Study on the Effect of Deepening on Gaillard Cut Slopes

Estudio Sobre el Efecto de la Profundización en las Laderas del Corte Gaillard

Panama Canal Authority

Abril del 2002

Conclusiones
(No existe Resumen Ejecutivo)

Panama Canal Authority
Engineering and Projects Department
Engineering Division
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Volume 1

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estimates reflect two conditions as shown in tables 4a and 4b: 1) underwater excavation, and 2) Dry excavation respectively.

Total volume and costs estimate necessary to increase the stability of those area that will be affected by a deepening program of Gaillard Cut beyond the 1.00m already planned is summarized as follows:

Activity	Deepening to 29' PLD (8.84m) Evaluation Elevation: 27' PLD (8.22m)		Deepening to 24' PLD (7.31m) Evaluation Elevation: 22' PLD (6.70m)	
	Volume (m3)	Cost	Volume (m3)	Cost
Dry excavation	5,387,502	21,550,007	8,162,251	32,649,006
Underwater Excavation	923,165	13,847,478	2,574,882	38,623,227
Special Work at Purple Rock	Lump Sum	200,000	Lump Sum	200,000
Contingency		7,119,497		14,294,447
Total		42,716,981		85,766,679

5.0 Conclusions

1. The Gaillard Cut slopes are, in general, considered safe for the current Deepening Program (bottom elevation 34' PLD). The basic reason for this is that slopes during the Cut Widening Program were designed for a bottom elevation of 32.3' PLD (10.00m). Note that the widening did not touch half of the slopes. Especially important is that the widening was laid out to avoid affecting several sensitive areas.

2. There are only three areas that are considered problematic for the current Deepening Program: West Culebra Slide, East Culebra Slide and Purple Rock Slide. Remedial works are being planned for West Culebra and Purple Rock in Fiscal Year 2002 and for East Culebra in Fiscal Year 2003.

3. Stability analyses show that drilling and blasting to elevation 27' PLD, but not removing the material from the bottom of the channel has little effect in reducing the stability of the slopes. No further work is required for this condition, except in those considered sensitive areas. On the other hand, drilling and blasting to elevation 22' PLD does considerable reduce the stability of many slopes and a stabilization program will be required similar to (case 7.2).

4. Any deepening project that extends below elevation 34' PLD will affect the stability of the existing slopes in Gaillard Cut. It is estimated that if we deepen 5 more feet (1.50m) below elevation 34" PLD, 56 % of the slopes in Gaillard Cut will require some stabilization measure. In general, for every 3 feet (1.00m) that we go lower than 34' PLD will require 4 to 5 million cubic meter of additional excavation on the existing slopes.

5. Notwithstanding the above statement, a deepening project to lower the bottom of channel to a elevation less than 34' PLD can be accomplished successfully if we implement the adequate stabilization measures as described in this study.

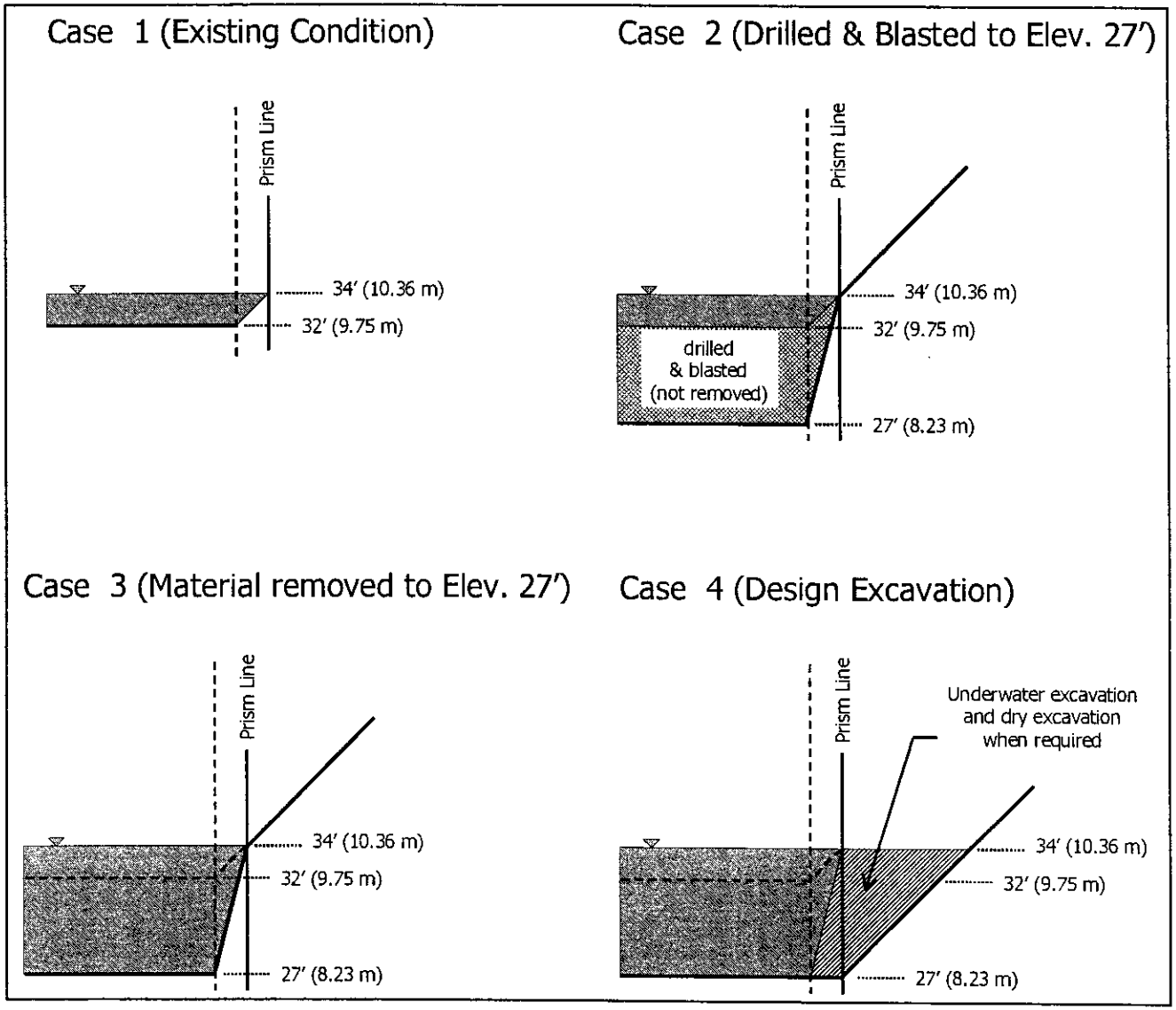

Figure 1a Design elevations for stability análisis and volume computation

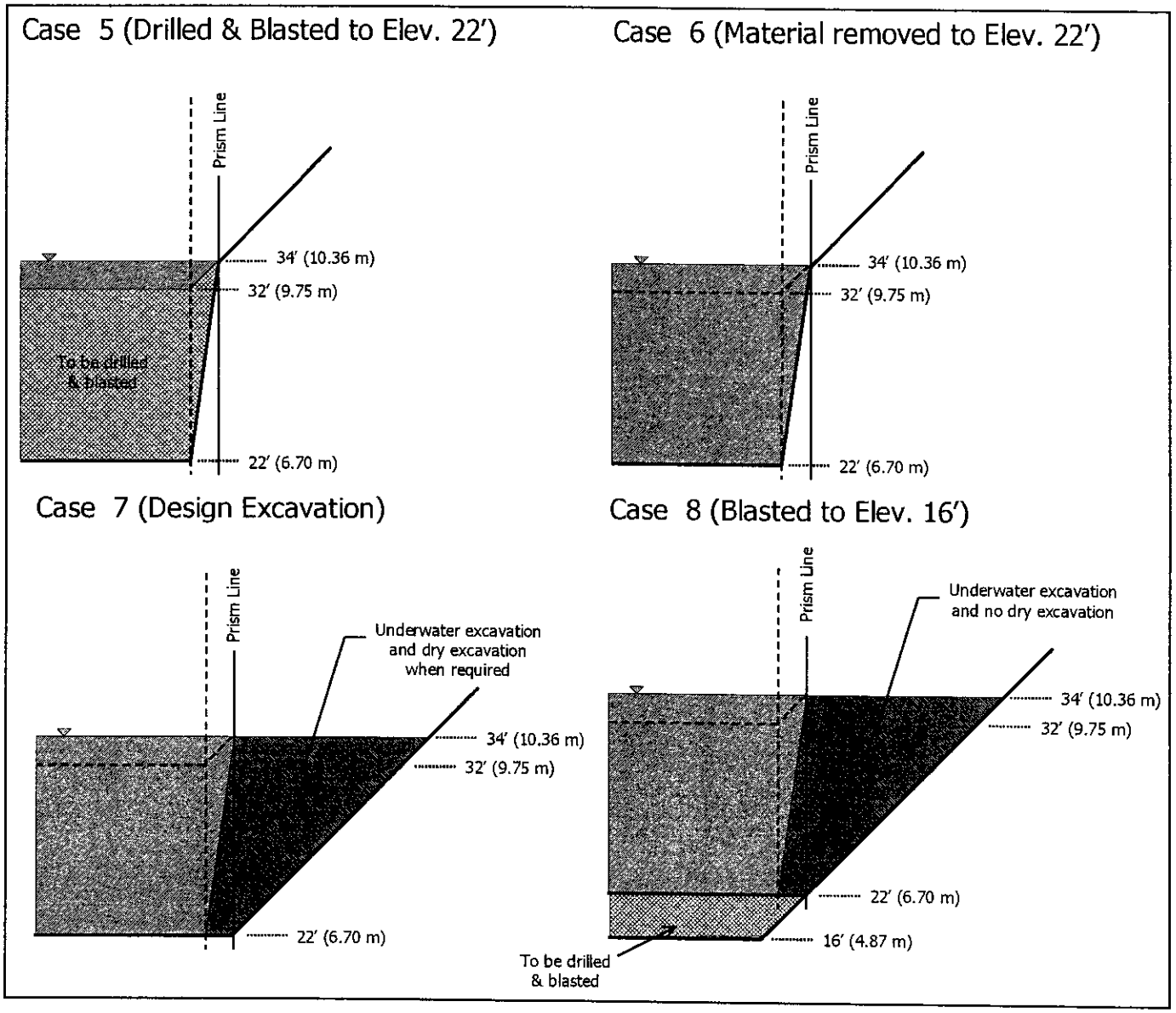

Figure 1b Design elevations for stability analysis and volume computation

Fn. #	FORMATION	MECHANISMS	FUNCTION	EQUATION	BLASTED MATERIAL	UNIT WEIGHT
1	La Boca	First Time	Fully Softened	$\phi = 17.5 + 20.3 / (1+\sigma n / 200)$	No	21.2 - 22.0
2	La Boca	Reactivated	Residual	$\phi = 7.5 + 14.0 / (1+\sigma n / 150)$	Si	
7	Cucaracha	First Time	Fully Softened	$\phi = 13.5 + 17.1 / (1+\sigma n / 373)$	No	21.2 - 22.0
8	Cucaracha	Reactivated (lab)	Residual	$\phi = 7.4 + 8.7 / (1+\sigma n / 100)$	Si	
25	Cucaracha	Reactivated (backanalysis)	Residual	$\phi = 8.5 + 13.0 / (1+\sigma n / 100)$	Si	
26	Cucaracha	First time	Fully Softened	$\phi = 13.5 + 24.0 / (1+\sigma n / 373)$	No	
9	Culebra	First Time	Fully Softened (upper)	$\phi = 13.1 + 20.9 / (1+\sigma n / 120)$	No	21.2 - 22.0
10	Culebra	Reactivated	Residual	$\phi = 9.1 + 5 \log (2400 / \sigma n)$	Si	
11	Gatuncillo	First Time	Fully Softened	$\phi = 12.0 + 20.7 / (1+\sigma n / 362)$	No	21.2 - 22.0
12	Gatuncillo	Reactivated	Residual	$\phi = 7.3 + 6 \log (4600 / \sigma n)$	Si	
3	Las Cascadas (Tuff)	First Time	Fully Softened	$\phi = 14.2 + 10.7 / (1+\sigma n / 475)$	No	22.0 - 22.8
5	Las Cascadas (Tuff,)	Reactivated (lab)	Residual	$\phi = 5.0 + 8.5 / (1+\sigma n / 200)$	Si (for Tuff only)	
27	Las Cascadas (Weak Plane - La Pita)	Weak Plane (backanalysis)	Barton (σc=1110 psi)	$\phi = 8 + 10 \log (1110 / \sigma n)$	Si (for Agg. & An)	
4	Las Cascadas (Aggl. & Andesite)	First Time	Hoek & Brown	$m = 0.3$, $s = 0.0001$, $\sigma c = 1200$ psi	No	
6	Las Cascadas (Aggl. & Andesite)	Poor Quality Rock	Hoek & Brown	$m = 0.069$, $s = 0.000003$, $\sigma c = 1200$ psi	Si (for Agg. & An)	
16	Bas Obispo	Plane failure along a disc.(option 2)	Barton (σc=3000 psi)	$\phi = 16 + 5 \log (3000 / \sigma n)$	No	
17	Bas Obispo	Plane failure along a disc.(option 3)	Barton (σc=5515 psi)	$\phi = 16 + 5 \log (5515 / \sigma n)$	No	
13	Bas Obispo	First Time (option 1)	Hoek & Brown	$m = 0.34$, $s = 0.0001$, $\sigma c = 3000$ psi	No	
14	Bas Obispo	First Time (option 2)	Hoek & Brown	$m = 0.34$, $s = 0.0001$, $\sigma c = 5515$ psi	No	
18	Bas Obispo	Poor Quality Rock (option 1)	Hoek & Brown	$m = 0.069$, $s = 0.000003$, $\sigma c = 3000$ psi	Si	
19	Bas Obispo	Poor Quality Rock (option 2)	Hoek & Brown	$m = 0.069$, $s = 0.000003$, $\sigma c = 5515$ psi	Si	
20	Pedro Miguel Agg	First Time	Hoek & Brown	$m = 0.34$, $s = 0.0001$, $\sigma c = 5515$ psi	No	22.8 - 23.5
21	Pedro Miguel Agg	Reactivated & Plane Failure	Barton (σc=5515 psi)	$\phi = 16 + 5 \log (5515 / \sigma n)$	No	
22	Pedro Miguel Agg	Poor Quality Rock	Hoek & Brown	$m = 0.069$, $s = 0.000003$, $\sigma c = 5515$ psi	Si	
23	Basalt	First Time	Hoek & Brown	$m = 1.21$, $s = 0.0021$, $\sigma c = 7255$ psi	No	23.5
24	Basalt	Poor Quality Rock	Hoek & Brown	$m = 0.069$, $s = 0.000003$, $\sigma c = 7255$ psi	Si	

Table 1 Design Shear Strength Envelopes

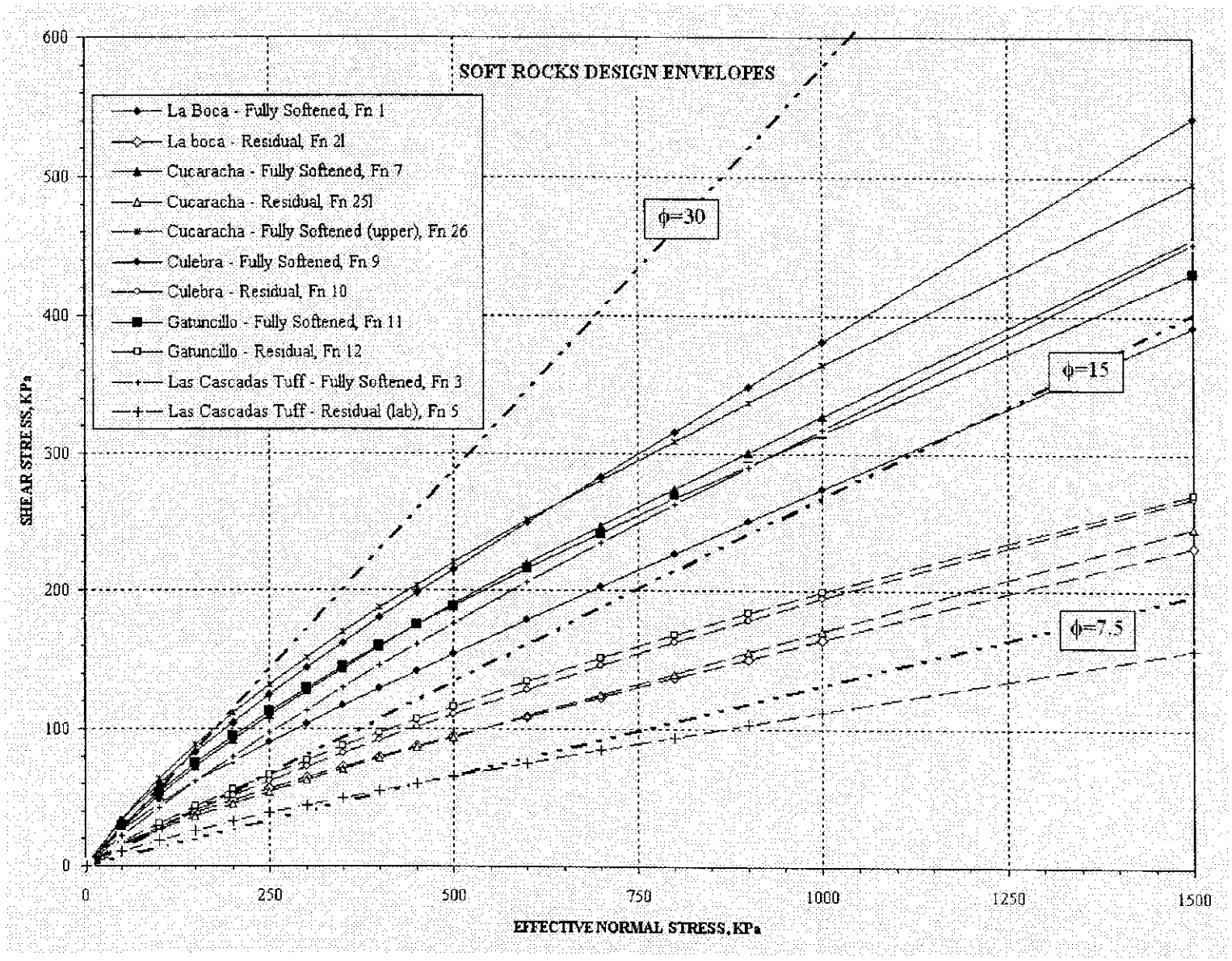

Figure 2a Soft Rocks Shear Strength Envelopes

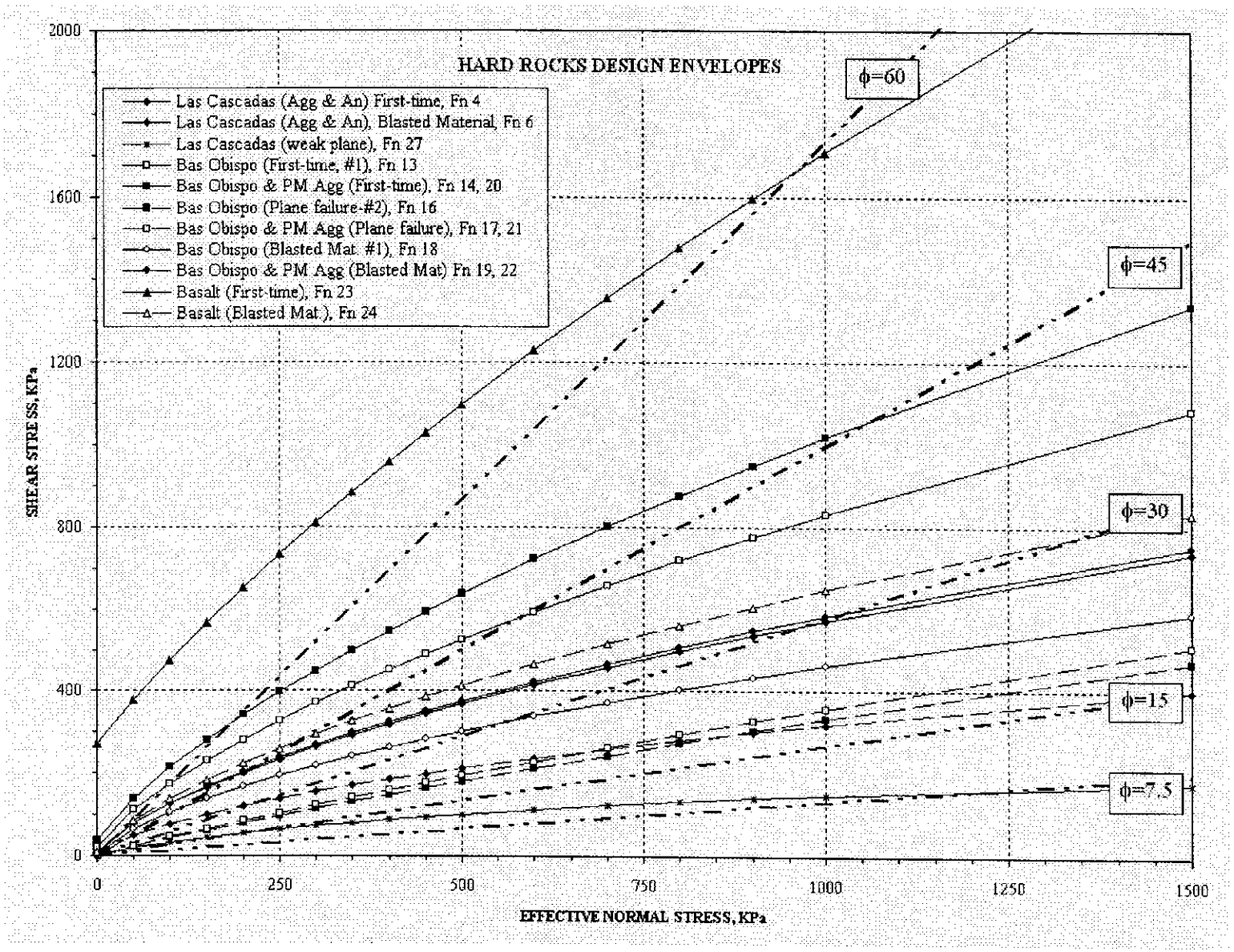

Figure 2b Hard Rocks Shear Strength Envelopes

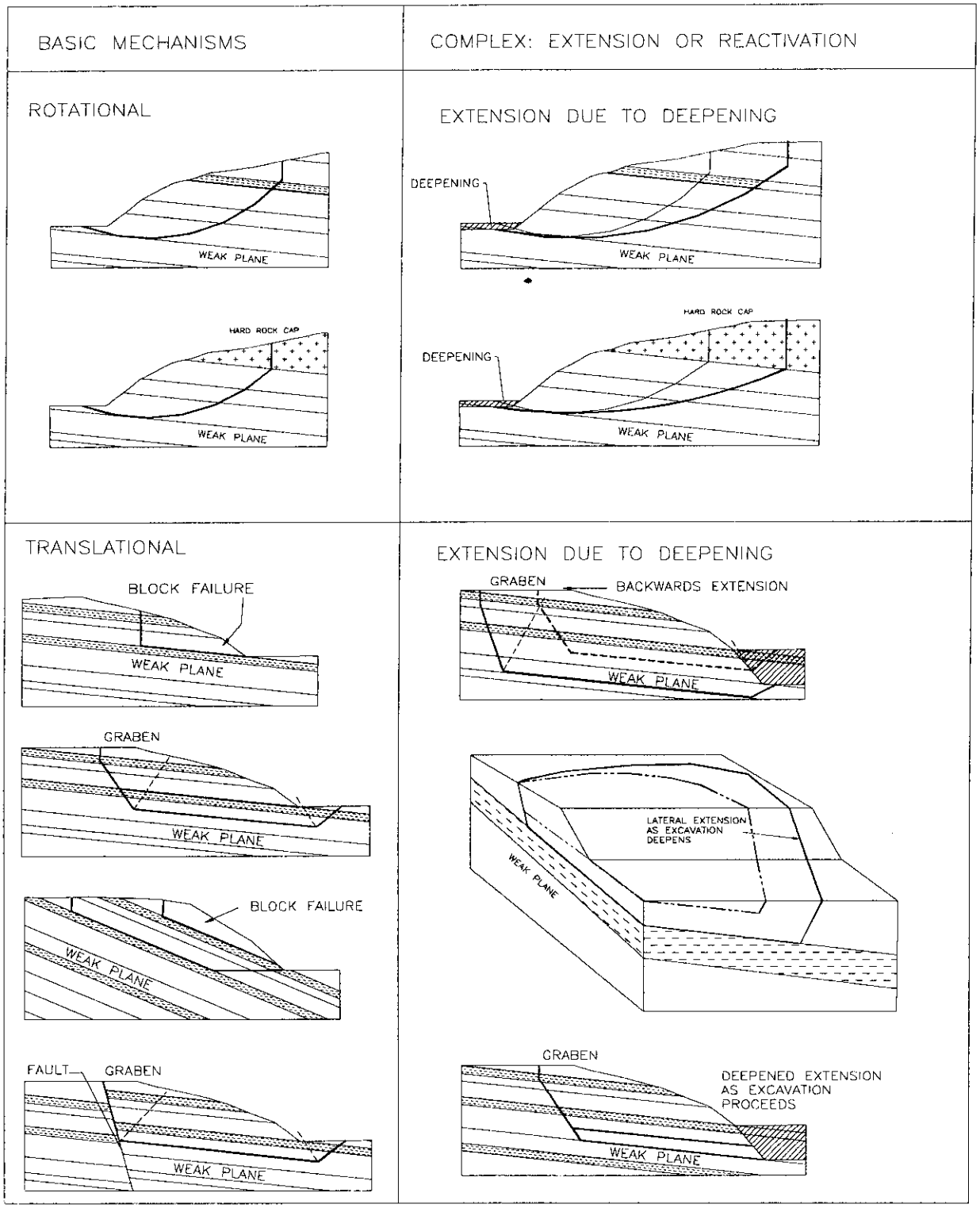

Figure 3 Assumed failure mechanisms as a function of structural setting

West Bank -Summary of Stability Analyses

Station	Representative Stations	Factor of Safety										Dry excavation is required
		Case 1	Case 2	Case 3	Case 4.1	Case 4.2	Case 5	Case 6	Case 7.1	Case 7.2	Case 8	
		Existing	27 ft (blasted)	27 ft (removed)	27 ft (design-underwater slope)	27 ft (design-&dry excav.)	22 ft (blasted)	22 ft (removed)	22 ft (design-underwater slope)	22 ft (design-&dry excav.)	16 ft (blasted)	
51k+600 W (1692+91)	50k+320 to 52k+160	2.834	2.814	2.772	2.684	2.684	2.744	2.691	2.501	2.501	2.486	NO
53k+171 W (1744+45)	52k+160 to 53k+780	1.261	1.245	1.214	1.182	1.238	1.198	1.168	1.122	1.200	1.092	YES
54k+300 W (1781+49)	53k+780 to 55k+000	0.976	0.972	0.958	0.889	1.021	0.944	0.908	0.861	1.000	0.862	YES
55k+930 W (1835+00)	55k+000 to 56k+740	1.864	1.850	1.800	1.797	1.797	1.800	1.752	1.694	1.694	1.689	NO
56k+898 W (1866+73)	56k+740 to 57k+050	1.359	1.349	1.318	1.267	1.267	1.307	1.279	1.213	1.330	1.198	YES
57k+098 W (1873+29)	57k+050 to 57k+475	3.847	3.847	3.829	3.792	3.792	3.822	3.794	3.744	3.744	3.733	NO
57k+820 W (1897+00)	57k+475 to 57k+925	0.971	0.971	0.959	0.949	1.012	0.958	0.952	0.937	1.037	0.937	YES
58k+120 W (1906+82)	57k+925 to 58k+760	1.006	1.005	0.990	0.980	1.046	0.989	0.973	0.957	1.001	0.955	YES
58k+887 W (1932+00)	58k+760 to 59k+000	1.070	1.069	1.062	1.054	1.054	1.062	1.055	1.042	1.188	1.041	YES
59k+070 W (1938+00)	59k+000 to 59k+260	1.000	0.999	0.990	0.978	1.107	0.988	0.982	0.963	1.121	0.961	YES
59k+485 W (1951+60)	59k+260 to 59k+780	0.962	0.960	0.955	0.944	1.169	0.953	0.952	0.941	1.160	0.916	YES
59k+881 W (1964+60)	59k+780 to 60k+050	0.933	0.931	0.921	0.914	0.938	0.920	0.910	0.900	0.936	0.897	YES
60k+240 W (1976+37)	60k+050 to 60k+400	1.039	1.037	1.015	1.010	1.056	1.013	0.992	0.980	1.048	0.978	YES
60k+950 W (1999+61)	60k+400 to 61k+240	1.190	1.183	1.152	1.117	1.372	1.144	1.122	1.069	1.309	1.052	YES
61k+600 W (2021+00)	61k+240 to 61k+900	1.417	1.414	1.382	1.356	1.356	1.380	1.351	1.315	1.315	1.309	NO
62k+000 W (2034+12)	61k+900 to 62k+200	1.072	1.055	1.042	1.030	1.092	1.028	1.001	1.001	1.090	0.935	YES
63k+050 W (2068+56)	62k+910 to 63k+150	2.493	2.486	2.451	2.442	2.442	2.443	2.413	2.397	2.397	2.384	N/A
63k+327 W (2077+65) (a)	63k+150 to 63k+725	2.220	2.220	2.212	2.204	2.197	2.212	2.205	2.194	2.187	2.194	N/A
63k+327 W (2077+65) (b)	63k+150 to 63k+725	1.245	1.235	1.216	1.089	1.174	1.156	1.123	1.033	1.108	1.007	N/A

Table 2 Summary of Stability Analyses (West Bank)

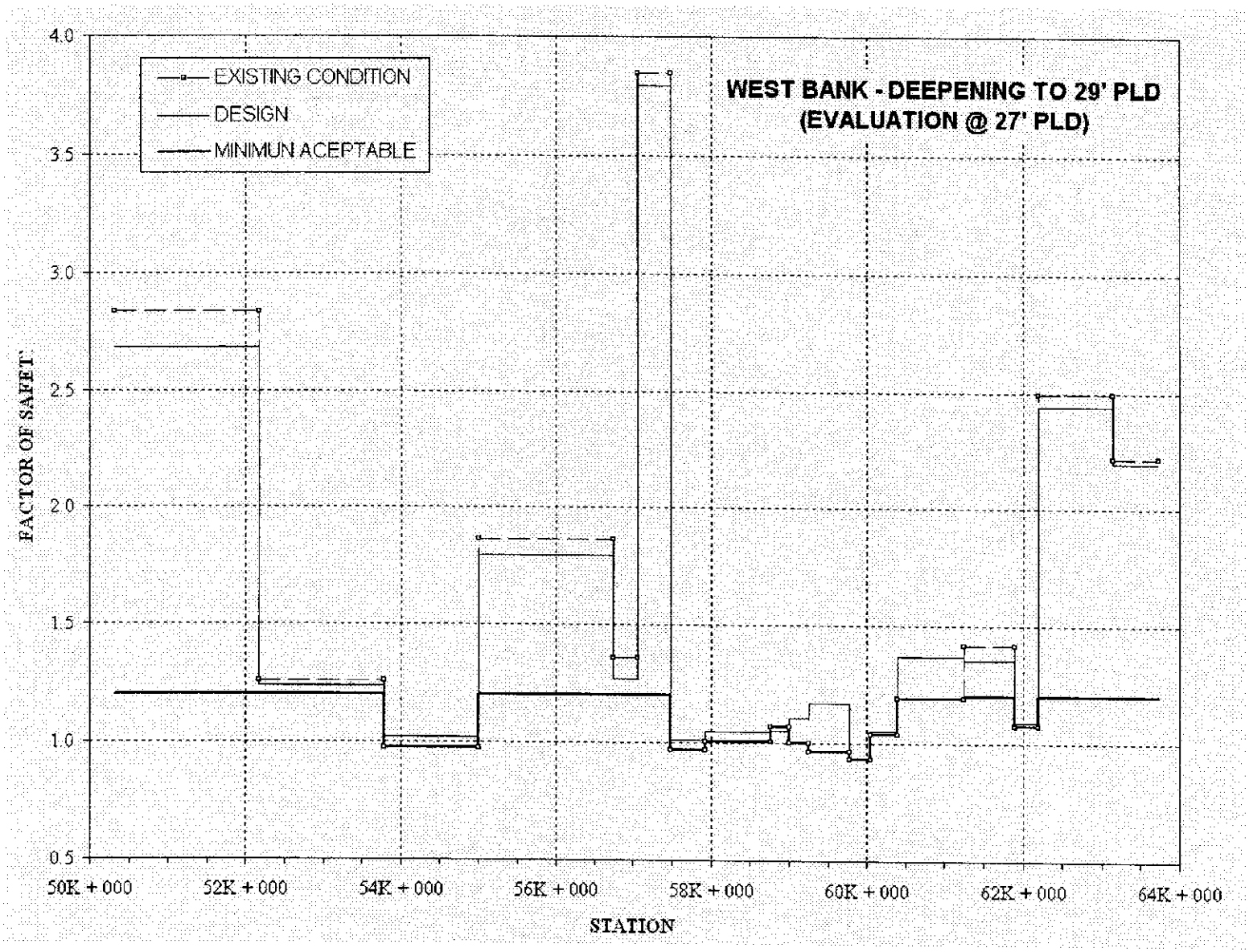

Figure 4a Results of stability analyses (West bank, elevation 27'PLD)

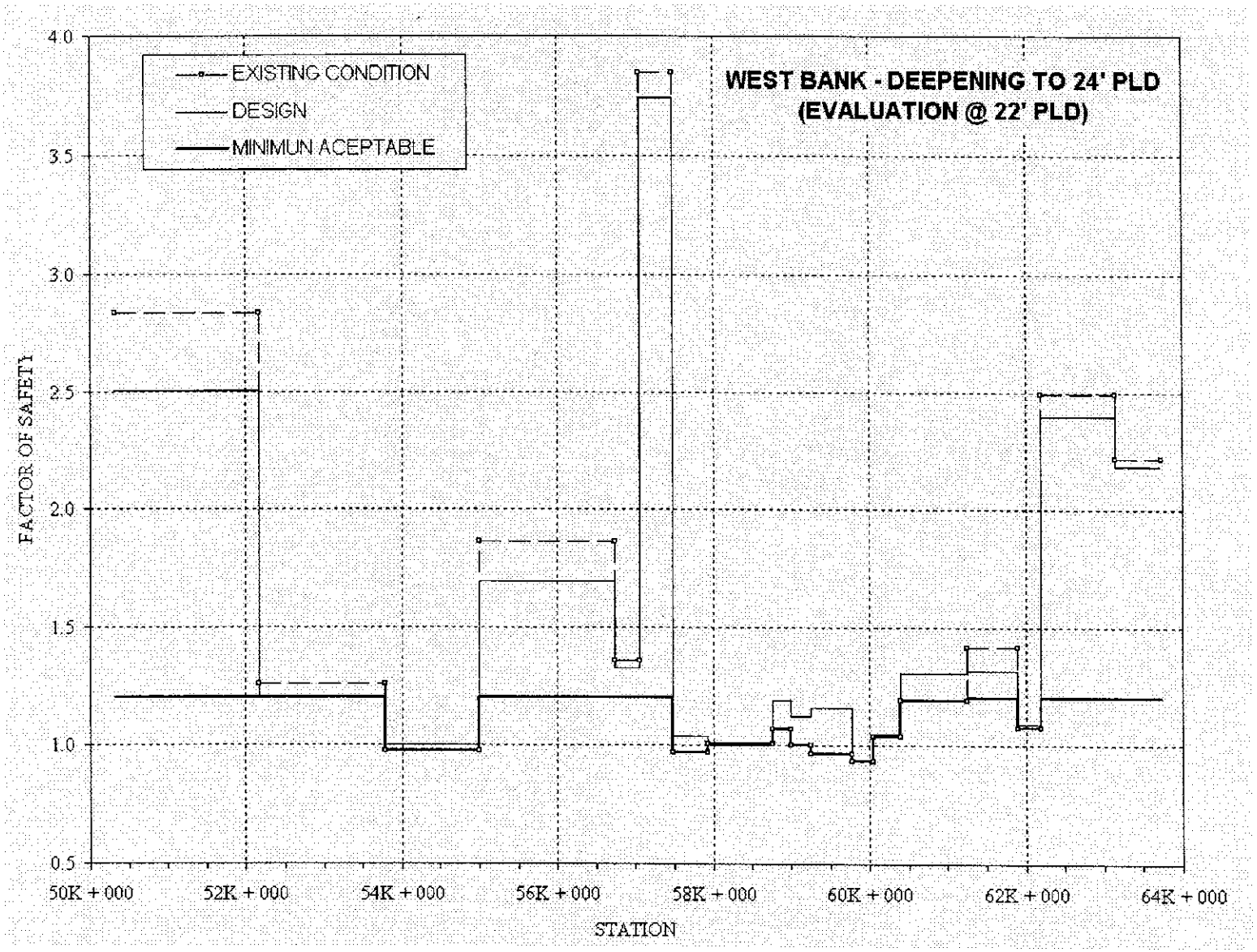

Figure 4b Results of stability analyses (West bank, elevation 22'PLD)

East Bank - Summary of Stability Analyses

Station	Representative Stations	Factor of Safety										Dry excavation is required
		Case 1	Case 2	Case 3	Case 4.1	Case 4.2	Case 5	Case 6	Case 7.1	Case 7.2	Case 8	
		Existing	27 ft (blasted)	27 ft (removed)	27 ft (design-underwater slope)	27 ft (design-&dry excav.)	22 ft (blasted)	22 ft (removed)	22 ft (design-underwater slope)	22 ft (design-&dry excav.)	16 ft (blasted)	
51k+328 E (1684+00)	50k+780 to 52k+060	2.925	2.883	2.828	2.727	2.727	2.776	2.687	2.523	2.523	2.479	NO
53k+371 E (1751+00)	52k+060 to 53k+550	1.508	1.496	1.457	1.433	1.433	1.439	1.396	1.362	1.362	1.346	NO
53k+950 E (1770+04)	53k+550 to 54k+880	1.345	1.330	1.272	1.195	1.195	1.221	1.147	1.056	1.212	1.021	YES
55k+280 E (1813+65)	54k+880 to 55k+400	1.038	1.021	1.000	0.985	1.065	0.976	0.947	0.914	1.034	0.908	YES
55k+830 E (1831+70)	55k+400 to 56k+000	0.991	0.988	0.970	0.958	0.996	0.961	0.947	0.917	0.990	0.917	YES
56k+460 E (1852+36) (a)	56k+000 to 56k+560	0.921	0.919	0.892	0.861	0.912	0.875	0.843	0.789	0.913	0.784	YES
56k+460 E (1852+36) (b)	56k+000 to 56k+560	1.091	1.090	1.077	1.020	1.061	1.054	1.029	0.944	1.050	0.936	
57k+060 E (1872+00) (a)	56k+560 to 57k+160	1.343	1.343	1.322	1.304	1.304	1.311	1.276	1.228	1.228	1.227	NO
57k+060 E (1872+00) (b)	56k+560 to 57k+160	1.291	1.288	1.274	1.271	1.271	1.269	1.254	1.234	1.234	1.230	
57k+270 E (1878+93)	57k+160 to 57k+520	2.996	2.982	2.957	2.927	2.927	2.927	2.864	2.763	2.763	2.754	YES
57k+635 E (1890+91)	57k+320 to 57k+675	1.290	1.289	1.281	1.271	1.271	1.280	1.248	1.225	1.225	1.223	NO
58k+035 E (1904+00)	57k+675 to 58k+295	1.001	0.992	0.962	0.861	0.996	0.950	0.923	0.795	1.006	0.772	YES
58k+520 E (1920+00)	58k+295 to 59k+600	1.054	1.053	1.048	1.046	1.046	1.047	1.045	1.041	1.125	1.041	YES
59k+668 E (1957+61)	59k+600 to 59k+800	0.931	0.931	0.928	0.927	1.036	0.928	0.926	0.922	1.035	0.922	YES
59k+918 E (1966+00)	59k+800 to 60k+050	1.345	1.345	1.340	1.333	1.333	1.340	1.332	1.324	1.324	1.324	NO
60k+244 E (1976+50)	60k+050 to 60k+355	1.051	1.051	1.047	1.045	1.045	1.047	1.043	1.039	1.063	1.039	YES
60k+412 E (1982+00) (a)	60k+355 to 60k+500	1.199	1.199	1.186	1.176	N/A	1.186	1.173	1.161	N/A	1.160	YES SPECIAL WORK
60k+412 E (1982+00) (b)	60k+355 to 60k+500	0.845	0.831	0.802	0.737	N/A	0.778	0.754	0.676	N/A	0.541	
60k+412 E (1982+00) (c)	60k+355 to 60k+500	0.794	0.794	0.793	0.634	N/A	0.753	0.717	0.588	N/A	0.588	
60k+594 E (1988+00) (a)	60k+500 to 60k+695	1.049	1.048	1.045	1.033	1.268	1.044	1.044	1.025	1.265	1.025	YES
60k+594 E (1988+00) (b)	60k+500 to 60k+695	1.023	1.014	0.965	0.896	1.022	0.956	0.891	0.812	0.954	0.785	
60k+747 E (1993+00) (a)	60k+695 to 60k+850	1.251	1.227	1.203	1.131	1.174	1.198	1.162	1.080	1.188	1.079	YES
60k+747 E (1993+00) (b)	60k+695 to 60k+850	0.996	0.987	0.981	0.960	1.015	0.981	0.936	0.950	1.059	0.938	
60k+747 E (1993+00) (c)	60k+695 to 60k+850	1.183	1.182	1.172	1.163	1.185	1.171	1.160	1.149	1.163	1.148	
61k+720 E (2025+00)	61k+420 to 61k+825	2.766	2.765	2.735	2.658	2.658	2.735	2.707	2.614	2.614	2.612	NO

Table 3 Summary of Stability Analyses (East Bank)

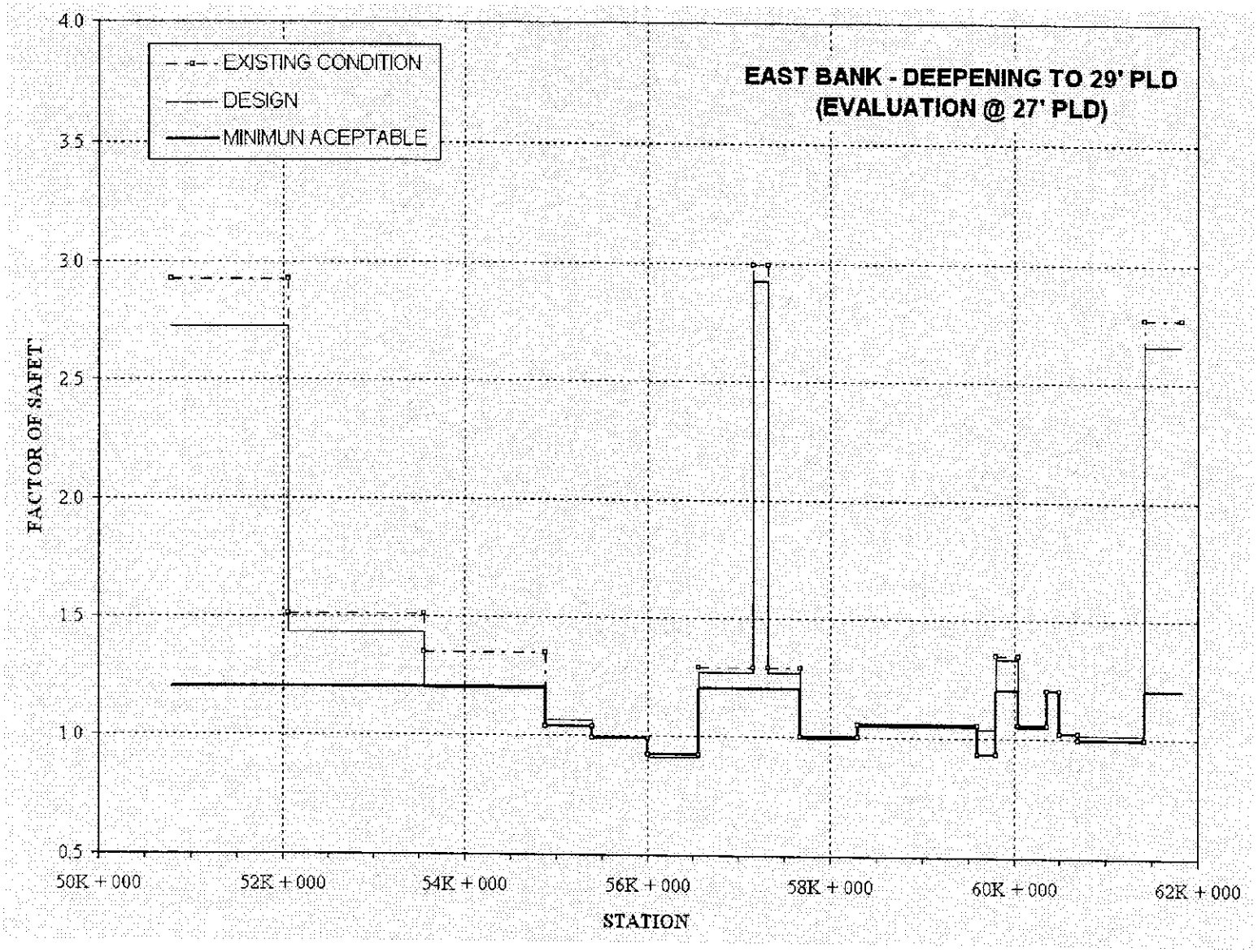

Figure 5a Results of stability analyses (East bank, elevation 27'PLD)

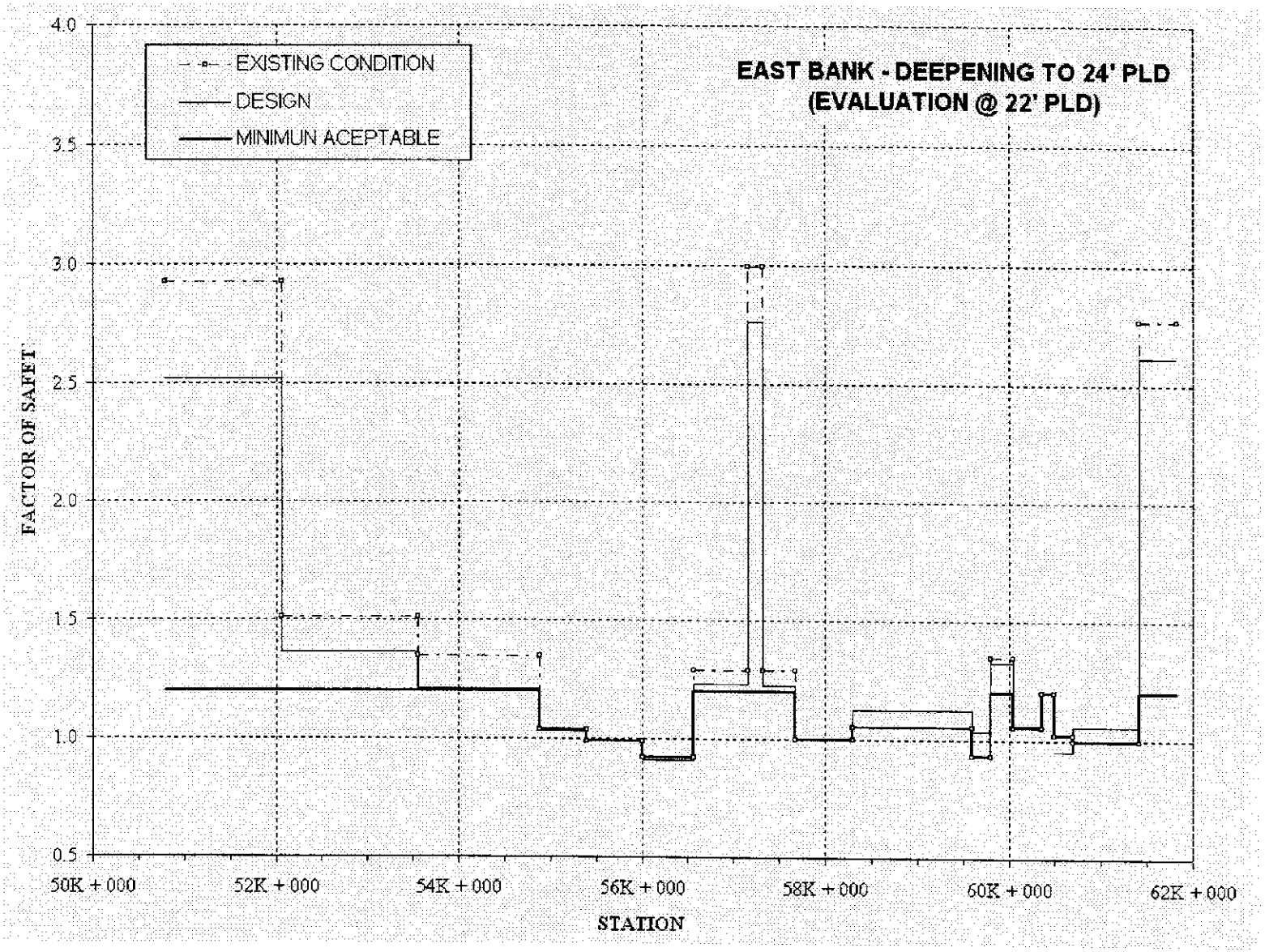

Figure 5b Results of stability analyses (East bank, elevation 22'PLD)

Table 4a Excavation Volume Summary (West Bank)

CHANNEL DEEPENING PROJECT (EXCAVATION VOLUME, m3

GAILLARD CUT - WEST SIDE

Sector	Station of Templates	Station West Side	Slope Condition	Excavation Type	Dry Exc. Volume	Underwater Exc. Volume	Total Exc. Volume
Elliot	50K + 320	51K + 600	Existing	Not Required	-----	-----	-----
	@		Design 27 feet	Underwater	6,629.2	59,247.4	65,876.6
	52K + 159		Design 22 feet	Underwater	31,789.9	163,488.9	195,278.8
Boringuen	52K + 160	53K + 171	Existing	Not Required	-----	-----	-----
	@		Design 27 feet	Dry & underwater	180,070.0	33,132.3	213,202.3
	53K + 779		Design 22 feet	Dry & underwater	455,397.6	146,108.5	601,506.0
Las Casacadas	53K + 780	54K + 300	Existing	Not Required	-----	-----	-----
	@		Design 27 feet	Dry & underwater	432,029.9	108,788.9	540,818.9
	54K + 999		Design 22 feet	Dry & underwater	537,958.8	142,133.5	680,092.3
Culebra	55K + 000	55K + 930	Existing	Not Required	-----	-----	-----
	@		Design 27 feet	Underwater	34,496.8	40,645.4	75,142.2
	56K + 739		Design 22 feet	Underwater	44,246.6	162,722.0	206,968.6
Empire (West Empire Slide)	56K + 740	56K + 898	Existing	Not Required	-----	-----	-----
	@		Design 27 feet	Underwater	3,039.7	25,645.1	28,684.8
	57K + 049		Design 22 feet	Dry & underwater	463,981.2	34,062.4	498,043.6
Empire	57K + 050	57K + 098	Existing	Not Required	-----	-----	-----
	@		Design 27 feet	Underwater	1,064.4	16,197.3	17,261.7
	57K + 474		Design 22 feet	Underwater	1,653.2	27,497.2	29,150.4
Lirio (Old Lirio Slide)	57K + 475	57K + 820	Existing	Not Required	-----	-----	-----
	@		Design 27 feet	Dry & underwater	402,986.3	20,336.0	423,322.3
	57K + 924		Design 22 feet	Dry & underwater	404,066.3	29,764.7	433,831.0
Lirio (Culebra Village Slide)	57K + 925	58K + 120	Existing	Not Required	-----	-----	-----
	@		Design 27 feet	Dry & underwater	842,976.8	20,093.2	863,070.0
	58K + 759		Design 22 feet	Dry & underwater	844,058.3	41,380.0	885,438.3
Hodges Hill	58K + 760	58K + 887	Existing	Not Required	-----	-----	-----
	@		Design 27 feet	Underwater	326.5	10,656.3	10,982.8
	58K + 999		Design 22 feet	Dry & underwater	234,854.0	17,033.4	251,887.3
Hodges Hill	59K + 000	59K + 070	Existing	Not Required	-----	-----	-----
	@		Design 27 feet	Dry & underwater	197,930.4	9,012.7	206,943.1

CHANNEL DEEPENING PROJECT (EXCAVATION VOLUME, m3

GAILLARD CUT - WEST SIDE

Sector	Station of Templates	Station West Side	Slope Condition	Excavation Type	Dry Exc. Volume	Underwater Exc. Volume	Total Exc. Volume
	59K + 259		Design 22 feet	Dry & underwater	237,435.1	15,411.5	252,846.7
West Culebra	59K + 260	59K + 485	Existing	Not Required	-----	-----	-----
	@		Design 27 feet	Dry & underwater	226,606.4	28,298.7	254,905.0
	59K + 779		Design 22 feet	Dry & underwater	226,632.3	41,097.5	267,729.8
Model Slope	59K + 780	59K + 881	Existing	Not Required	-----	-----	-----
	@		Design 27 feet	Dry & underwater	151,625.5	5,084.0	156,709.5
	60K + 049		Design 22 feet	Dry & underwater	193,858.1	11,752.1	205,610.2
Contractor Hill	60K + 050	60K + 240	Existing	Not Required	-----	-----	-----
	@		Design 27 feet	Dry & underwater	46,114.8	25,276.4	71,391.1
	60K + 399		Design 22 feet	Dry & underwater	224,768.2	54,851.4	279,619.7
Escobar	60K + 400	60K + 950	Existing	Not Required	-----	-----	-----
	@		Design 27 feet	Dry & underwater	142,660.2	26,252.0	168,912.2
	61K + 259		Design 22 feet	Dry & underwater	144,372.0	48,774.0	193,146.0
Escobar	61K + 240	61K + 600	Existing	Not Required	-----	-----	-----
	@		Design 27 feet	Underwater	201.8	12,064.7	12,266.5
	61K + 899		Design 22 feet	Underwater	894.7	28,281.2	29,175.9
Escobar (Luis Goyo)	61K + 900	62K + 000	Existing	Not Required	-----	-----	-----
	@		Design 27 feet	Dry & underwater	10,833.7	14,260.5	25,094.2
	62K + 199		Design 22 feet	Dry & underwater	16,763.9	21,008.7	37,772.6
Cartagena (Tie-Up Viejo)	62K + 200	62K + 550	Existing	Not Required	-----	-----	-----
	@		Design 27 feet	Underwater	1,990.2	26,780.5	28,770.7
	62K + 909		Design 22 feet	Underwater	3,018.6	44,543.0	47,561.6
Cartagena	62K + 910	63K + 050	Existing	Not Required	-----	-----	-----
	@		Design 27 feet	Underwater			
	63K + 149		Design 22 feet	Underwater			
Cartagena	63K + 150	63K + 327	Existing	Not Required	-----	-----	-----
	@		Design 27 feet	Dry & underwater		-	
	63K + 725		Design 22 feet	Dry & underwater		-	
TOTAL VOLUME TO BE EXCAVATED FOR 27 FEET:					**2,651,522.5**	**481,771.4**	**3,133,293.9**
TOTAL VOLUME TO BE EXCAVATED FOR 22 FEET:					**4,065,748.7**	**1,031,909.8**	**5,097,658.6**

Note: Underwater Excavation: Includes dredging and some dry excavation

Dry & Underwater Excavation: Includes dredging and dry excavation required for the stabilization of the Gaillard Cut Slopes

Table 4b Excavation Volume Summary (East Bank)

CHANNEL DEEPENING PROJECT (EXCAVATION VOLUME, m3)

GAILLARD CUT - EAST SIDE

Sector	Station of Templates	Station West Side	Slope Condition	Excavation Type	Dry Exc. Volume	Underwater Exc. Volume	Total Exc. Volume
	50K + 780		Existing	Not Required	-----	-----	-----
Chagres	@	51K + 328	Design 27 feet	Underwater	134,872.56	132,923.80	267,796.36
(Northeast)	52K + 059		Design 22 feet	Underwater	158,718.11	168,404.11	327,122.22
	52K + 060		Existing	Not Required	-----	-----	-----
Chagres	@	53K + 371	Design 27 feet	Underwater	29,366.98	125,813.69	155,180.67
(Southeast)	53K + 549		Design 22 feet	Underwater	42,476.02	165,210.95	207,686.97
	53K + 550		Existing	Not Required	-----	-----	-----
Sardinilla	@	53K + 950	Design 27 feet	Underwater	15,793.12	71,387.94	87,181.06
	54K + 879		Design 22 feet	Dry & underwater	547,926.06	101,399.80	649,325.86
	54K + 880		Existing	Not Required	-----	-----	-----
Sardinilla	@	55K + 250	Design 27 feet	Dry & underwater	241,714.83	17,981.03	259,695.86
(North La Pita)	55K + 399		Design 22 feet	Dry & underwater	316,137.79	54,789.32	370,927.11
	55K + 400		Existing	Not Required	-----	-----	-----
La Pita	@	55K + 830	Design 27 feet	Dry & underwater	143,973.86	19,364.37	163,338.23
(Central)	55K + 999		Design 22 feet	Dry & underwater	382,287.18	62,142.13	444,429.31
	56K + 000		Existing	Not Required	518,582.78	-----	-----
Masamirí	@	56K + 460	Design 27 feet	Dry & underwater	620,352.36	82,644.42	537,707.93
(South La Pita)	56K + 559		Design 22 feet	Dry & underwater	-----	679,862.14	679,862.14
	56K + 560		Existing	Not Required	-----	-----	-----
Summit	@	57K + 060	Design 27 feet	Underwater	549.63	8,982.14	9,531.77
	57K + 159		Design 22 feet	Underwater	6,064.20	46,223.28	52,287.48
	57K + 160		Existing	Not Required	-----	-----	-----
Summit	@	57K + 270	Design 27 feet	Underwater	0.00	2,631.00	2,631.00
	57K + 319		Design 22 feet	Underwater	2,545.59	13,449.06	15,994.65
	57K + 320		Existing	Not Required	-----	-----	-----
Summit	@	57K + 635	Design 27 feet	Underwater	0.00	8,679.00	8,679.00
	57K + 674		Design 22 feet	Underwater	1,278.00	33,255.02	34,533.02
	57K + 675		Existing	Not Required	-----	-----	-----
Summit	@	58K + 035	Design 27 feet	Dry & underwater	379,653.45	43,436.24	423,089.69

CHANNEL DEEPENING PROJECT (EXCAVATION VOLUME, m3)

GAILLARD CUT - EAST SIDE

Sector	Station of Templates	Station West Side	Slope Condition	Excavation Type	Dry Exc. Volume	Underwater Exc. Volume	Total Exc. Volume
(Northeast Culebra)	58K + 294		Design 22 feet	Dry & underwater	554,142.37	59,604.29	613,746.66
	58K + 295		Existing	Not Required	-----	-----	-----
Summit	@	58K + 520	Design 27 feet	Underwater	0.00	15,174.93	15,174.93
(Northeast Culebra)	59K + 599		Design 22 feet	Dry & underwater	170,722.17	46,928.30	217,650.47
	59K + 600		Existing	Not Required	-----	-----	-----
Culebra	@	59K + 668	Design 27 feet	Dry & underwater	625,055.01	2,278.58	627,333.59
(Southeast)	59K + 799		Design 22 feet	Dry & underwater	625,071.59	9,215.36	634,286.95
	59K + 800		Existing	Not Required	-----	-----	-----
Gold Hill	@	59K + 918	Design 27 feet	Underwater	2,736.35	21,715.63	24,451.98
	60K + 049		Design 22 feet	Underwater	3,267.78	29,757.48	33,025.26
	60K + 050		Existing	Not Required	-----	-----	-----
Cucaracha	@	60K + 244	Design 27 feet	Underwater	185.38	5,484.78	5,670.16
(Cucaracha Slide)	60K + 354		Design 22 feet	Dry & underwater	676,180.02	10,371.42	686,551.49
	60K + 355		Existing	Not Required	Remedial work being planned		
Cucaracha	@	60K + 412	Design 27 feet	Rock Anchor	Special stabilization work is required		
(Purple Rock)	60K + 499		Design 22 feet	Rock Anchor			
	60K + 500		Existing	Not Required	-----	-----	-----
Cucaracha	@	60K + 594	Design 27 feet	Dry & underwater	423,903.85	12,156.17	436,060.02
(South Extension)	60K + 694		Design 22 feet	Dry & underwater	424,411.51	16,524.38	440,935.89
	60K + 695		Existing	Not Required	-----	-----	-----
Cucaracha	@	60K + 747	Design 27 feet	Dry & underwater	95,398.63	3,335.57	98,734.20
(South Extension)	60K + 850		Design 22 feet	Dry & underwater	157,731.84	5,601.80	163,333.64
	61K + 420		Existing	Not Required	-----	-----	-----
Nitro	@	61K + 720	Design 27 feet	Underwater	22,423.20	32,693.31	55,116.51
	61K + 825		Design 22 feet	Underwater	27,542.42	40,233.12	67,775.54
	TOTAL VOLUME TO BE EXCAVATED FOR 27 FEET:				**2,735,979.21**	**441,393.75**	**3,177,372.96**
	TOTAL VOLUME TO BE EXCAVATED FOR 22 FEET:				**4,096,502.70**	**1,542,971.96**	**5,639,474.66**

Note: Underwater Excavation: Includes dredging and some dry excavation

Dry & Underwater Excavation: Includes dredging and dry excavation required for the stabilization of the Gaillard Cut Slopes