Velasquez site's remaining capacity after depositing Pacific southern plug dredged material should be reserved for future Pacific entrance navigation channel dredging maintenance.

5.4.7 Farfan disposal site

- Land site Farfan is located on the west bank of the Pacific entrance, south of the former Rodman Naval Station, and south of the Inter-American Highway. The site has 125 ha and could hold up to 4.79 million cubic meters of dredged material after raising Farfan's existing dike at an estimated cost of $ 0.57 million; and up to 5.19 million cubic meters after site extension of 103 ha to the west at an estimated cost of $ 0.77 million. Existing site capacity could be around 3.66 million cubic meters at +7 m PLD.
- The site is an alternative to the Velasquez site to accommodate 1 million loose cubic meters of dredged material from dredging work for the new Pacific locks southern plug. However, it is not recommended for holding

the 7.3 million loose cubic meters from dredging work for the new Pacific locks southern access channel. The Farfan site should have sufficient capacity for future Pacific entrance navigation channel maintenance.

5.4.8 Palo Seco disposal site

- Underwater site Palo Seco is located on the west side of the Pacific entrance, adjacent to the Palo Seco area. Its area is 1.30 million square meters, and has volumetric capacity for 1.02 million cubic meters of material.
- The site was used to deposit Pacific entrance navigation channel maintenance dredging material. It is believed that dredging material in Palo Seco tends to flow to the Pacific entrance navigation channel.

5.4.9 Tortolita disposal site

- The open water Tortolita site is located on the west area of the Pacific entrance, east of Tortolita Island. Its area is 1.62 million square meters, and has a remaining capacity of 7.9 million cubic meters.
- The site was used to deposit rock material, concrete slabs from the Miraflores Locks tow track repair and replacement program, and material from demolition of tie up station No. 4 in La Boca.
- The Tortolita site has sufficient capacity to hold 7.28 million loose cubic meters from dredging work for the new Pacific locks southern access channel.
- Average discharge pumping or barge transportation distance from the new locks southern access channel to the Tortolita site is 13 km.

5.4.10 Tortolita South disposal site

- The open water Tortolita south site is located on the west area of the Pacific entrance, and south west of the Tortolita. site. It measures 1.32 million square meters, and has remaining capacity for 9.56 million cubic meters.
- The site could hold the 8.45 million loose cubic meters from widening and deepening the Pacific entrance navigation channel to 225 m and 13.7 m draft.
- Average discharge pumping distance from the Pacific entrance navigation channel mid point to the Tortolita South site is approximately 7.5 km.

5.4.11 Pacific entrance open water disposal site

- The Pacific entrance open water disposal site is located south of Taboga and Taboguilla islands. This site is known as M6 in M&N's final report, and would have volume capacity for 11 to 80 million cubic meters of material,

depending on the area selected for use from its 225 ha to 1,600 ha, assuming fill depth would not exceed 5 meters.

- The site would have sufficient capacity to accommodate the 7.28 million cubic meters of material resulting from dredging of the new Pacific locks southern access channel, and 8.45 million cubic meters of material from widening and deepening the Pacific entrance navigation channel to 225 m and 13.7 m draft
- The disadvantage of using the site is its remoteness from dredging areas, which would increase dredging costs.

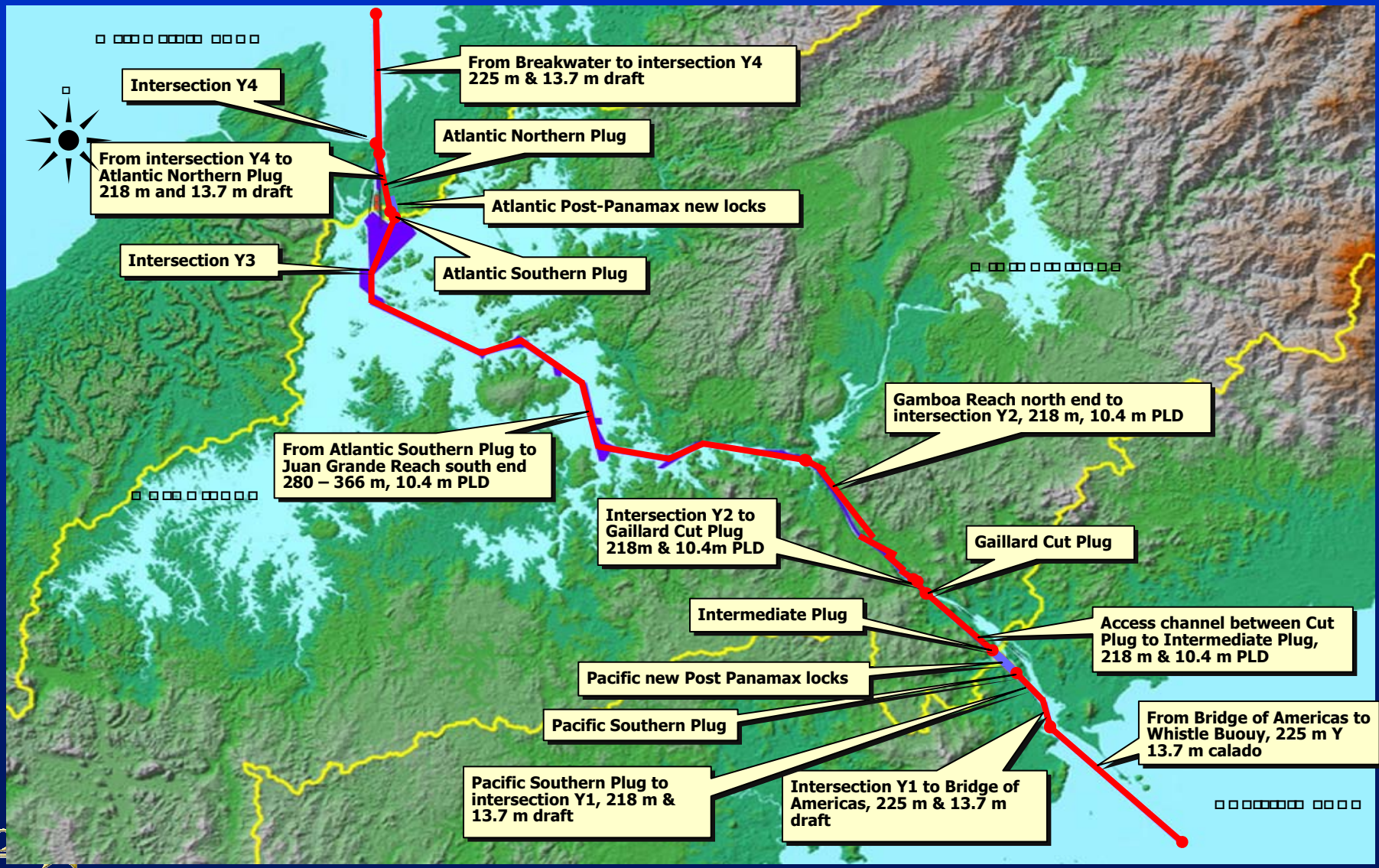
6 RECOMMENDED DISPOSAL SITES FOR NAVIGATION CHANNEL DREDGING MAINTENANCE

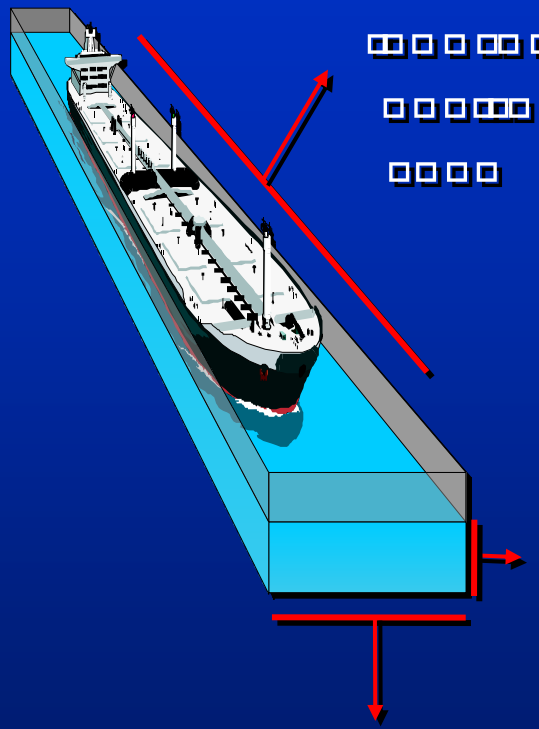
- The following table shows those disposal sites available to accommodate dredging material from future periodical navigation channel maintenance after Canal expansion:

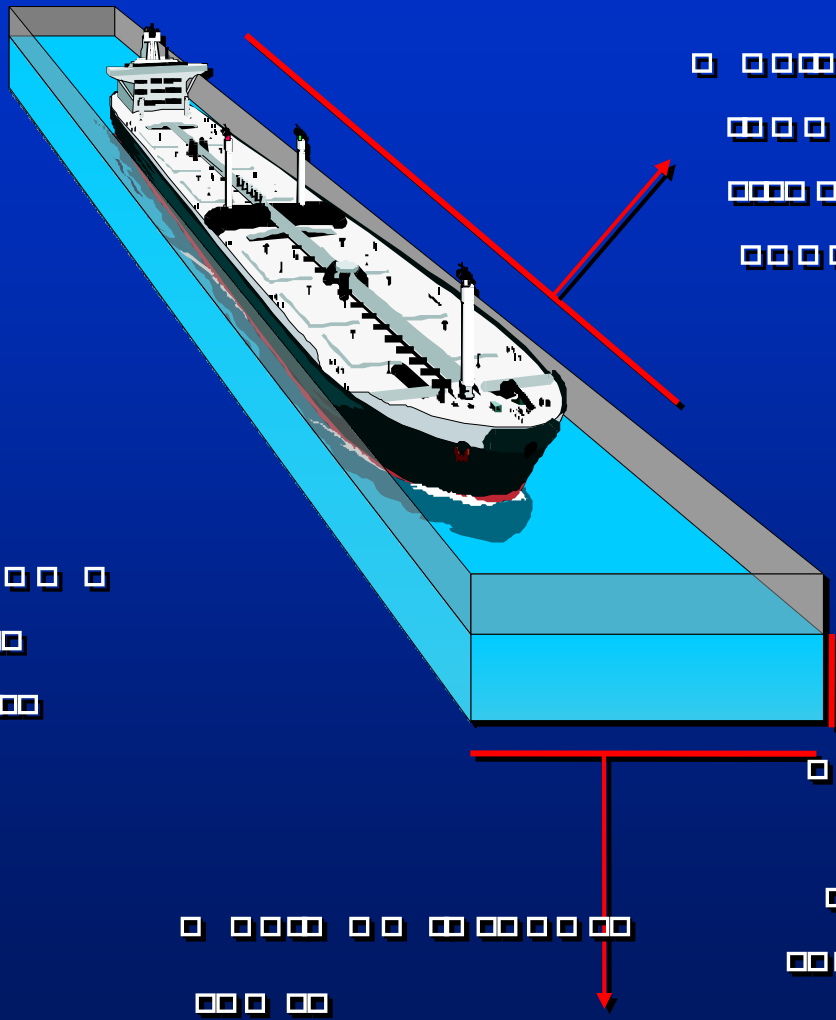
Atlantic area	1	Limon Bay Fan dumping	4.32	
	2	South Limon Bay site	0.40	
	3	Sherman	1.50	Site could be upgraded to increase volume capacity
Gatun Lake & Gaillard Cut	4	Along Gatun Lake navigation channel		Cutter suction dredge discharge material over islands or underwater
	5	Frijoles	6.00	
Pacific area	6	Victoria	0.66	
	7	Rosseau	0.55	
	8	Velasquez	1.30 to 2.29	
	9	Farfan	2.66 to 3.66	Assuming site's existing capacity
	10	Palo Seco	1.02	
	11	Tortolita	0.60	Extension of site boundaries would increase site volume capacity
	12	Tortolita South	1.00	Extension of site boundaries would increase site volume capacity
TOTAL REMAINING CAPACITY			**16.05**	

Table No. 4. Recommended disposal sites available for future periodical navigation channel dredging maintenance program after Canal Expansion work

Areas of expansion and construction of Canal navigation channels







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,

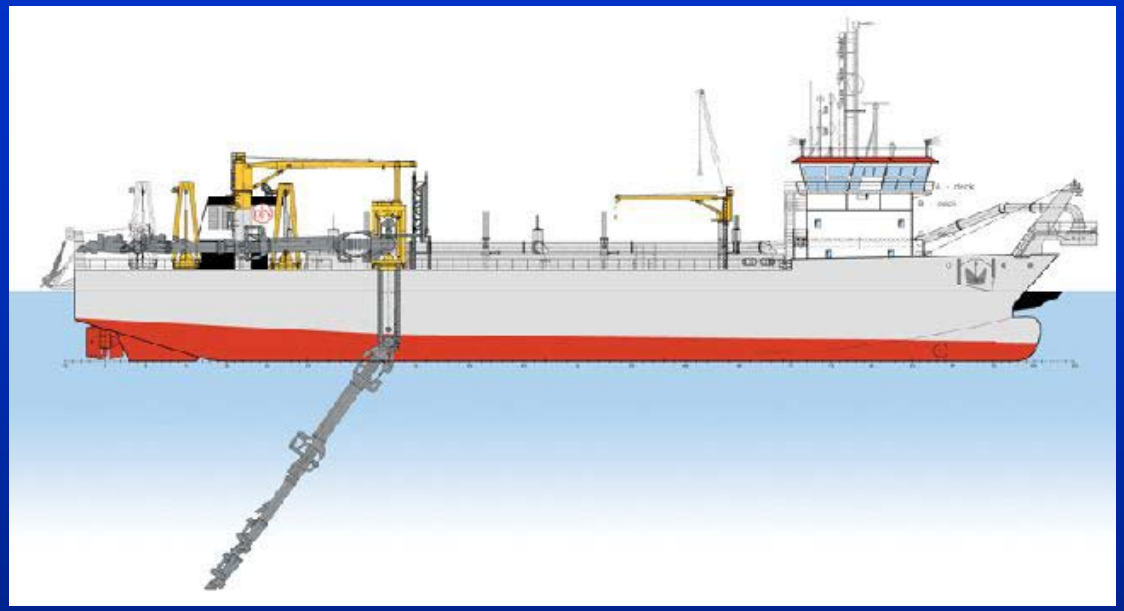
sorting, and frequent fossils indicating a partly water and partly terrestrial deposition. It is interbedded with hard, black, fine-grained, indurated tuffs with usually massive jointing and occasional basalt flows. The formation is blue-gray when fresh, oxidizing to grayish-brown. The average depth 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.




DRILLBOAT APACHE

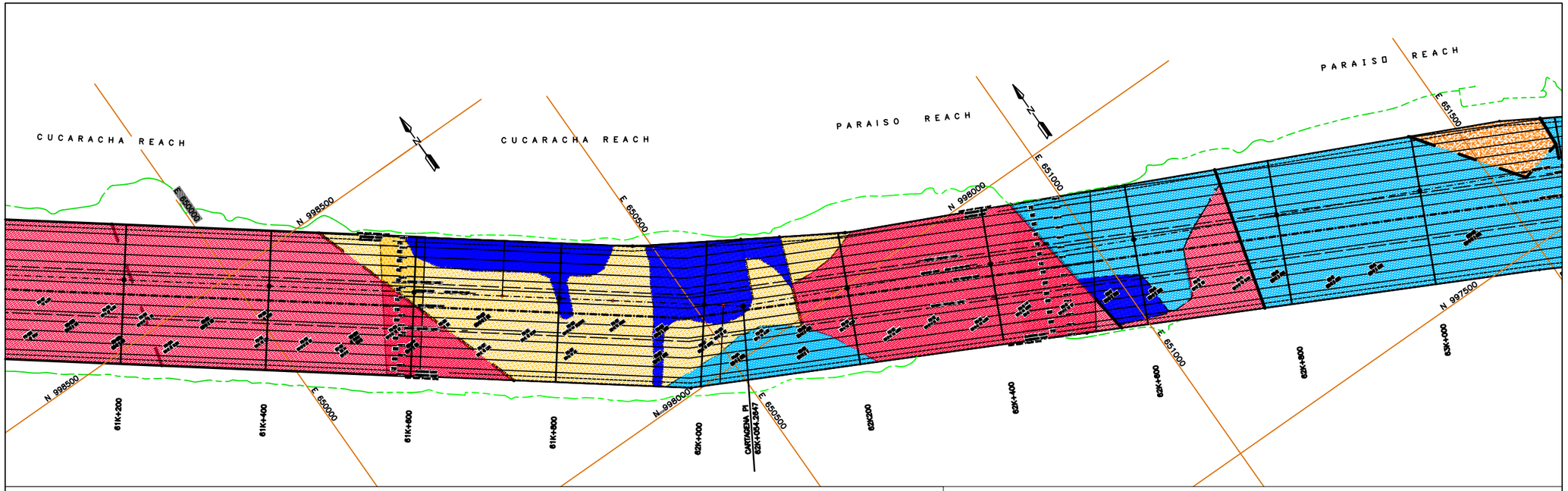

CAROLINA

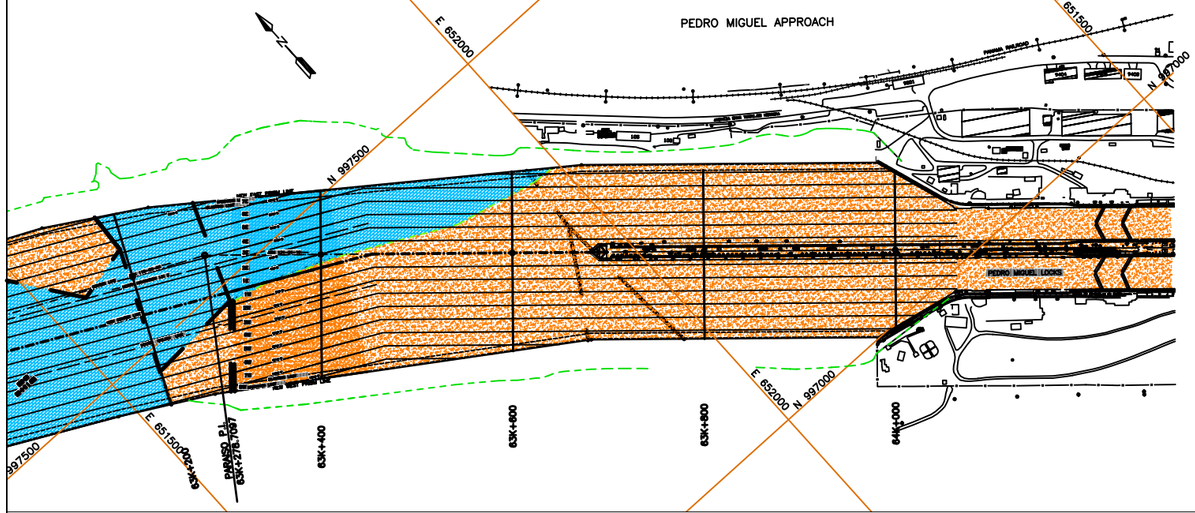
Dredgers Efectiveness for Different Type of Material

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 ●





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
- BASALT
- BAS OBISPO
- CUCARACHA
- CULEBRA
- LA BOCA
- LAS CASCADAS (>RH-3, <RH-3)
- 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	CHECKED BY: M. DE PUY, MANAGER, GEOTECHNICAL ENG.
DRAWN BY: SURVEYS BRANCH J. RAMESCH (IPIG)	APPROVED BY: LUIS D. ALFARO, MANAGER, ENGINEERING DIVISION

GEOLOGICAL FORMATIONS

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

PEÑA BLANCA REACH

BOHIO REACH

BUENA VISTA REACH

24K+600 24K+800 25K+000 25K+200 25K+400 25K+600 25K+800 26K+000 26K+200 26K+400 26K+600 26K+800 27K+000 27K+200 27K+400 27K+600 28K+000 28K+200 28K+400 S 28K+600 S 28K+800 S 29K+000 29K+200 29K+400 29K+600 29K+800 30K+000 30K+200 30K+400 30K+600 30K+800

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
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BBRE = BASALT BRECCIA	OB = OVERBURDEN
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FZ = FAULT ZONE	T = TUFF
GVL = RIVER GRAVEL	TAGG = AGGLOMERATIC TUFF
W = WEATHERED ROCK	

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)

HARDNESS SCALE

SOIL CONSISTENCY

SYMBOL	SOIL CONSISTENCY	UNCONFINED COMPRESSIVE STRENGTH MPa
OC-1	VERY LOW TO LOW	0.00 – 0.025
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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 100 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 24K+600 to STA 30K+800

SCALE: 1:3000 | DATE: MARCH 2004

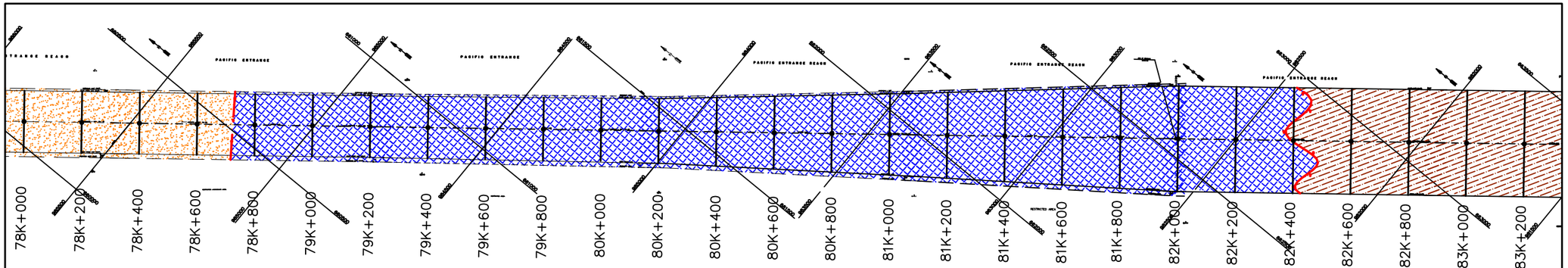
GEOLOGIST: J. RAMESCH

DRAWN BY: SURVEYS BRANCH J. RAMESCH (PPG)

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

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

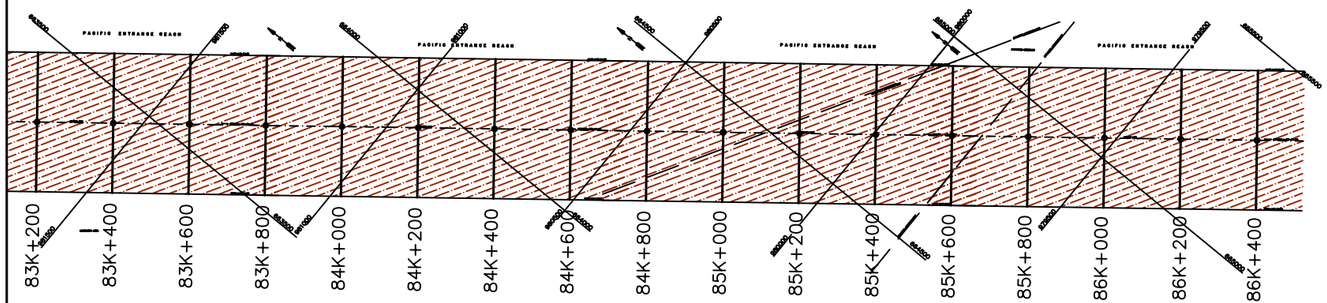
6123-116



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
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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

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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

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AGG = AGGLOMERATE
AGG,T = TUFFACEOUS AGGLOMERATE
ANDE = ANDESITE
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CONG = CONGLOMERATE
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FZ = FAULT ZONE
GVL = RIVER GRAVEL
W = WEATHERED ROCK
RS or RD = RIVER SEDIMENT
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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

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SHEET 2 of 2

PANAMA CANAL AUTHORITY

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

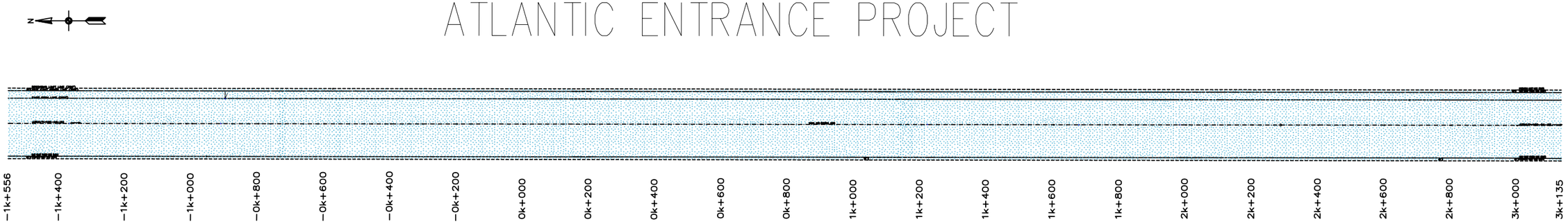
CANAL EXPANSION PROJECT
PACIFIC ENTRANCE
PLAN VIEW WITH GEOLOGY
STA 77K+000 to STA 86K+400

SCALE: 1:5000 | DATE: JUNE 2002

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

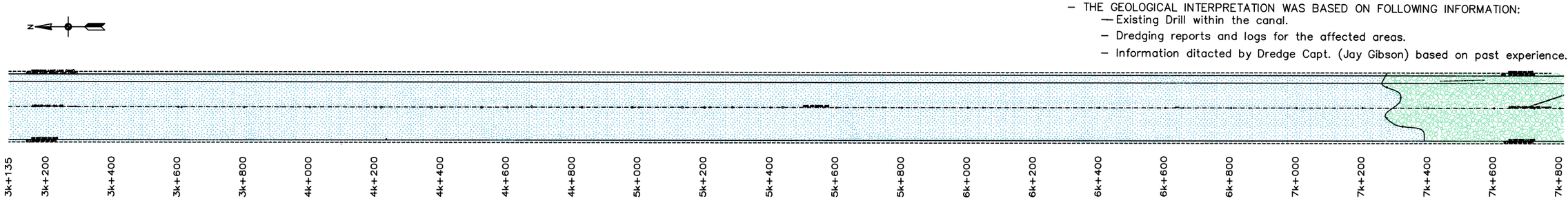
CHECKED BY: M. DE PUY, MANAGER, GEOTECHNICAL ENG.
APPROVED BY: LUIS D. ALFARO, MANAGER, ENGINEERING DIVISION

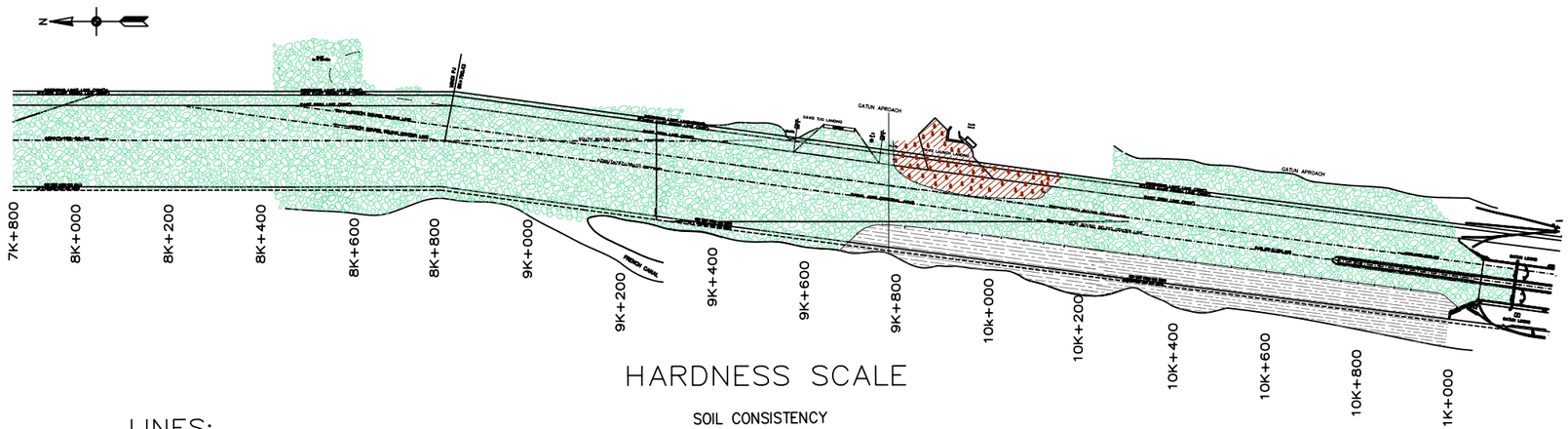
ATLANTIC ENTRANCE PROJECT



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

LINES:

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

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

1:5000 400 200 0 400 METERS

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

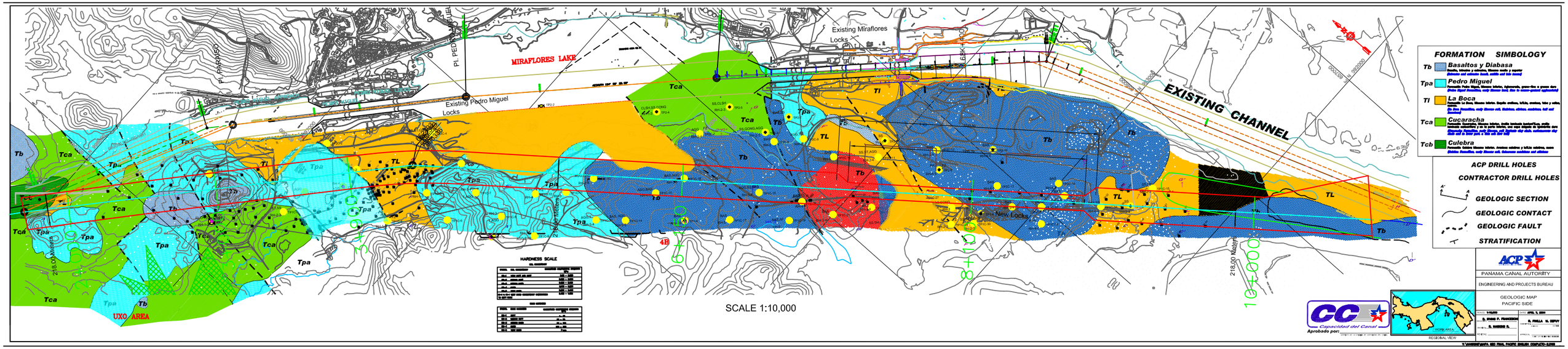
GEOLOGY: I. DIAZ

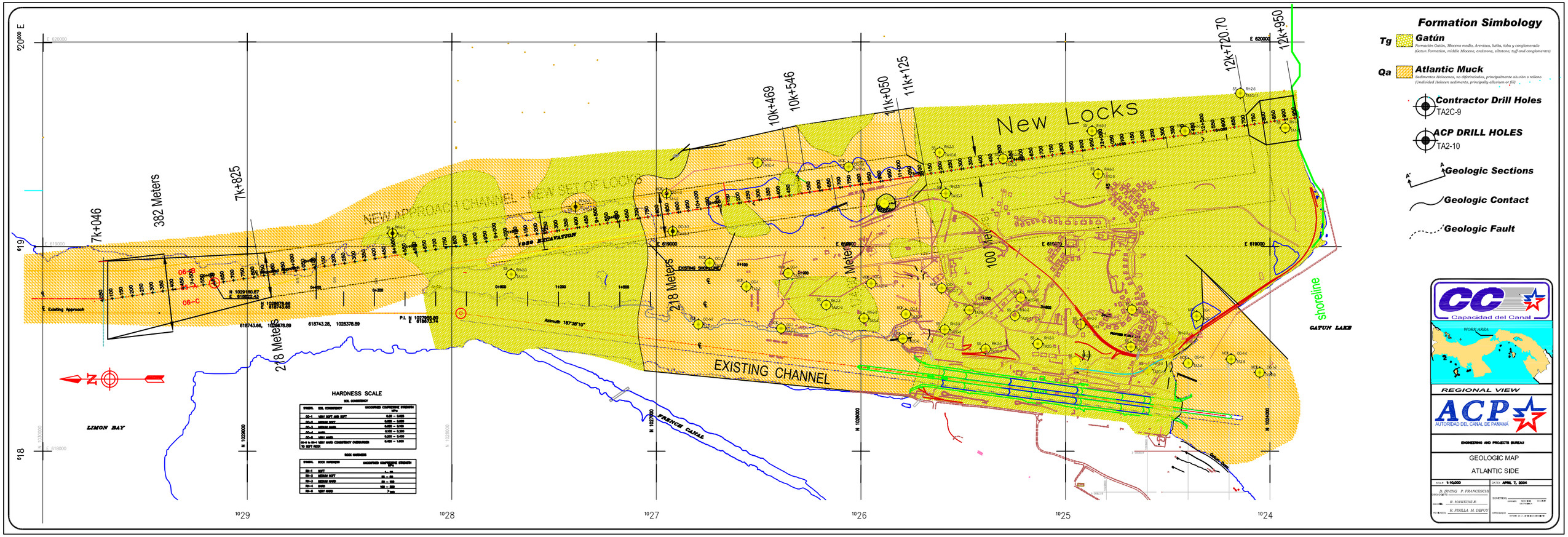
DRAWNS BY: M. CARRIZO/A. LU (IPIT) I. DIAZ (IPIG)

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

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

6123–118


MIRAFLORES LAKE
Existing Pedro Miguel Locks
Existing Miraflores Locks
New Locks
EXISTING CHANNEL
PL. PARAISO
PL. PEDRO MIGUEL
UXO AREA
218,00 Meters
Tb
Tca
Tpa
Tl
TL
Tcb
HARDNESS SCALE
SCALE 1:10,000
FORMATION SIMBOLOGY
Basaltos y Diabasa
Pedro Miguel
La Boca
Cucaracha
Culebra
ACP DRILL HOLES
CONTRACTOR DRILL HOLES
GEOLOGIC SECTION
GEOLOGIC CONTACT
GEOLOGIC FAULT
STRATIFICATION
PANAMA CANAL AUTORITY
ENGINEERING AND PROJECTS BUREAU
GEOLOGIC MAP
PACIFIC SIDE
Capacidad del Canal
Aprobado por
WORK AREA
REGIONAL VIEW



Formation Simbology

Tg — **Gatún**
Formación Gatún, Mioceno medio, Arenisca, 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

Geologic Contact

Geologic Fault

Capacidad del Canal

REGIONAL VIEW

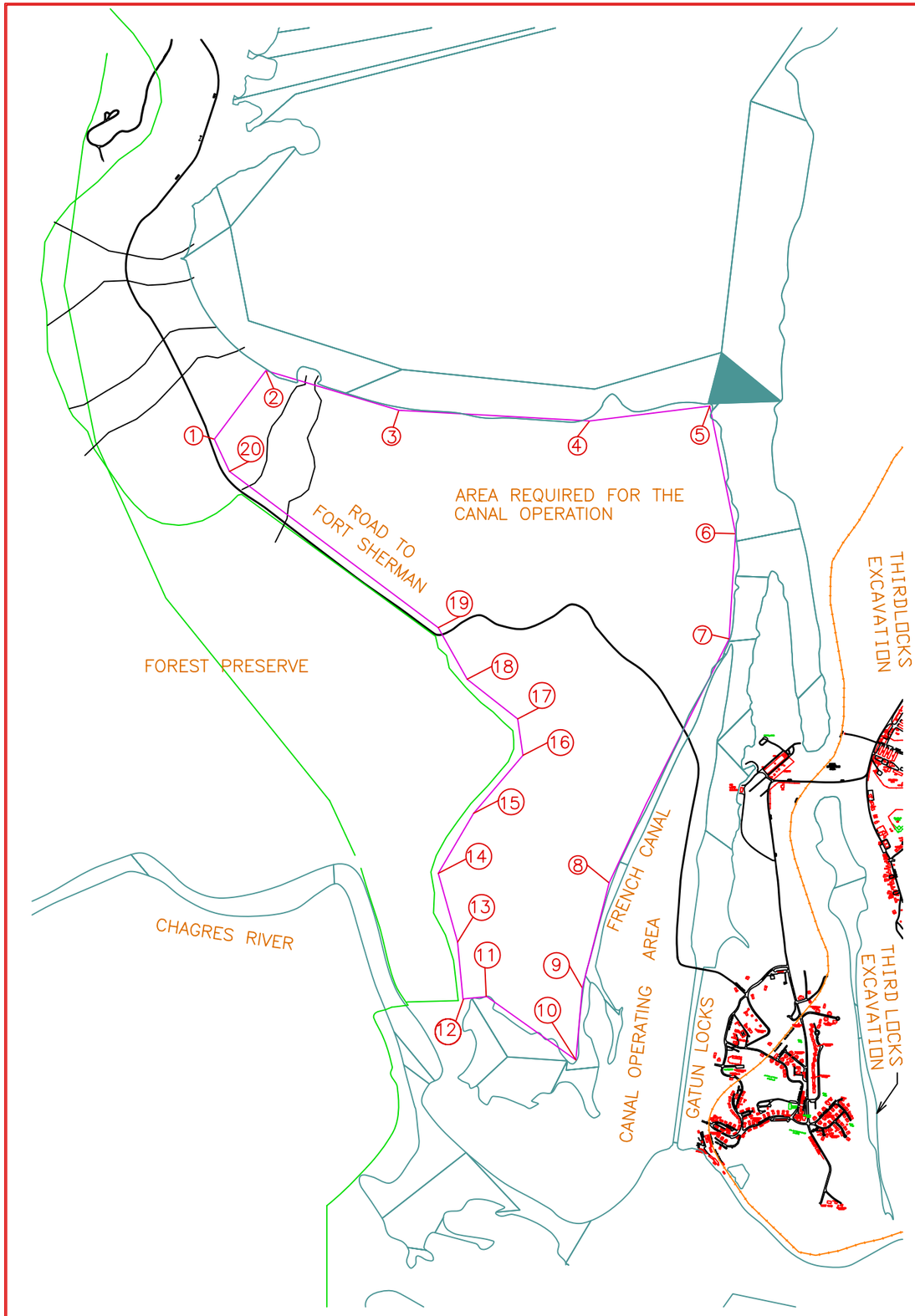
ACP
AUTORIDAD DEL CANAL DE PANAMÁ

ENGINEERING AND PROJECTS BUREAU

GEOLOGIC MAP
ATLANTIC SIDE

SCALE: 1:10,000
DATE: APRIL 7, 2004

D. IRVING P. FRANCESCHI — DESIGNED
R. HAWKINS R. — DRAWN
R. PINILLA M. DEPUY — REVIEWED
SOMETECH — CHECKED
APPROVED



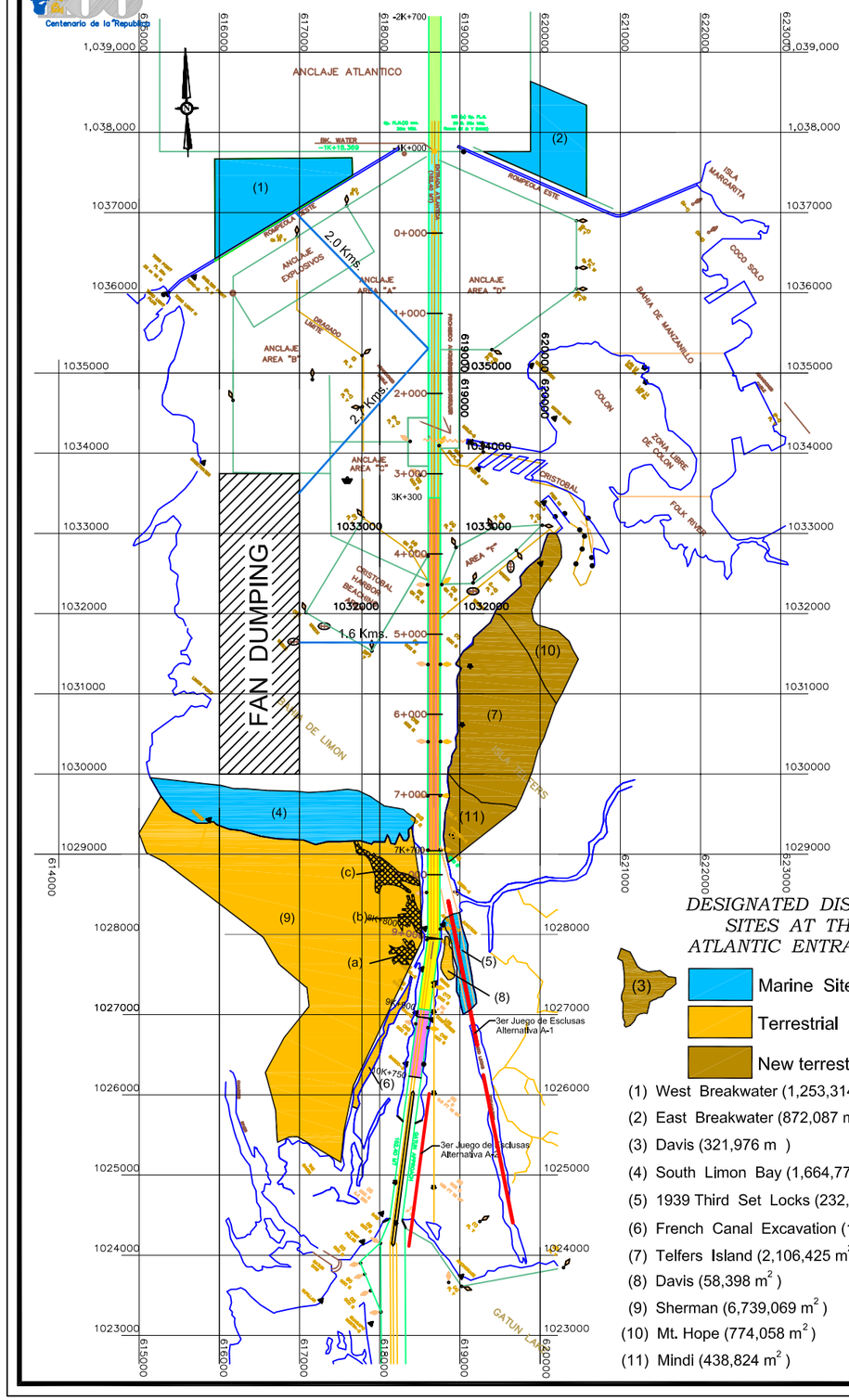
POINT	EASTING	NORTHING
1	615261.646	1029016.781
2	615591.488	1029456.905
3	616443.582	1029202.458
4	617666.070	1029133.932
5	618435.743	1029229.527
6	618600.664	1028411.171
7	618559.434	1027737.231
8	617790.562	1026173.882
9	617618.769	1025499.942
10	617577.539	1025039.188
11	617002.822	1025446.75
12	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

ATLANTIC ENTRANCE DEPENING AND NEW LOCKS DISPOSAL SITES

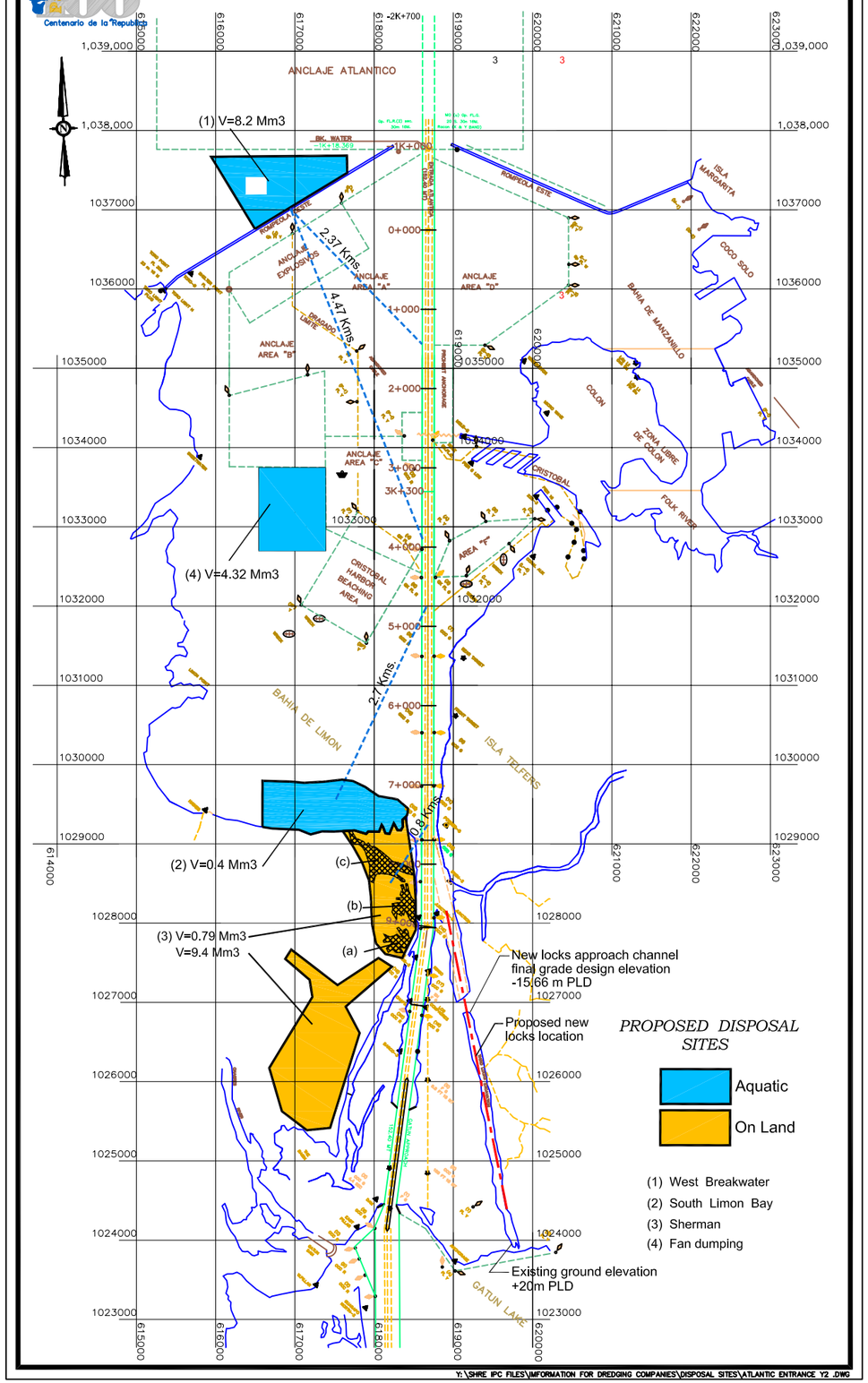


DESIGNATED DISPOSAL SITES AT THE ATLANTIC ENTRANCE

- 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



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

GATUN APPROACH
FROM BEACON No.16 TO N. END GATUN LOCKS
MIN. DEPTH 42'
(M.L.W. 0.4 P.L.D.)

GATUN REACH
FROM S. END GATUN LOCKS TO BUOY No.15
MIN. DEPTH 45' M.L.L.

PEÑA BLANCA REACH
FROM BUOY No.15 TO BUOY No.12
MIN. DEPTH 45' M.L.L.

BUENA VISTA REACH

ANCHORAGE BASIN

proposed anchorage for Post-Panamax Vessel

A=3.2M sq m
V=32 M cu m
8Km from Atlantic new locks mid point

A=1,6 M sq m
V=17,3M Cu m
6 Km from Atlantic entrance new locks mid point

Trinidad Dam
V=approx. 20 Mm3
41 Km. from Gaillard Cut mid point
& 10.5 Km from Atlantic new locks mid point

V=42.2 M cu m
A= 4,2 M sq m
34.7 Km.
from Gaillard Cut mid point

V=22.3 Mm3
A= 2,6 M sq m
32 Km. from Gaillard Cut mid point

Disposal site Frijoles
23 Km. from Gaillard cut
V=11 Mm3

Disposal site No. 14
19 Km. from Gaillard cut
V=0 m3

No 11
No 10
No 13
No 12
No 9
No 8
No 7
No 6
No 5
No 4 1/2
No 4
No 3
No 2 1/2
No 2
No 1

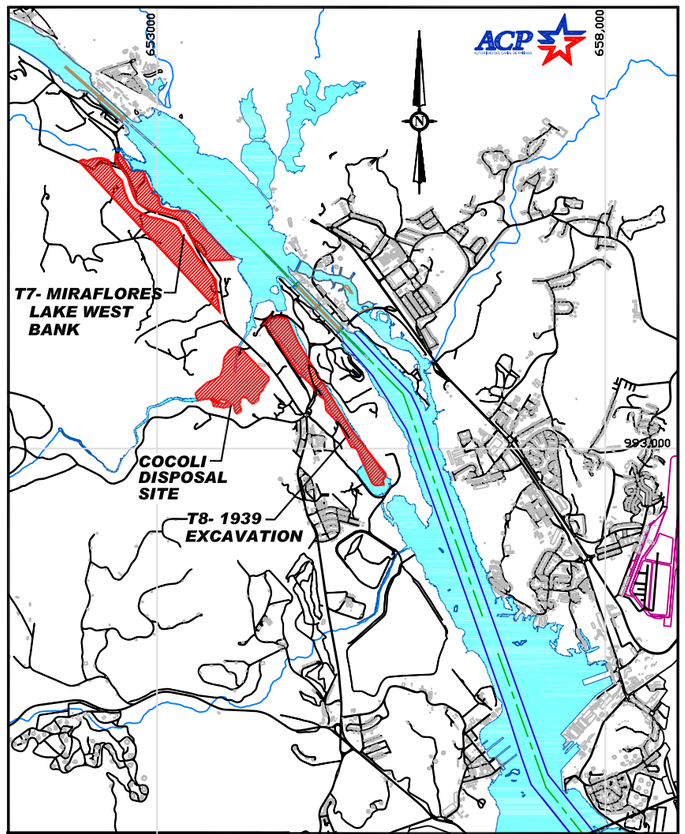
PANAMA CANAL AUTHORITY

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

GATUN LAKE DISPOSAL SITE

SCALE: HOR. 1:50,000 MT	DATE: JANUARY 03, 2001
SUBMITTED BY:	
DRAWN BY: UNIDAD DE CARTOGRAFIA	CHEKED BY TOPHOGRAFY MANAGER AND SURVEY
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

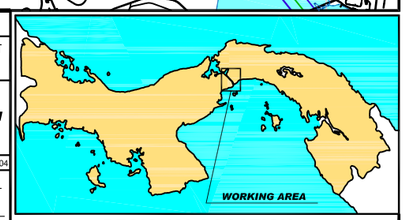


PANAMA CANAL AUTHORITY

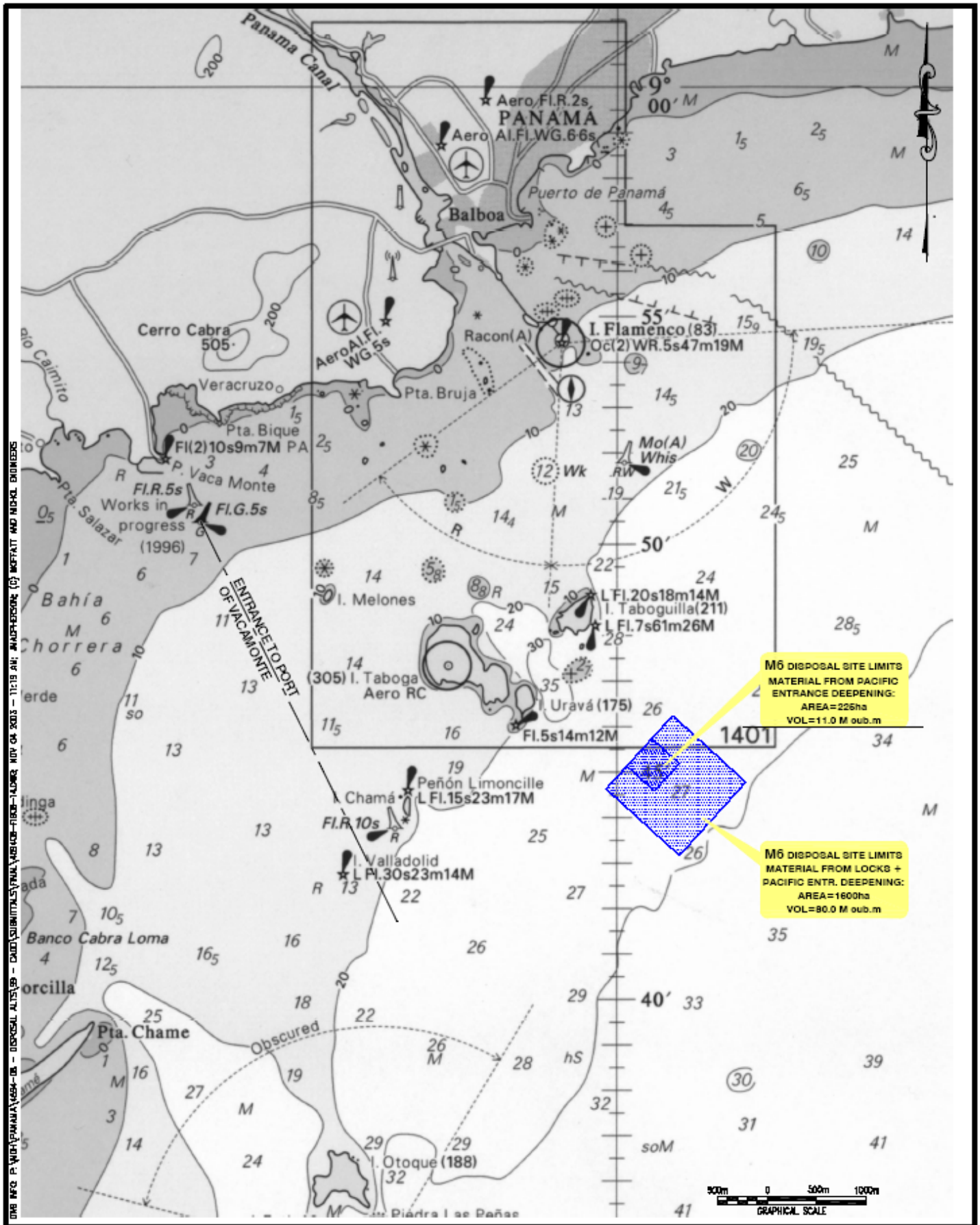
ENGINEERING AND PROJECT DEPARTMENT
COROZAL, REPUBLIC OF PANAMA

DISPOSAL SITE LOCATION FOR PACIFIC NEW LOCKS AND APPROACH CHANNEL DRY EXCAVATION

SCALE 1: 25000	DATE: AUGUST 31 , 2004
DESIGN R. PINILLA	SUBMITTED BY: CHIEF, LOCKS TEAM
DRAWN BY: R. HAWKINS R.	APPROVED BY: CHIEF, CANAL CAPACITY DIVISION
CHECK BY: C. GEORGE	



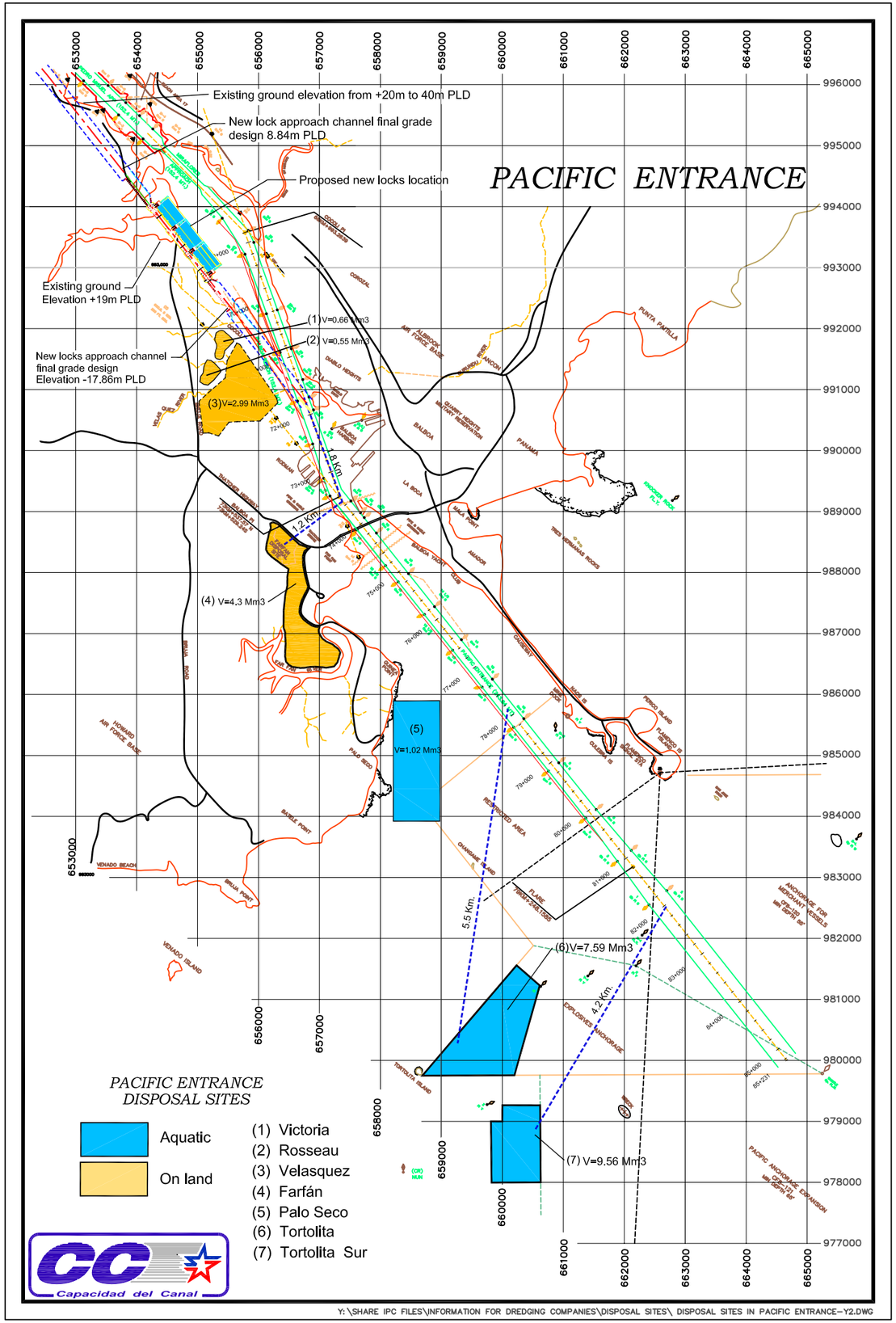
REGIONAL LOCATION

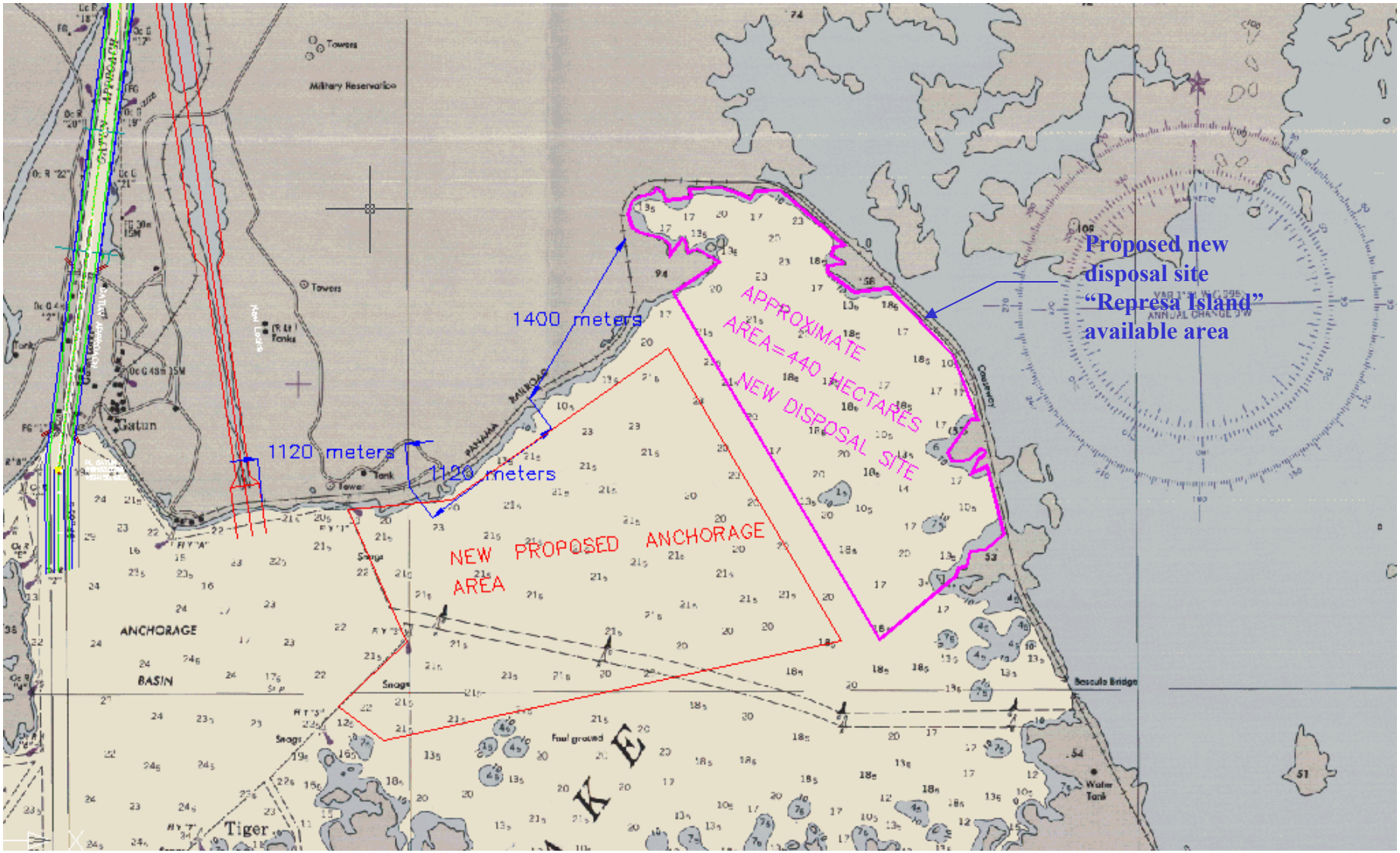


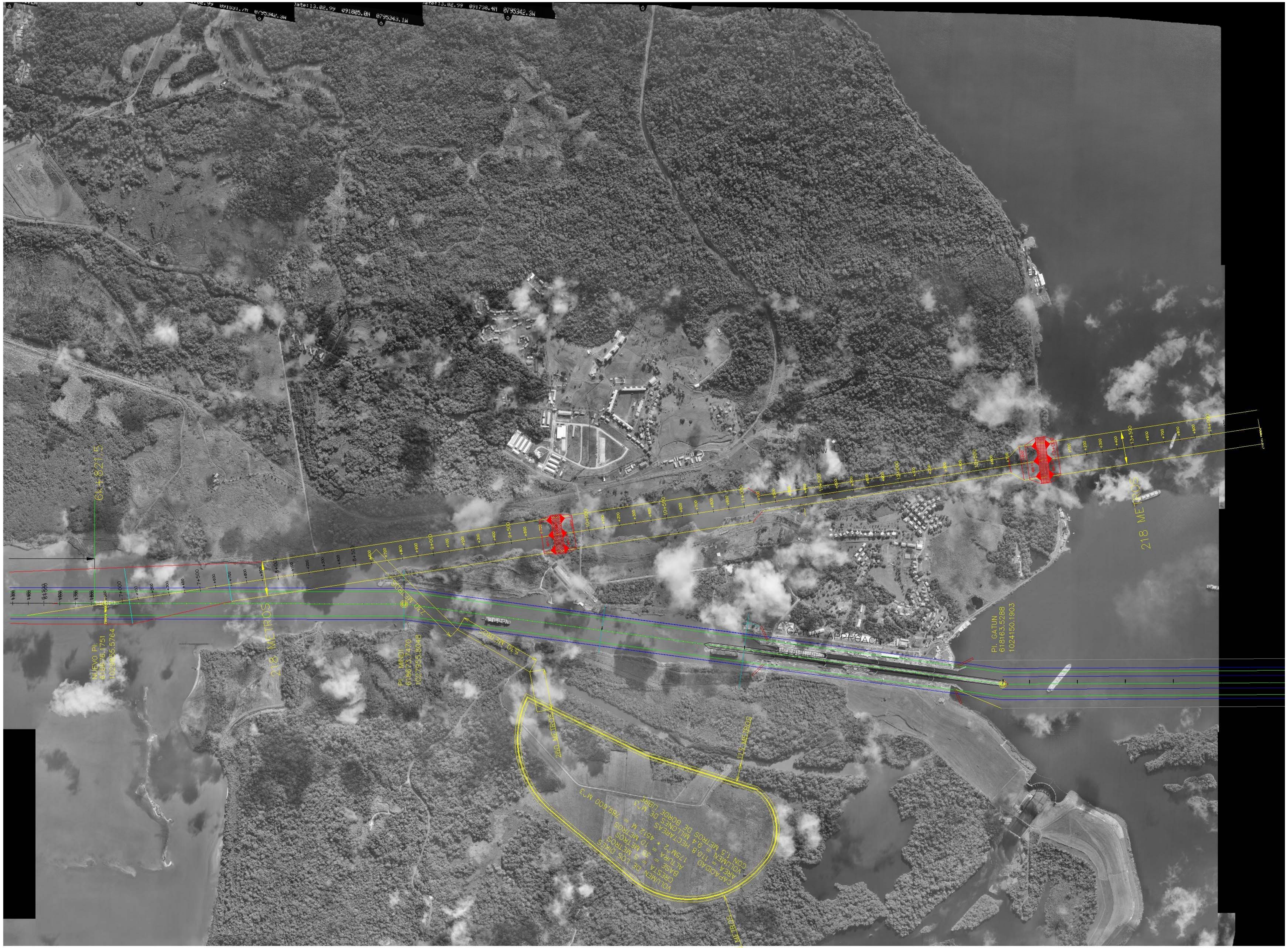
MOFFATT & NICHOL ENGINEERS
LOUIS BERGER GROUP INC.

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


Proposed new disposal site "Represa Island" available area
1400 meters
1120 meters
1120 meters
APPROXIMATE AREA=440 HECTARES NEW DISPOSAL SITE
NEW PROPOSED ANCHORAGE AREA
ANCHORAGE BASIN
Gatun
Towers
Military Reservation
Tiger
Bascula Bridge
Water Tank


6k+821.5
NUEVO PI.
618676.1751
218 METROS
GATUN APPROACH
PI. GATUN
618163.5288
1024150.1903
218 METROS

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)