Panama Canal Authority
Engineering and Projects Department
Engineering Division
Geotechnical Branch

Study on the effect of deepening on Gaillard Cut slopes

Volume 2
Appendix A: Stability Analysis – West Bank

Prepared by:

Maximiliano De Puy, Manager
Antonio Abrego
Jaime Arrocha
Manuel Barrelier
Luis Carlos Fernández
Pastora Franceschi
Jennifer Ramesch

April 2002

ACP
AUTORIDAD DEL CANAL DE PANAMA

Appendix A

Channel Deepening

Stability Analysis
Gaillard Cut – West Bank

April, 2002

Panama Canal Authority
Engineering Division - Geotechnical Branch

Summary of Stability Analises

Gaillard Cut - West Bank

Station	Representative Stations	Factor of Safety									
		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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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

Index

51k + 600

53k + 171

54k + 300

55k + 930

56k + 898

57k + 098

57k + 820

58k + 120

58k + 887

59k + 070

59k + 485

59k + 881

60k + 240

60k + 950

61k + 600

62k + 000

63k + 050

63k + 327

station 51k + 600 (1692 + 91)

West

Station: 51k + 600 (Elliot)

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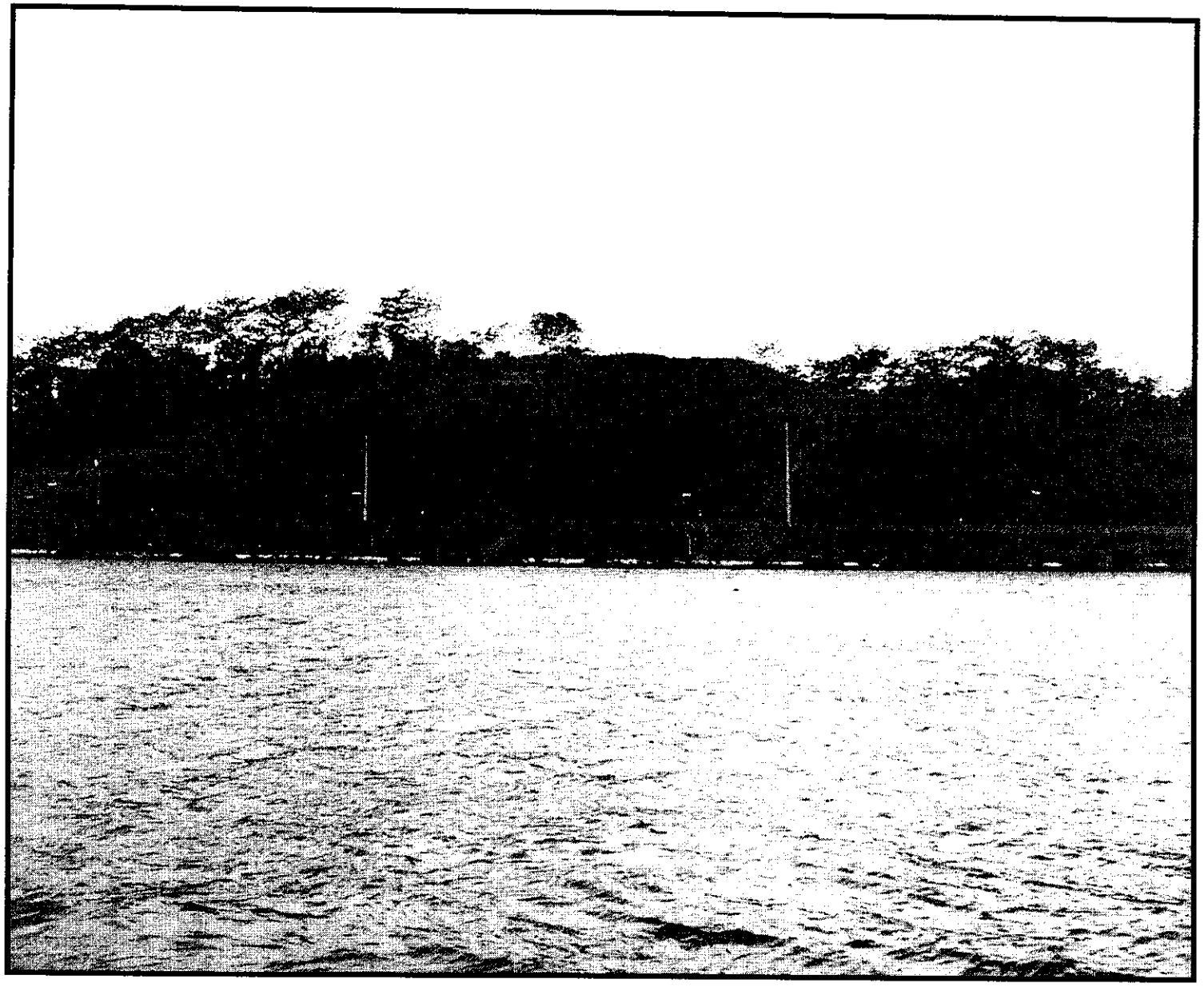

Case 1, Channel bottom = 32 ft

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Comments: West Bank 51K+600 - Channel bottom = 32 ft (case 1)
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P.W.P. Option: Piezometric lines with Ru
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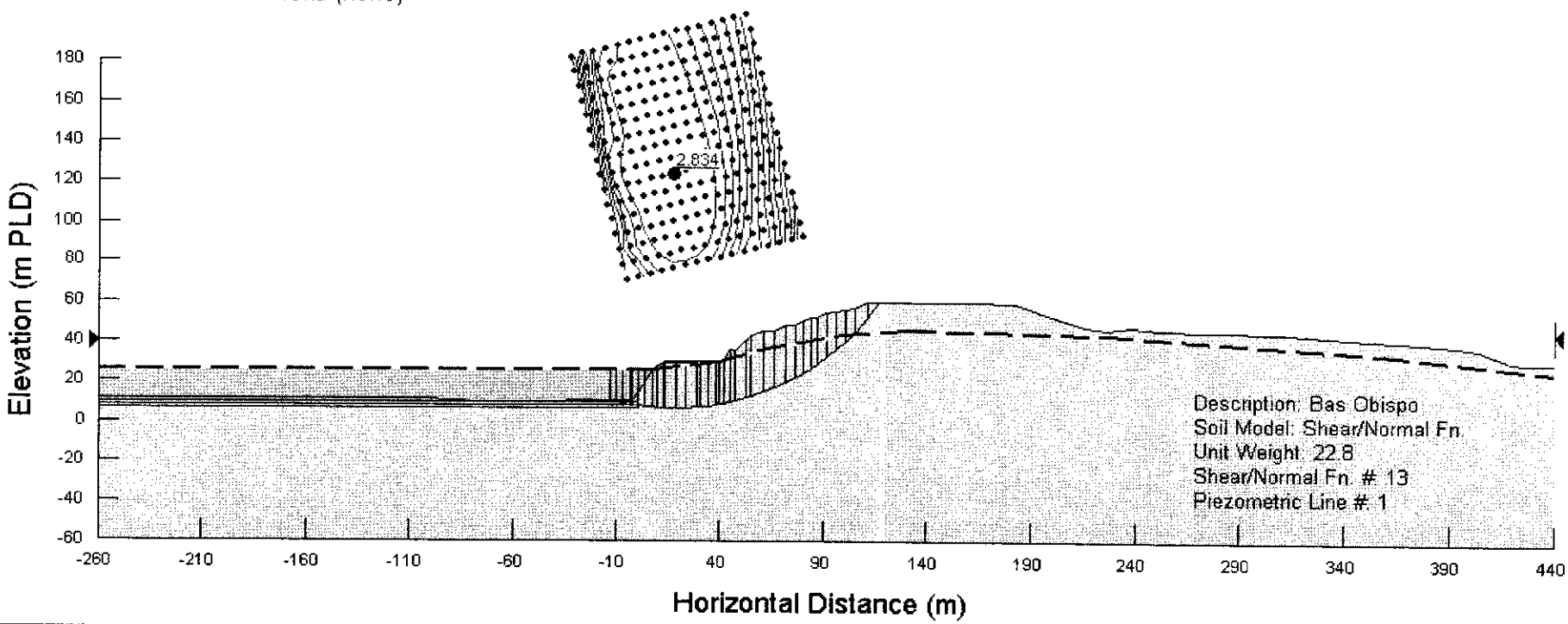

Case 2, Channel bottom = 27 ft, Blasted material only

Description: Channel Deepening
Comments: West Bank 51K+600 - Channel bottom = 27 ft & blasted material only (case 2)
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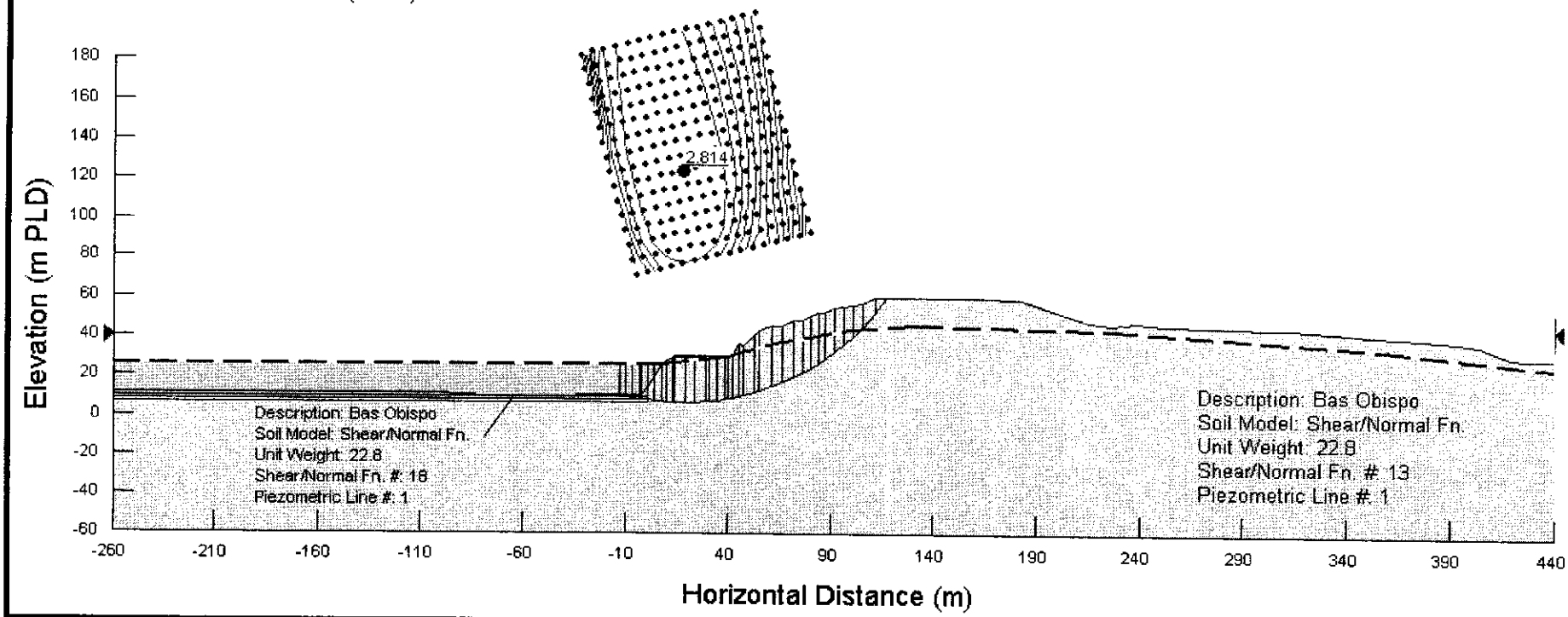

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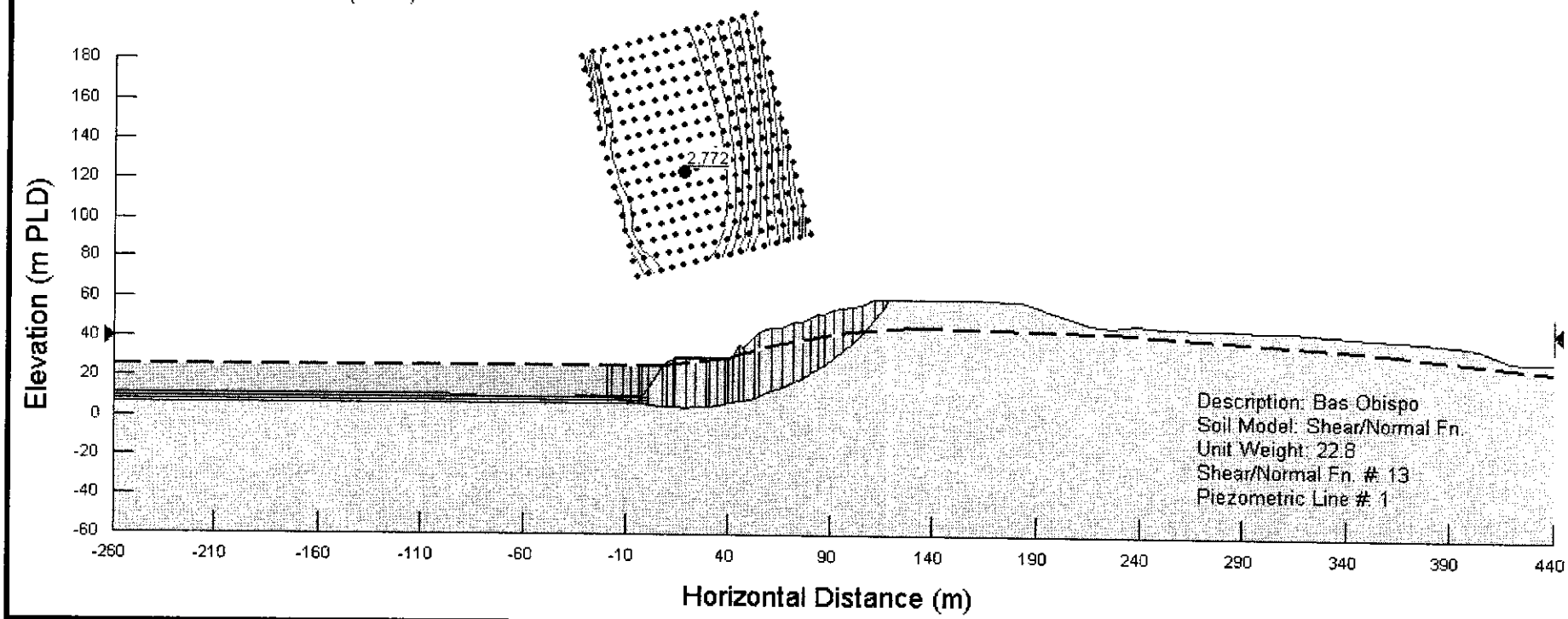

Case 4, Channel bottom = 27 ft, Design (underwater slope)

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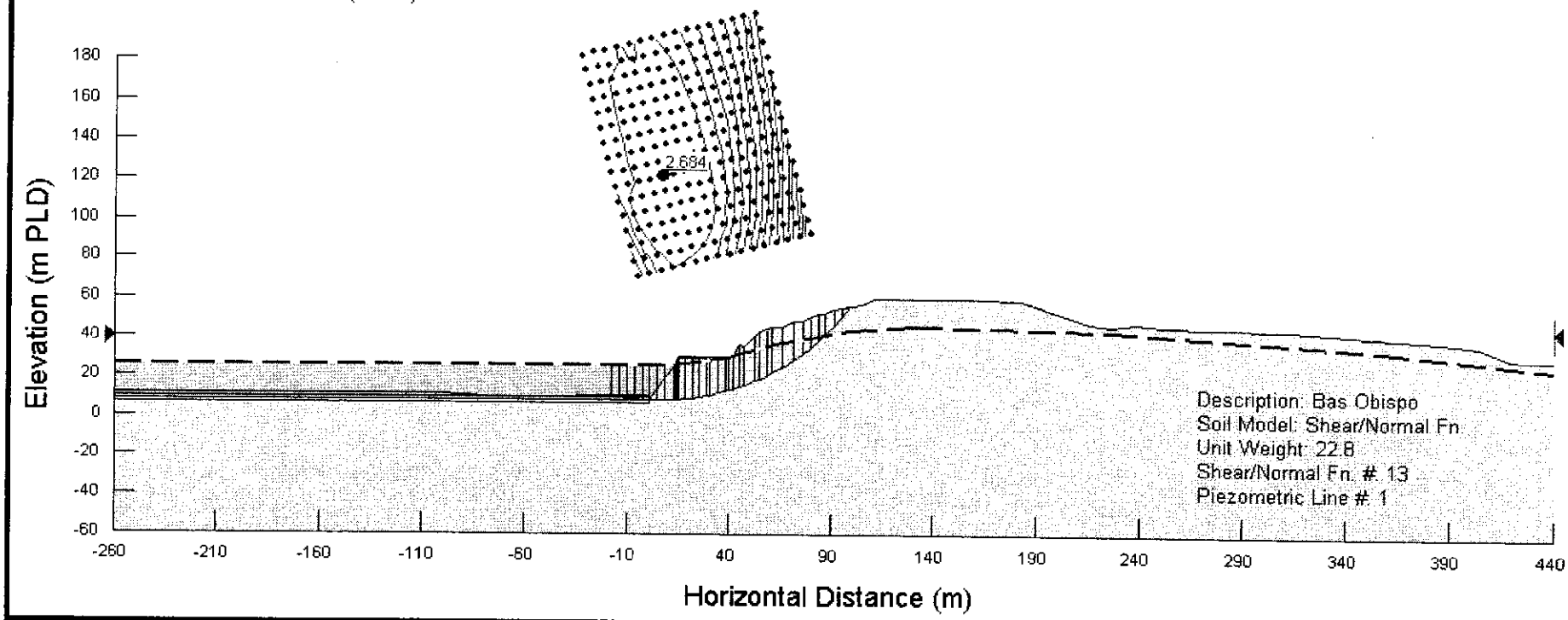

Case 5, Channel bottom = 22 ft, Blasted material only

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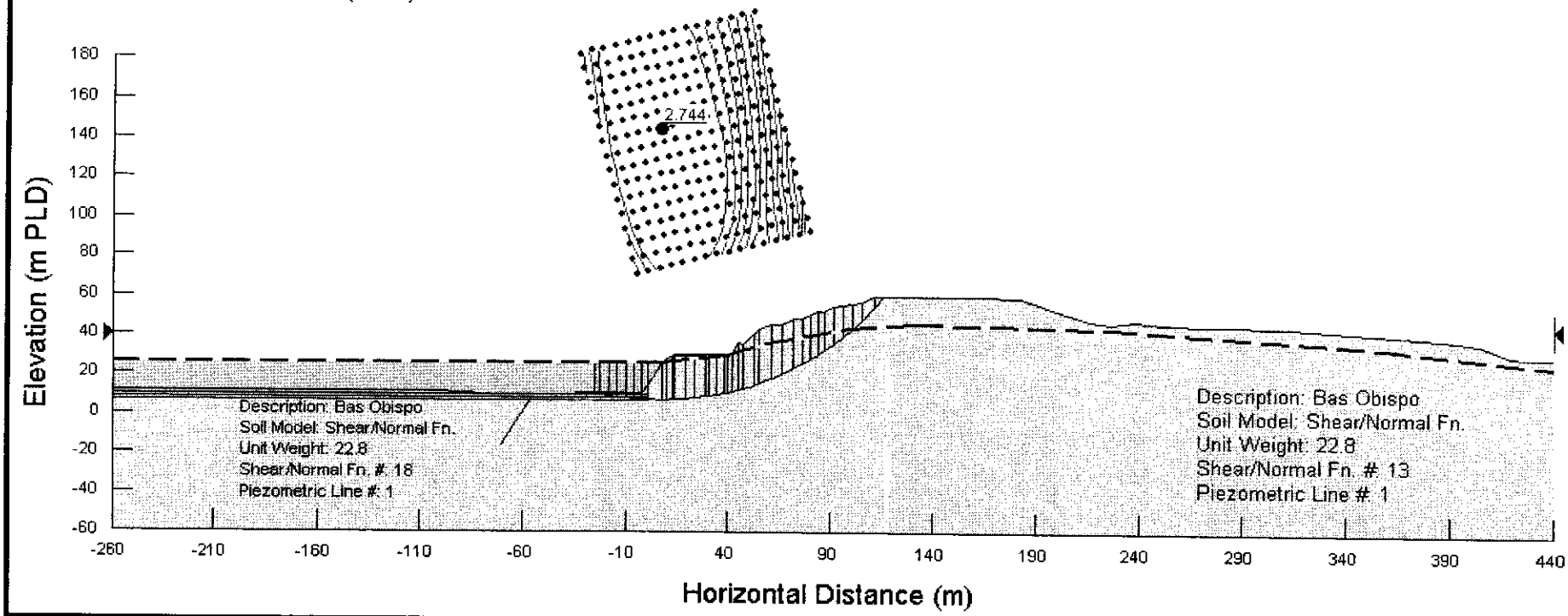

Case 6, Channel bottom = 22 ft, Blasted & removed

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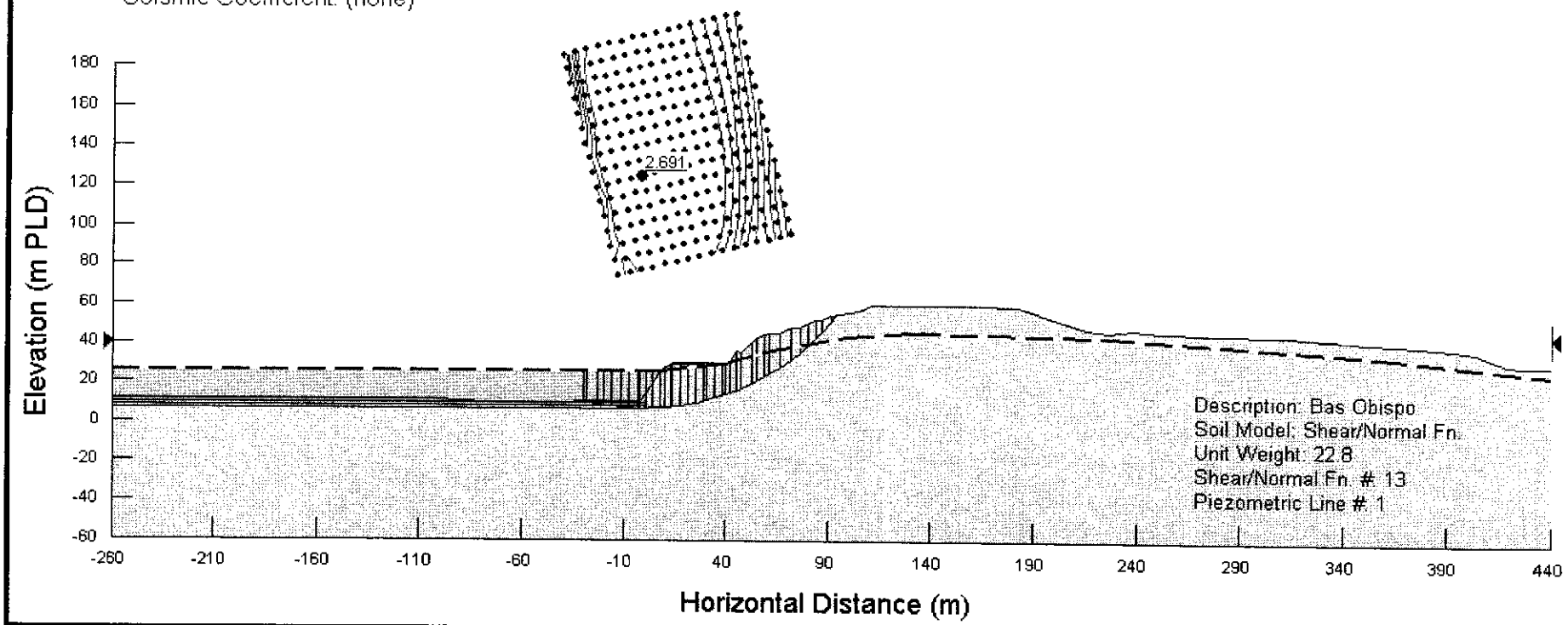

Case 7, Channel bottom = 27 ft, Design (underwater slope)

Description: Channel Deepening
Comments: West Bank 51K+600 - Channel bottom = 22 ft + design (case 7)
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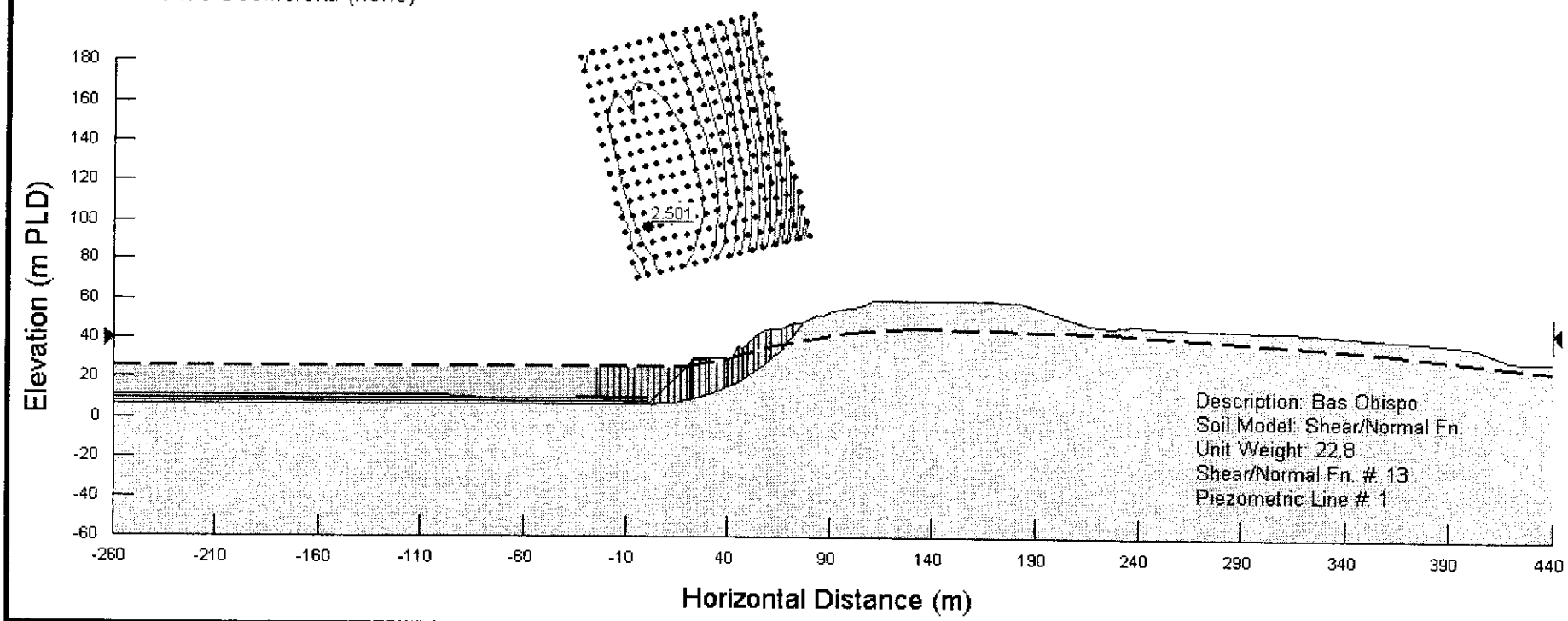

Case 8, Channel bottom = 16 ft, Blasted

Description: Channel Deepening
Comments: West Bank 51K+600 - Channel bottom = 22 ft + design + blasted 16 ft (case 8)
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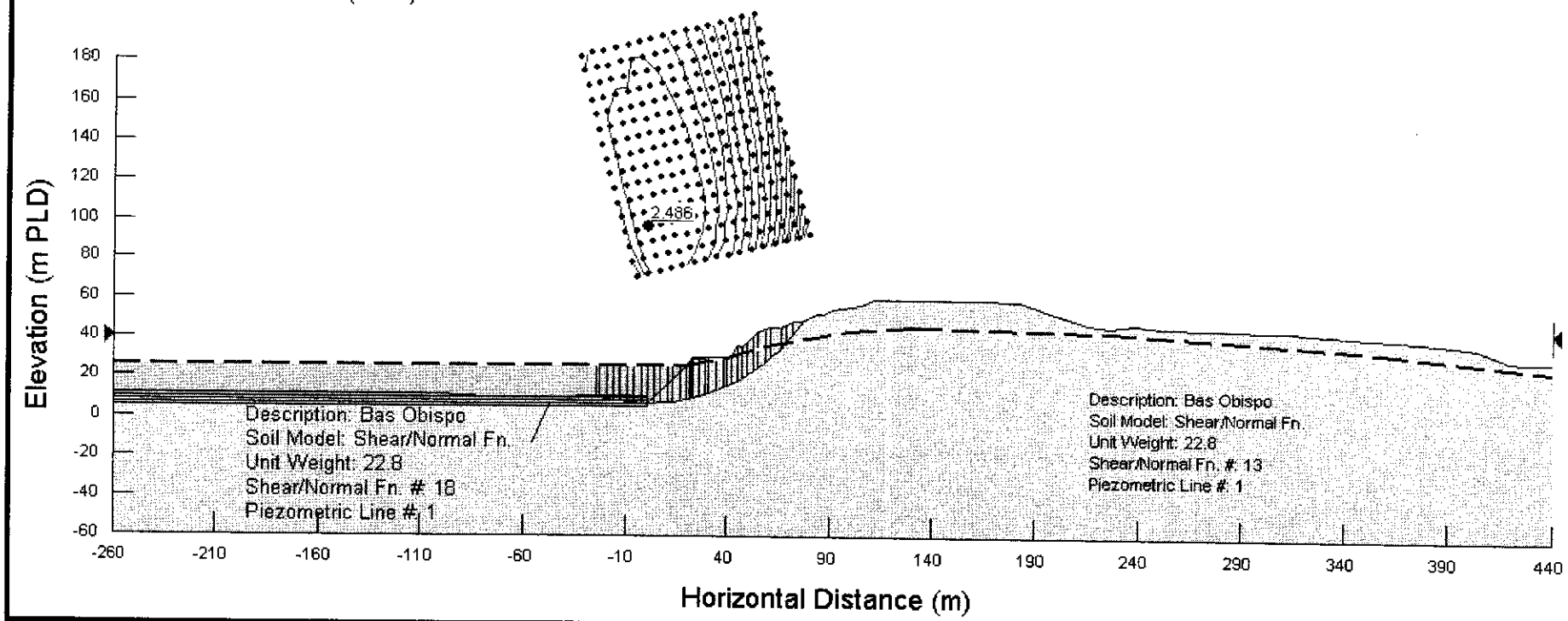
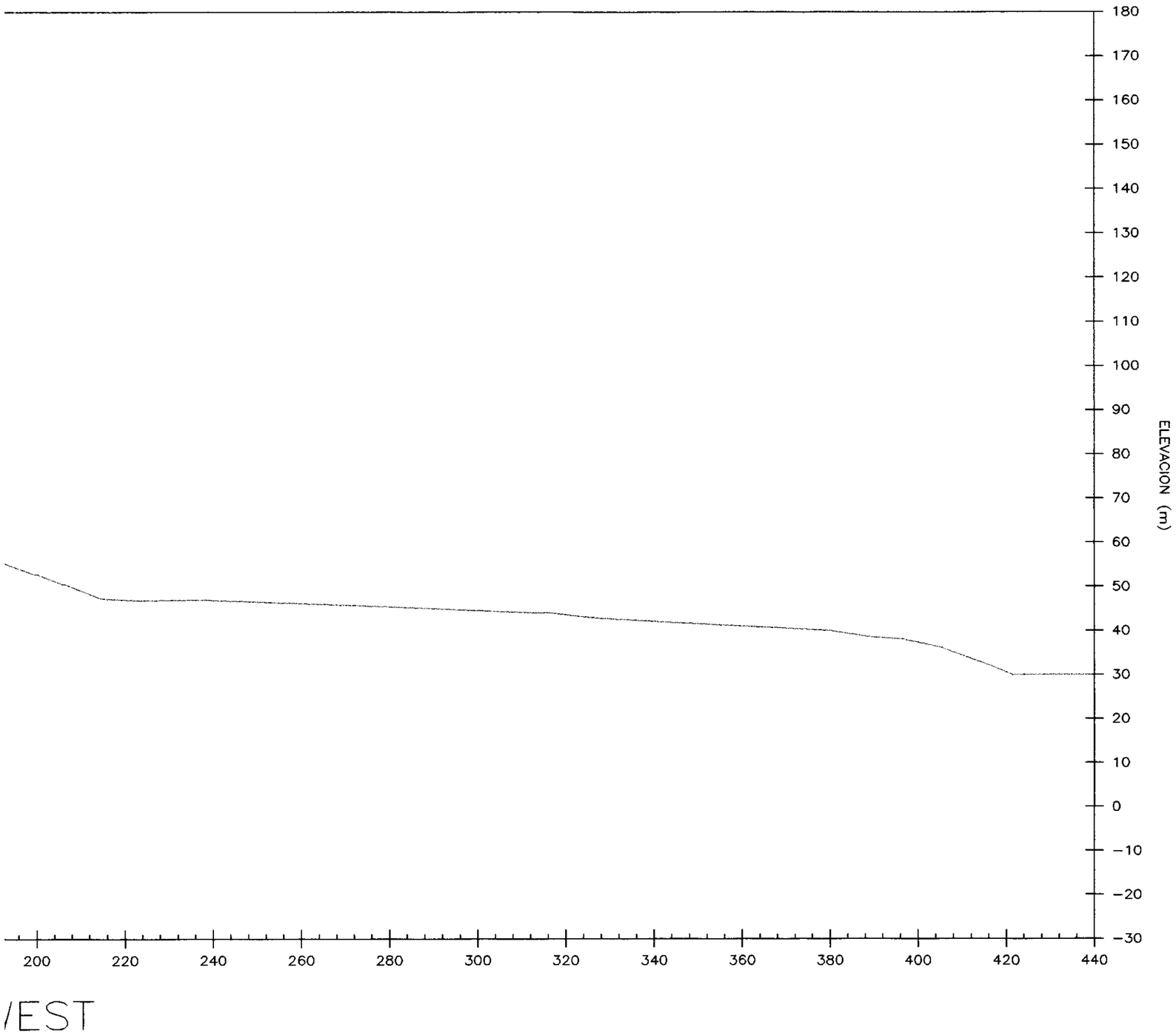


Summary, 51k + 600 (1692 + 91)

General Description	Range of stations:	50k + 320 to 52k + 160			
	Sector:	Elliot			
	Maximum height (m):	49			
	Cotangent of slope angle (cot. β):	2.47			
History	Last slide event:	West Bas Obispo Slide (during first widening)			
Geology	Formation:	Bas Obispo			
	Lithology:	Agglomerate			
	Critical stratum at toe:	Agglomerate			
	Apparent dip of bedding:	No defined			
Stability Analysis	Critical failure mechanism:	Rotational			
	Shear strength model:	First time, Bas Obispo			
		Operative average pore pressure ratio (aproximate), Ru:	Factor of Safety	Relative Factor of Safety	Percentage of Change (%)
	Case 1: Channel bottom = 32 ft	0.333	2.834	1.000	0.00
	Case 2: Channel bottom = 27 ft, Blasted material only		2.814	0.993	-0.71
	Case 3: Channel bottom = 27 ft, Blasted & removed		2.772	0.978	-2.19
	Case 4.1: Channel bottom = 27 ft, Design (underwater slope)		2.684	0.947	-5.29
	Case 4.2: Channel bottom = 27 ft, Design (& dry excavation)	0.329	2.684	0.947	-5.29
	Case 5: Channel bottom = 22 ft, Blasted material only		2.744	0.968	-3.18
	Case 6: Channel bottom = 22 ft, Blasted & removed		2.691	0.950	-5.05
	Case 7.1: Channel bottom = 22 ft, Design (underwater slope)		2.501	0.882	-11.75
	Case 7.2: Channel bottom = 22 ft, Design (& dry excavation)	0.352	2.501	0.882	-11.75
	Case 8: Channel bottom = 16 ft, Blasted		2.486	0.877	-12.28
Conclusions:	No stabilization is required				



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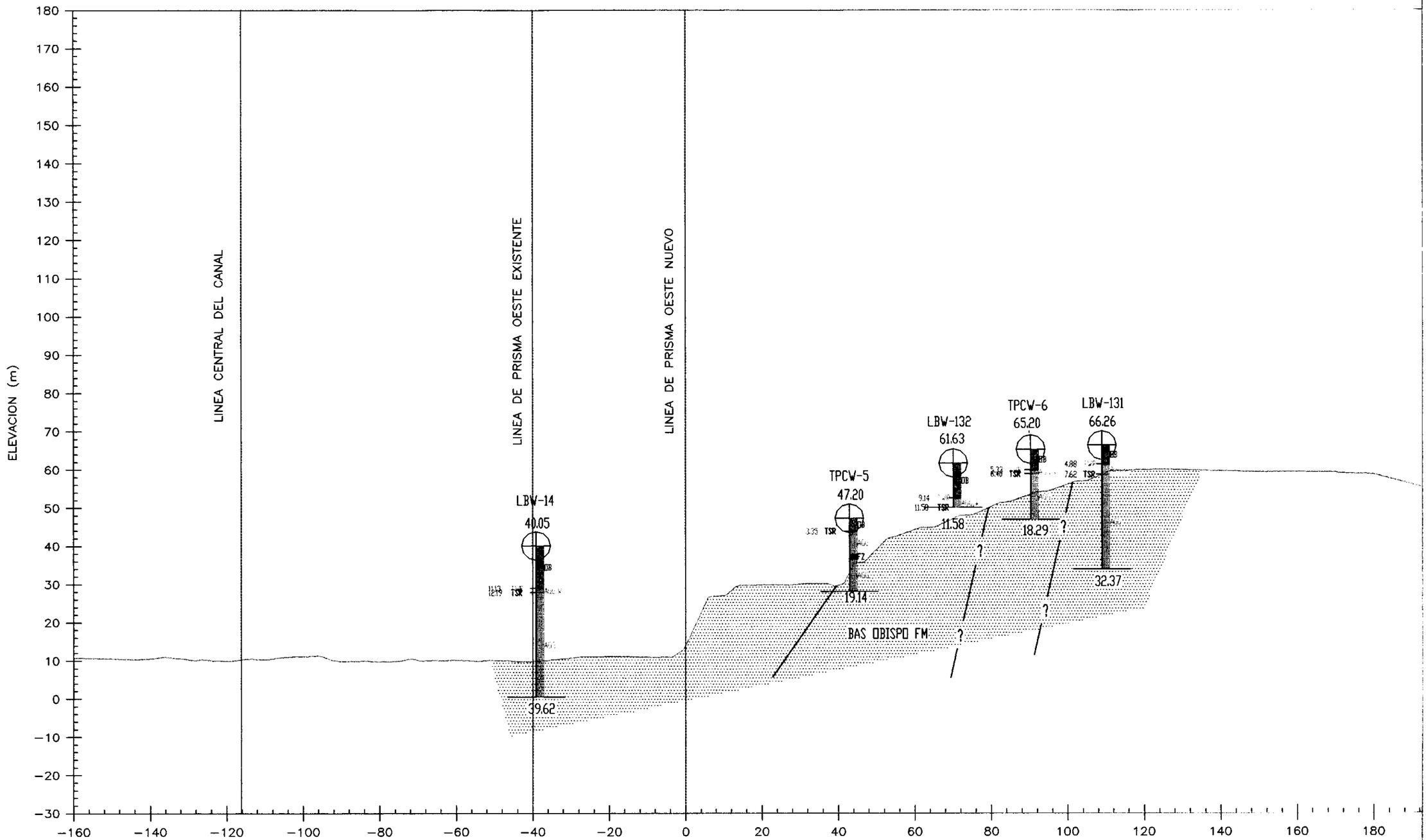
SECCION GEOLOGICA

CORTE GAILLARD

ESTACION 51K+600 (1692+91) OESTE

ESCALA: 1:1000	FECHA: ABRIL 2002
GEOLOGIA POR: P. FRANCESCHI	DIBUJADO POR: J. RAMESCH



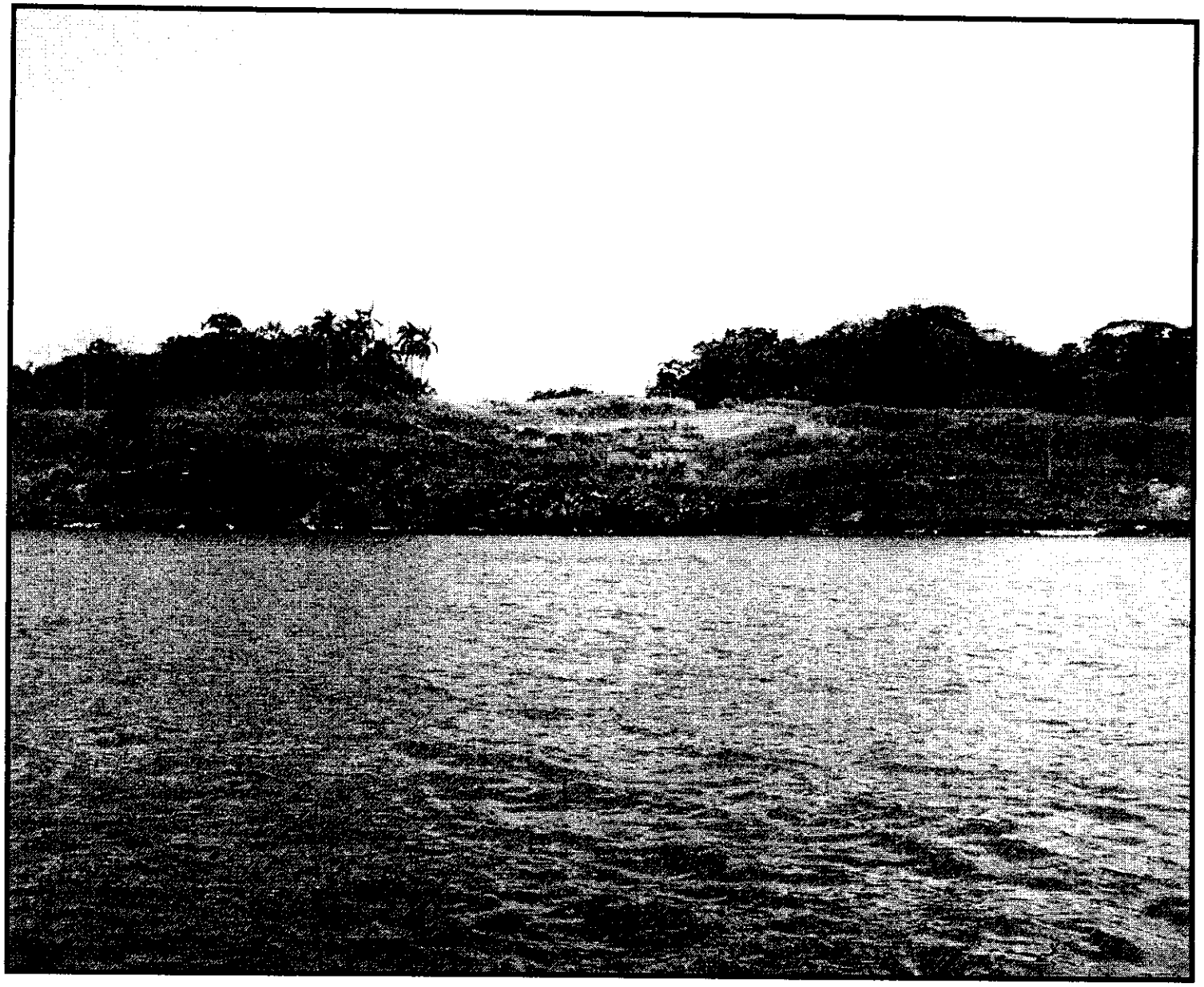
51K+600 (1692+91) W

station 53k + 171 (1744 + 45)

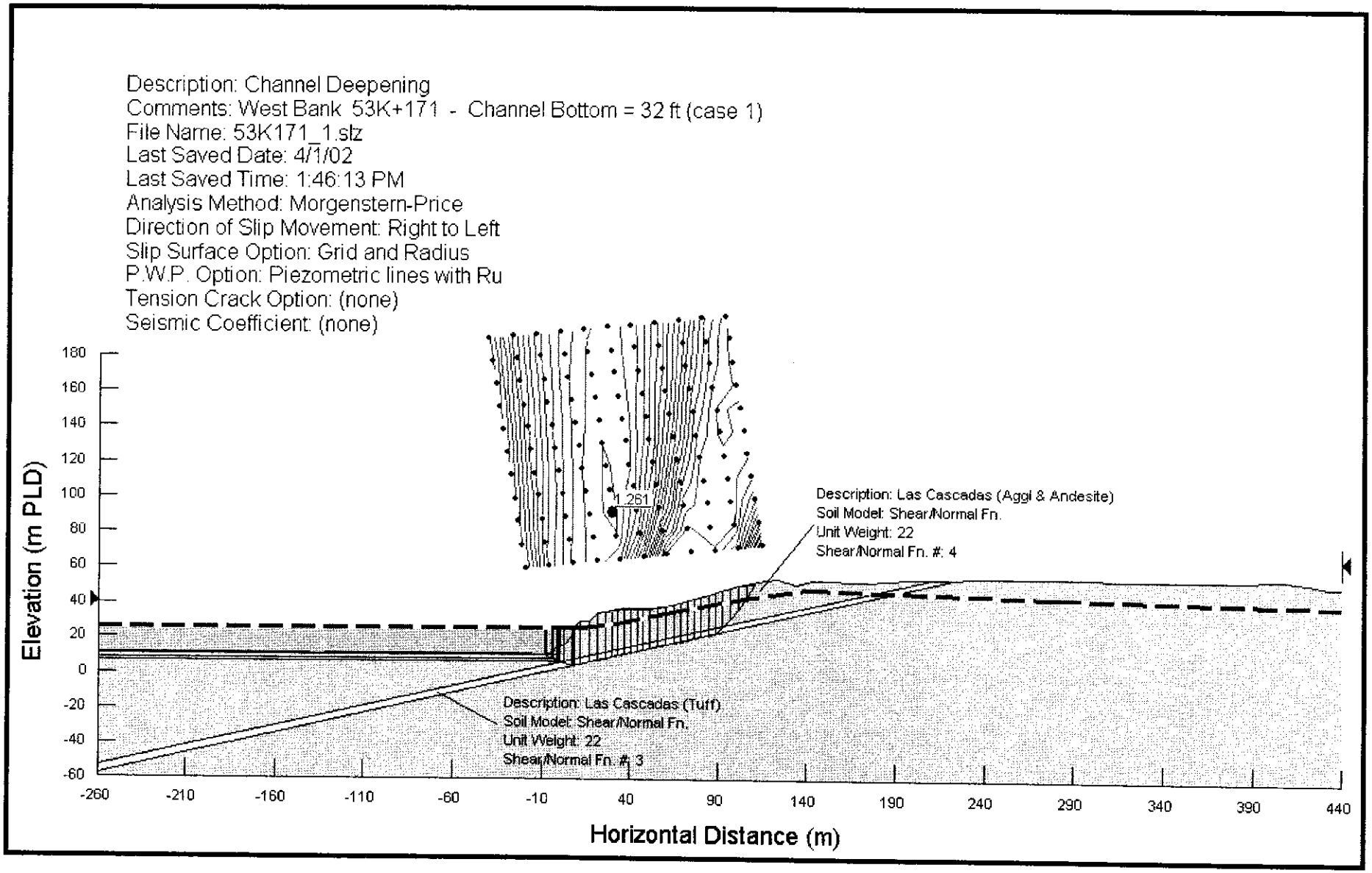
West

Station: 53k + 171 (Borinquen)

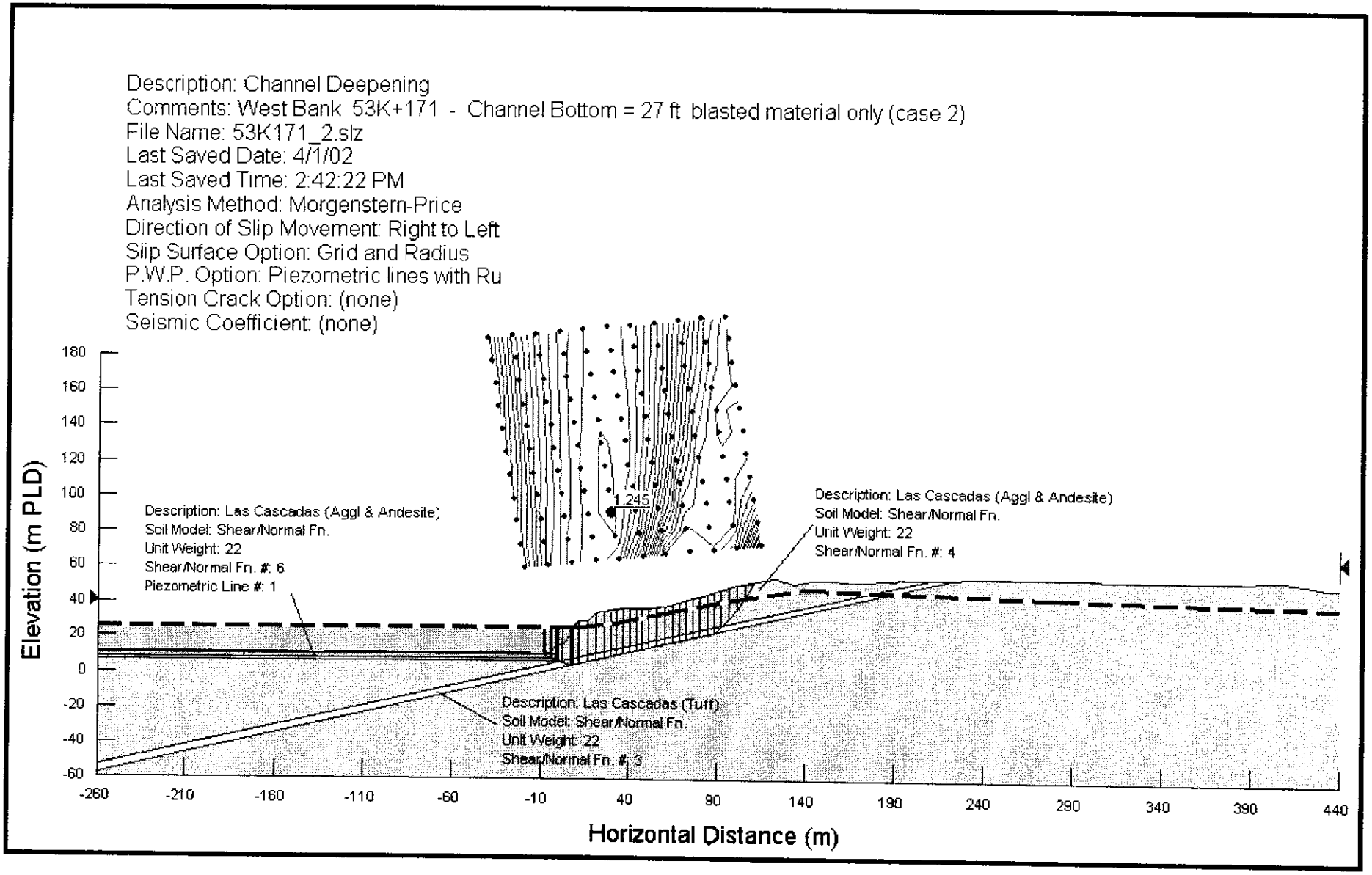
April 16, 2002



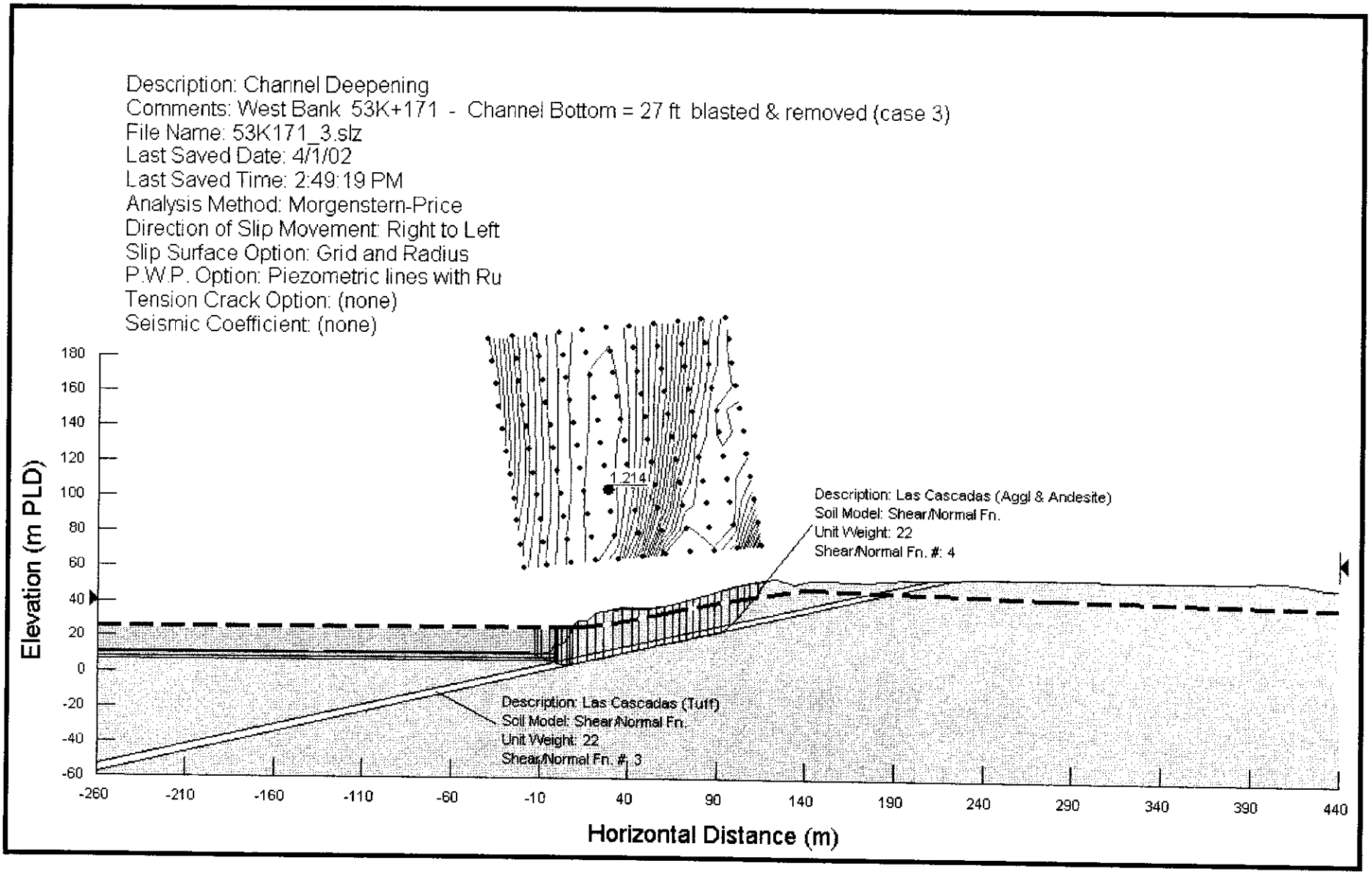
Case 1, Channel bottom = 32 ft



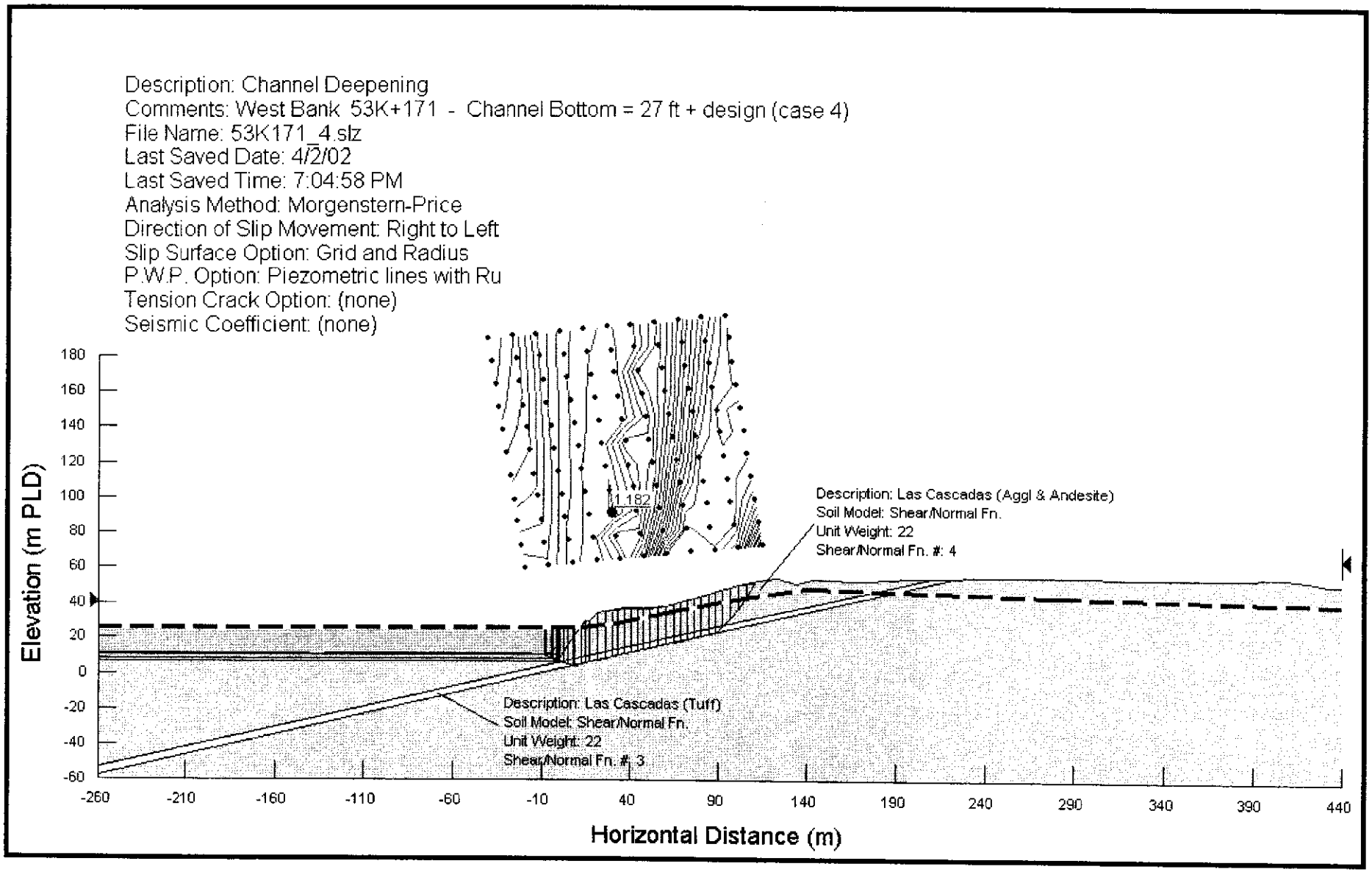
Case 2, Channel bottom = 27 ft, Blasted material only



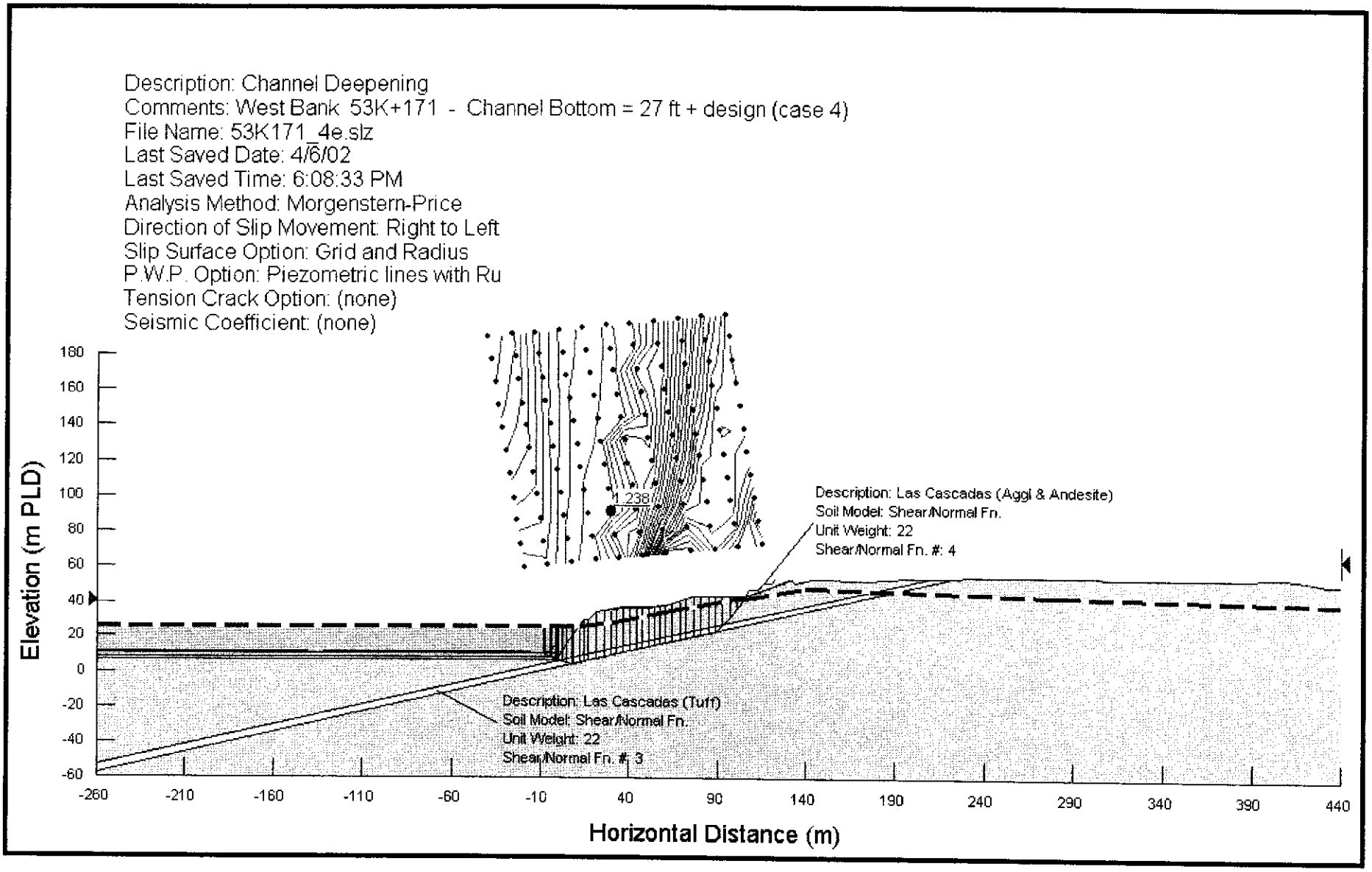
Case 3, Channel bottom = 27 ft, Blasted & removed



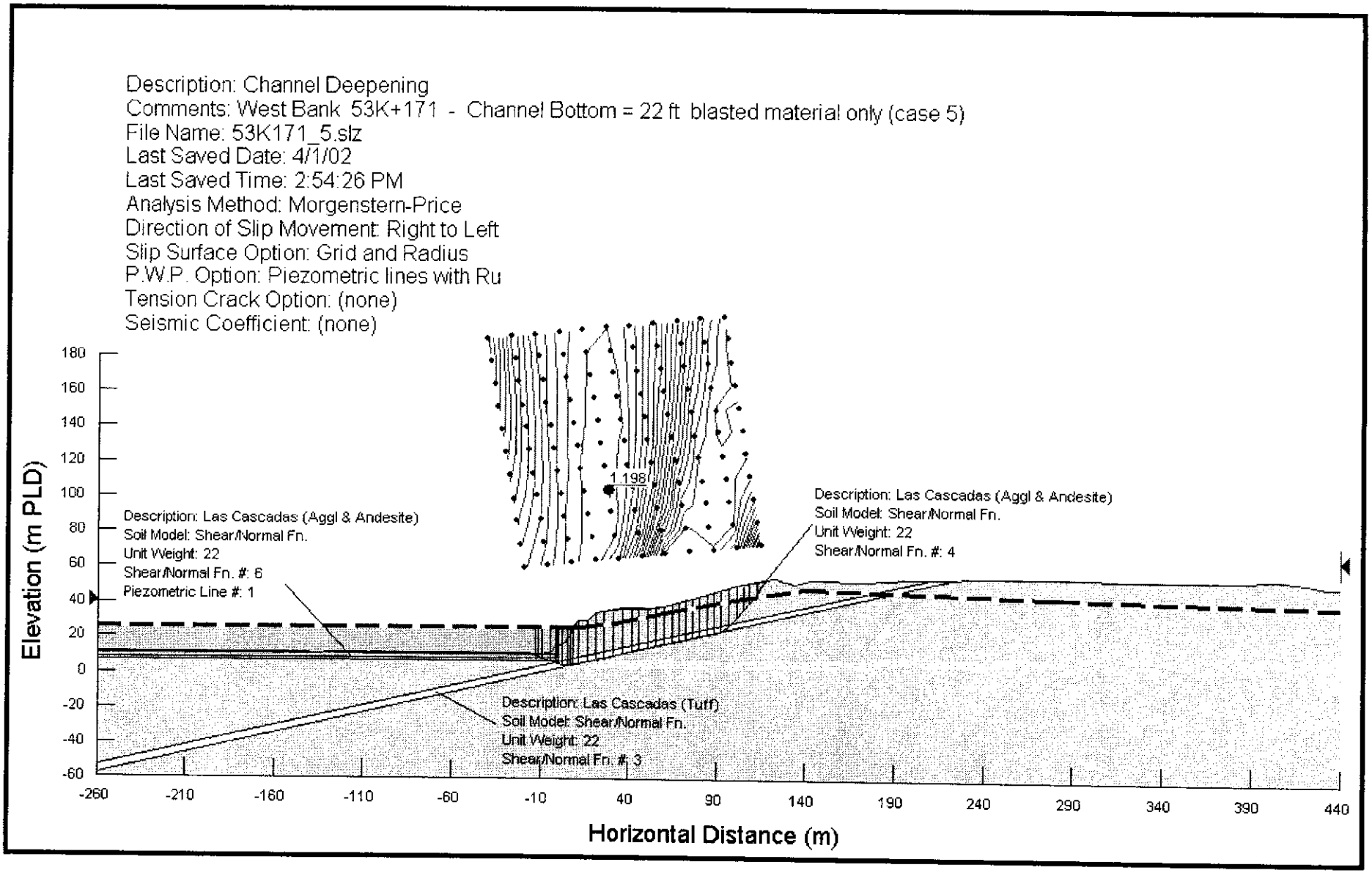
Case 4.1, Channel bottom = 27 ft, Design (underwater slope)



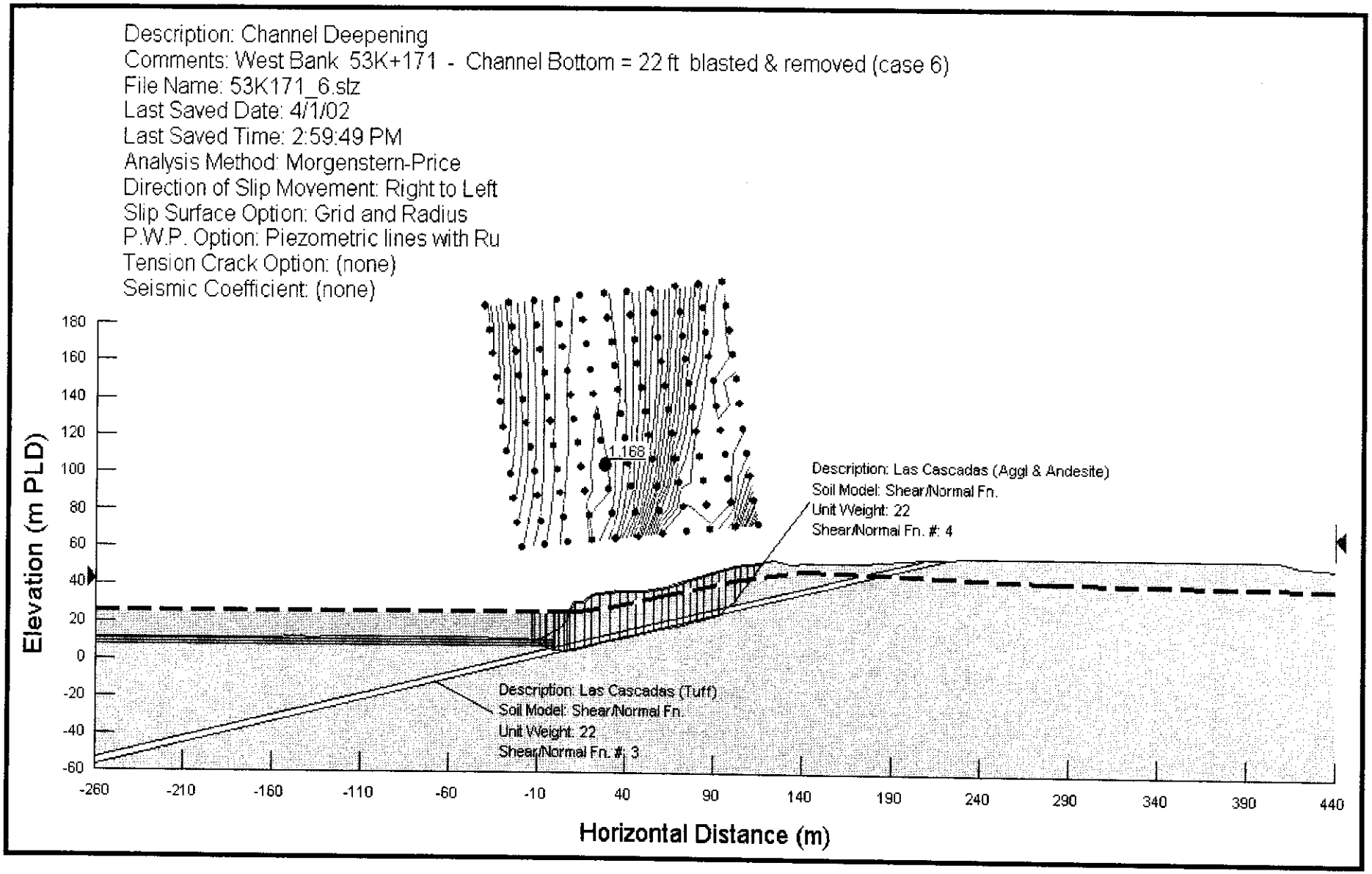
Case 4.2, Channel bottom = 27 ft, Design (& dry excavation)



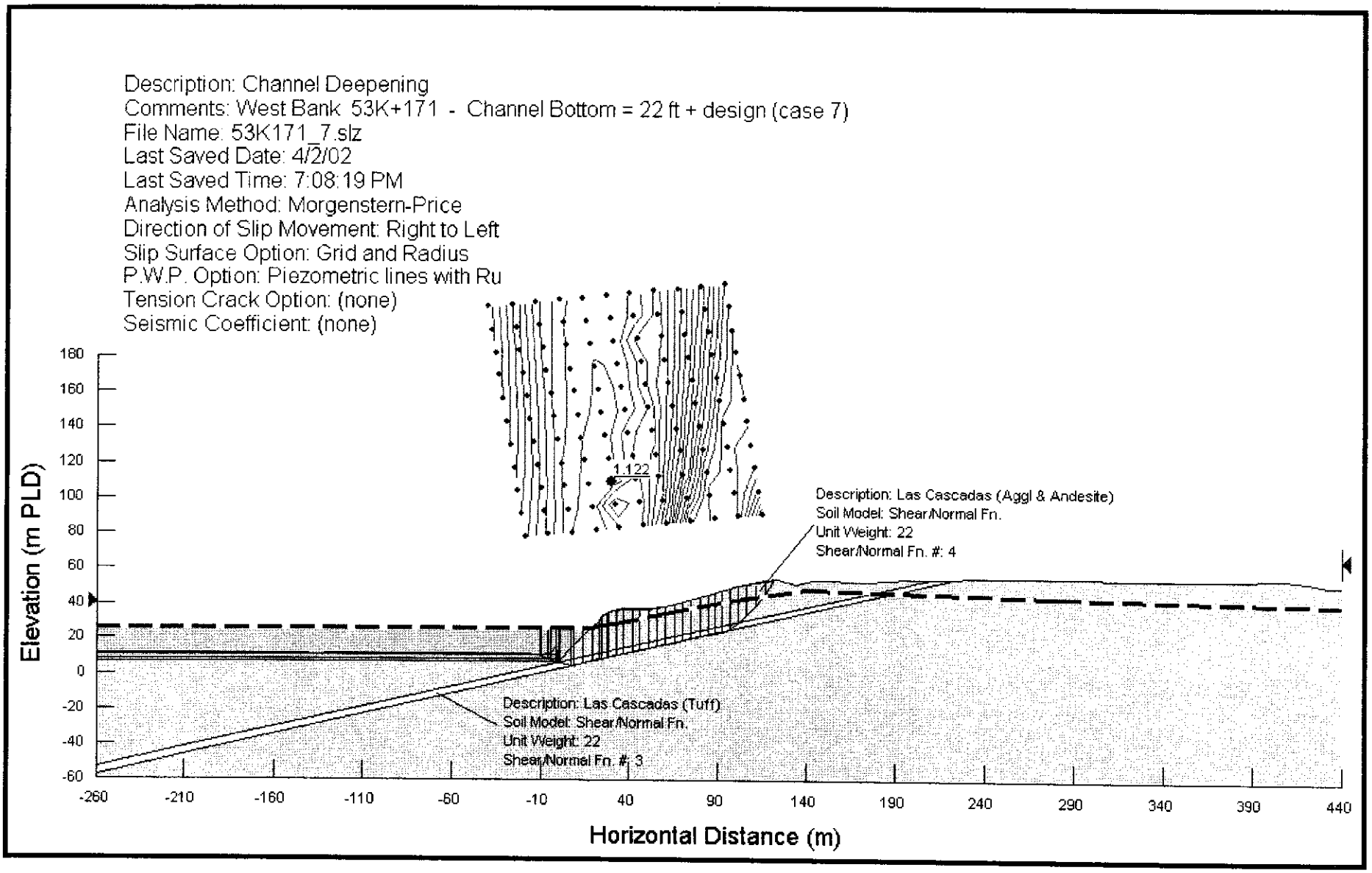
Case 5, Channel bottom = 22 ft, Blasted material only



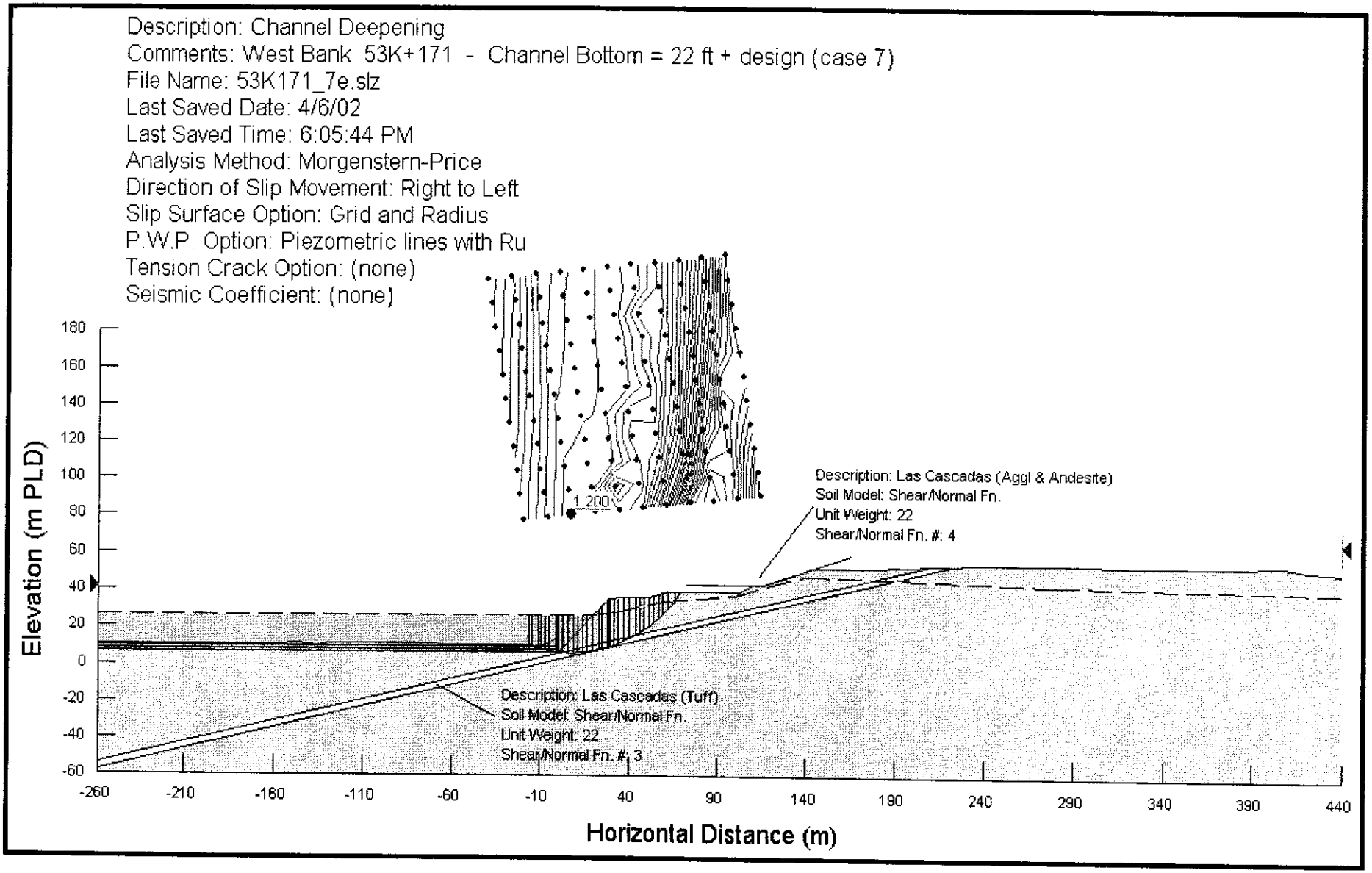
Case 6, Channel bottom = 22 ft, Blasted & removed



Case 7.1, Channel bottom = 27 ft, Design (underwater slope)



Case 7.2, Channel bottom = 27 ft, Design (& dry excavation)



Case 8, Channel bottom = 16 ft, Blasted

Description: Channel Deepening
Comments: West Bank 53K+171 - Channel Bottom = 22 ft + design + blasted 16 ft (case 8)
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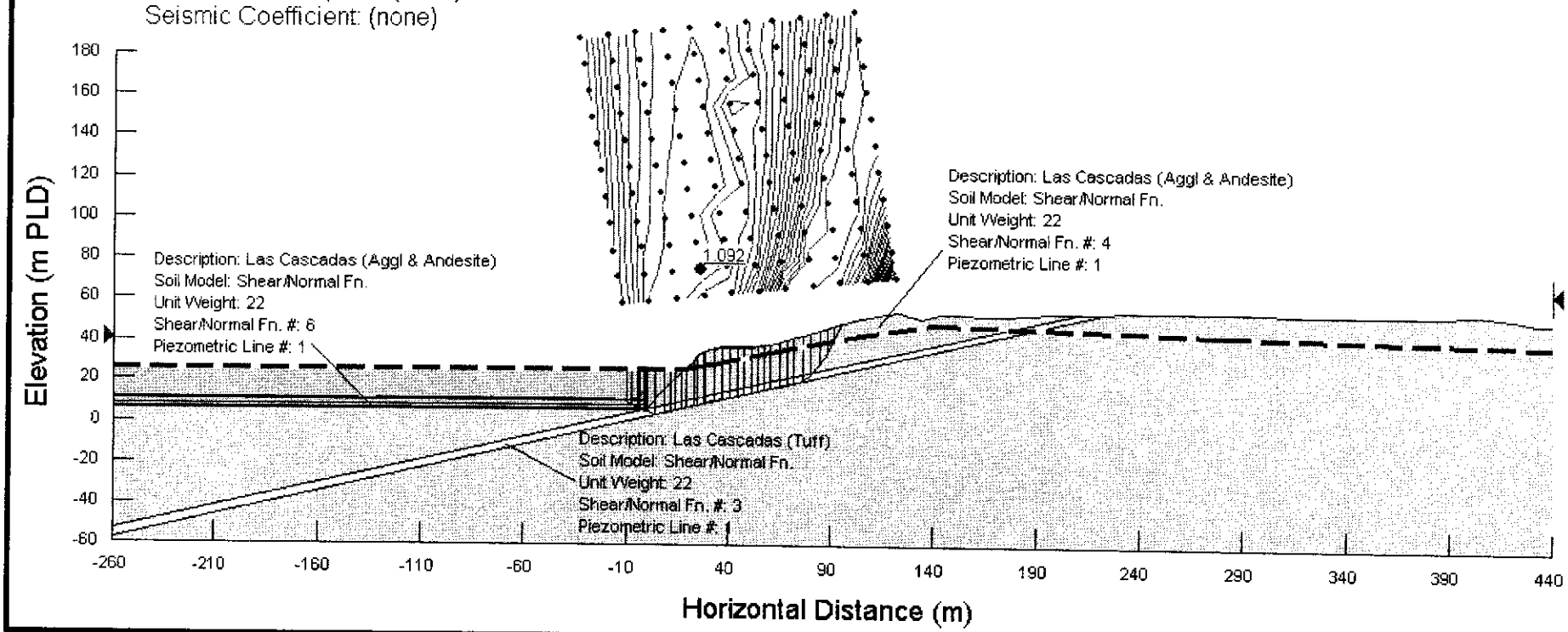
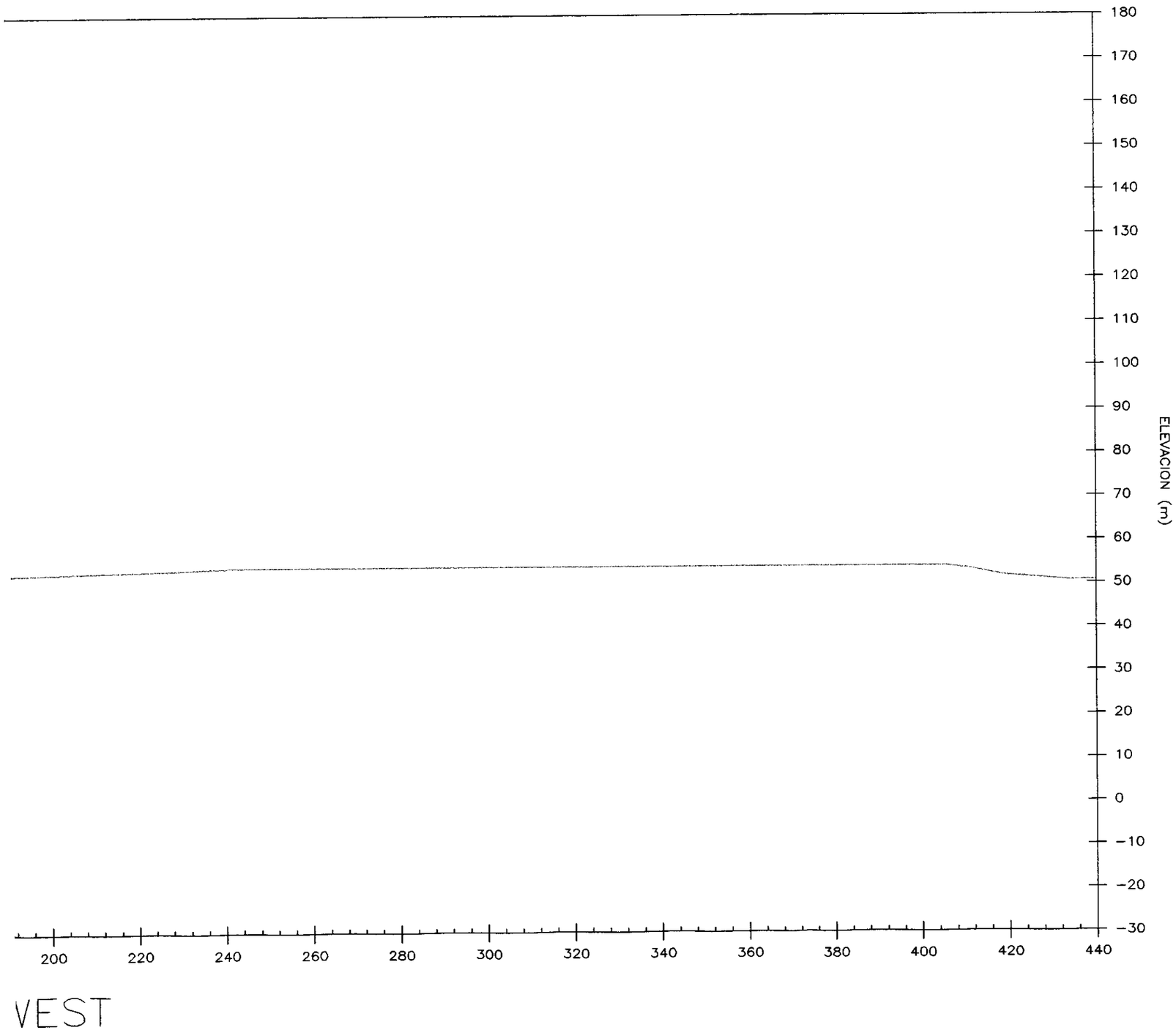
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: (none)
Seismic Coefficient: (none)



Summary, 53k + 171 (1744 + 45)

General Description	Range of stations:	52k + 160 to 53k + 780			
	Sector:	Borinquen			
	Maximum height (m):	45			
	Cotangent of slope angle (cot. β):	3.1			
History	Last slide event:	June 1, 1997 (Borinquen Slide)			
Geology	Formation:	Las Cascadas			
	Lithology:	Tuff / Agglomerate			
	Critical stratum at toe:	Tuff in weak plane			
	Apparent dip of bedding:	Toward slope, but a fault or weak plane dip toward canal			
Stability Analysis	Critical failure mechanism:	Translational along weak plane			
	Shear strength model:	Between fully softened and residual of Las Cascadas tuff			
		Operative average pore pressure ratio (aproximate), Ru:	Factor of Safety	Relative Factor of Safety	Percentage of Change (%)
	Case 1: Channel bottom = 32 ft	0.352	1.261	1.000	0.00
	Case 2: Channel bottom = 27 ft, Blasted material only		1.245	0.987	-1.27
	Case 3: Channel bottom = 27 ft, Blasted & removed		1.214	0.963	-3.73
	Case 4.1: Channel bottom = 27 ft, Design (underwater slope)		1.182	0.937	-6.26
	Case 4.2: Channel bottom = 27 ft, Design (& dry excavation)	0.373	1.238	0.982	-1.82
	Case 5: Channel bottom = 22 ft, Blasted material only		1.198	0.950	-5.00
	Case 6: Channel bottom = 22 ft, Blasted & removed		1.168	0.926	-7.38
	Case 7.1: Channel bottom = 22 ft, Design (underwater slope)		1.122	0.890	-11.02
	Case 7.2: Channel bottom = 22 ft, Design (& dry excavation)	0.352	1.200	0.952	-4.84
	Case 8: Channel bottom = 16 ft, Blasted		1.092	0.866	-13.40
Conclusions:	Stabilization is required for Case 4 and Case 7				



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ESTACION 53K+171 (1744+45) OESTE

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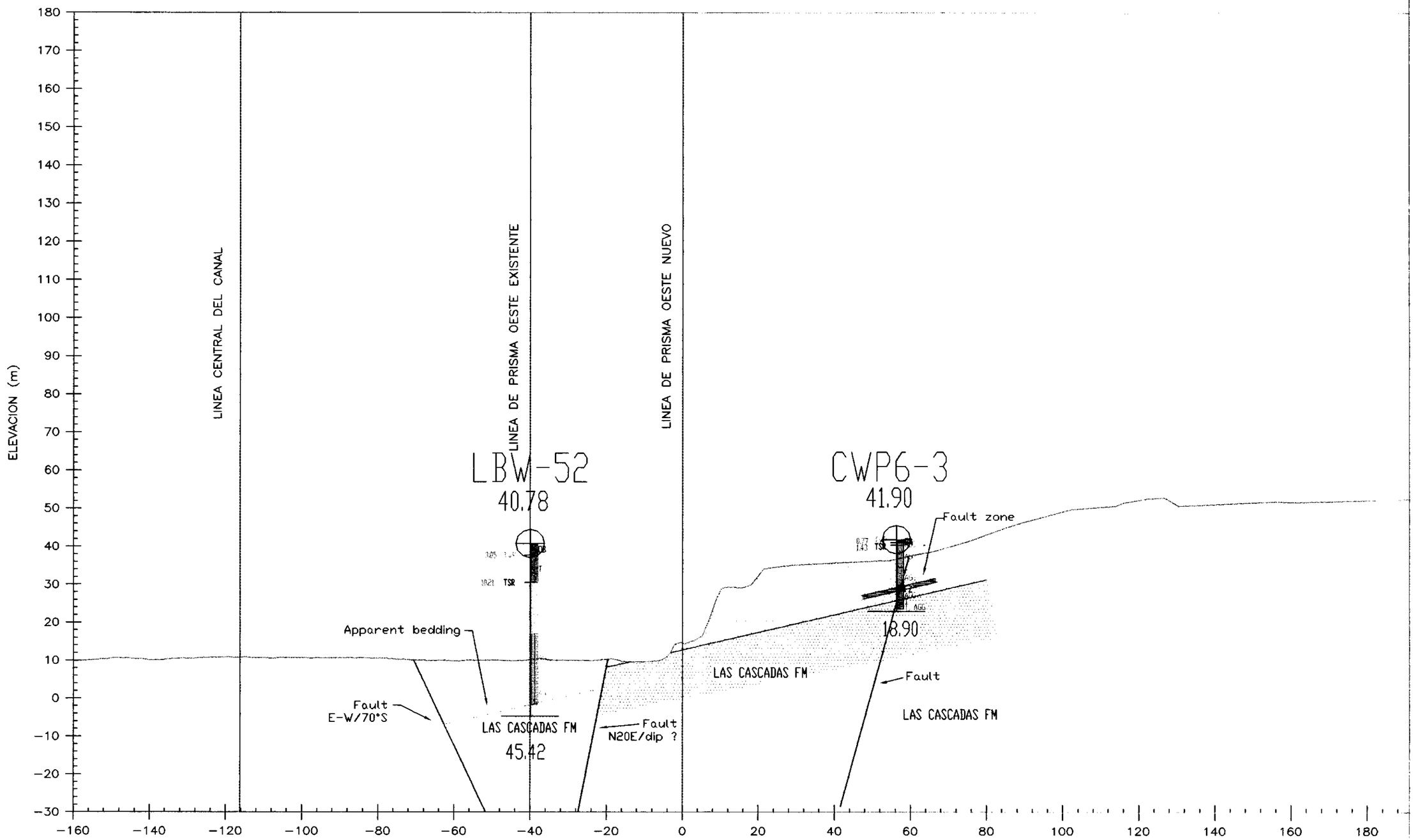


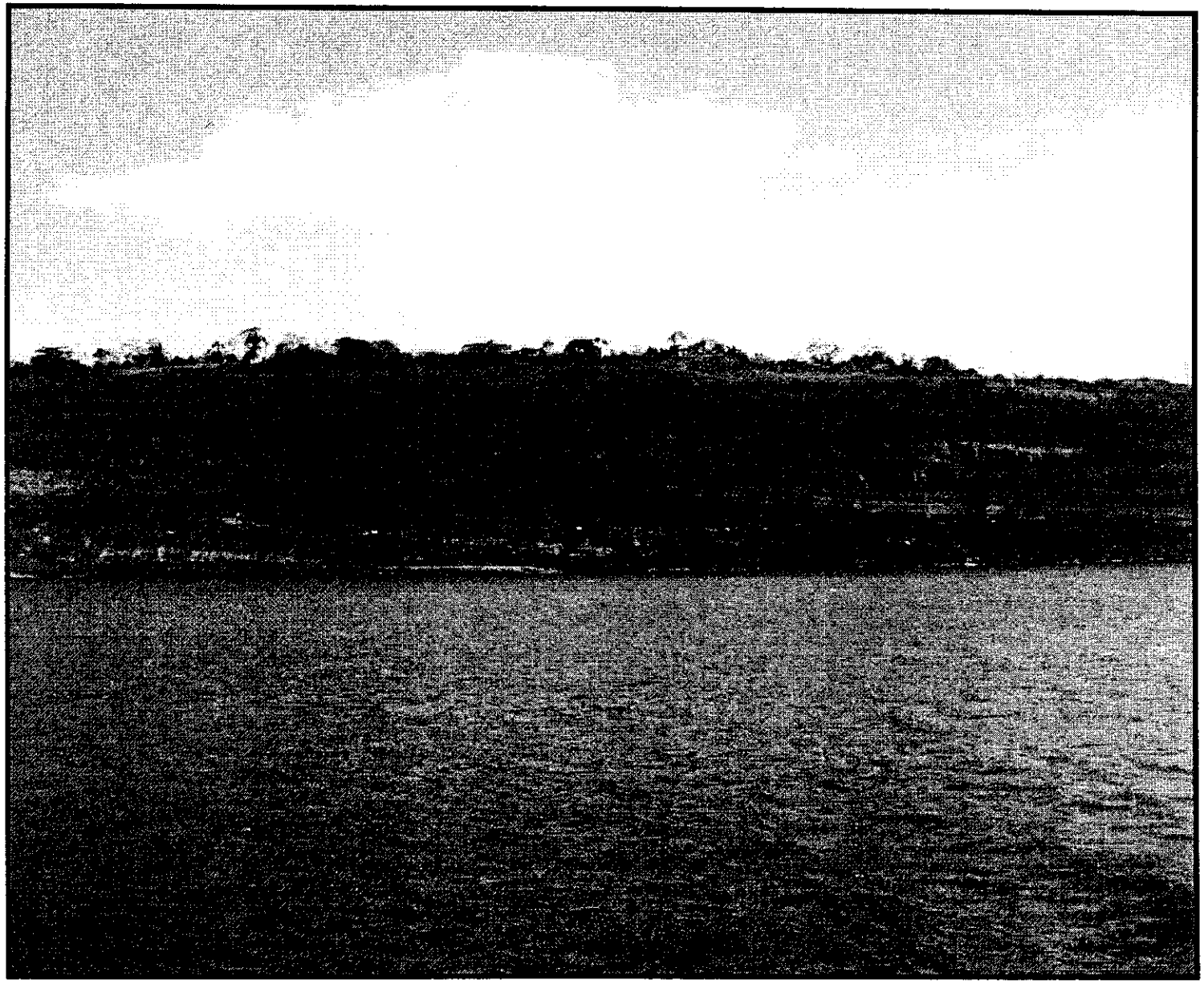
53K+171 (1744+45) V

station 54k + 300 (1781 + 49)

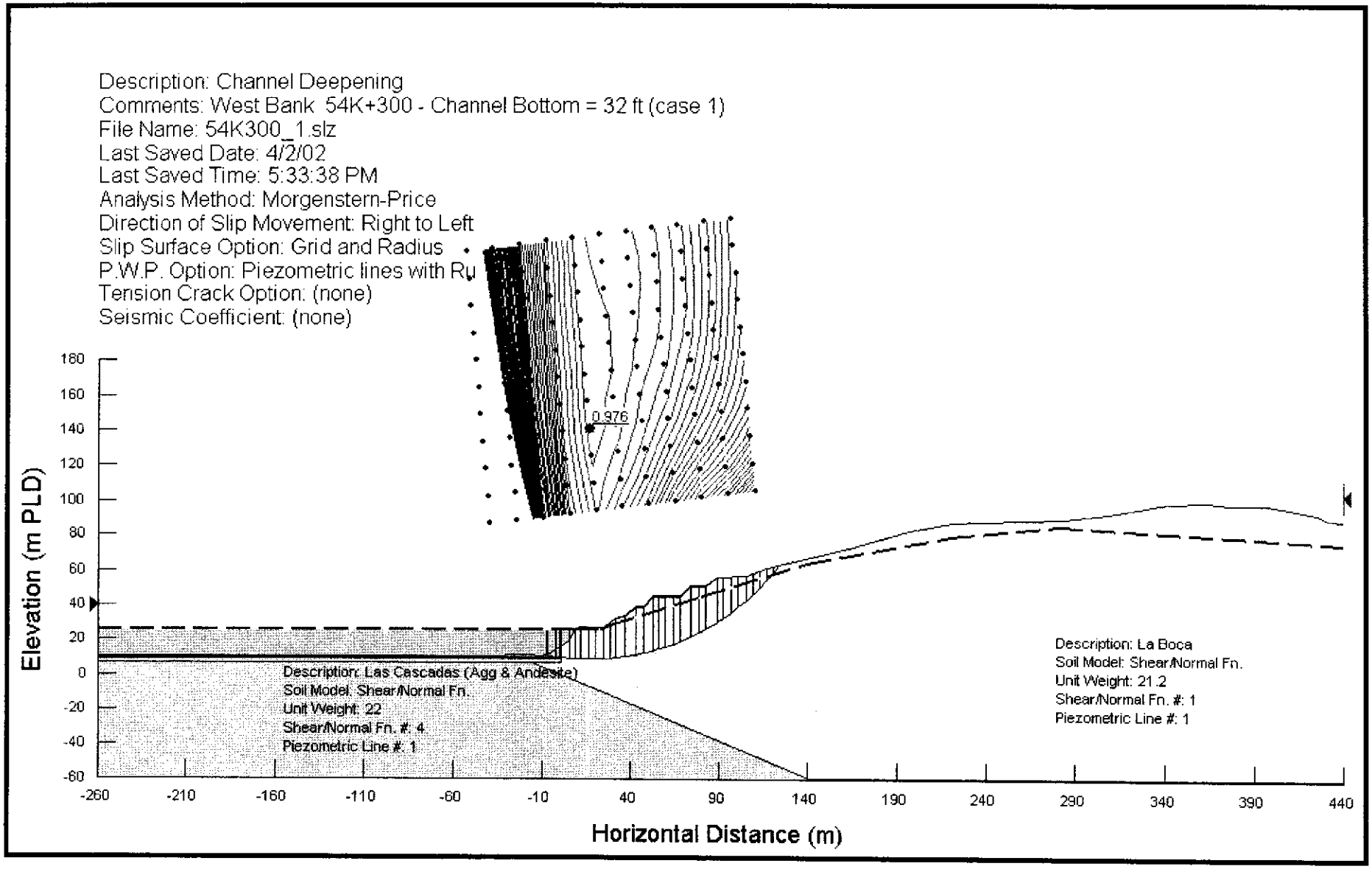
West

Station: 54k + 300 (Cascadas)

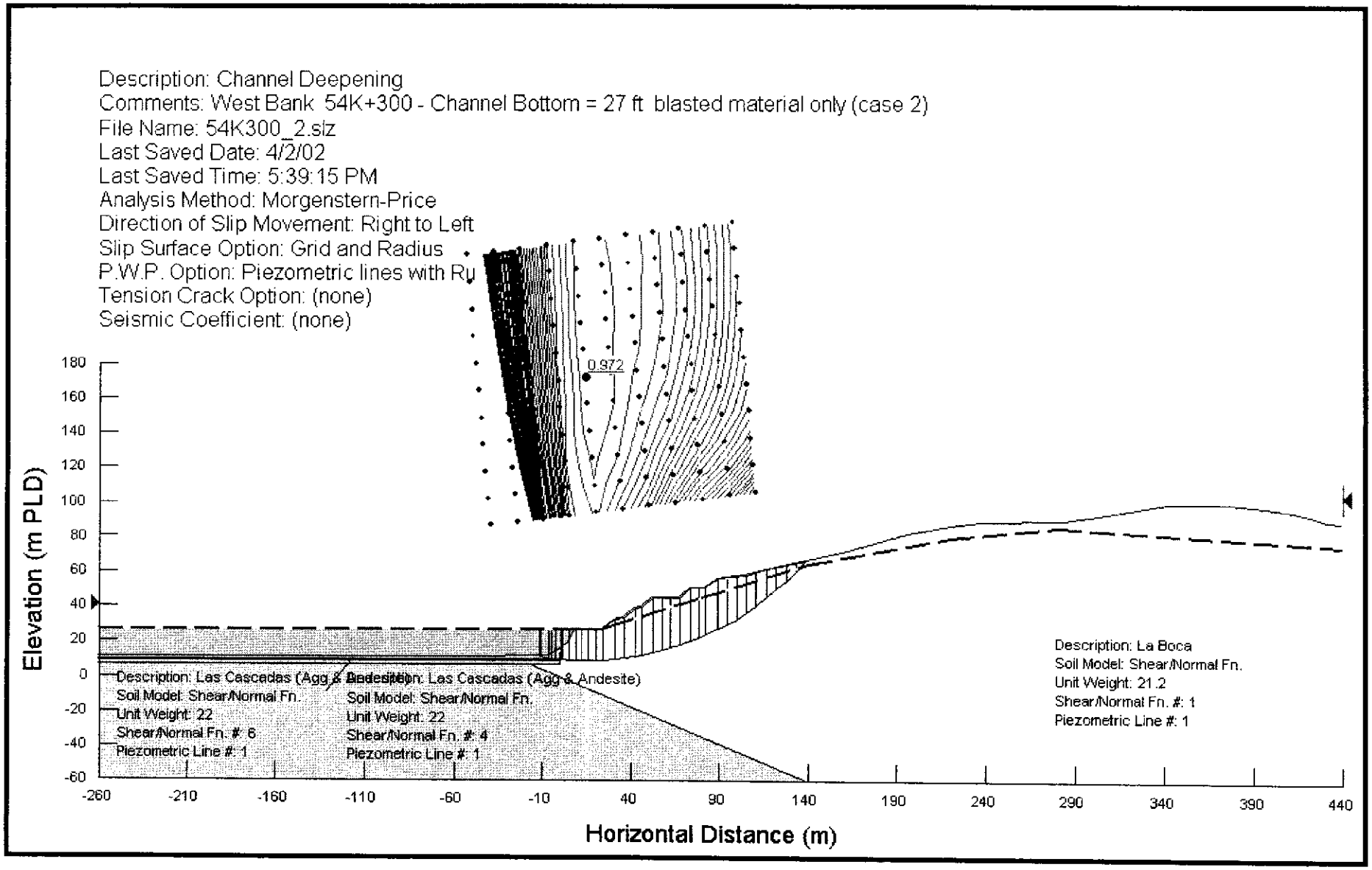
April 16, 2002



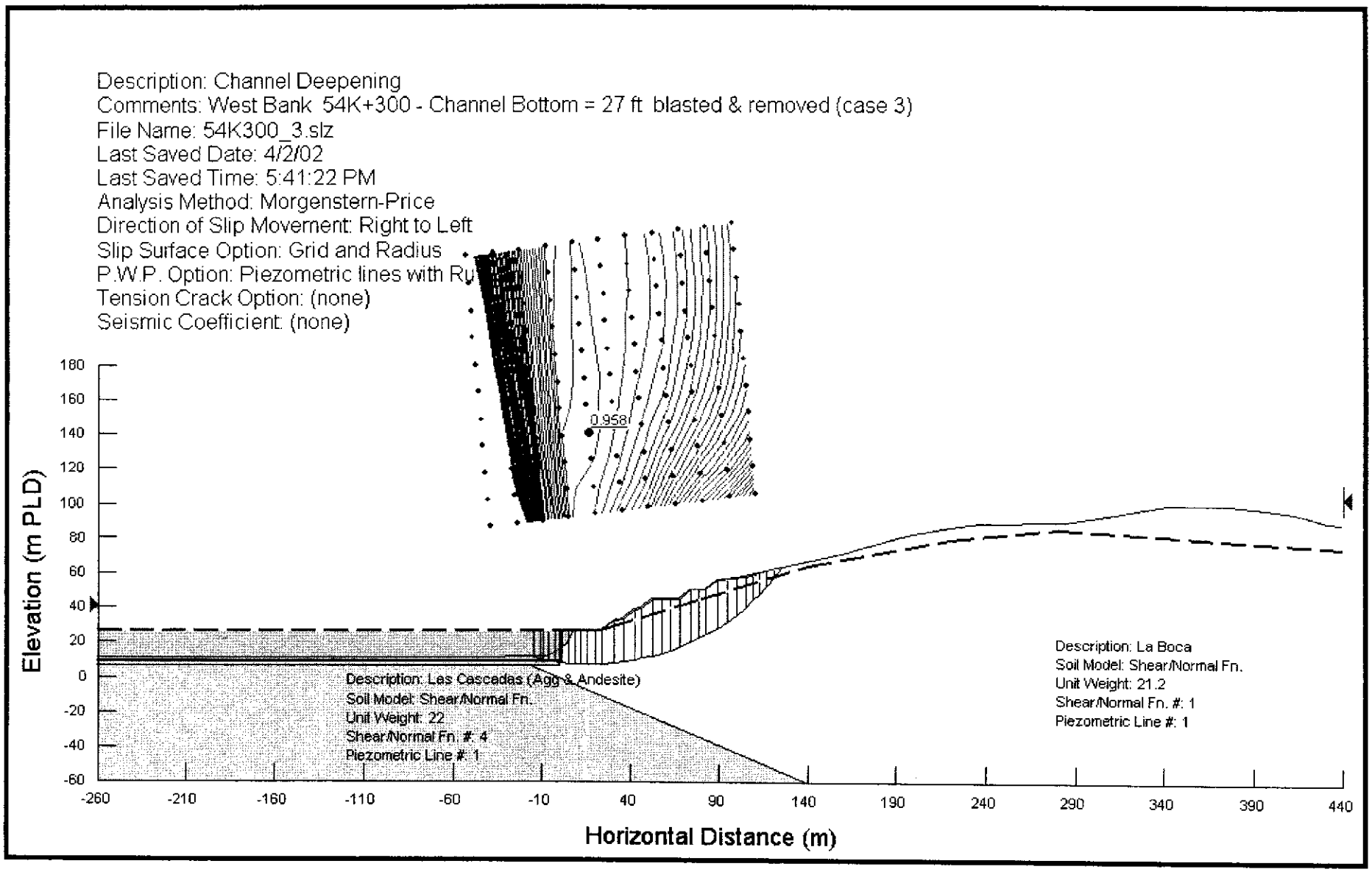
Case 1, Channel bottom = 32 ft



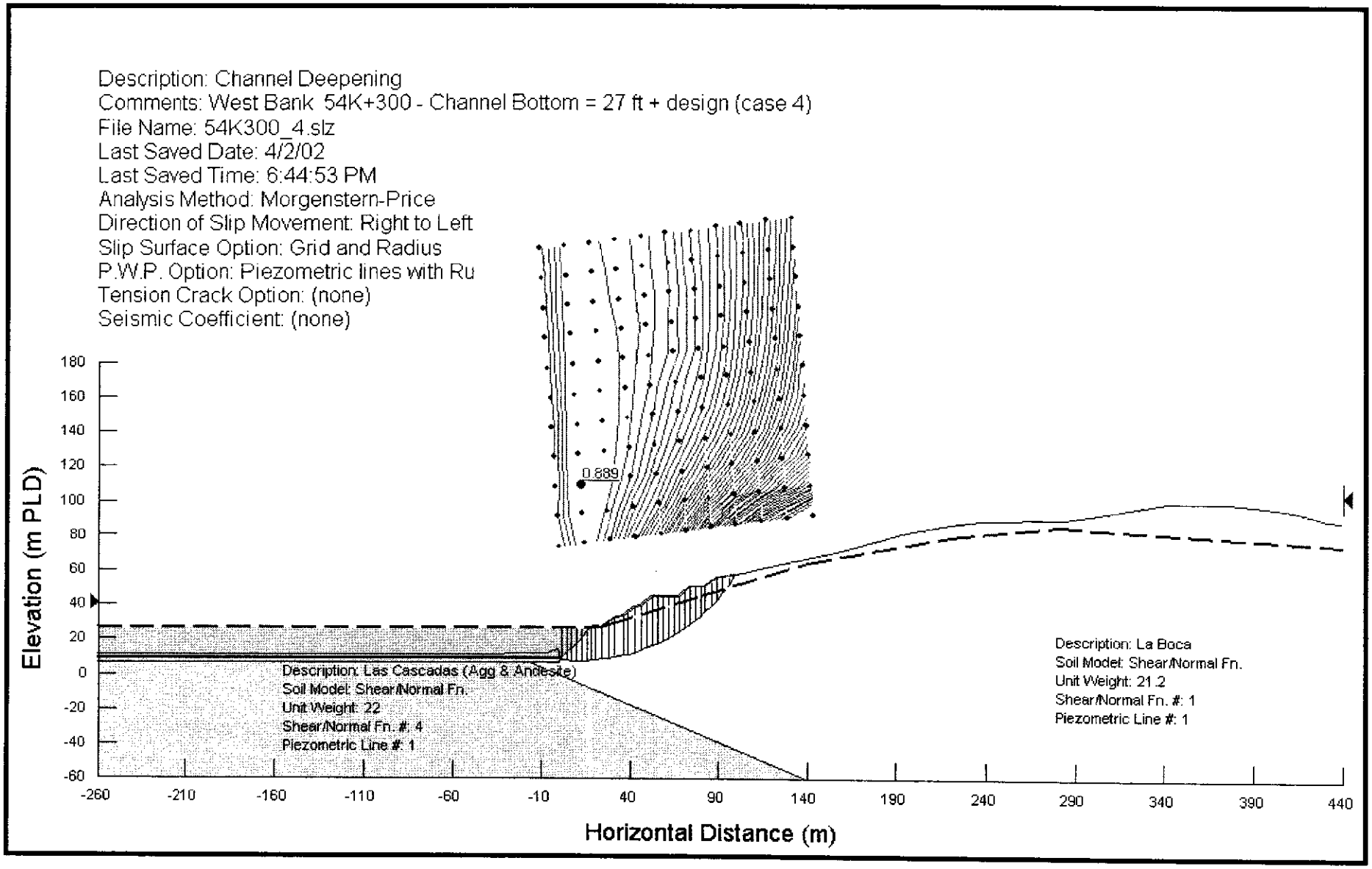
Case 2, Channel bottom = 27 ft, Blasted material only



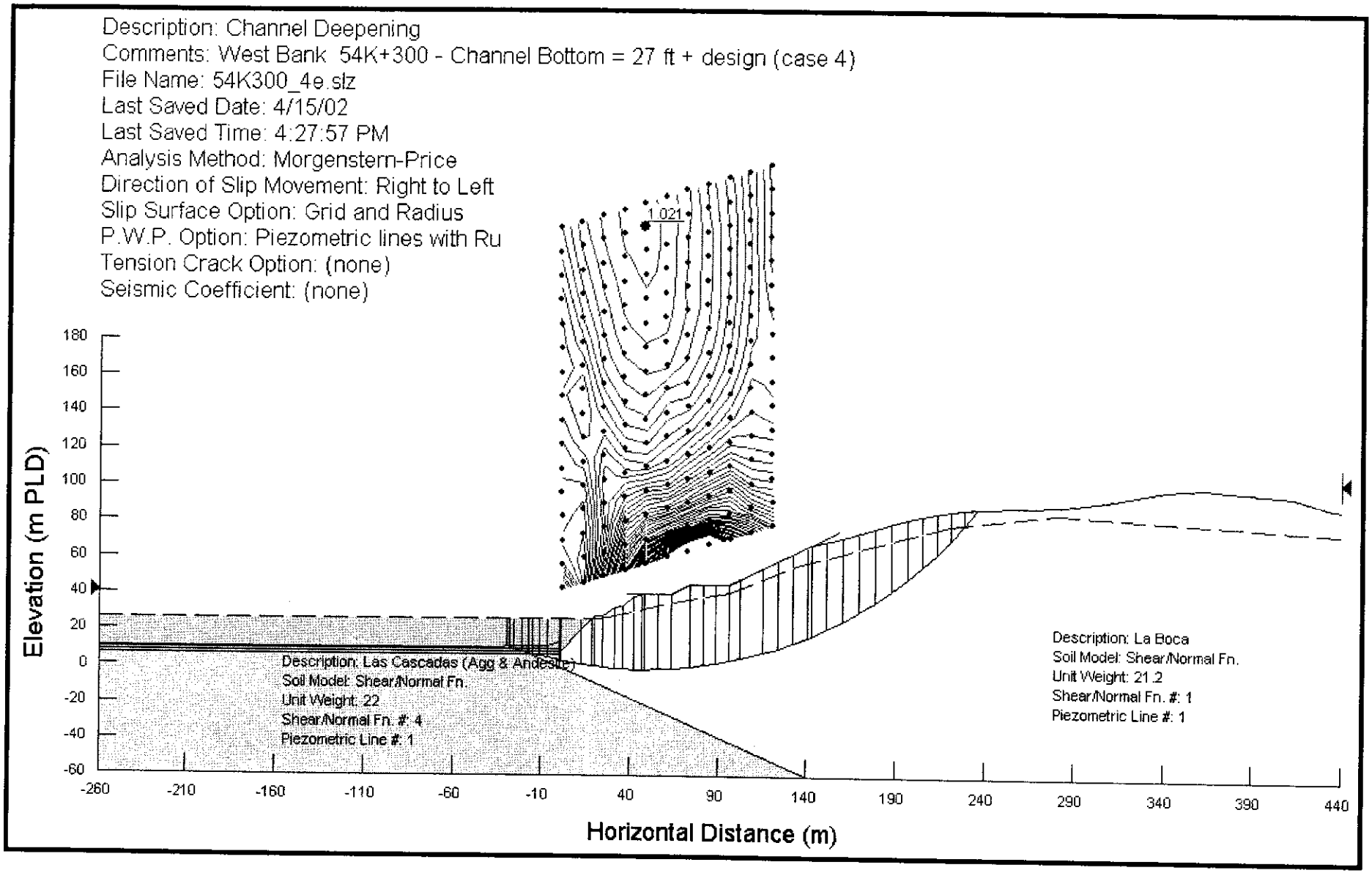
Case 3, Channel bottom = 27 ft, Blasted & removed



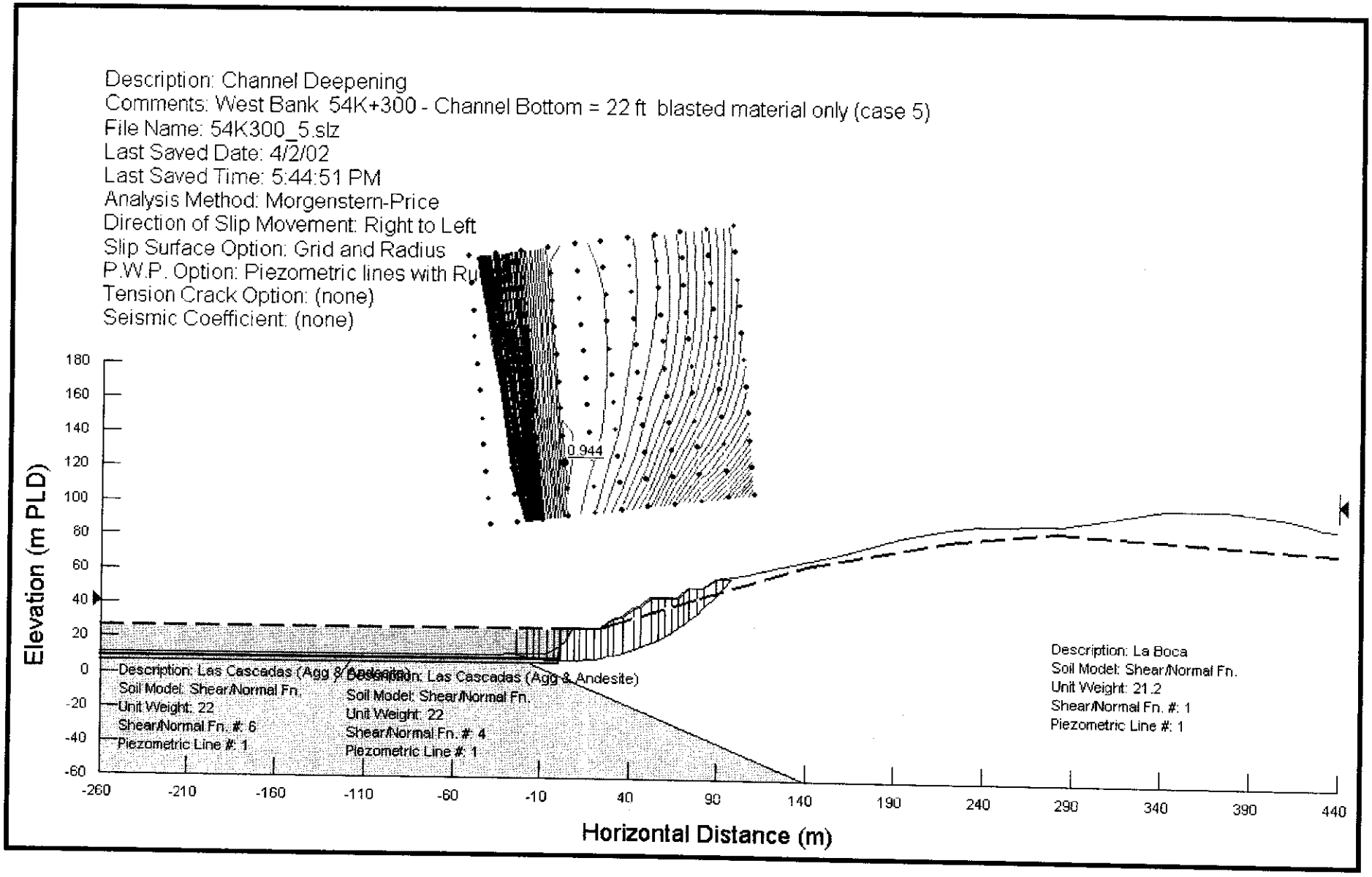
Case 4.1, Channel bottom = 27 ft, Design (underwater slope)



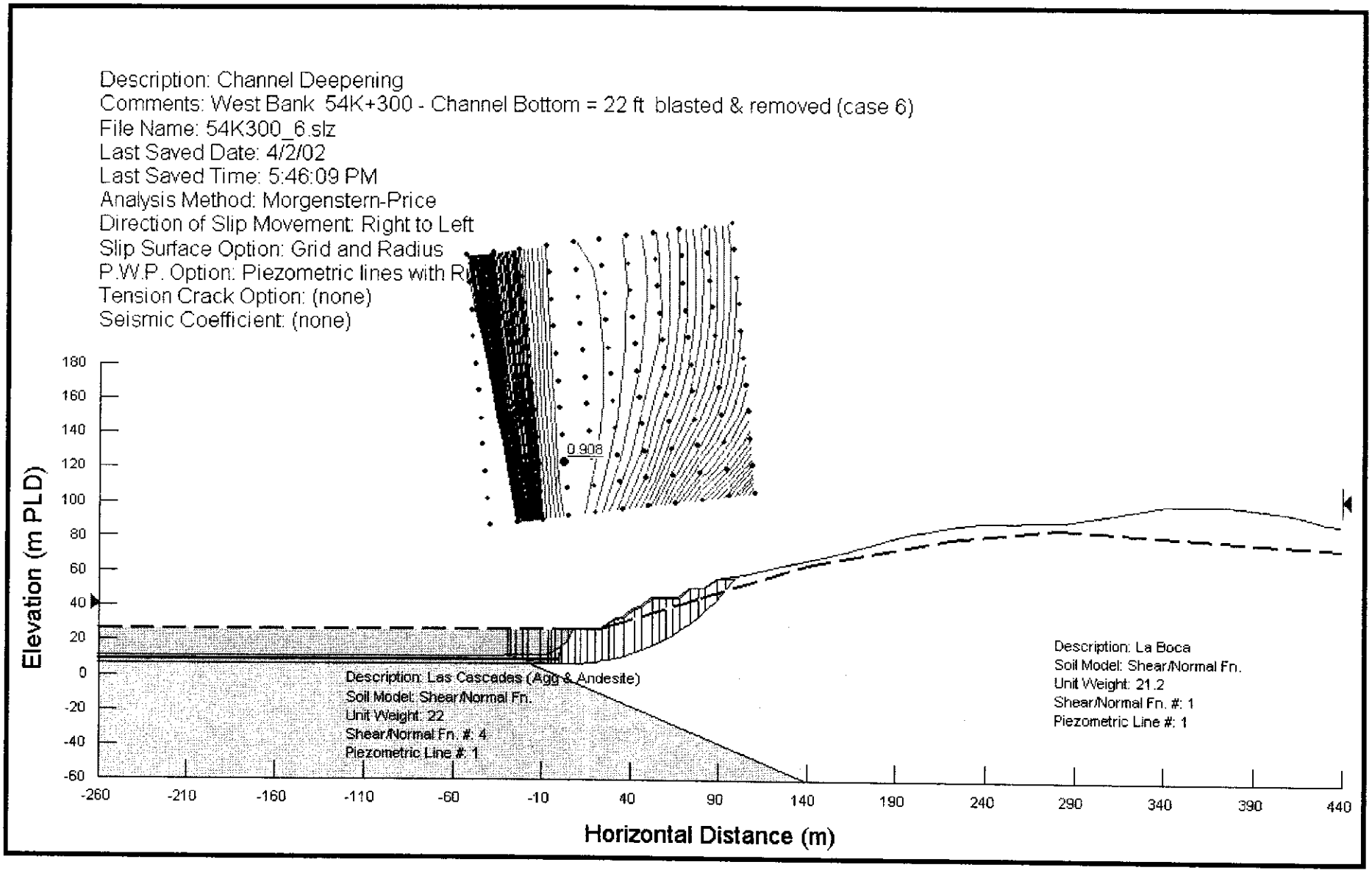
Case 4.2, Channel bottom = 27 ft, Design (& dry excavation)



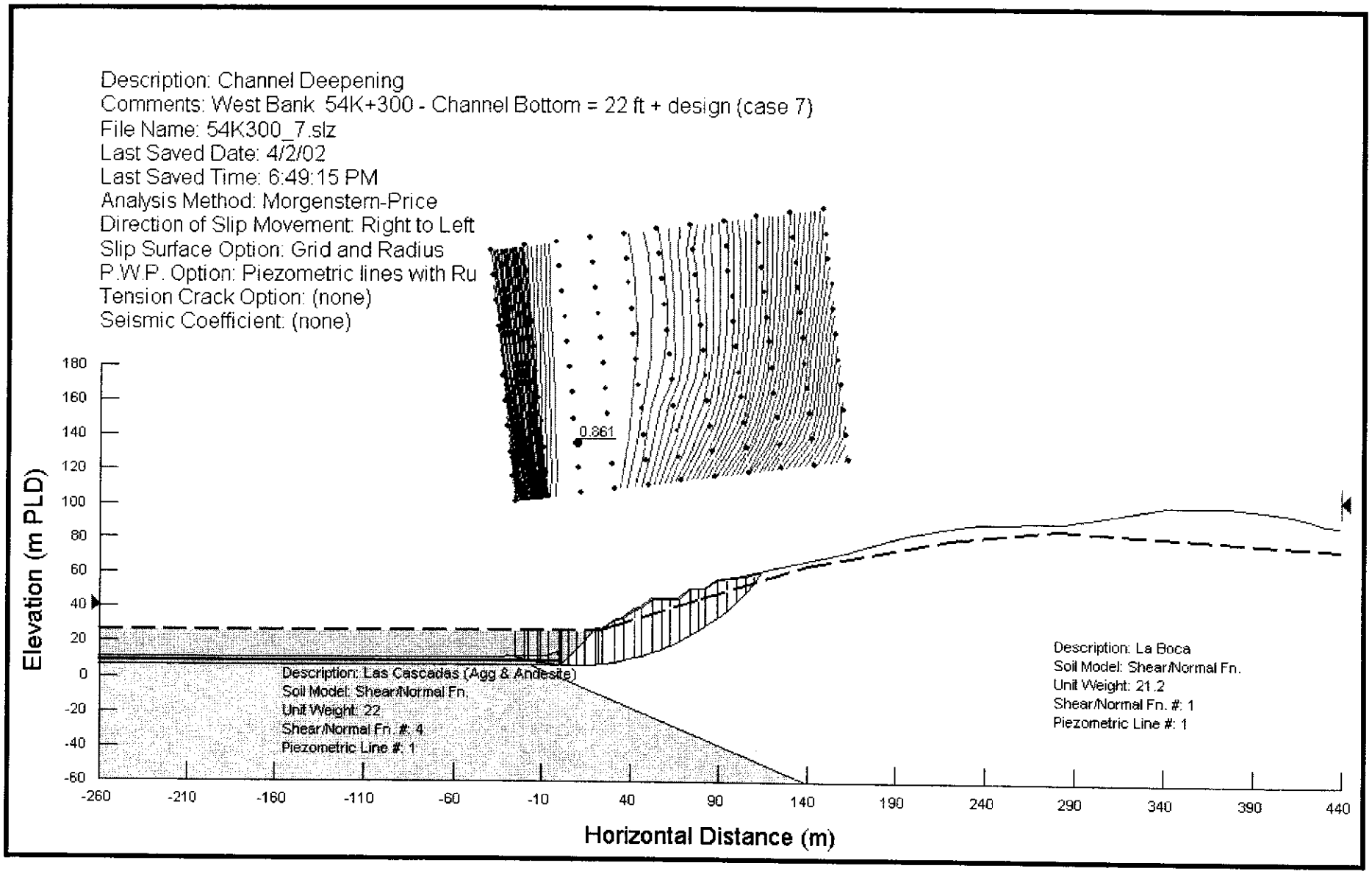
Case 5, Channel bottom = 22 ft, Blasted material only



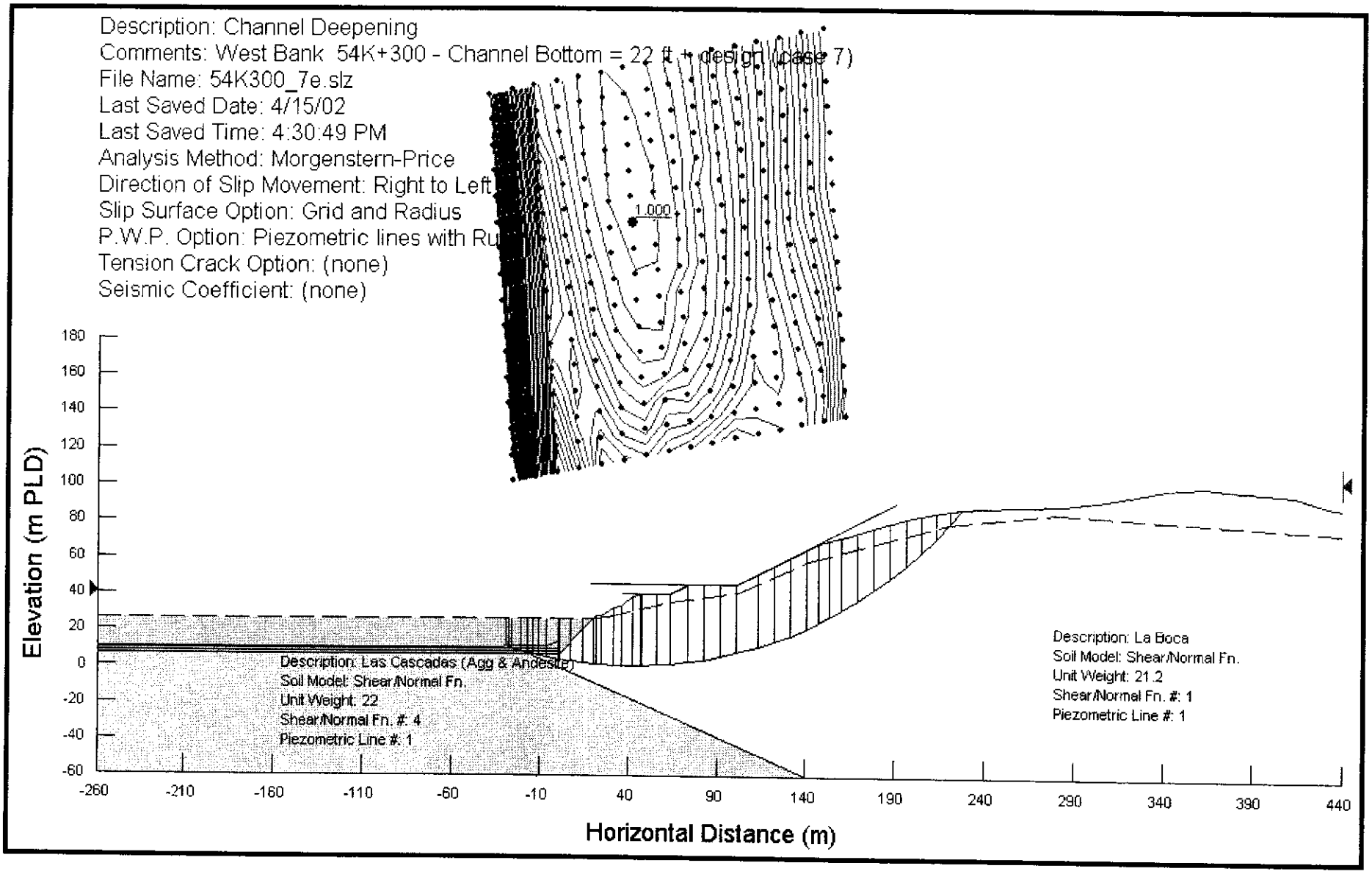
Case 6, Channel bottom = 22 ft, Blasted & removed



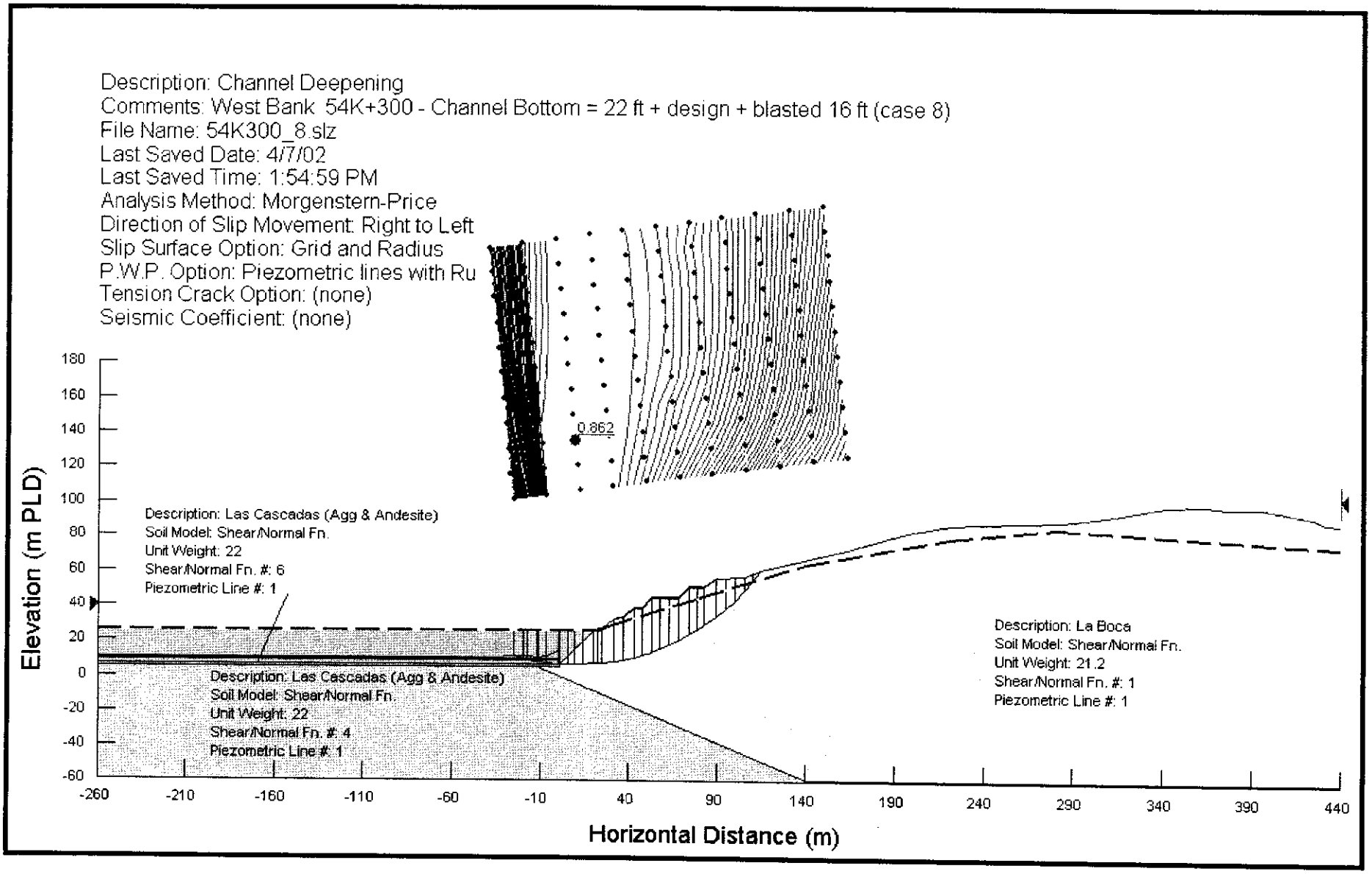
Case 7.1, Channel bottom = 27 ft, Design (underwater slope)



Case 7.2, Channel bottom = 27 ft, Design (& dry excavation)

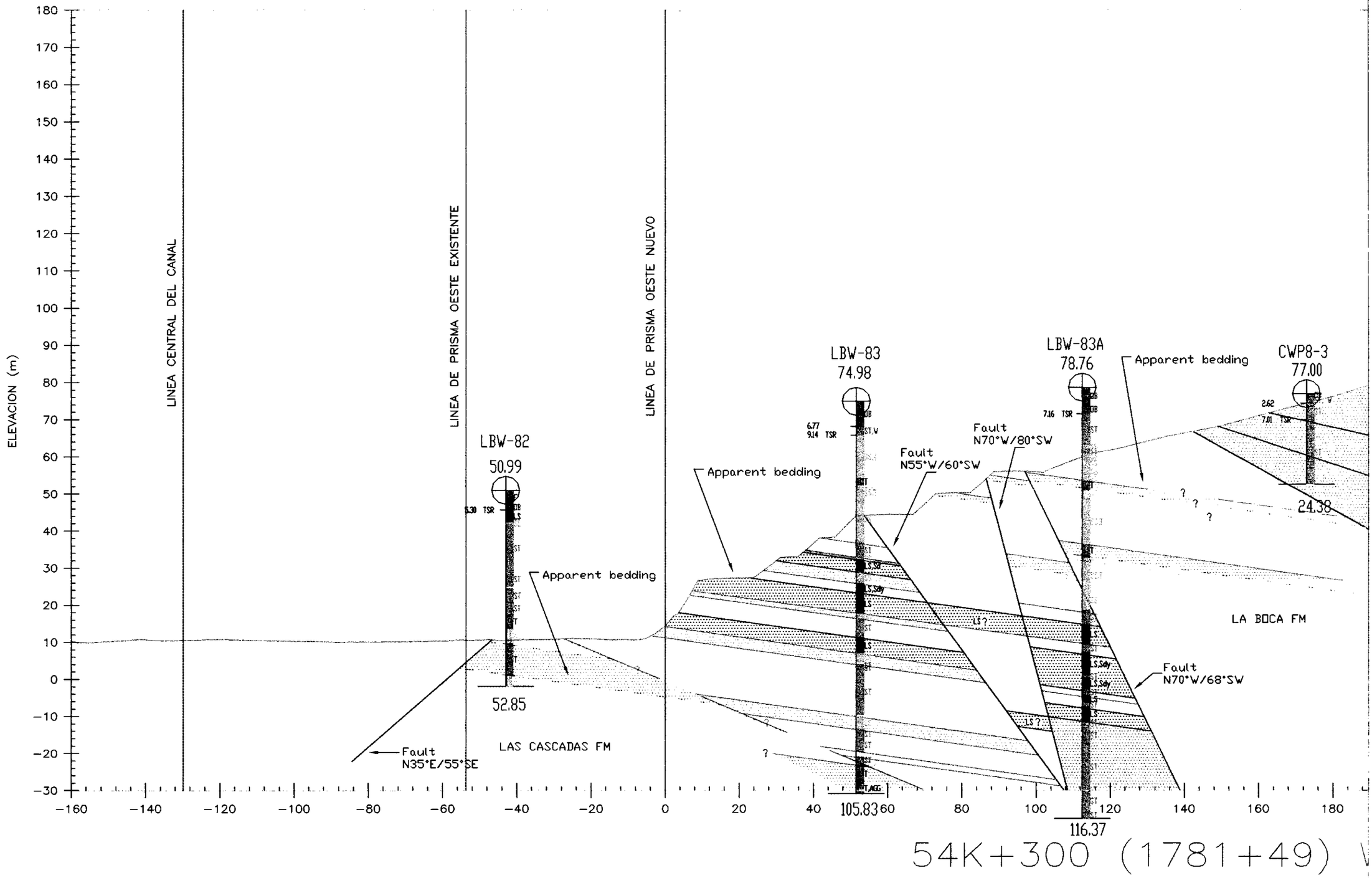


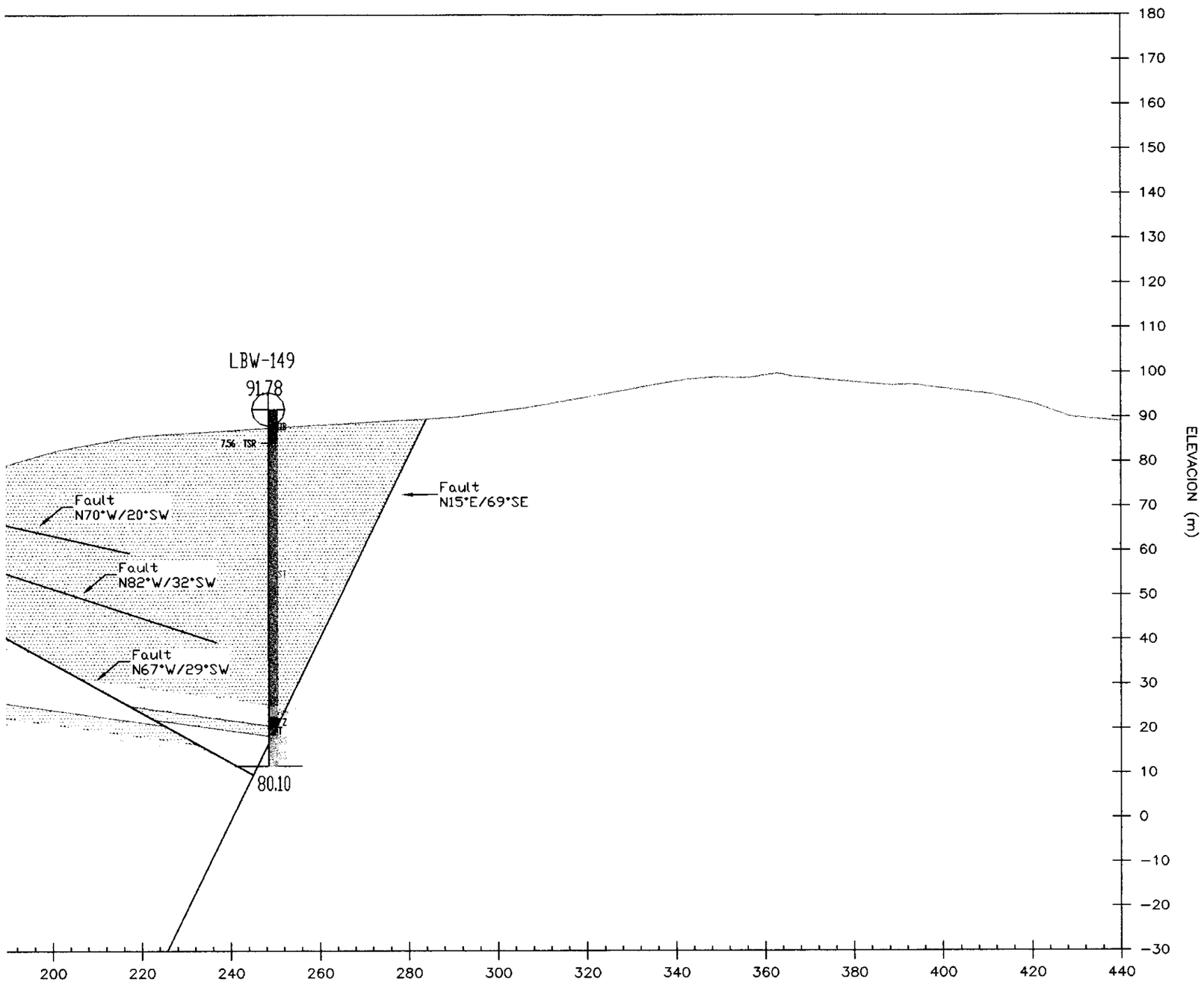
Case 8, Channel bottom = 16 ft, Blasted



Summary, 54k + 300 (1781 + 49)

General Description	Range of stations:	53k + 780 to 55k + 000			
	Sector:	Cascadas			
	Maximum height (m):	90			
	Cotangent of slope angle (cot. β):	4.01			
History	Last slide event:	February, 1930 (White House Yard Slide)			
Geology	Formation:	La Boca / Las Cascadas			
	Lithology:	Siltstone / Tuff / Sandstone / Agglomerate tuff / Limestone			
	Critical stratum at toe:	Sandstone / Siltstone / Tuff agglomerate			
	Apparent dip of bedding:	Toward the slope			
Stability Analysis	Critical failure mechanism:	Rotational			
	Shear strength model:	Fully softened La Boca & First time Cascadas agglomerate			
		Operative average pore pressure ratio (aproximate), Ru:	Factor of Safety	Relative Factor of Safety	Percentage of Change (%)
	Case 1: Channel bottom = 32 ft	0.370	0.976	1.000	0.00
	Case 2: Channel bottom = 27 ft, Blasted material only		0.972	0.996	-0.41
	Case 3: Channel bottom = 27 ft, Blasted & removed		0.958	0.982	-1.84
	Case 4.1: Channel bottom = 27 ft, Design (underwater slope)		0.889	0.911	-8.91
	Case 4.2: Channel bottom = 27 ft, Design (& dry excavation)	0.357	1.021	1.046	4.61
	Case 5: Channel bottom = 22 ft, Blasted material only		0.944	0.967	-3.28
	Case 6: Channel bottom = 22 ft, Blasted & removed		0.908	0.930	-6.97
	Case 7.1: Channel bottom = 22 ft, Design (underwater slope)		0.861	0.882	-11.78
	Case 7.2: Channel bottom = 22 ft, Design (& dry excavation)	0.378	1.000	1.025	2.46
	Case 8: Channel bottom = 16 ft, Blasted		0.862	0.883	-11.68
Conclusions:	Stabilization is required for Case 4 and Case 7				


ELEVACION (m)
LINEA CENTRAL DEL CANAL
LINEA DE PRISMA OESTE EXISTENTE
LINEA DE PRISMA OESTE NUEVO
LBW-82
50.99
52.85
LBW-83
74.98
105.83
LBW-83A
78.76
116.37
CWP8-3
77.00
24.38
Apparent bedding
Apparent bedding
Apparent bedding
Fault
N35°E/55°SE
Fault
N55°W/60°SW
Fault
N70°W/80°SW
Fault
N70°W/68°SW
LAS CASCADAS FM
LA BOCA FM
54K+300 (1781+49)



AUTORIDAD DEL CANAL DE PANAMA

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ALTOS DE BALBOA, REPUBLICA DE PANAMA

SECCION GEOLOGICA

CORTE GAILLARD

ESTACION 54K+300 (1781+49) OESTE

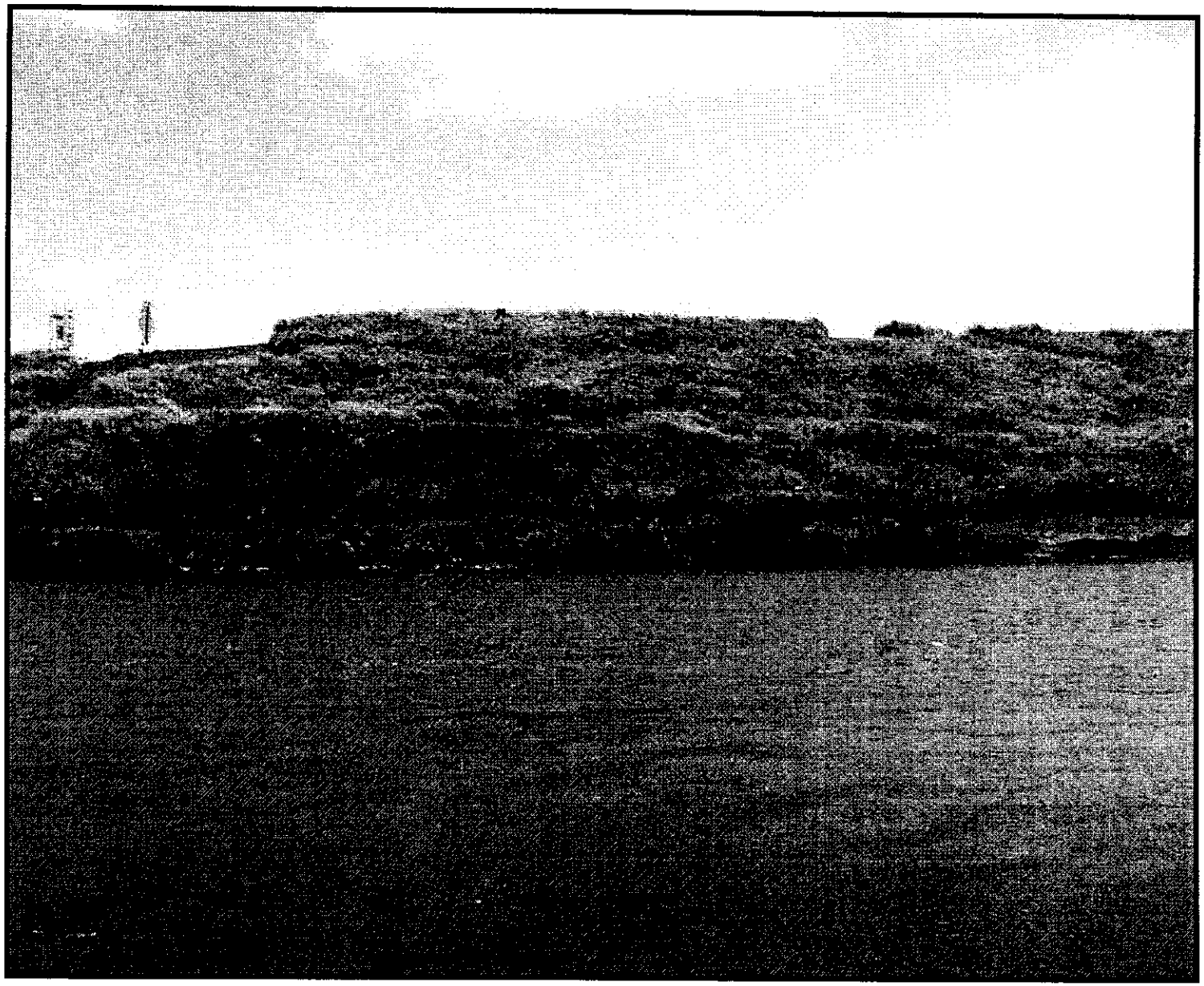
ESCALA: 1:1000	FECHA: ABRIL 2002
GEOLOGIA POR: P. FRANCESCHI	DIBUJADO POR: J. RAMESCH

station 55k + 930 (1835 + 00)

West

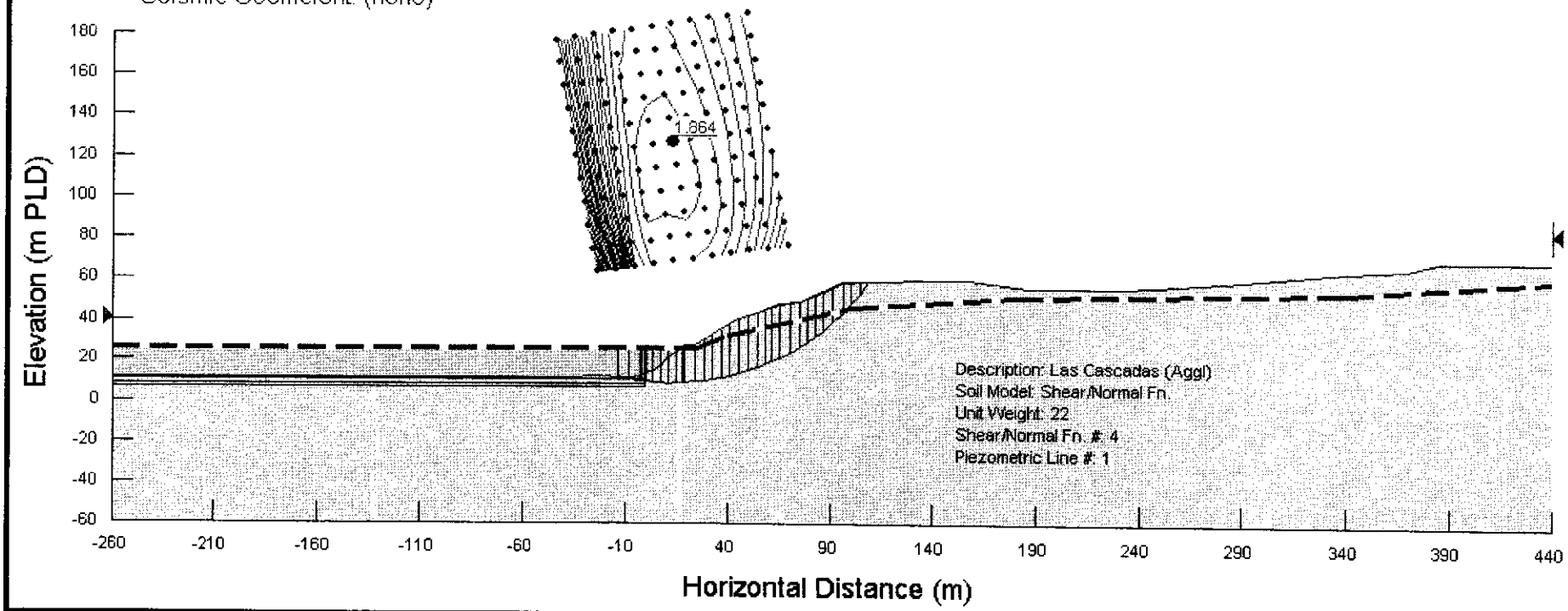
Station: 55k + 930 (Cunette)

April 16, 2002

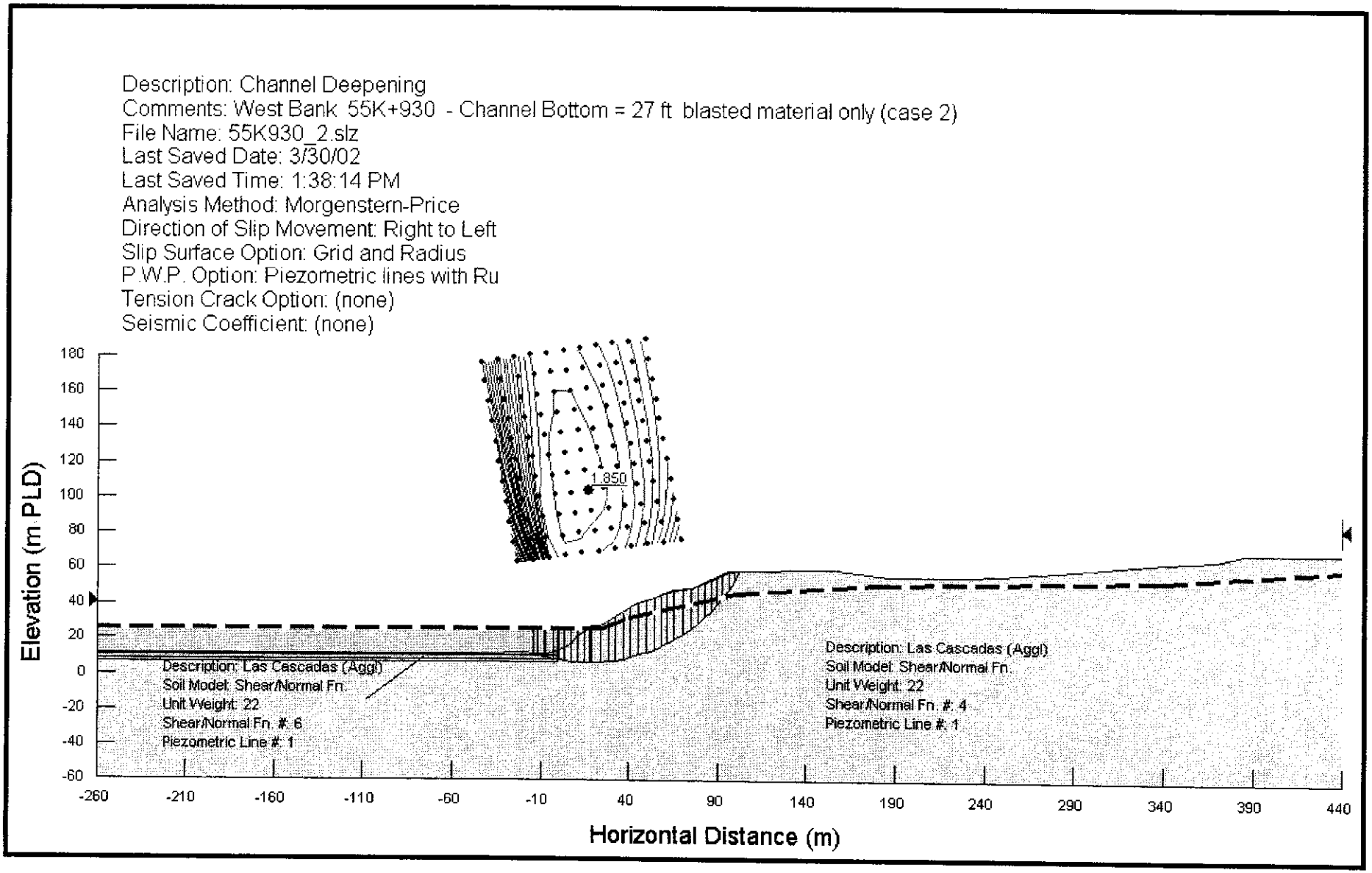


Case 1, Channel bottom = 32 ft

Description: Channel Deepening
Comments: West Bank 55K+930 - Channel Bottom = 32 ft (case 1)
File Name: 55K930_1.slz
Last Saved Date: 3/30/02
Last Saved Time: 1:21:36 PM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: (none)
Seismic Coefficient: (none)

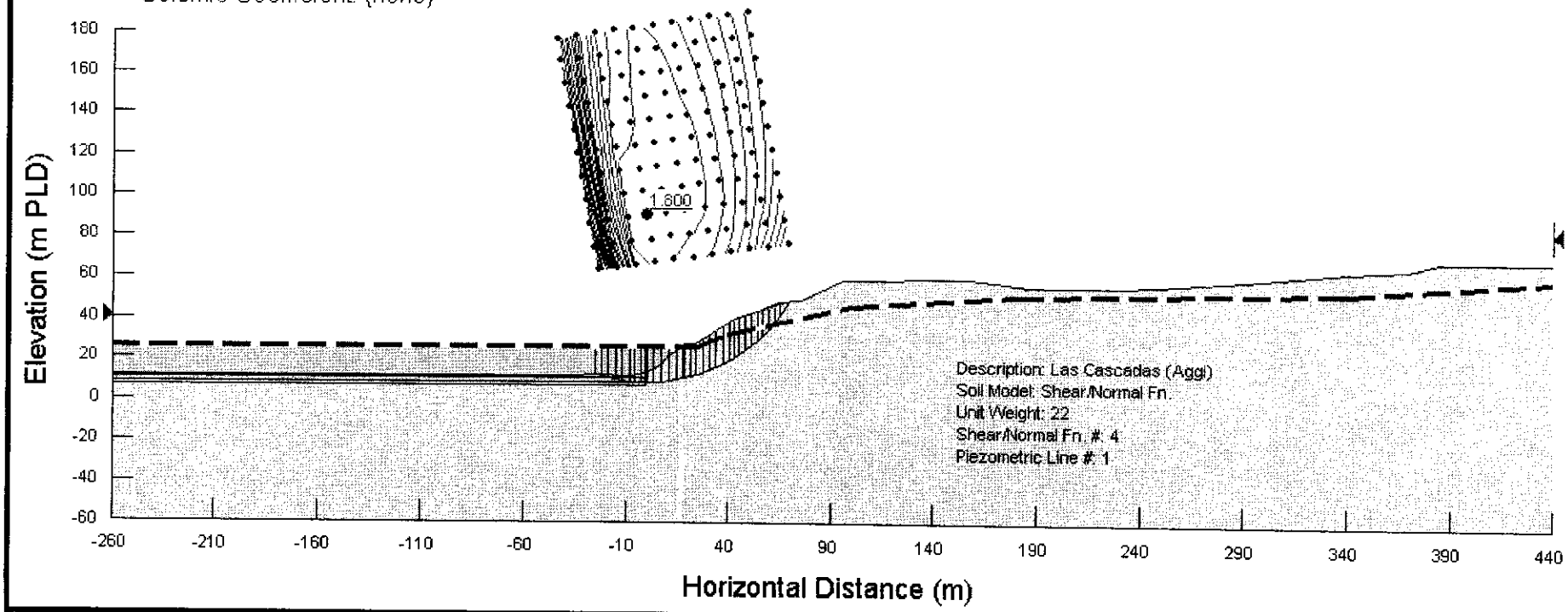


Case 2, Channel bottom = 27 ft, Blasted material only

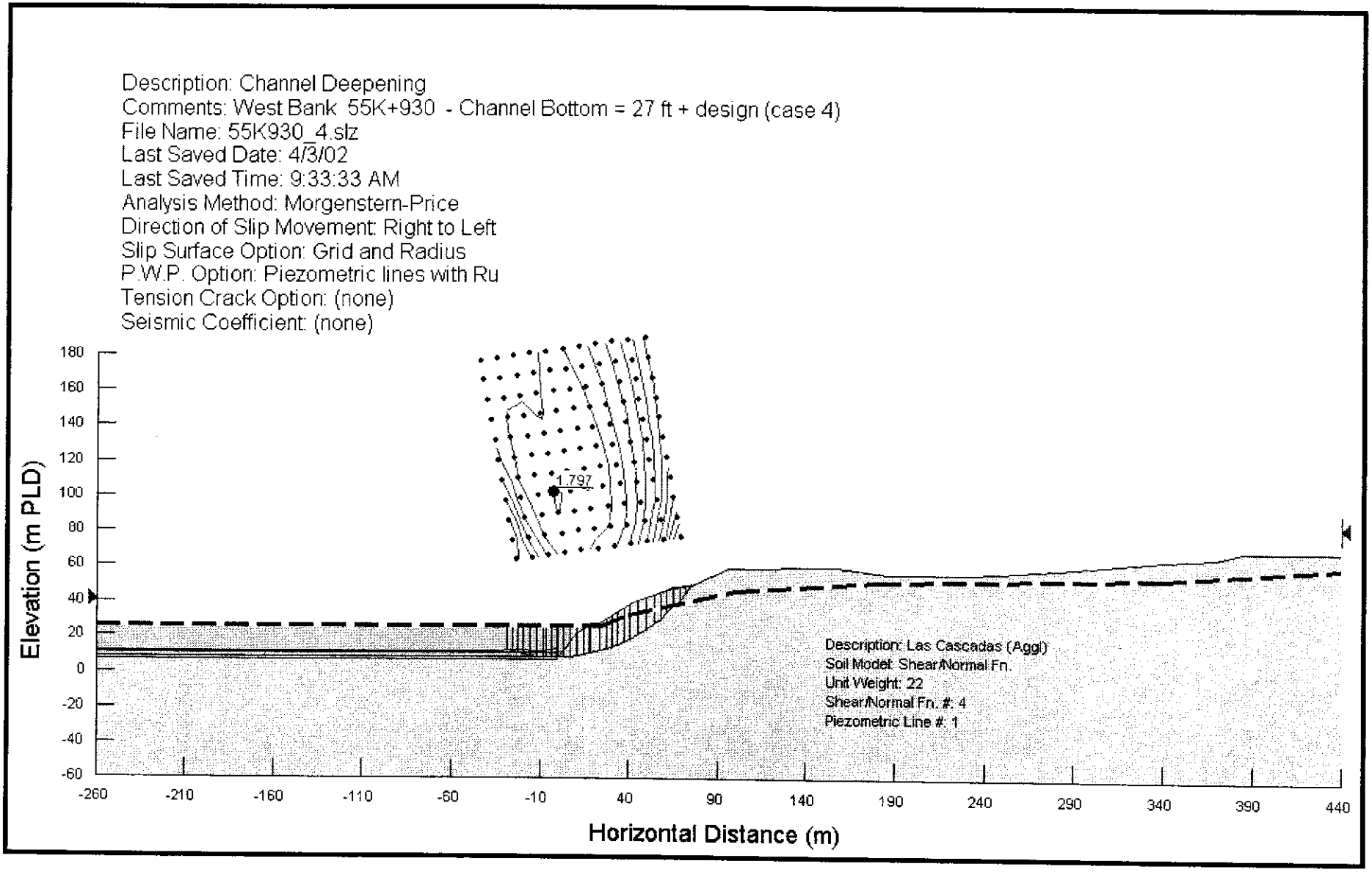


Case 3, Channel bottom = 27 ft, Blasted & removed

Description: Channel Deepening
Comments: West Bank 55K+930 - Channel Bottom = 27 ft blasted & removed (case 3)
File Name: 55K930_3.slz
Last Saved Date: 3/30/02
Last Saved Time: 1:40:38 PM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: (none)
Seismic Coefficient: (none)

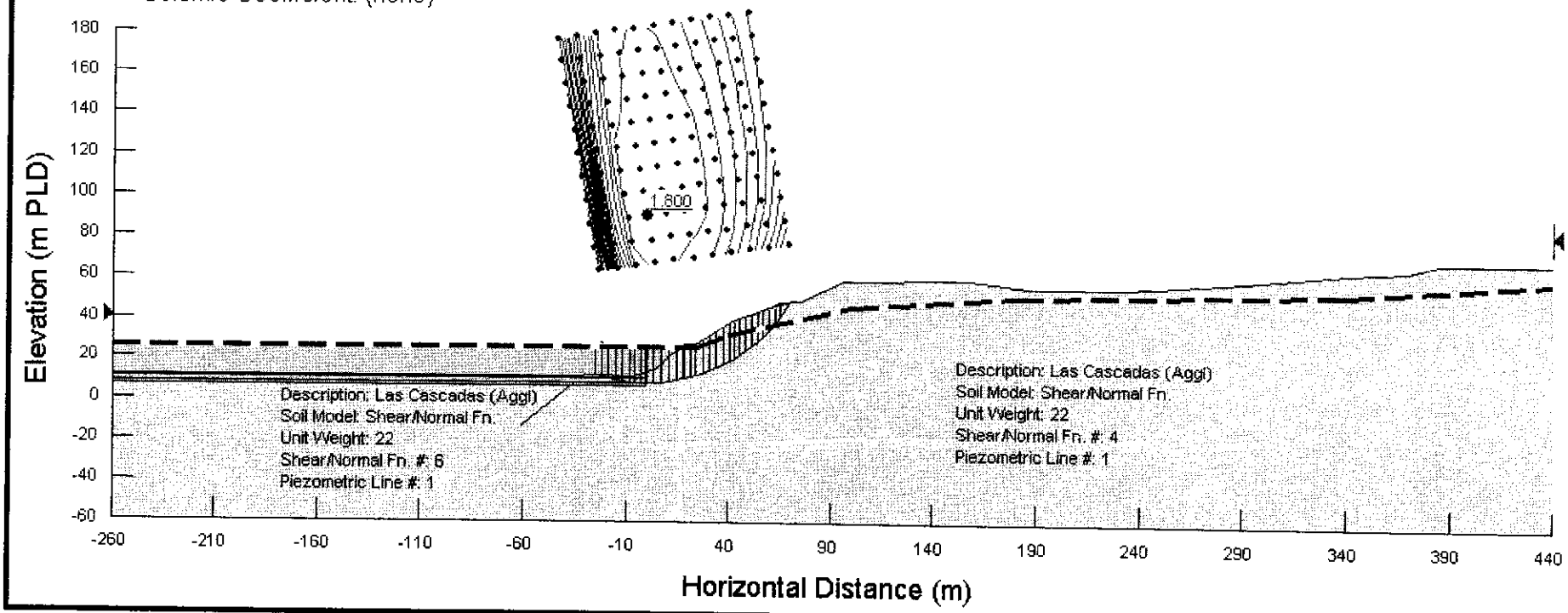


Case 4, Channel bottom = 27 ft, Design (underwater slope)

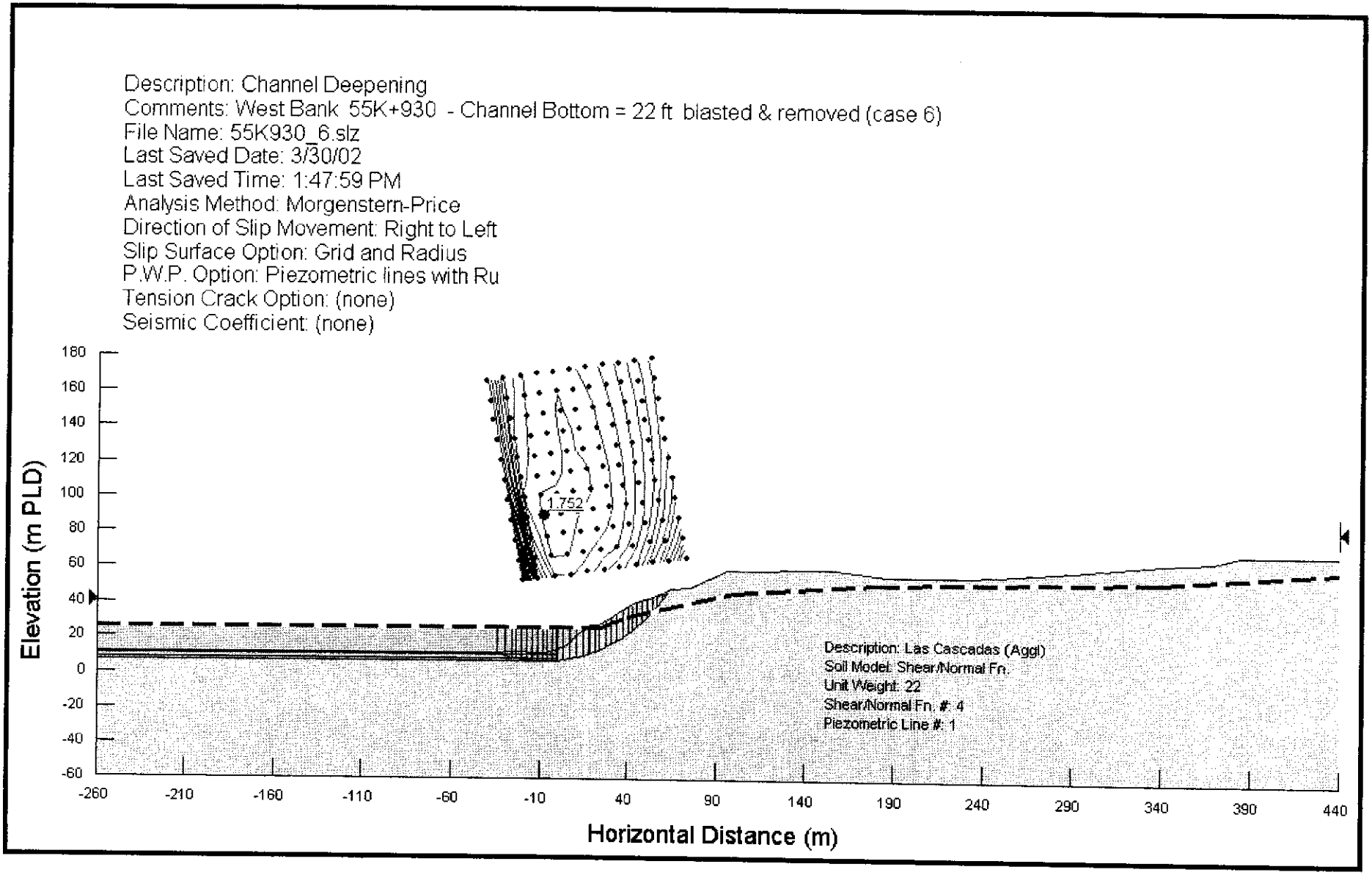


Case 5, Channel bottom = 22 ft, Blasted material only

Description: Channel Deepening
Comments: West Bank 55K+930 - Channel Bottom = 22 ft blasted material only (case 5)
File Name: 55K930_5.slz
Last Saved Date: 3/30/02
Last Saved Time: 1:45:02 PM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: (none)
Seismic Coefficient: (none)

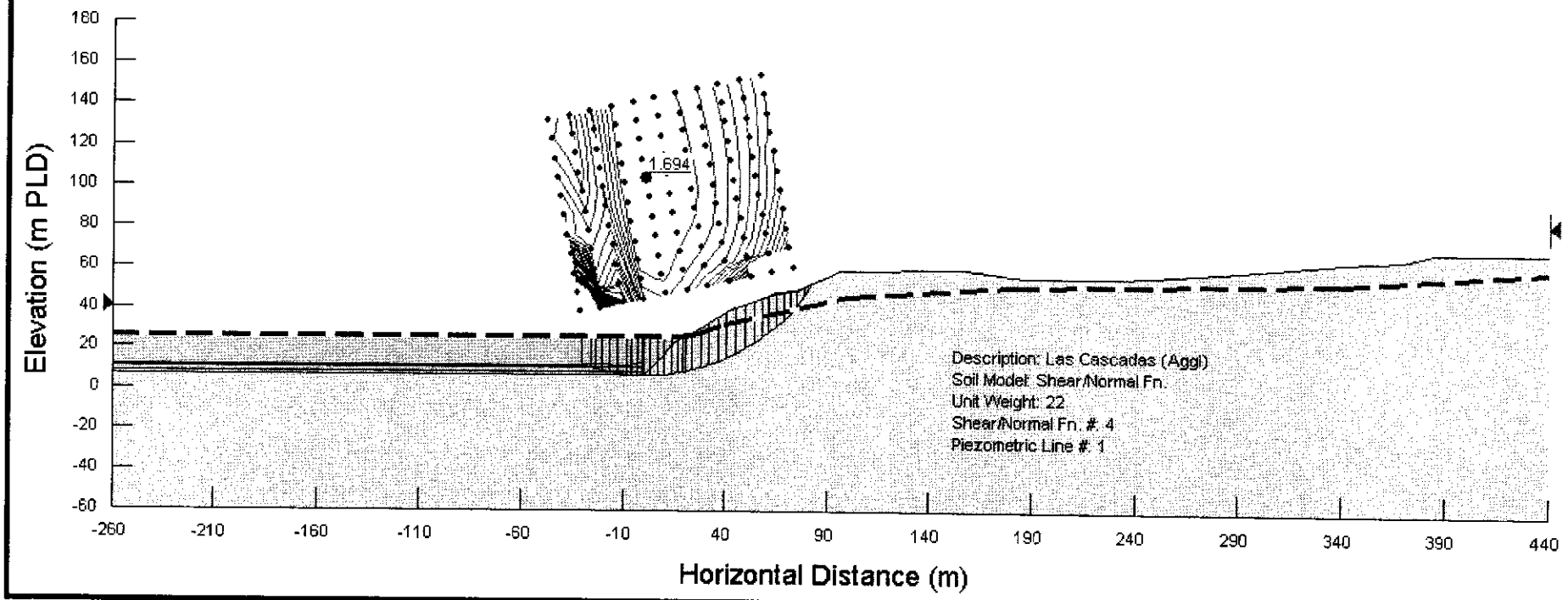


Case 6, Channel bottom = 22 ft, Blasted & removed



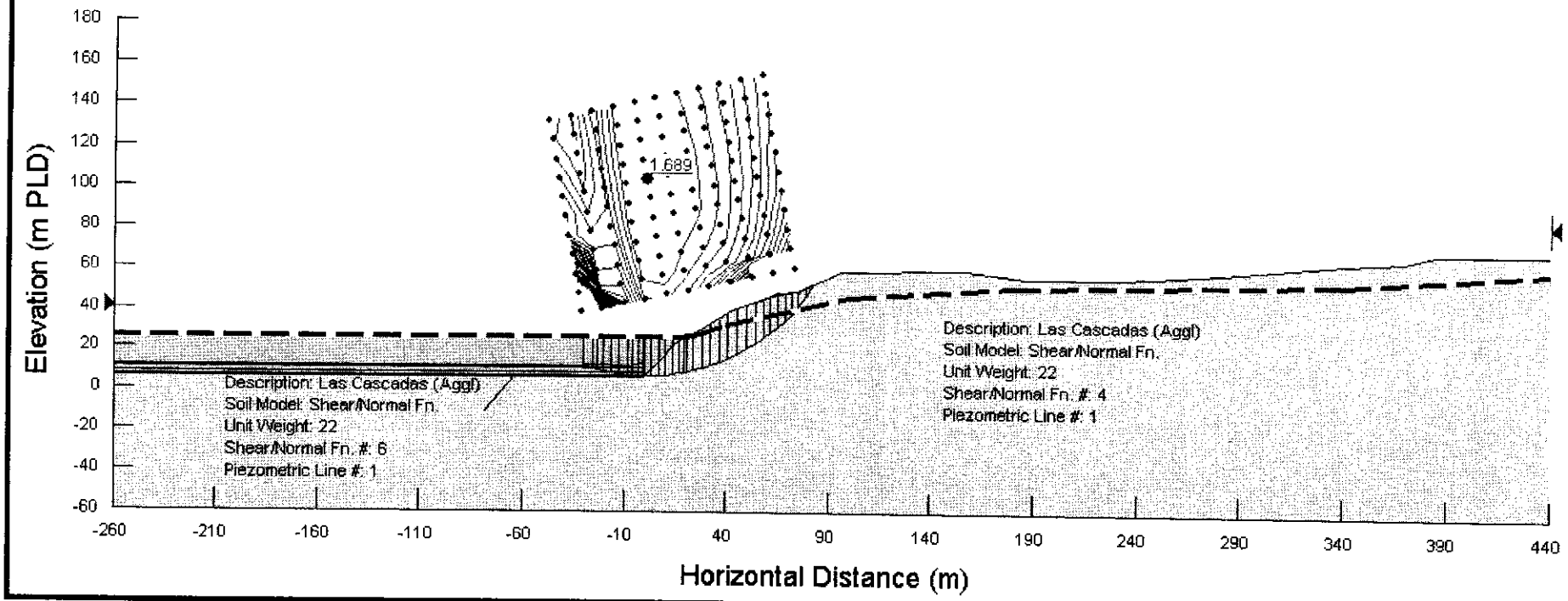
Case 7, Channel bottom = 27 ft, Design (underwater slope)

Description: Channel Deepening
Comments: West Bank 55K+930 - Channel Bottom = 22 ft + design (case 7)
File Name: 55K930_7.slz
Last Saved Date: 4/3/02
Last Saved Time: 9:42:17 AM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: (none)
Seismic Coefficient: (none)



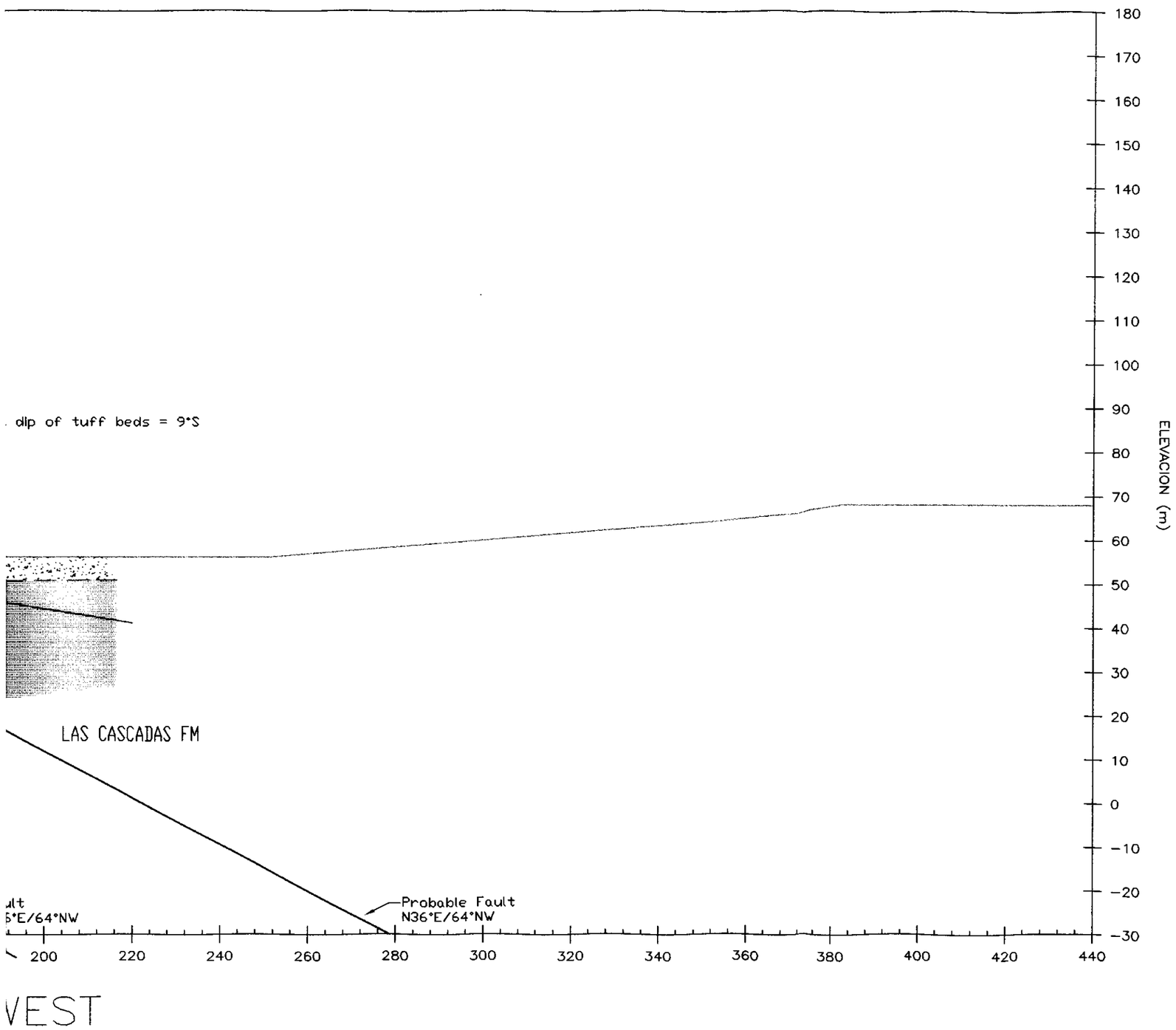
Case 8, Channel bottom = 16 ft, Blasted

Description: Channel Deepening
Comments: West Bank 55K+930 - Channel Bottom = 22 ft + design + blasted 16 ft (case 8)
File Name: 55K930_8.slz
Last Saved Date: 4/7/02
Last Saved Time: 1:55:52 PM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: (none)
Seismic Coefficient: (none)



Summary, 55k + 930 (1835 + 00)

General Description	Range of stations:	55k + 000 to 56k + 740			
	Sector:	Cunette			
	Maximum height (m):	48			
	Cotangent of slope angle (cot. β):	2.35			
History	Last slide event:	October 6, 1910 (Cunette Slide)			
Geology	Formation:	Las Cascadas			
	Lithology:	Agglomerate / Tuff / Andesite			
	Critical stratum at toe:	Agglomerate / Andesite			
	Apparent dip of bedding:	Not defined			
Stability Analysis	Critical failure mechanism:	Rotational			
	Shear strength model:	First time, Cascadas agglomerate			
		Operative average pore pressure ratio (aproximate), Ru:	Factor of Safety	Relative Factor of Safety	Percentage of Change (%)
	Case 1: Channel bottom = 32 ft	0.322	1.864	1.000	0.00
	Case 2: Channel bottom = 27 ft, Blasted material only		1.850	0.992	-0.75
	Case 3: Channel bottom = 27 ft, Blasted & removed		1.800	0.966	-3.43
	Case 4.1: Channel bottom = 27 ft, Design (underwater slope)		1.797	0.964	-3.59
	Case 4.2: Channel bottom = 27 ft, Design (& dry excavation)	0.324	1.797	0.964	-3.59
	Case 5: Channel bottom = 22 ft, Blasted material only		1.800	0.966	-3.43
	Case 6: Channel bottom = 22 ft, Blasted & removed		1.752	0.940	-6.01
	Case 7.1: Channel bottom = 22 ft, Design (underwater slope)		1.694	0.909	-9.12
	Case 7.2: Channel bottom = 22 ft, Design (& dry excavation)	0.331	1.694	0.909	-9.12
	Case 8: Channel bottom = 16 ft, Blasted		1.689	0.906	-9.39
Conclusions:	No stabilization is required				



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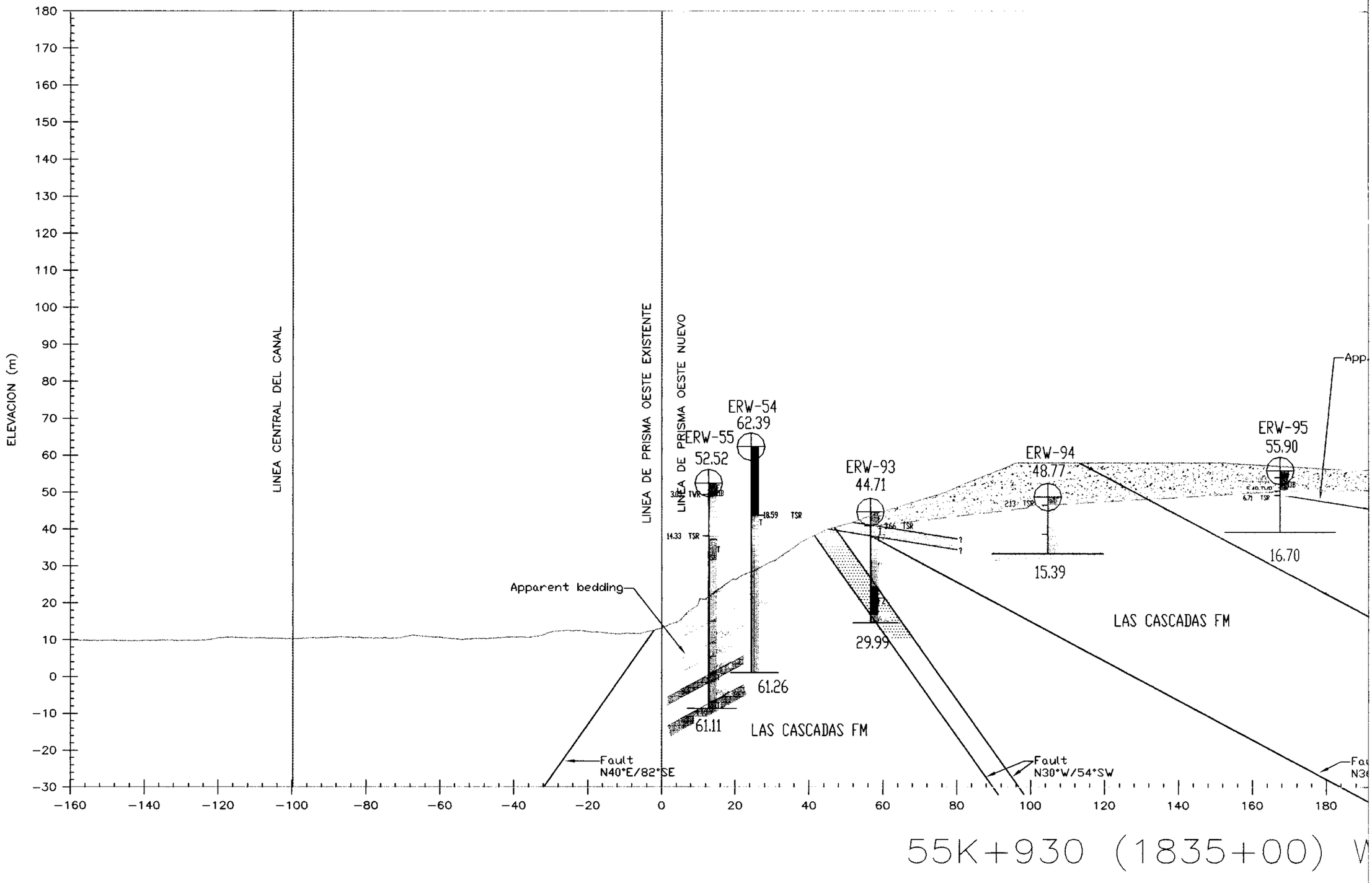
SECCION GEOLOGICA

CORTE GAILLARD

ESTACION 55K+930 (1835+00) OESTE

ESCALA: 1:1000	FECHA: ABRIL 2002
GEOLOGIA POR: P. FRANCESCHI	DIBUJADO POR: J. RAMESCH

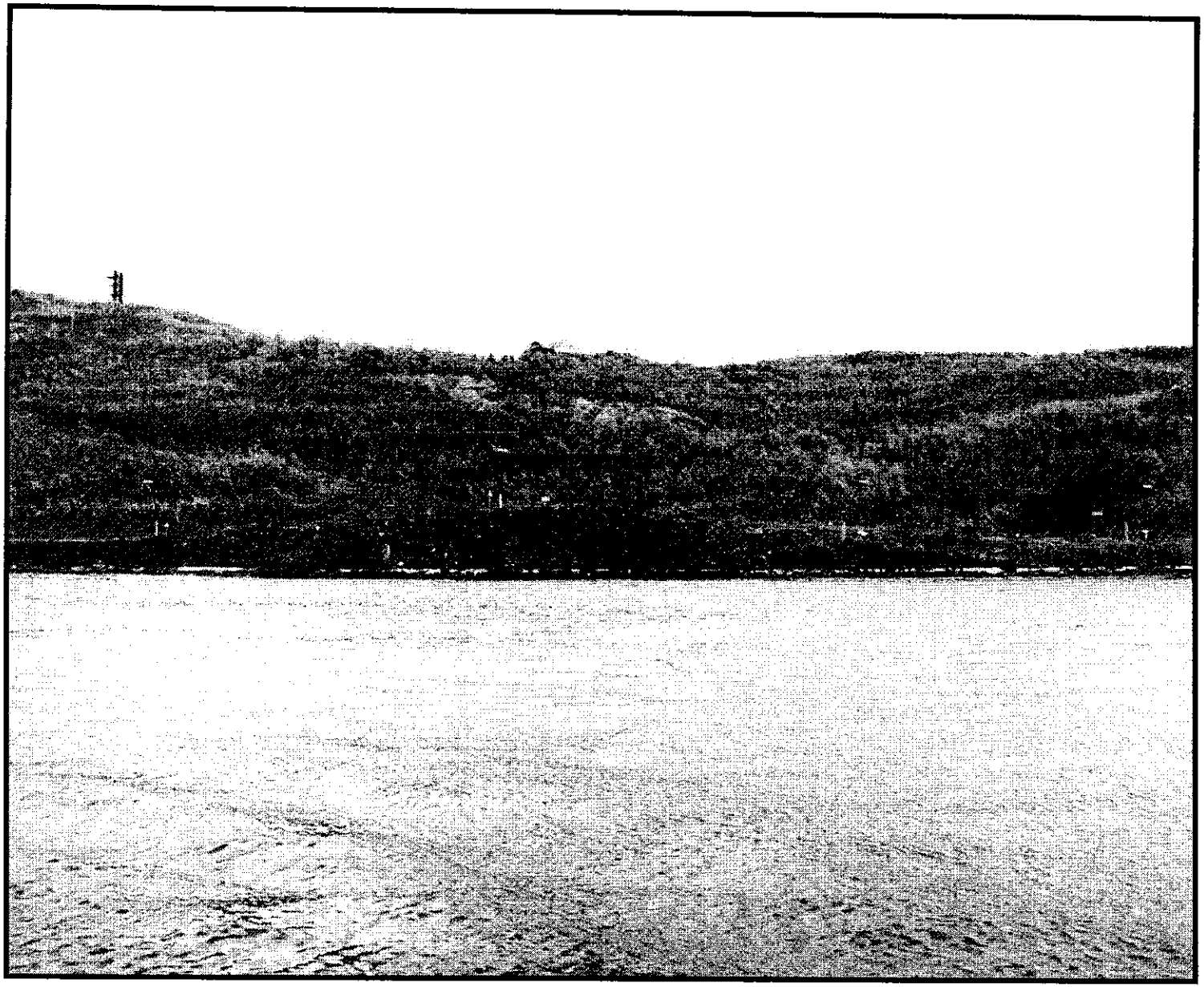

ELEVACION (m)
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-160
-140
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
120
140
160
180
LINEA CENTRAL DEL CANAL
LINEA DE PRISMA OESTE EXISTENTE
LINEA DE PRISMA OESTE NUEVO
ERW-54
62.39
ERW-55
52.52
ERW-93
44.71
ERW-94
48.77
ERW-95
55.90
3.05 TVR
14.33 TSR
18.59 TSR
3.66 TSR
2.13 TSR
6.71 TSR
61.26
61.11
29.99
15.39
16.70
Apparent bedding
LAS CASCADAS FM
LAS CASCADAS FM
Fault
N40°E/82°SE
Fault
N30°W/54°SW
55K+930 (1835+00)

station 56k + 898 (1866 + 73)

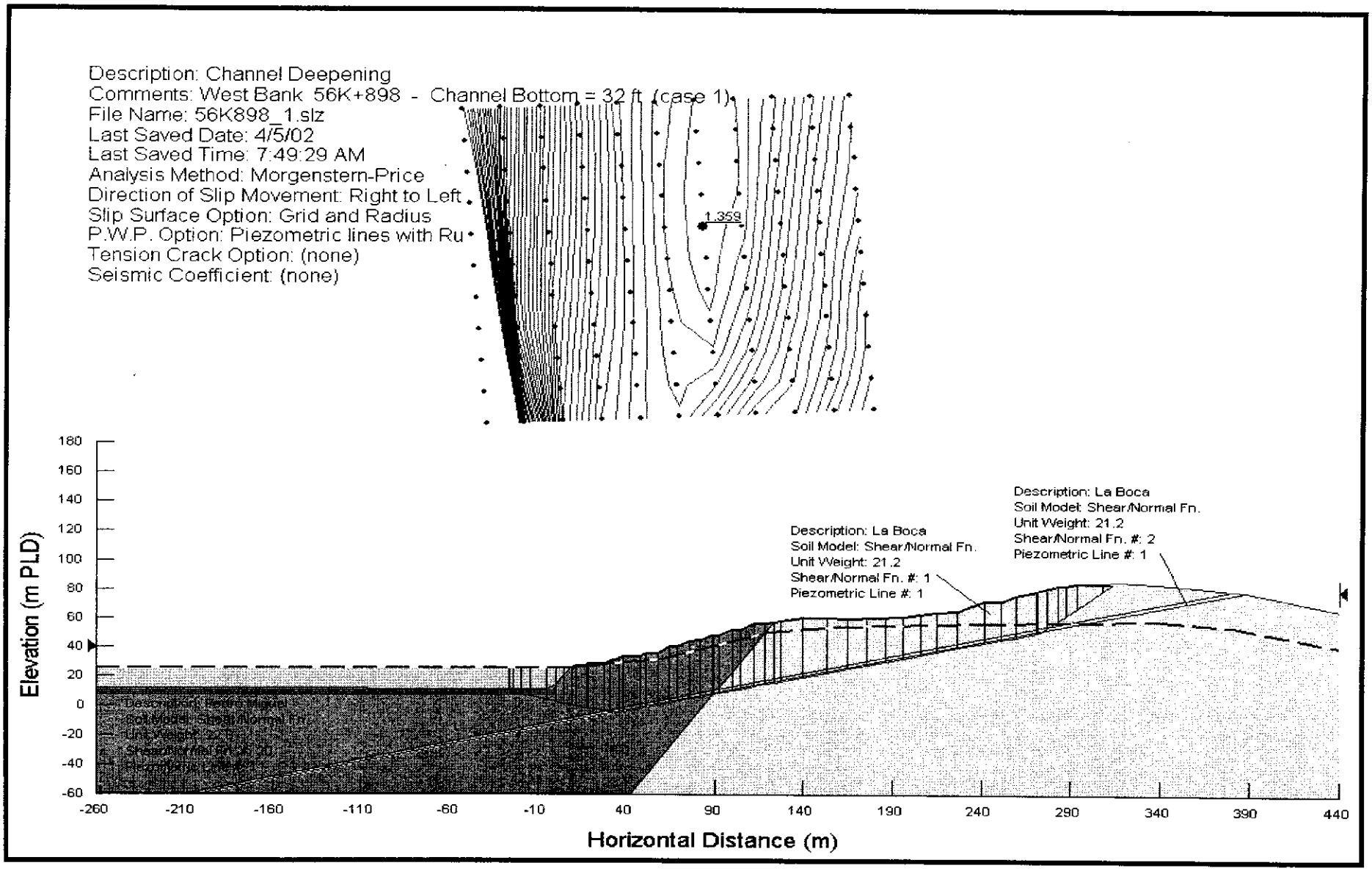
West

Station: 56k + 898 (Empire)

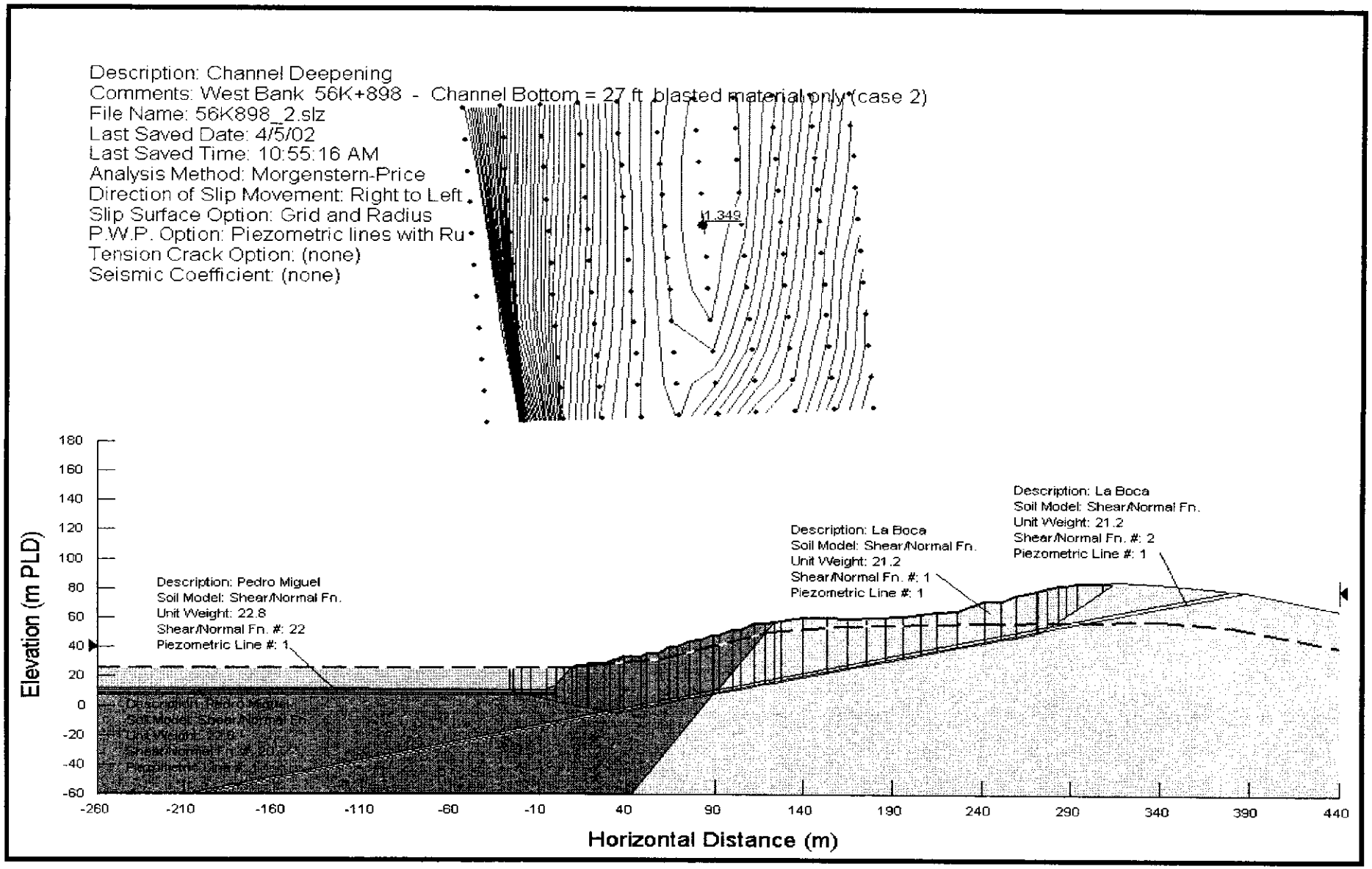
April 16, 2002



Case 1, Channel bottom = 32 ft

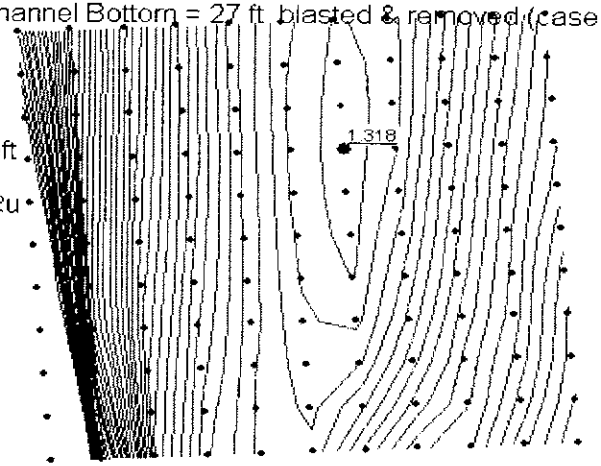


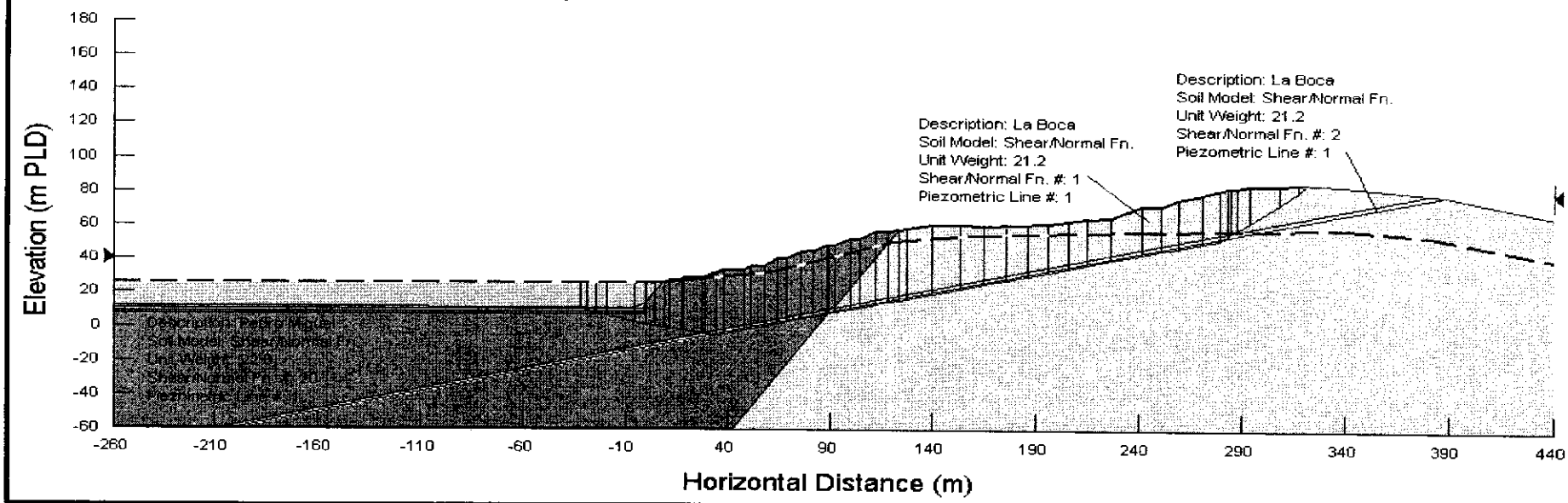
Case 2, Channel bottom = 27 ft, Blasted material only



Case 3, Channel bottom = 27 ft, Blasted & removed

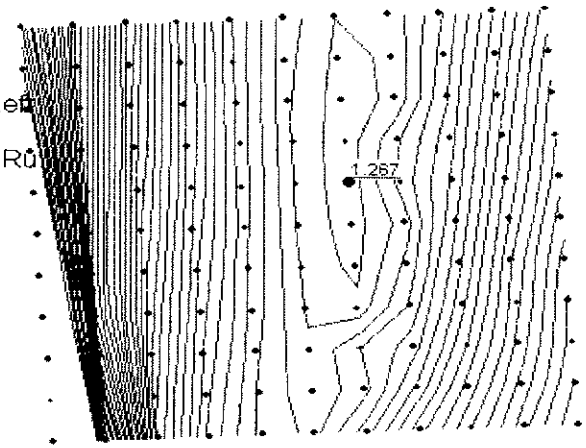
Description: Channel Deepening
Comments: West Bank 56K+898 - Channel Bottom = 27 ft, blasted & removed (case 3)
File Name: 56K898_3.slz
Last Saved Date: 4/5/02
Last Saved Time: 10:57:56 AM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: (none)
Seismic Coefficient: (none)

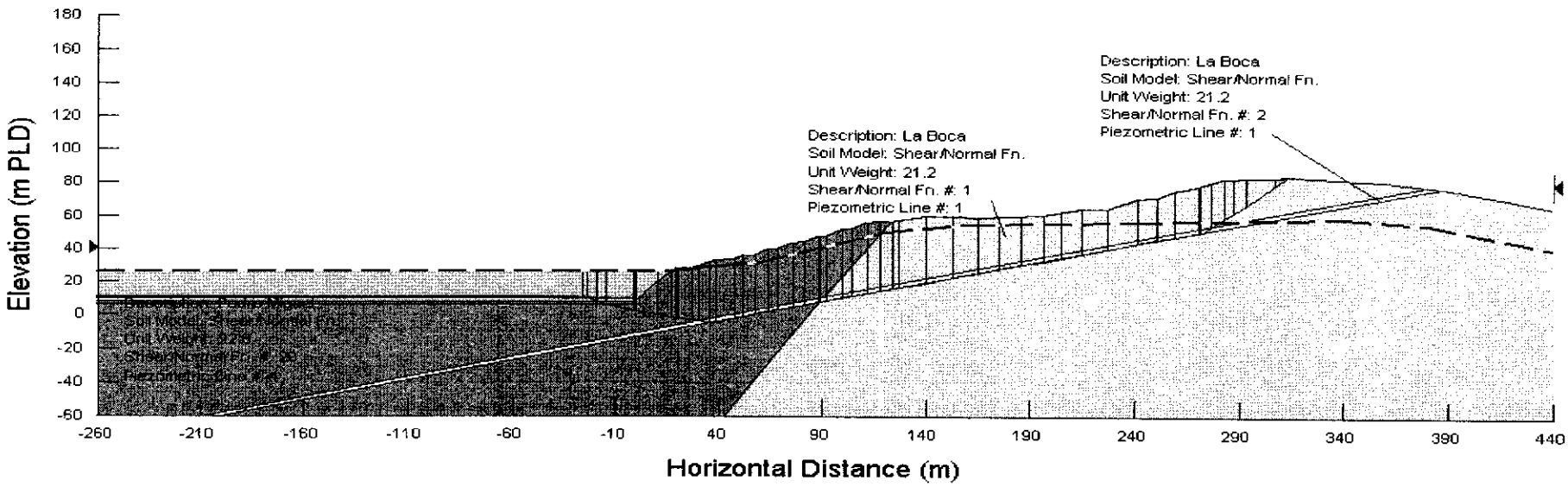




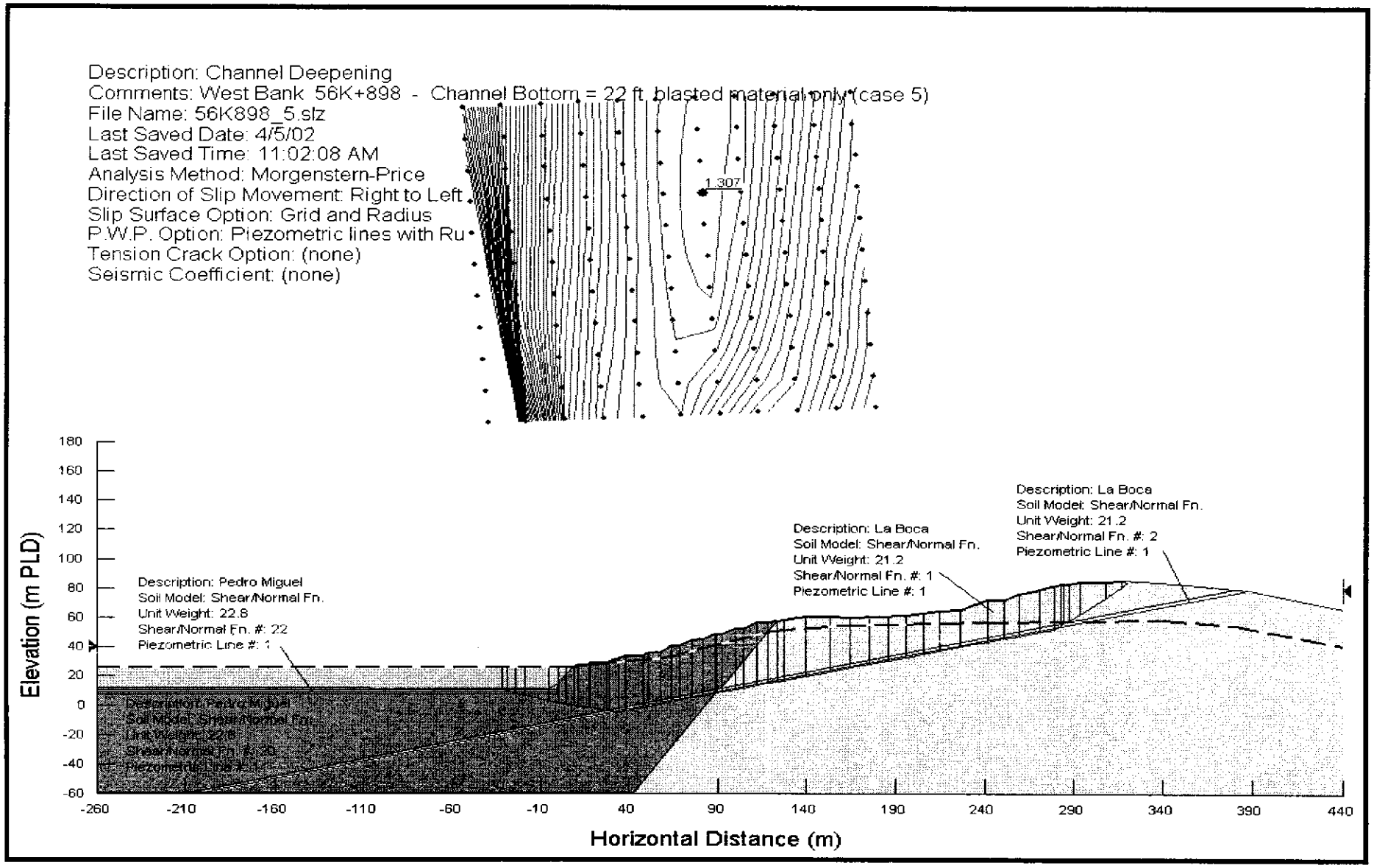
Case 4, Channel bottom = 27 ft, Design (underwater slope)

Description: Channel Deepening
Comments: West Bank 56K+898 - Channel Bottom = 27 ft + design (case 4)
File Name: 56K898_4.slz
Last Saved Date: 4/5/02
Last Saved Time: 7:59:10 AM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Le
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with RU
Tension Crack Option: (none)
Seismic Coefficient: (none)



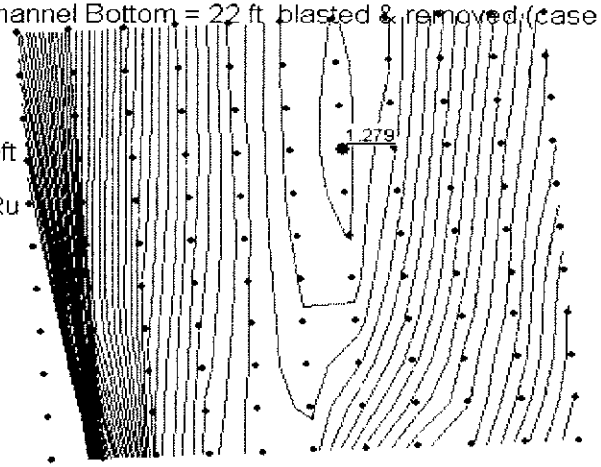


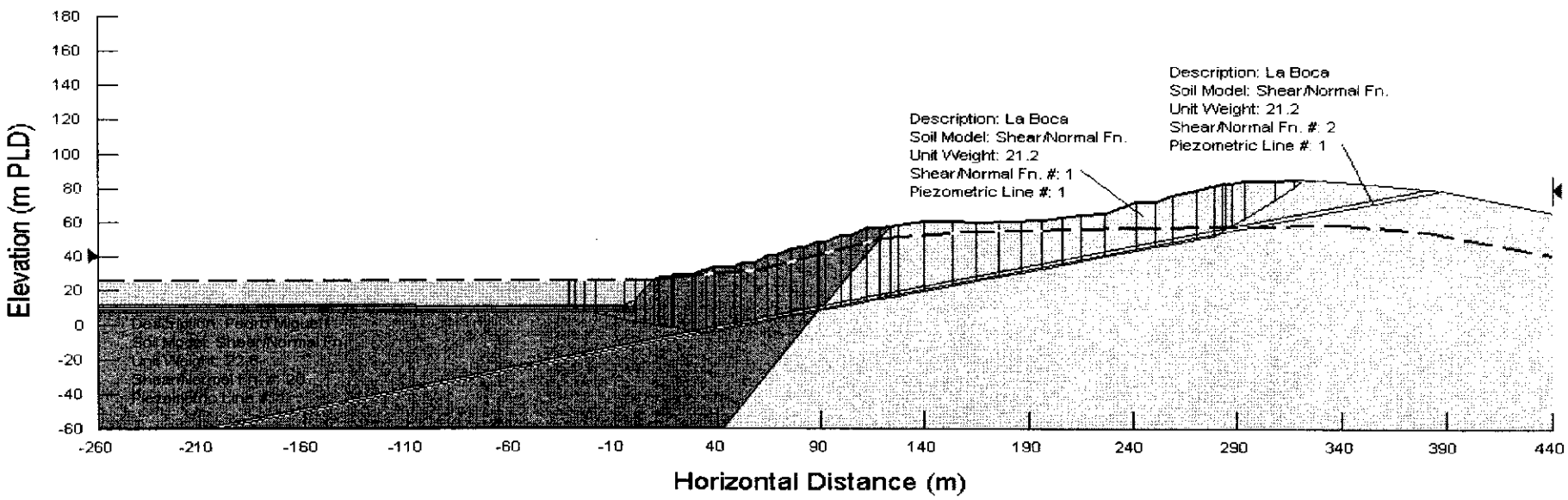
Case 5, Channel bottom = 22 ft, Blasted material only



Case 6, Channel bottom = 22 ft, Blasted & removed

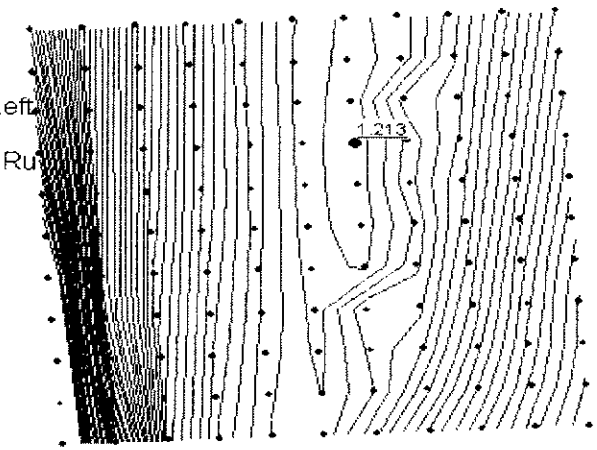
Description: Channel Deepening
Comments: West Bank 56K+898 - Channel Bottom = 22 ft blasted & removed (case 6)
File Name: 56K898_6.slz
Last Saved Date: 4/5/02
Last Saved Time: 11:03:36 AM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: (none)
Seismic Coefficient: (none)

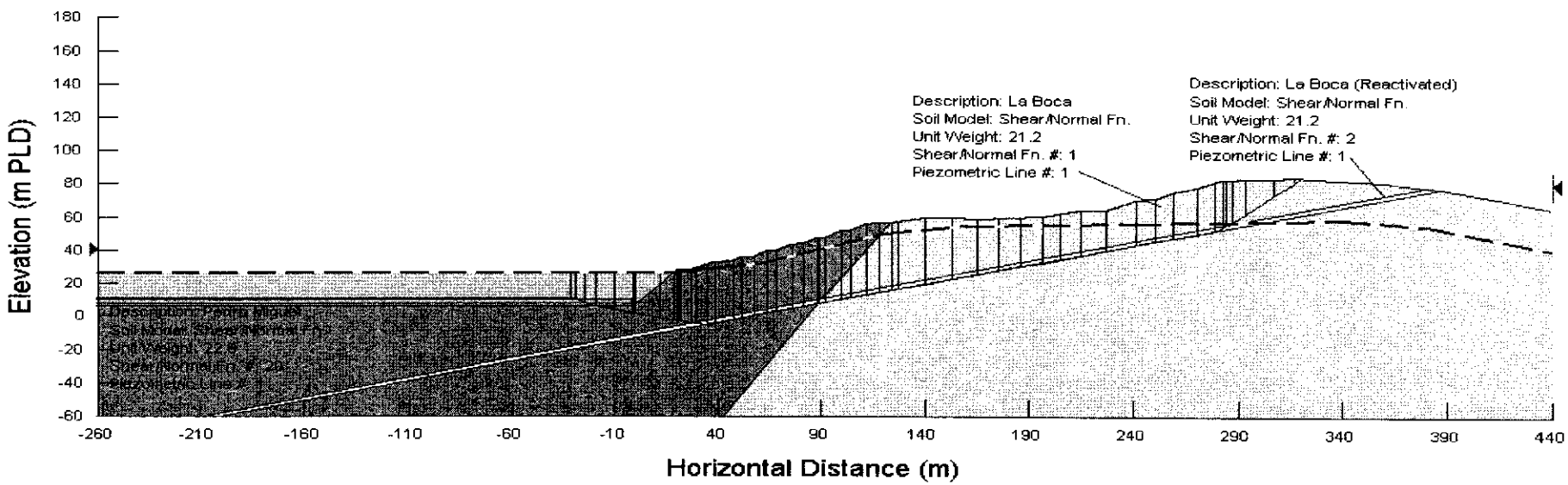




Case 7.1, Channel bottom = 27 ft, Design (underwater slope)

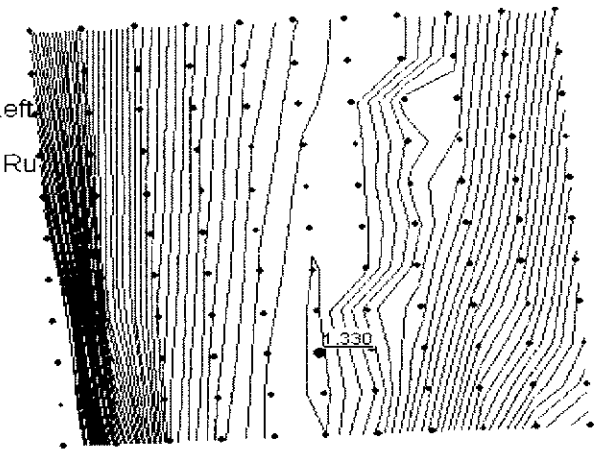
Description: Channel Deepening
Comments: West Bank 56K+898 - Channel Bottom = 22 ft + design (case 7)
File Name: 56K898_7.slz
Last Saved Date: 4/5/02
Last Saved Time: 8:11:17 AM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: (none)
Seismic Coefficient: (none)

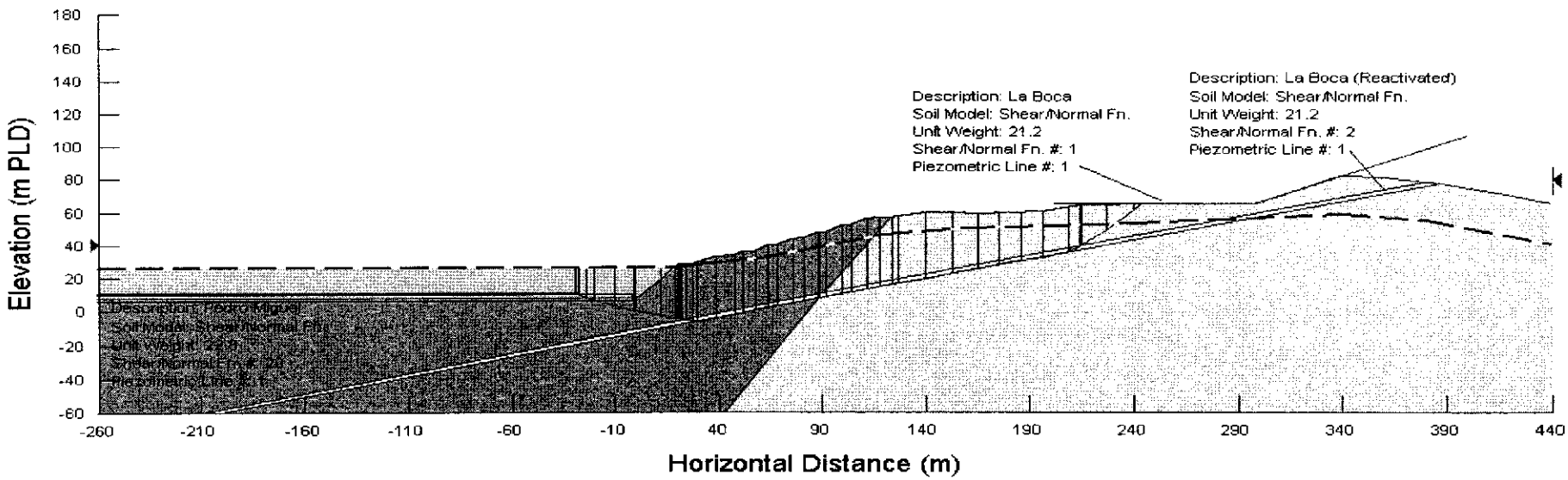




Case 7.2, Channel bottom = 27 ft, Design (& dry excavation)

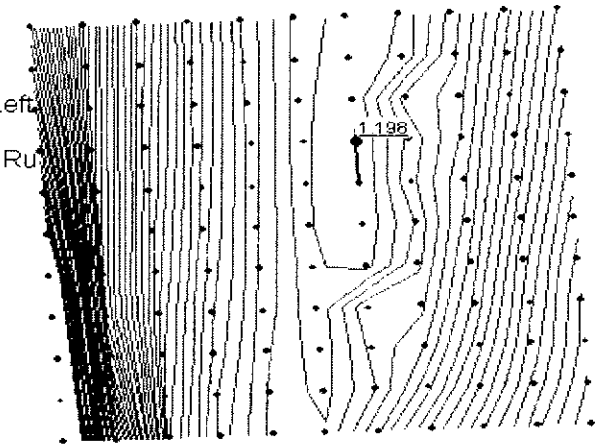
Description: Channel Deepening
Comments: West Bank 56K+898 - Channel Bottom = 22 ft + design (case 7)
File Name: 56K898_7e.slz
Last Saved Date: 4/7/02
Last Saved Time: 9:11:44 AM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: (none)
Seismic Coefficient: (none)

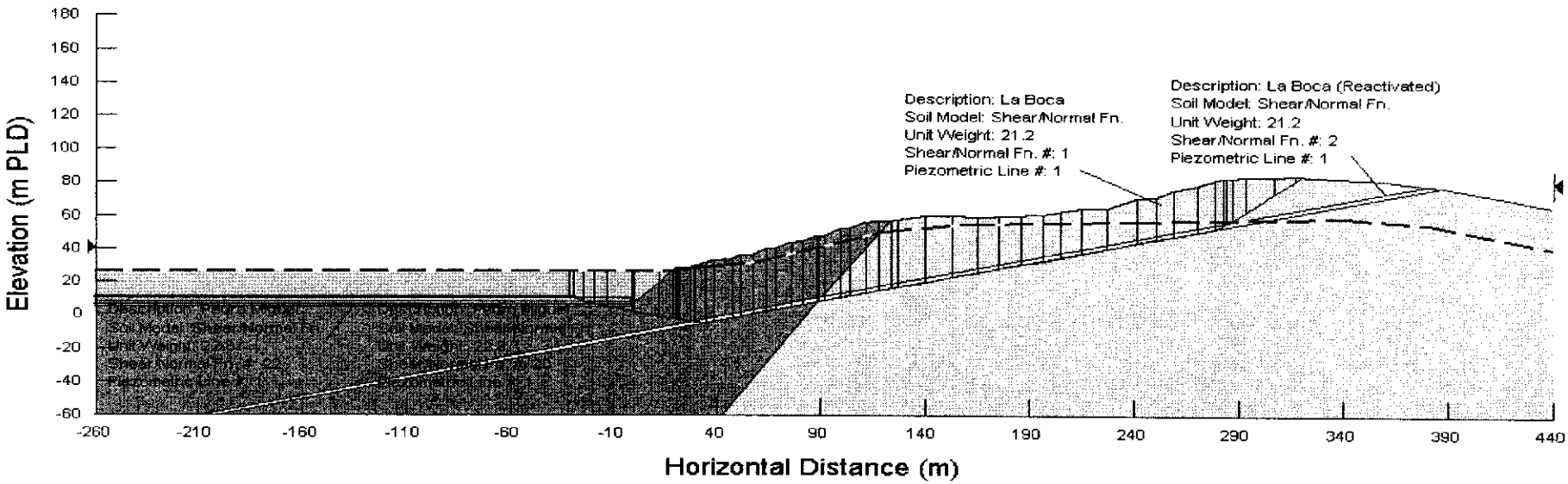




Case 8, Channel bottom = 16 ft, Blasted

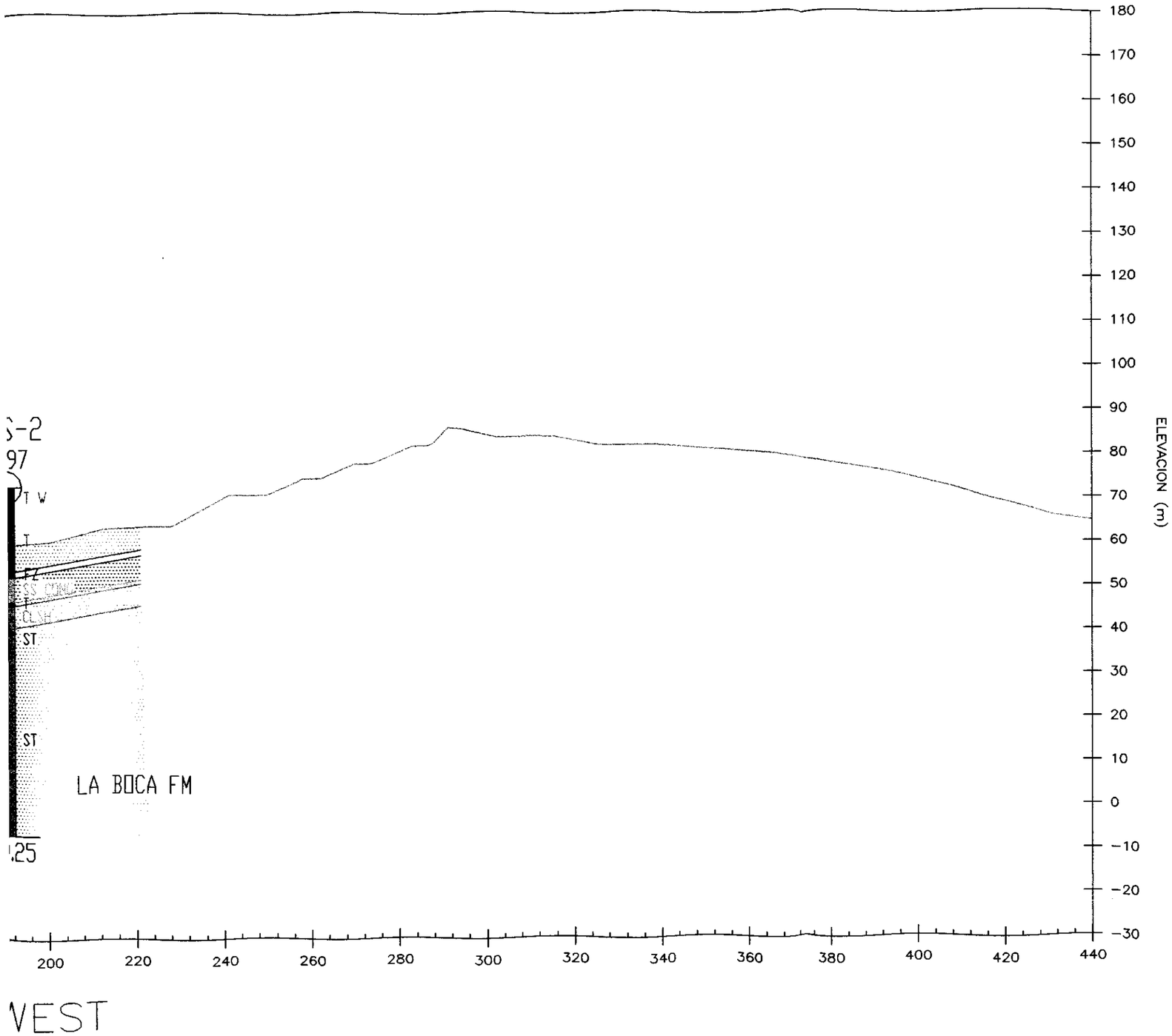
Description: Channel Deepening
Comments: West Bank 56K+898 - Channel Bottom = 22 ft + design + blasted 16 ft (case 8)
File Name: 56K898_8.slz
Last Saved Date: 4/7/02
Last Saved Time: 2:03:56 PM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: (none)
Seismic Coefficient: (none)





Summary, 56k + 898 (1866 + 73)

General Description	Range of stations:	56k + 740 to 57k + 050			
	Sector:	Empire			
	Maximum height (m):	76			
	Cotangent of slope angle (cot. β):	3.8			
History	Last slide event:	March, 1998 (West Empire Slide)			
Geology	Formation:	Pedro Miguel / La Boca			
	Lithology:	Agglomerate			
	Critical stratum at toe:	Agglomerate			
	Apparent dip of bedding:	Beds of La Boca dips toward the Canal			
Stability Analysis	Critical failure mechanism:	Translational along weak plane			
	Shear strength model:	Residual - La Boca, along weak plane / Fully softened - La Boca / First time - Pedro Miguel Agglomerate			
		Operative average pore pressure ratio (aproximate), Ru:	Factor of Safety	Relative Factor of Safety	Percentage of Change (%)
	Case 1: Channel bottom = 32 ft	0.337	1.359	1.000	0.00
	Case 2: Channel bottom = 27 ft, Blasted material only		1.349	0.993	-0.74
	Case 3: Channel bottom = 27 ft, Blasted & removed		1.318	0.970	-3.02
	Case 4.1: Channel bottom = 27 ft, Design (underwater slope)		1.267	0.932	-6.77
	Case 4.2: Channel bottom = 27 ft, Design (& dry excavation)	0.334	1.267	0.932	-6.77
	Case 5: Channel bottom = 22 ft, Blasted material only		1.307	0.962	-3.83
	Case 6: Channel bottom = 22 ft, Blasted & removed		1.279	0.941	-5.89
	Case 7.1: Channel bottom = 22 ft, Design (excavation)		1.213	0.893	-10.74
	Case 7.2: Channel bottom = 22 ft, Design (& dry excavation)	0.348	1.330	0.979	-2.13
	Case 8: Channel bottom = 16 ft, Blasted		1.198	0.882	-11.85
Conclusions:	Stabilization is required for Case 7				

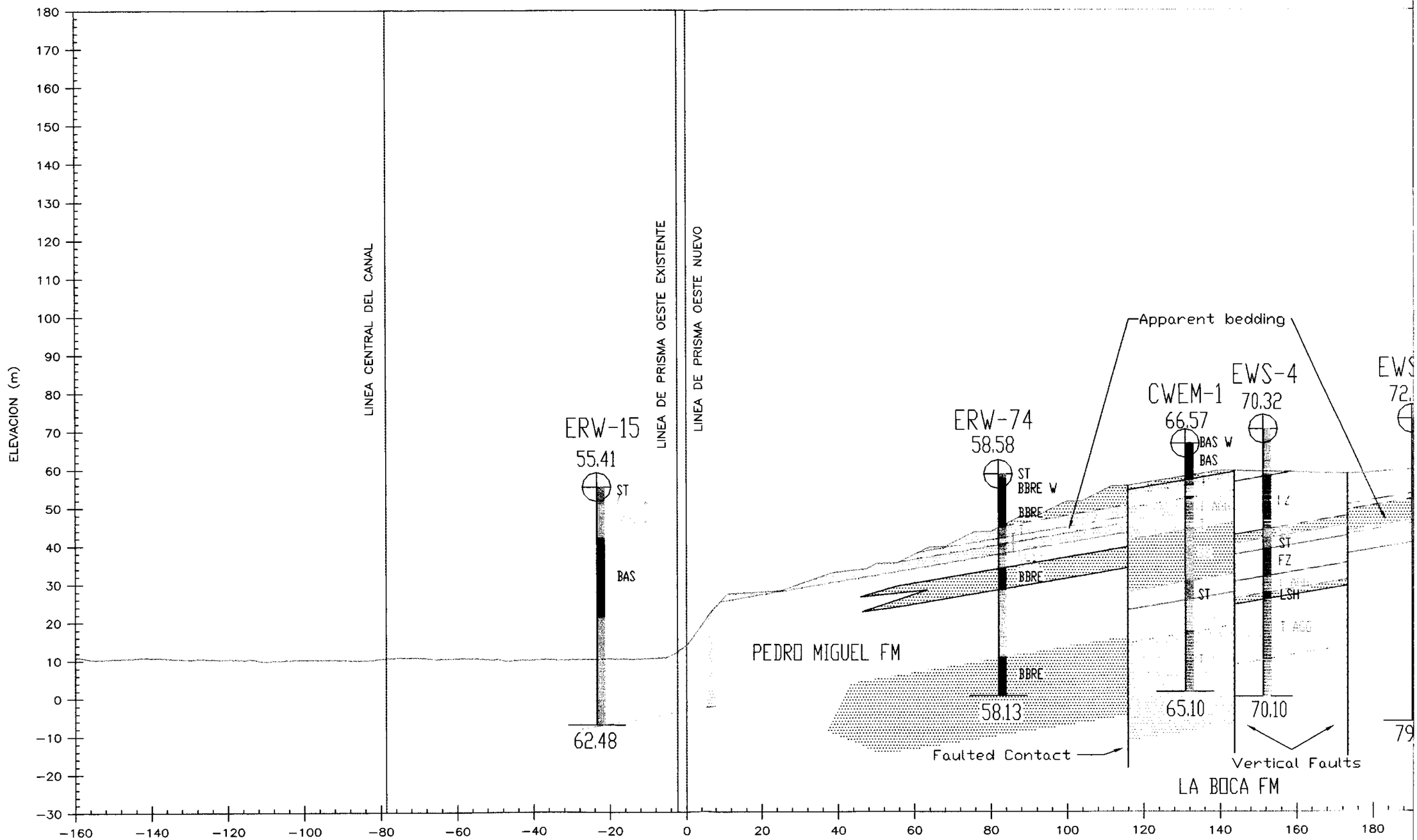


AUTORIDAD DEL CANAL DE PANAMA

DEPARTAMENTO DE INGENIERIA Y PROYECTOS
DIVISION DE INGENIERIA
ALTOS DE BALBOA, REPUBLICA DE PANAMA

SECCION GEOLOGICA
CORTE GAILLARD
ESTACION 56K+898 (1866+73) OESTE

ESCALA: 1:1000	FECHA: ABRIL 2002
GEOLOGIA POR: P. FRANCESCHI	DIBUJADO POR: J. RAMESCH

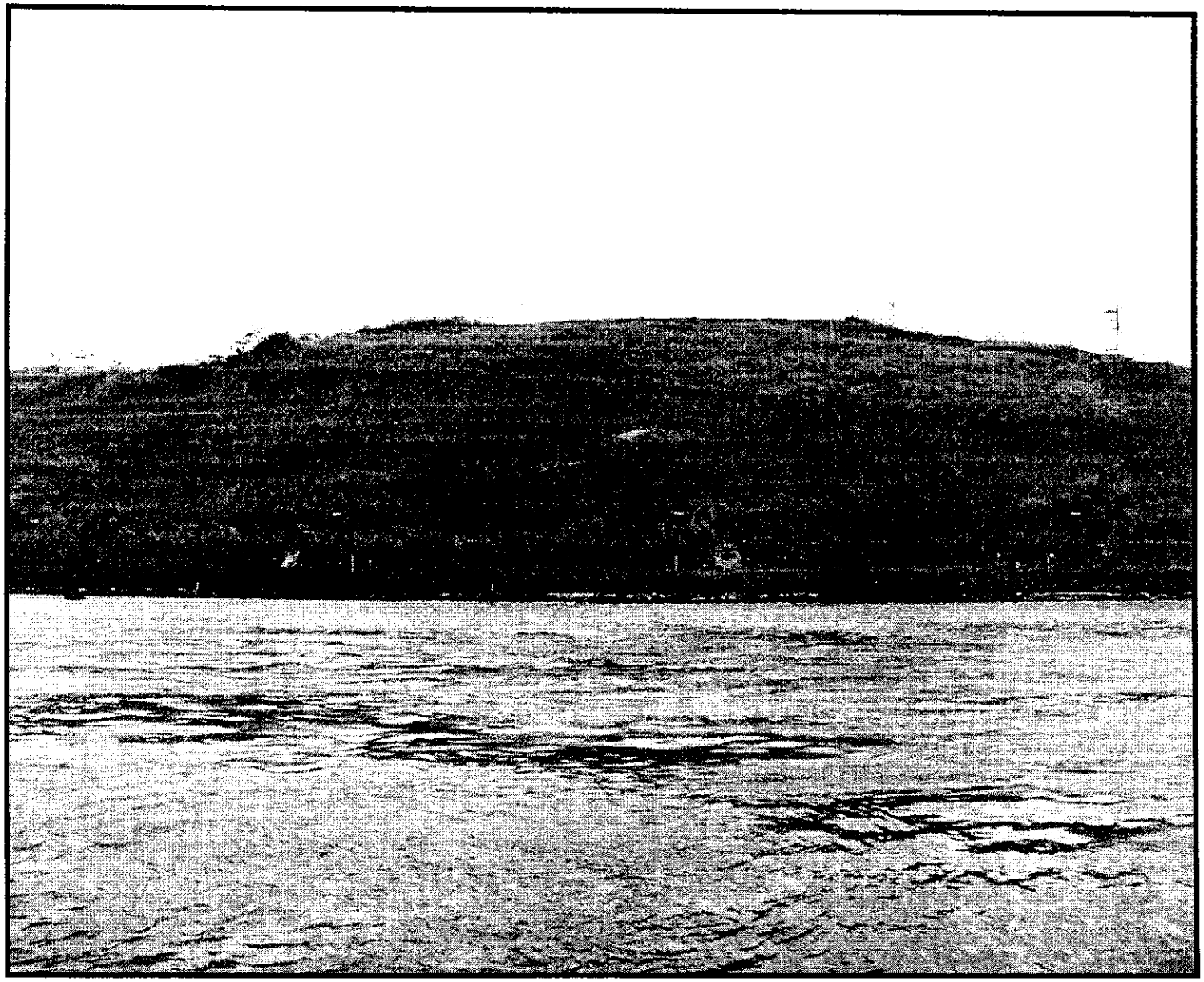

ELEVACION (m)
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-160
-140
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
120
140
160
180
LINEA CENTRAL DEL CANAL
LINEA DE PRISMA OESTE EXISTENTE
LINEA DE PRISMA OESTE NUEVO
ERW-15
55.41
ST
BAS
62.48
ERW-74
58.58
ST
BBRE W
BBRE
BBRE
BBRE
58.13
CWEM-1
66.57
BAS W
BAS
ST
65.10
EWS-4
70.32
ST
FZ
LSH
70.10
Apparent bedding
PEDRO MIGUEL FM
Faulted Contact
Vertical Faults
LA BOCA FM
56K+898 (1866+73)

station 57k + 098 (1873 + 29)

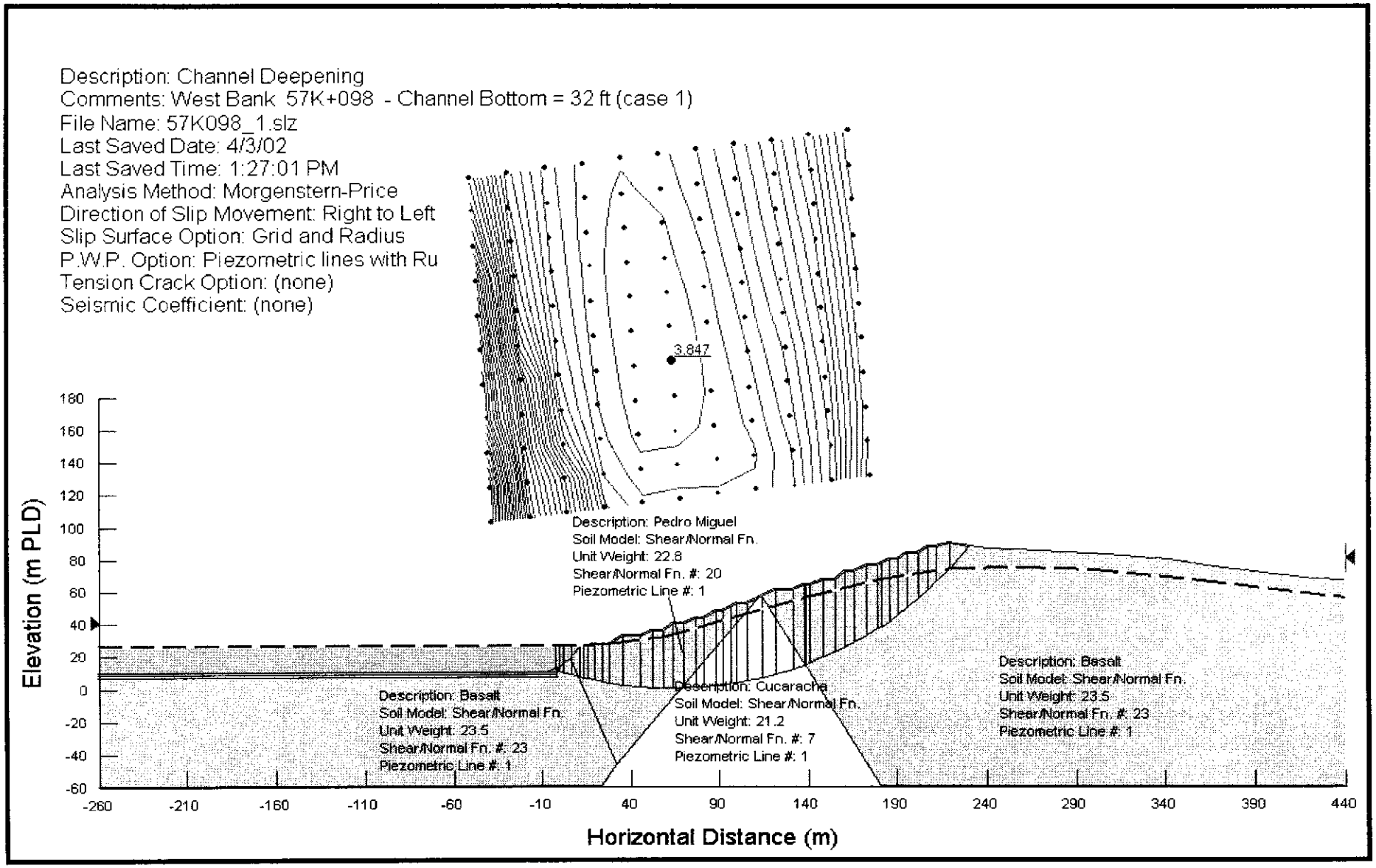
West

Station: 57k + 098 (Empire)

April 16, 2002

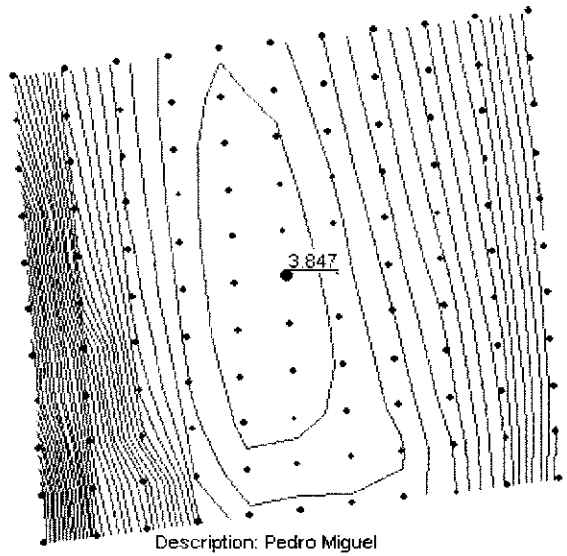


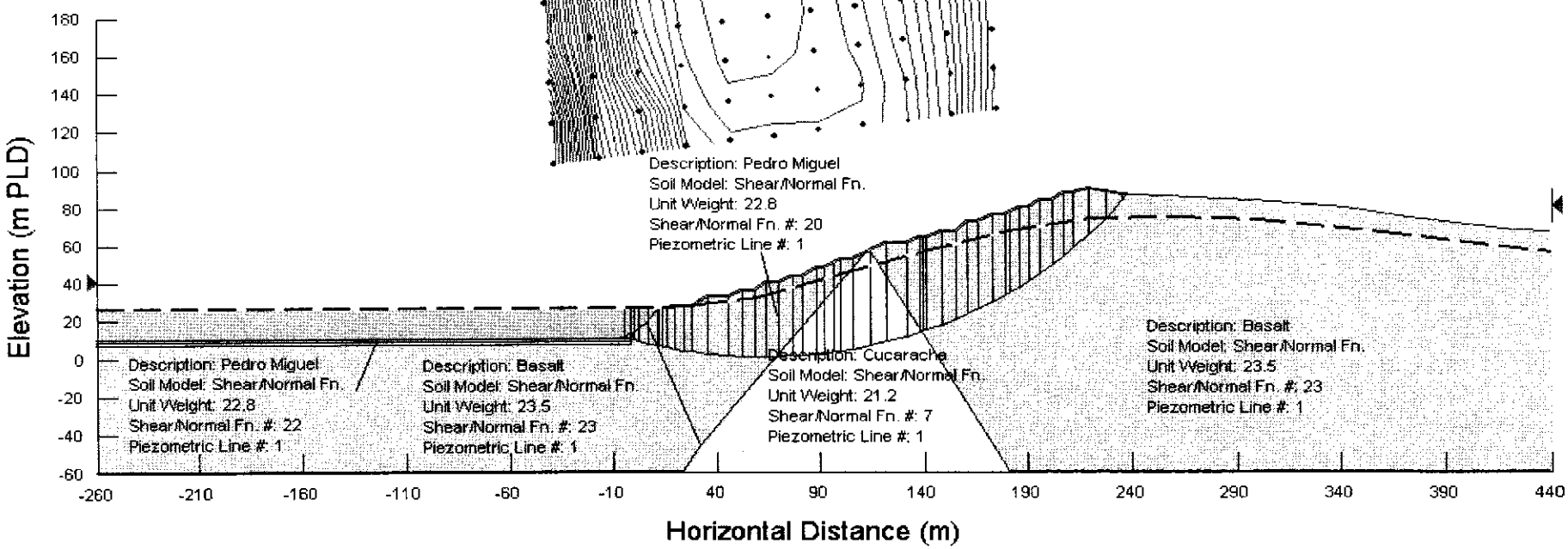
Case 1, Channel bottom = 32 ft



Case 2, Channel bottom = 27 ft, Blasted material only

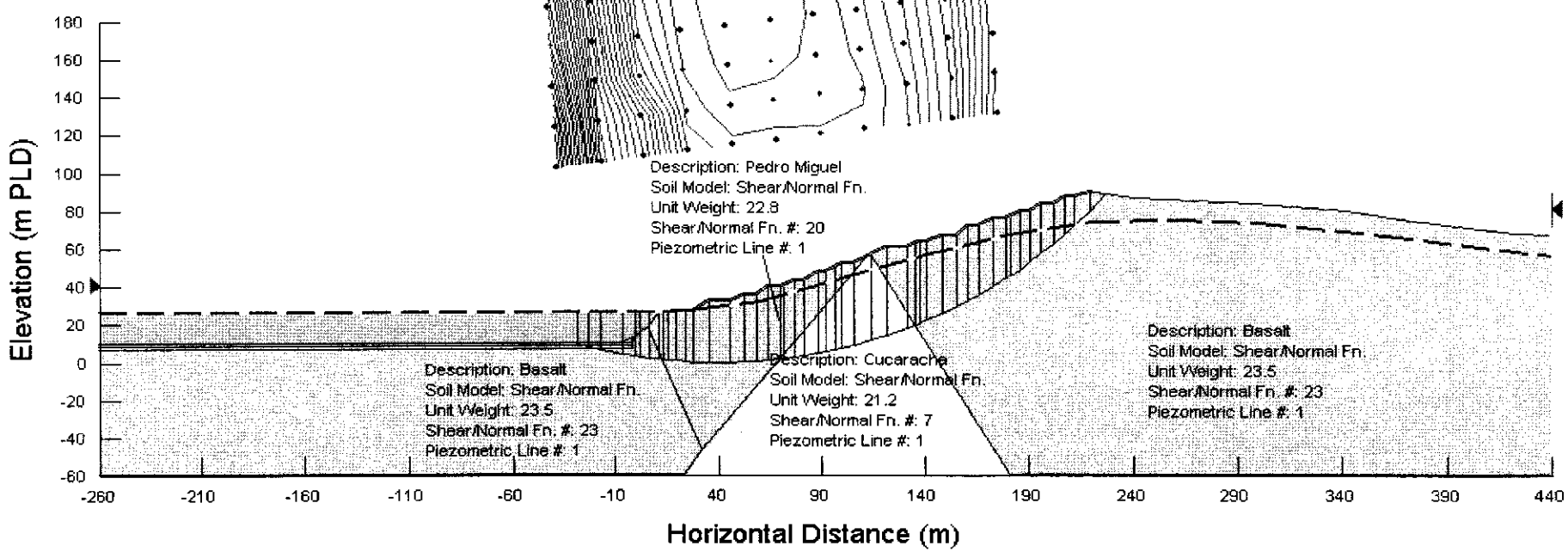
Description: Channel Deepening
Comments: West Bank 57K+098 - Channel Bottom = 27 ft blasted material only (case 2)
File Name: 57K098_2.slz
Last Saved Date: 4/3/02
Last Saved Time: 3:25:10 PM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: (none)
Seismic Coefficient: (none)



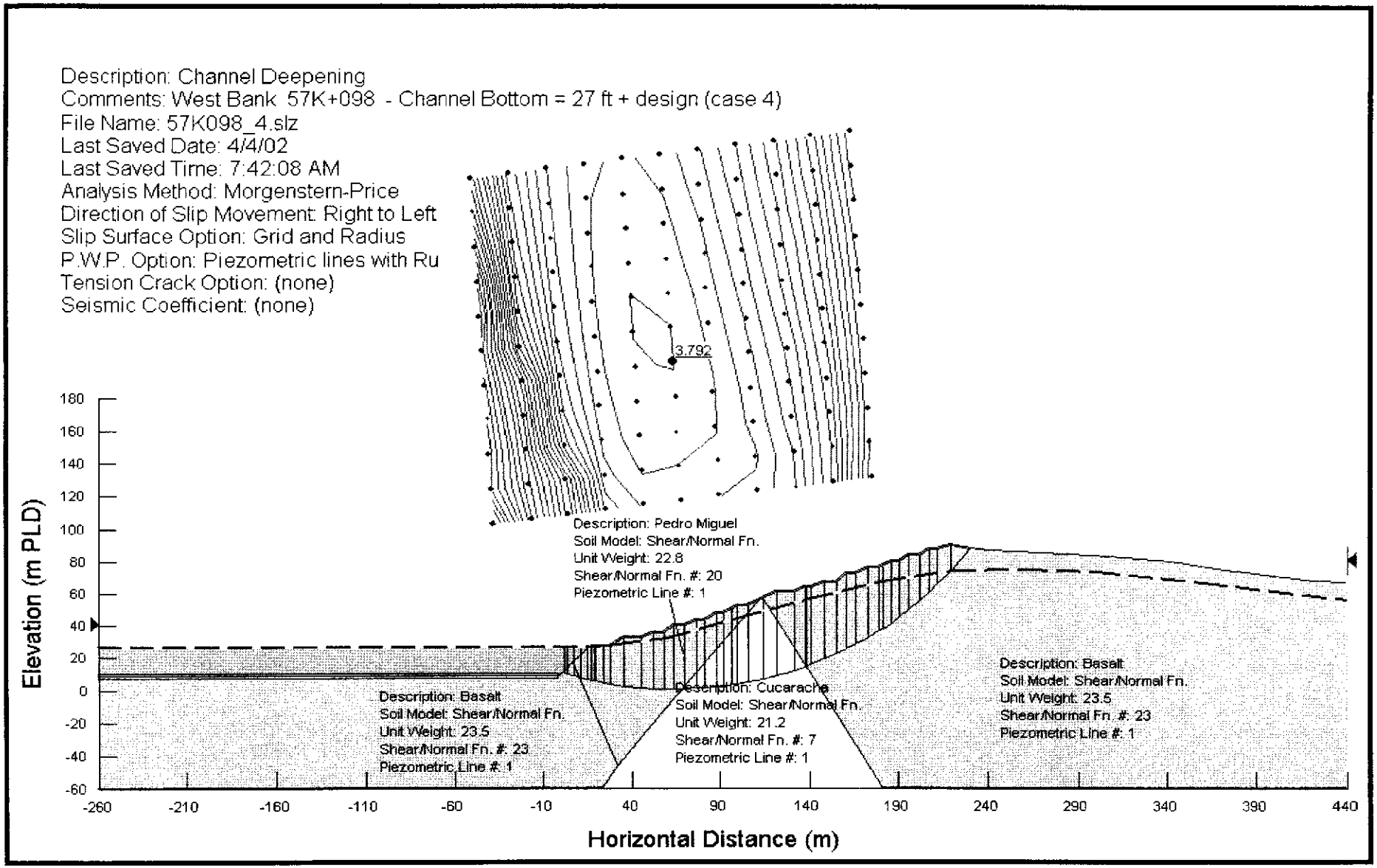


Case 3, Channel bottom = 27 ft, Blasted & removed

Description: Channel Deepening
Comments: West Bank 57K+098 - Channel Bottom = 27 ft blasted & removed (case 3)
File Name: 57K098_3.slz
Last Saved Date: 4/3/02
Last Saved Time: 3:30:14 PM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: (none)
Seismic Coefficient: (none)

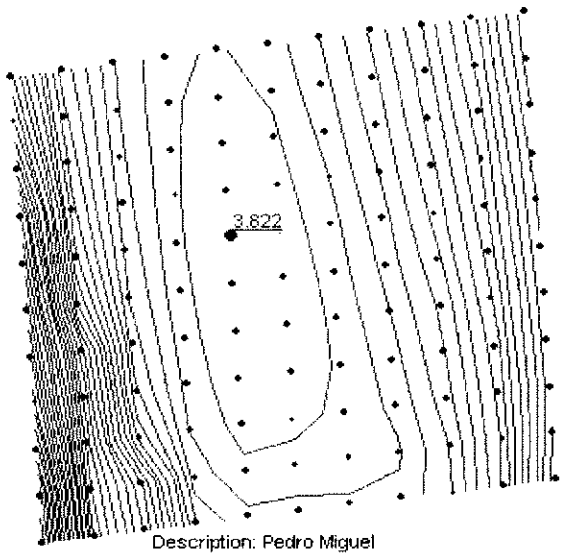


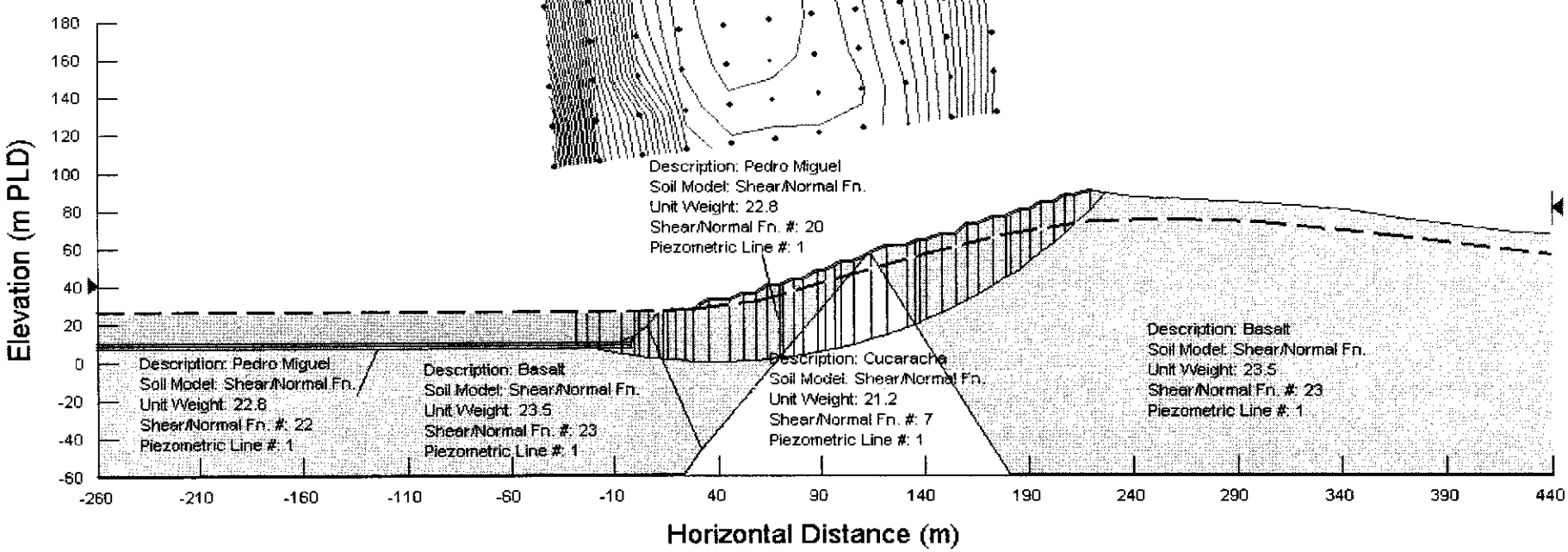
Case 4, Channel bottom = 27 ft, Design (underwater slope)



Case 5, Channel bottom = 22 ft, Blasted material only

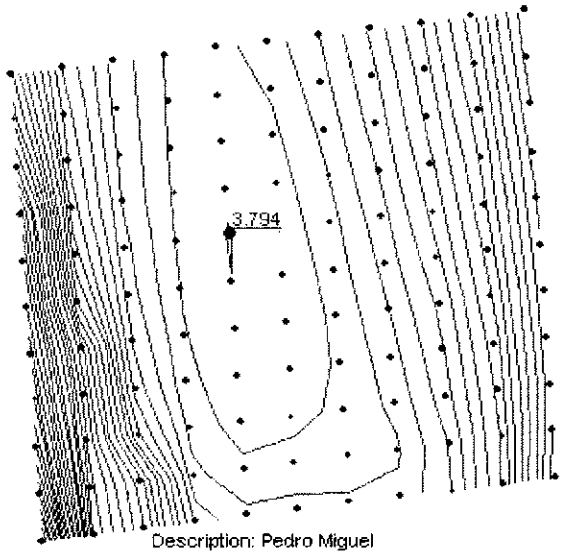
Description: Channel Deepening
Comments: West Bank 57K+098 - Channel Bottom = 22 ft blasted material only (case 5)
File Name: 57K098_5.slz
Last Saved Date: 4/3/02
Last Saved Time: 3:35:48 PM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: (none)
Seismic Coefficient: (none)

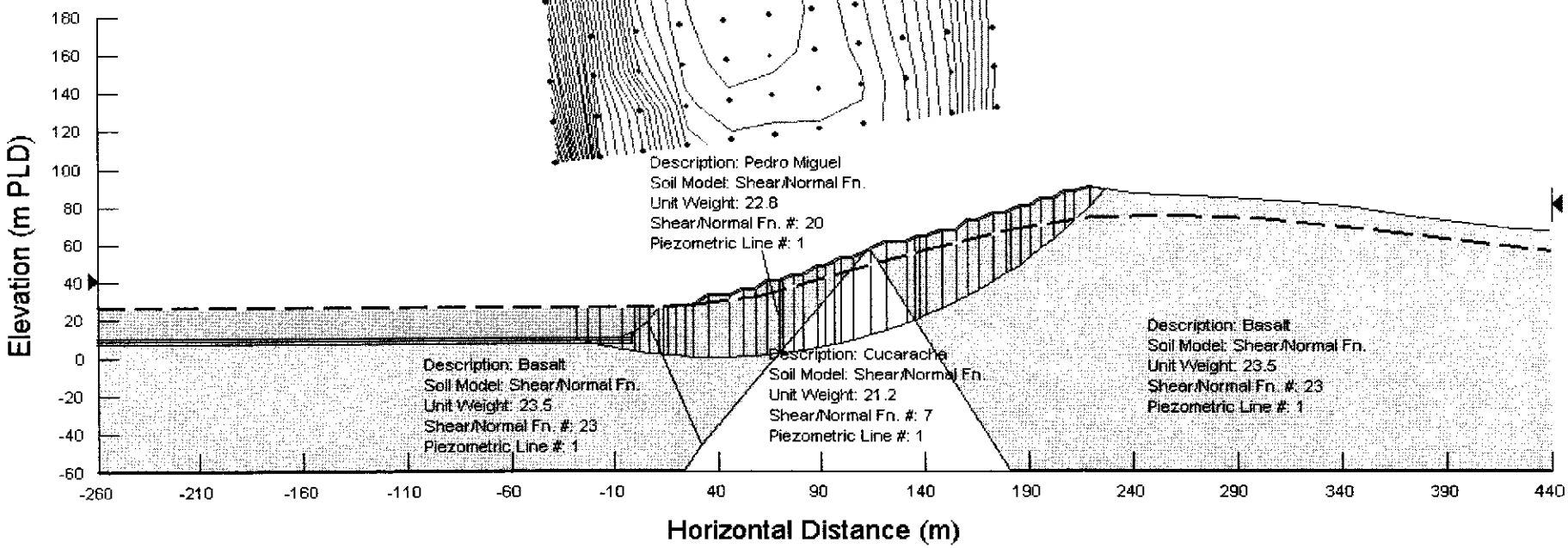




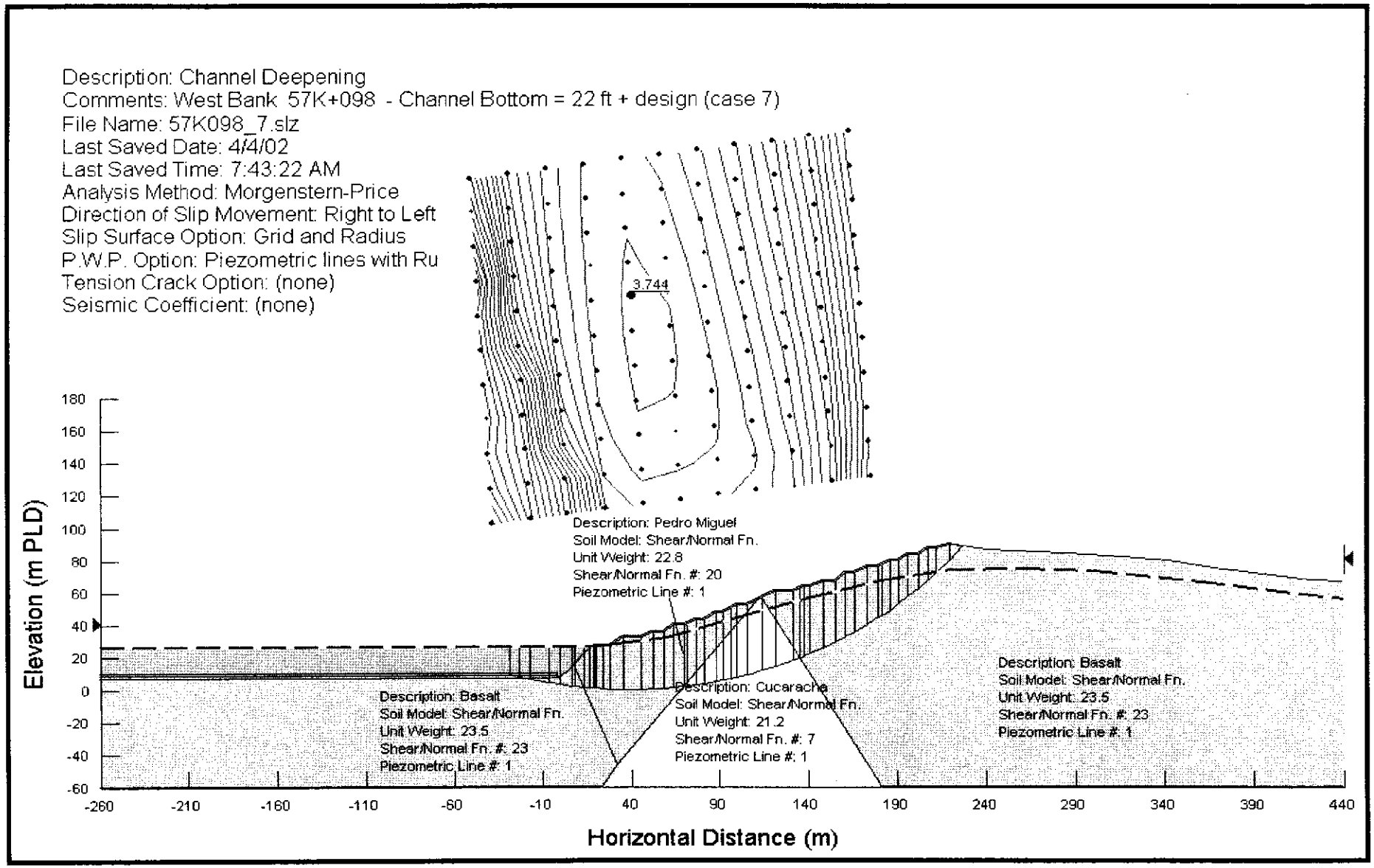
Case 6, Channel bottom = 22 ft, Blasted & removed

Description: Channel Deepening
Comments: West Bank 57K+098 - Channel Bottom = 22 ft blasted & removed (case 6)
File Name: 57K098_6.slz
Last Saved Date: 4/4/02
Last Saved Time: 7:39:42 AM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: (none)
Seismic Coefficient: (none)



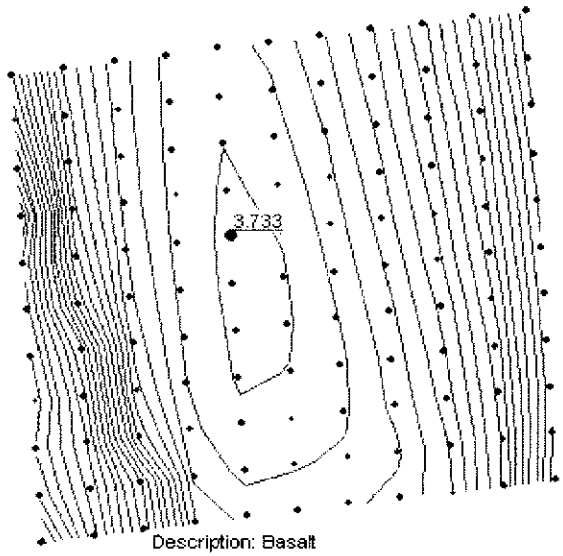


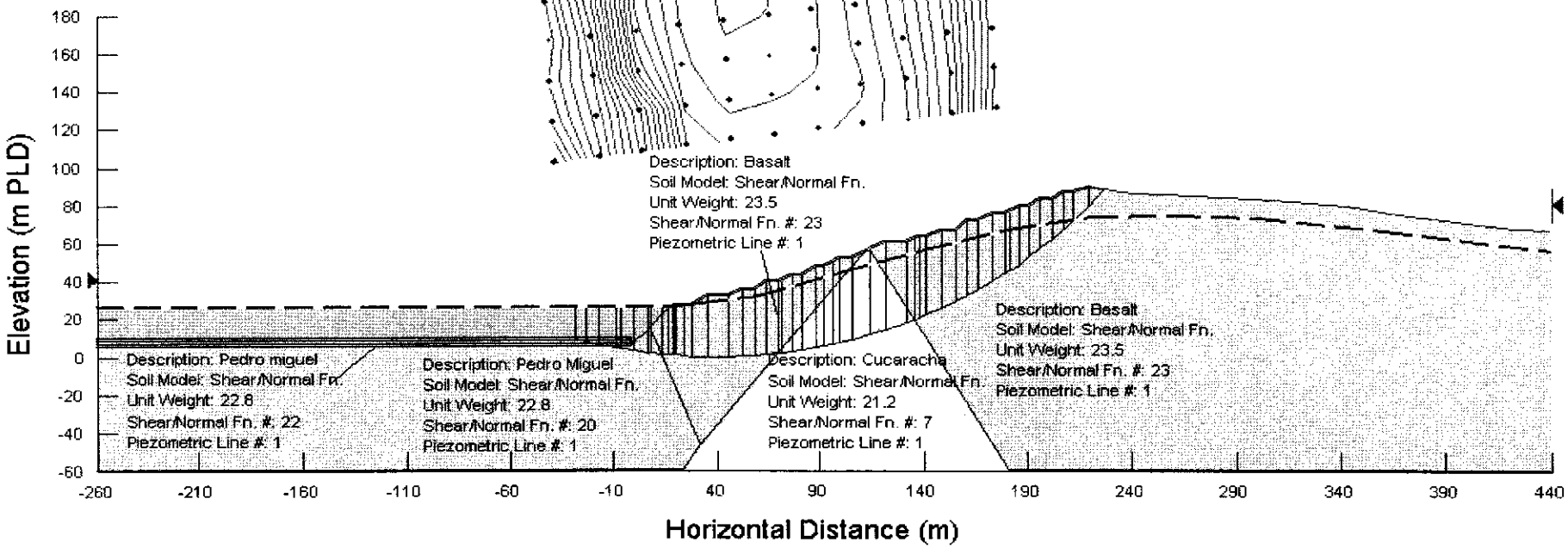
Case 7, Channel bottom = 27 ft, Design (underwater slope)



Case 8, Channel bottom = 16 ft, Blasted

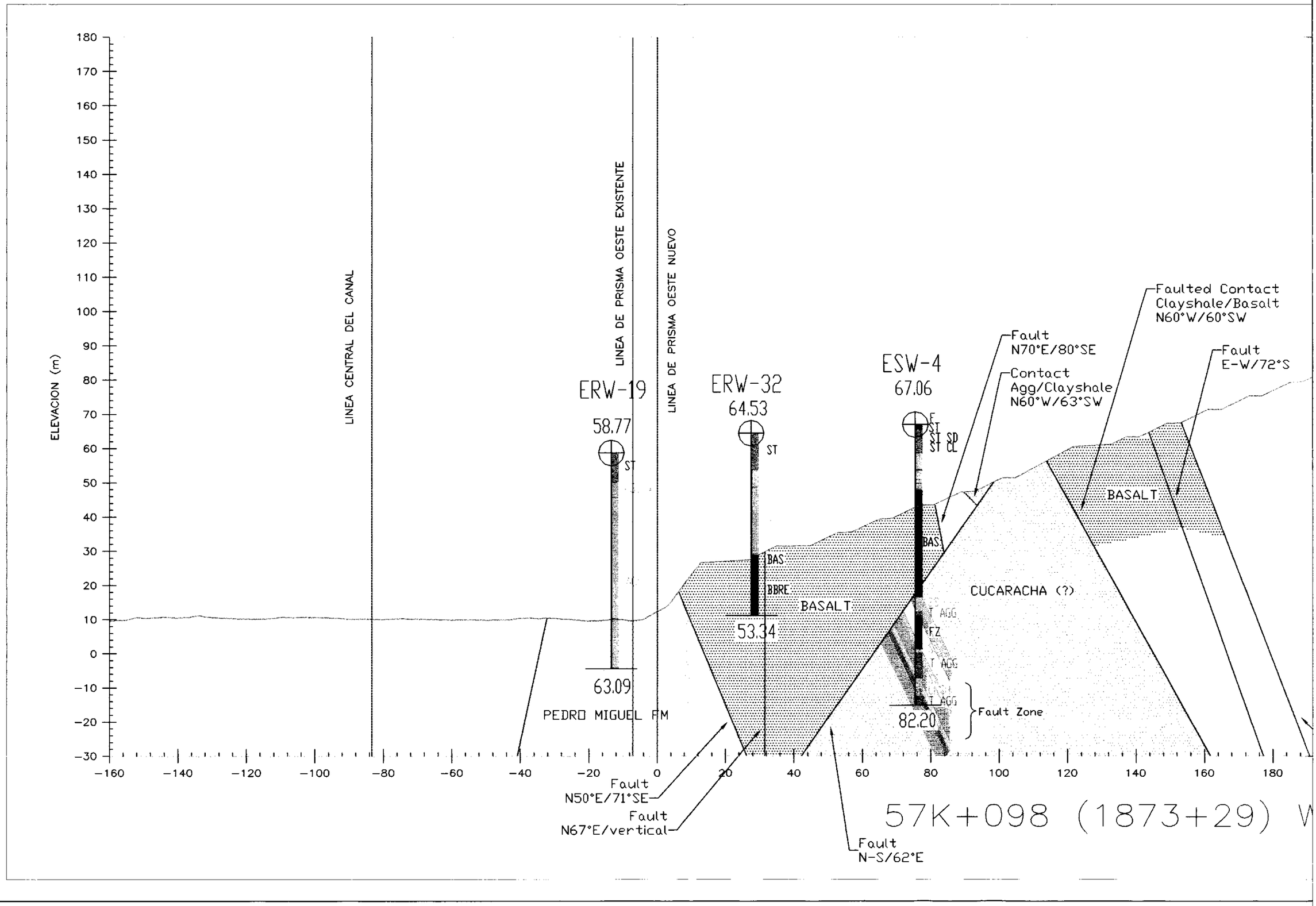
Description: Channel Deepening
Comments: West Bank 57K+098 - Channel Bottom = 22 ft + design + blasted 16 ft (case 8)
File Name: 57K098_8.slz
Last Saved Date: 4/7/02
Last Saved Time: 2:13:36 PM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: (none)
Seismic Coefficient: (none)

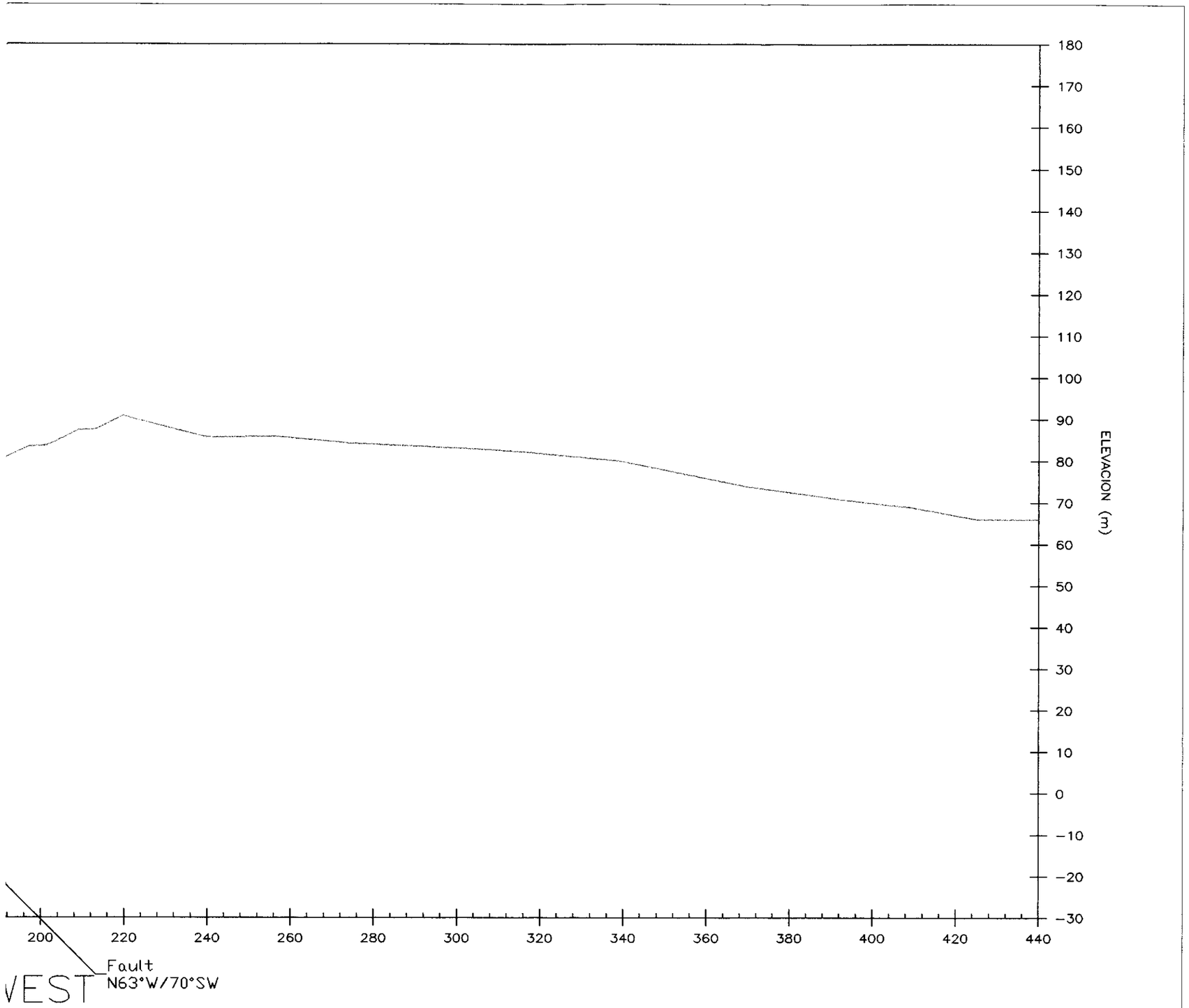




Summary, 57k + 098 (1873 + 29)

General Description	Range of stations:	57k + 050 to 57k + 475			
	Sector:	Empire			
	Maximum height (m):	80			
	Cotangent of slope angle (cot. β):	2.75			
History	Last slide event:	No event			
Geology	Formation:	Pedro Miguel / La Boca			
	Lithology:	Tuff / Siltstone			
	Critical stratum at toe:	Clayshale / Shale / Agglomerate / Basalt			
	Apparent dip of bedding:	No defined			
Stability Analysis	Critical failure mechanism:	Rotational			
	Shear strength model:	First time, Basalt / Fully softened, Cucaracha			
		Operative average pore pressure ratio (aproximate), Ru:	Factor of Safety	Relative Factor of Safety	Percentage of Change (%)
	Case 1: Channel bottom = 32 ft	0.367	3.847	1.000	0.00
	Case 2: Channel bottom = 27 ft, Blasted material only		3.847	1.000	0.00
	Case 3: Channel bottom = 27 ft, Blasted & removed		3.829	0.995	-0.47
	Case 4.1: Channel bottom = 27 ft, Design (underwater slope)		3.792	0.986	-1.43
	Case 4.2: Channel bottom = 27 ft, Design (& dry excavation)	0.367	3.792	0.986	-1.43
	Case 5: Channel bottom = 22 ft, Blasted material only		3.822	0.994	-0.65
	Case 6: Channel bottom = 22 ft, Blasted & removed		3.794	0.986	-1.38
	Case 7.1: Channel bottom = 22 ft, Design (underwater slope)		3.744	0.973	-2.68
	Case 7.2: Channel bottom = 22 ft, Design (& dry excavation)	0.363	3.744	0.973	-2.68
	Case 8: Channel bottom = 16 ft, Blasted		3.733	0.970	-2.96
Conclusions:	No stabilization is required				


ELEVACION (m)
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-160
-140
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
120
140
160
180
LINEA CENTRAL DEL CANAL
LINEA DE PRISMA OESTE EXISTENTE
LINEA DE PRISMA OESTE NUEVO
ERW-19
58.77
ST
63.09
PEDRO MIGUEL FM
ERW-32
64.53
ST
BAS
BBRE
BASALT
53.34
ESW-4
67.06
F
ST
ST SD
ST CL
BAS
T AGG
FZ
T AGG
T AGG
82.20
Fault Zone
CUCARACHA (?)
BASALT
Faulted Contact
Clayshale/Basalt
N60°W/60°SW
Fault
N70°E/80°SE
Contact
Agg/Clayshale
N60°W/63°SW
Fault
E-W/72°S
Fault
N50°E/71°SE
Fault
N67°E/vertical
Fault
N-S/62°E
57K+098 (1873+29) W



AUTORIDAD DEL CANAL DE PANAMA

DEPARTAMENTO DE INGENIERIA Y PROYECTOS
DIVISION DE INGENIERIA
ALTOS DE BALBOA, REPUBLICA DE PANAMA

SECCION GEOLOGICA

CORTE GAILLARD

ESTACION 57K+098 (1873+29) OESTE

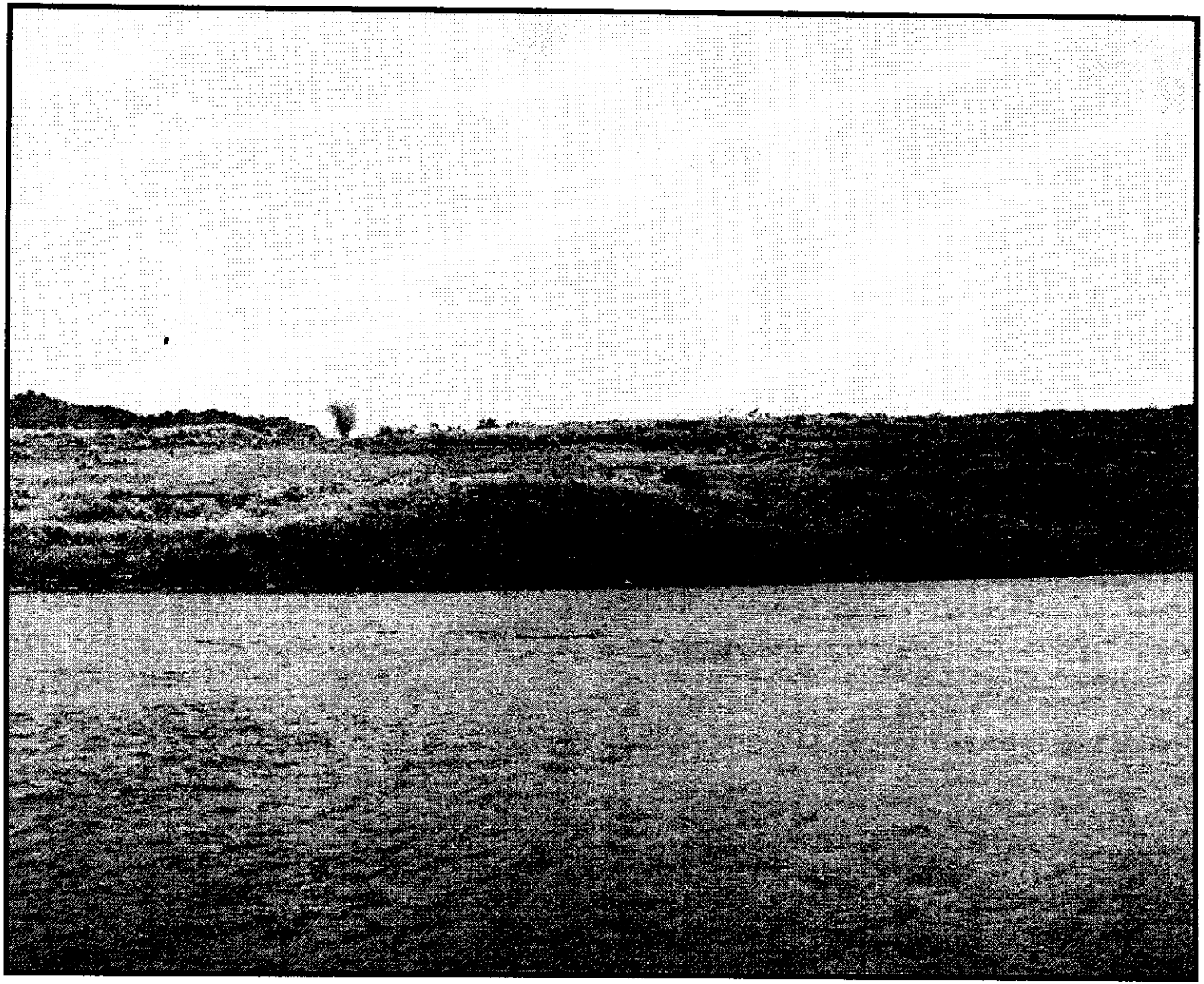
ESCALA: 1:1000	FECHA: ABRIL 2002
GEOLOGIA POR: P. FRANCESCHI	DIBUJADO POR: J. RAMESCH

station 57k + 820 (1897 + 00)

West

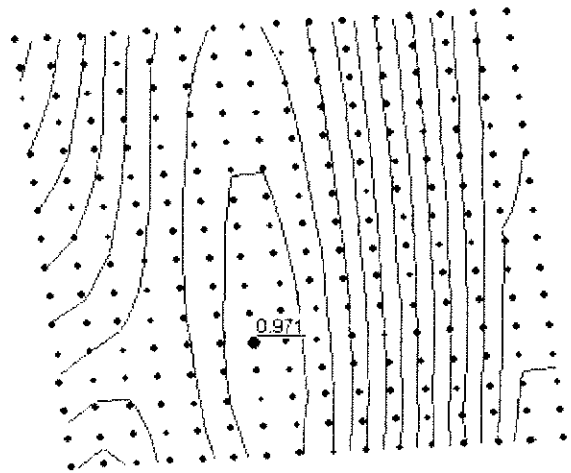
Station: 57k + 820 (Lirio)

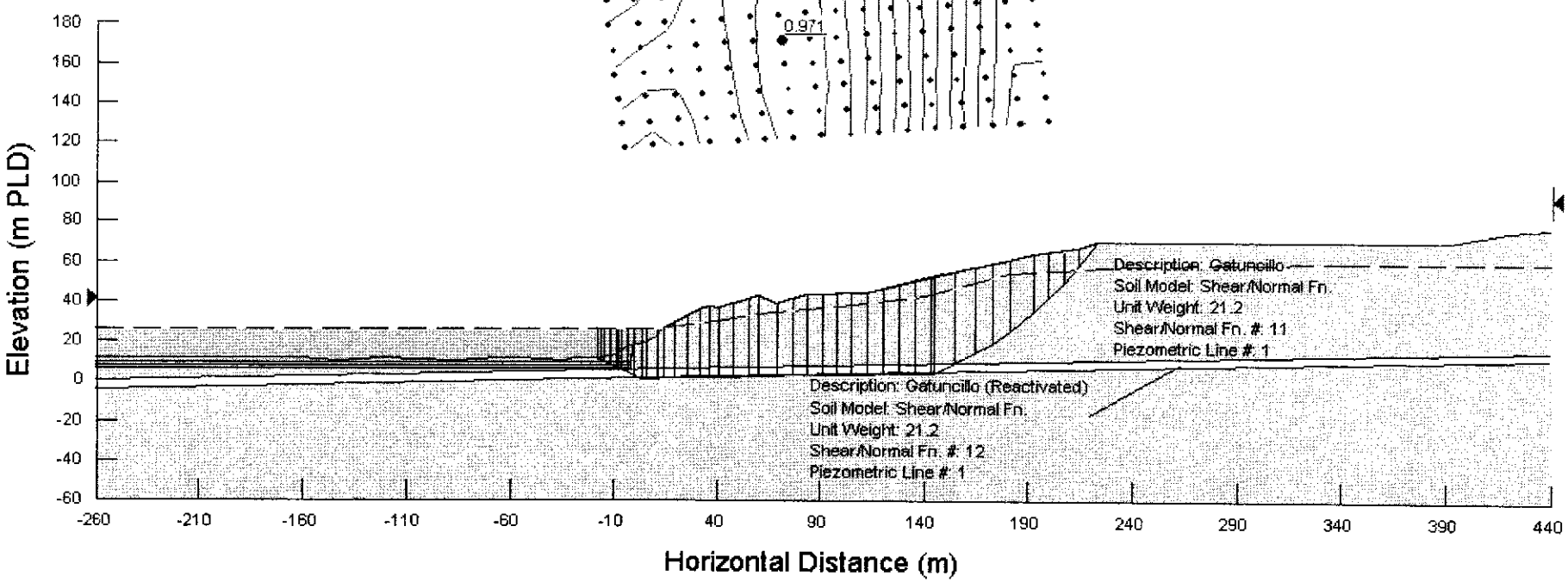
April 16, 2002



Case 1, Channel bottom = 32 ft

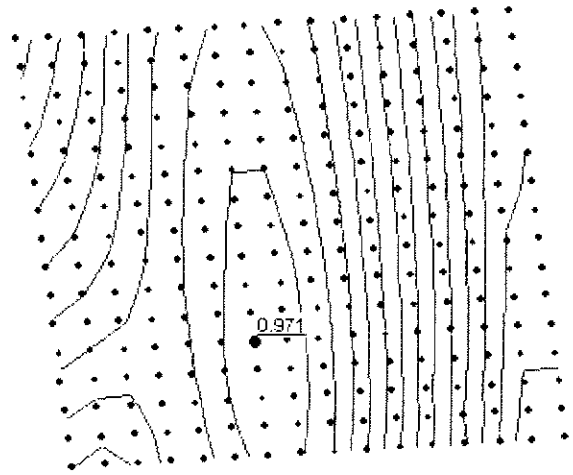
Description: Channel Deepening
Comments: West Bank 57K+820 - Channel Bottom = 32 ft (case 1)
File Name: 57K820_1.slz
Last Saved Date: 3/30/02
Last Saved Time: 2:33:32 PM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: (none)
Seismic Coefficient: (none)

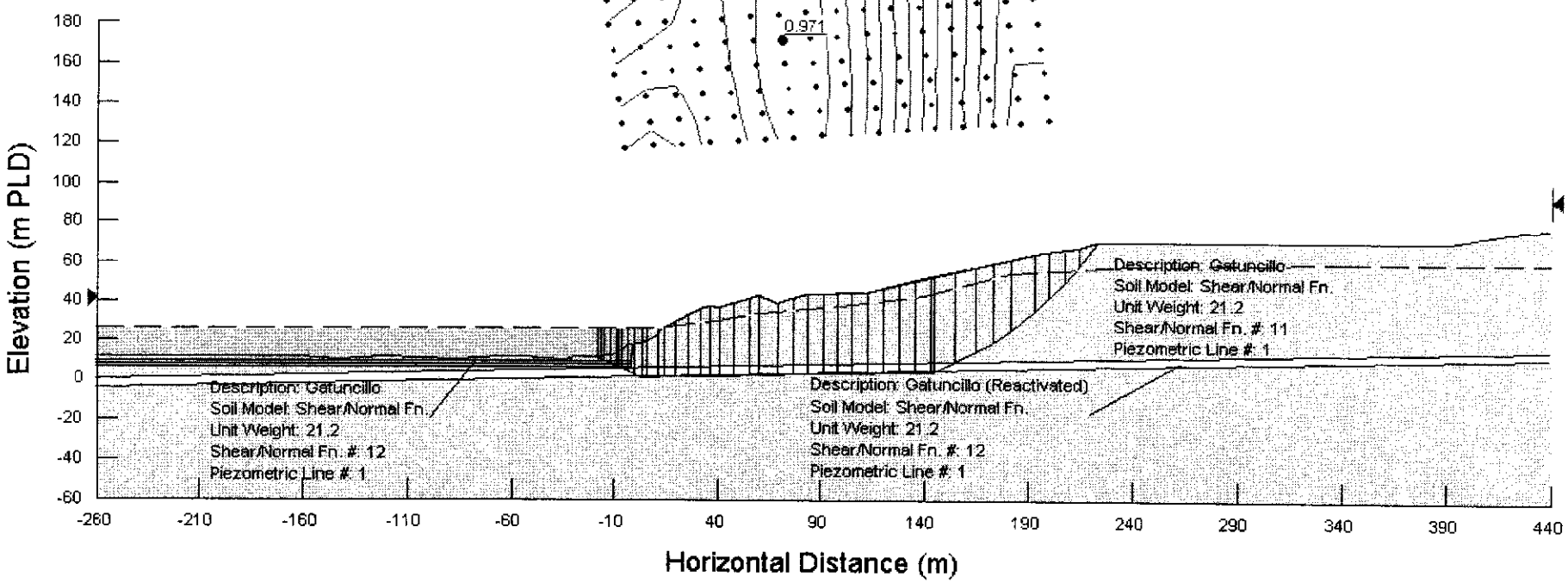




Case 2, Channel bottom = 27 ft, Blasted material only

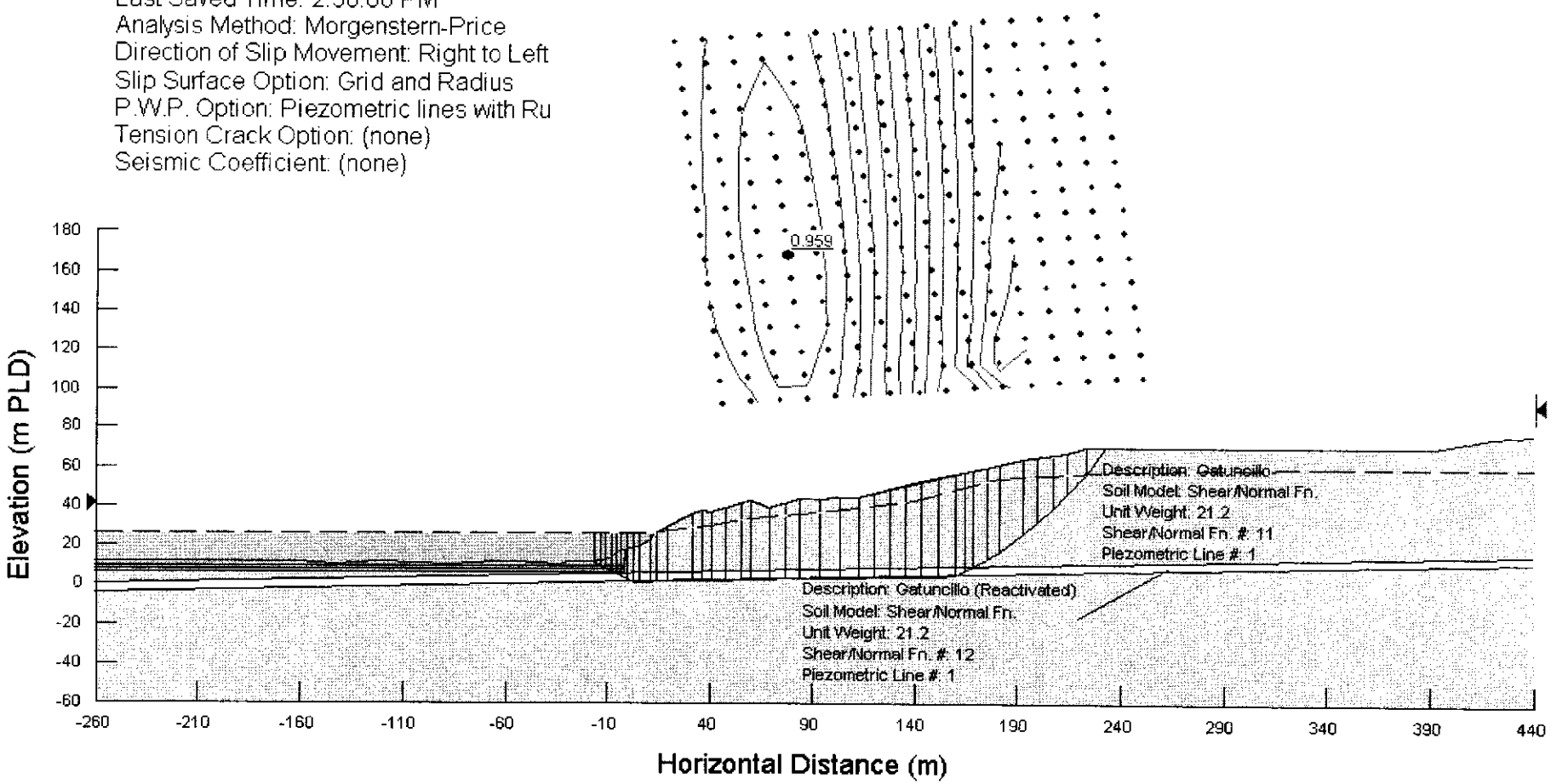
Description: Channel Deepening
Comments: West Bank 57K+820 - Channel Bottom = 27 ft blasted material only (case 2)
File Name: 57K820_2.slz
Last Saved Date: 3/30/02
Last Saved Time: 2:52:39 PM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: (none)
Seismic Coefficient: (none)





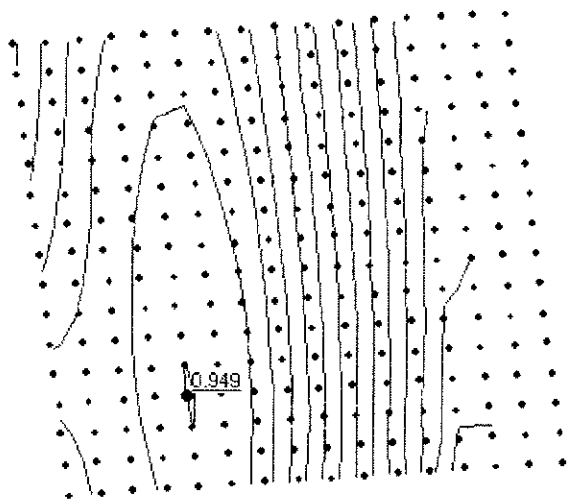
Case 3, Channel bottom = 27 ft, Blasted & removed

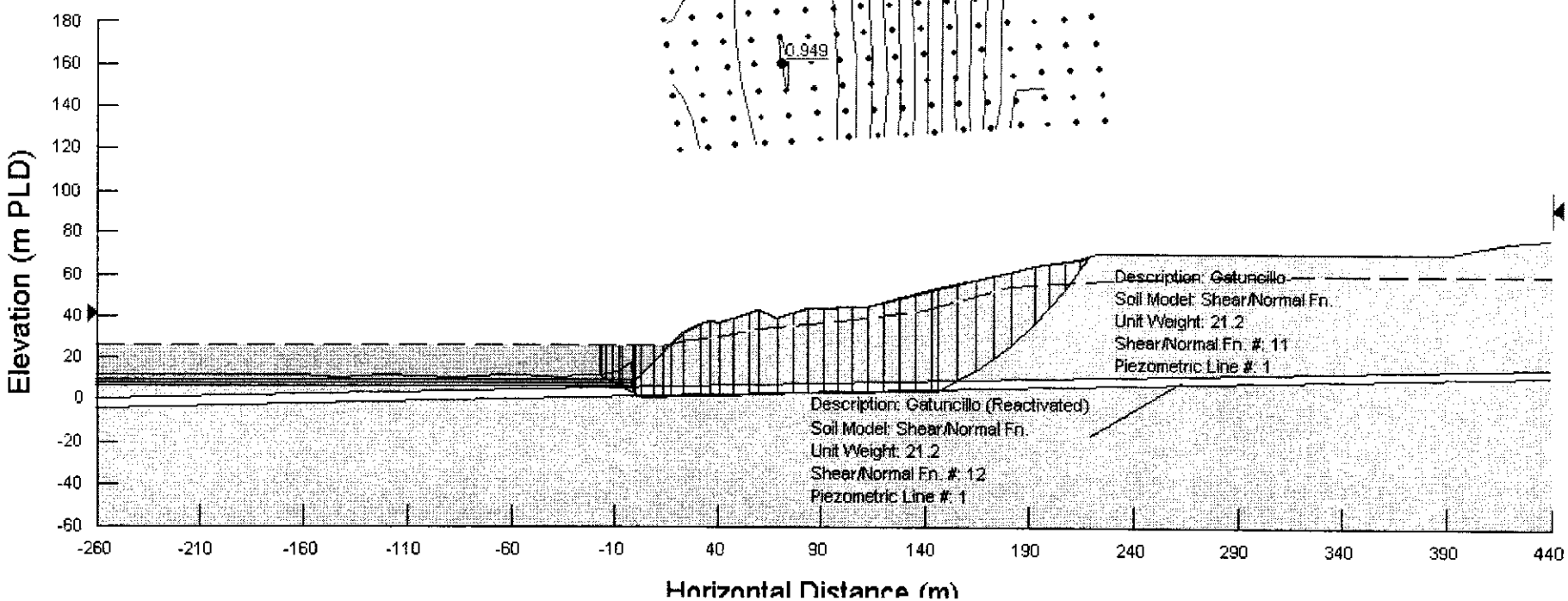
Description: Channel Deepening
Comments: West Bank 57K+820 - Channel Bottom = 27 ft blasted & removed (case 3)
File Name: 57K820_3.slz
Last Saved Date: 3/30/02
Last Saved Time: 2:56:08 PM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: (none)
Seismic Coefficient: (none)



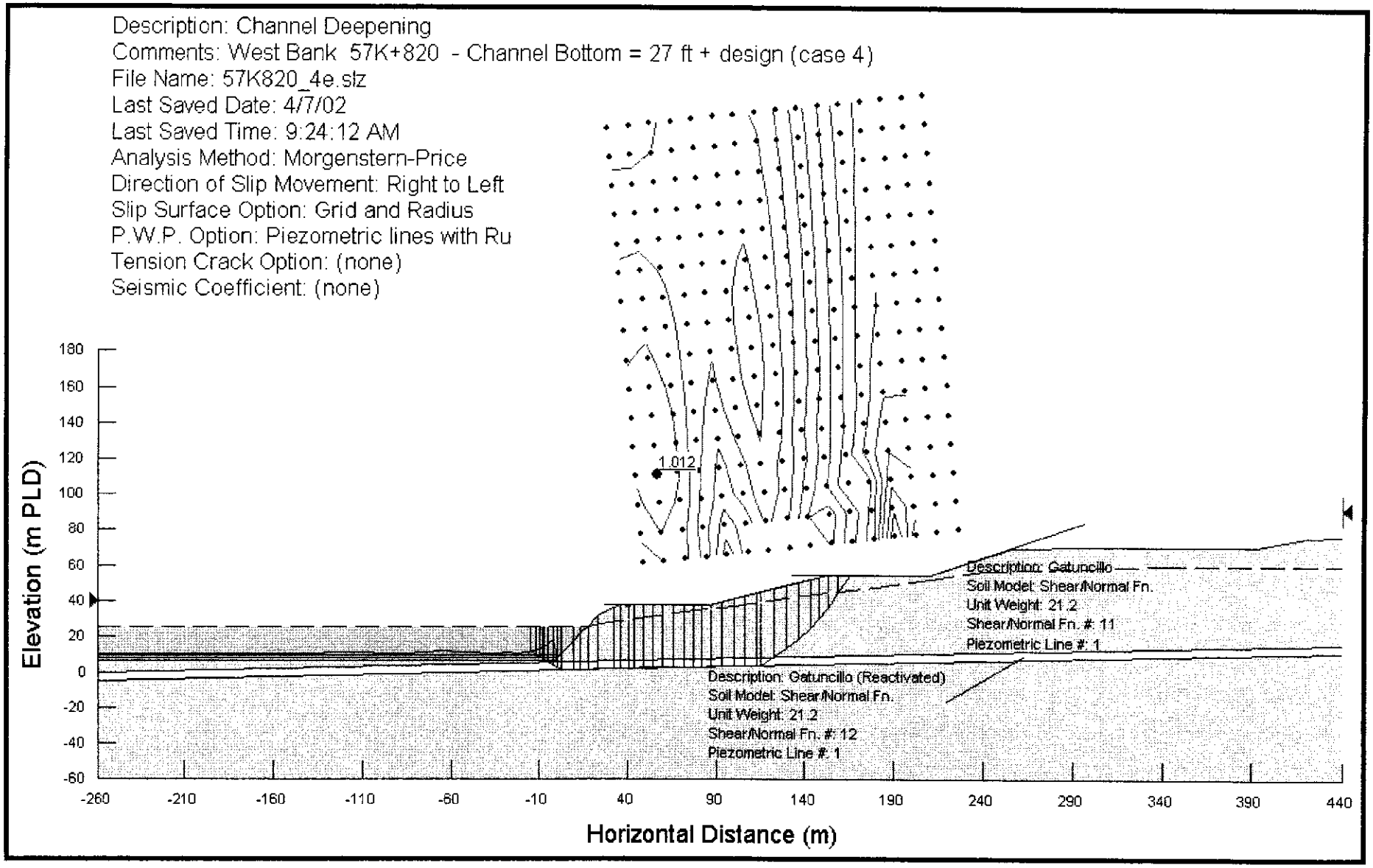
Case 4.1, Channel bottom = 27 ft, Design (underwater slope)

Description: Channel Deepening
Comments: West Bank 57K+820 - Channel Bottom = 27 ft + design (case 4)
File Name: 57K820_4.slz
Last Saved Date: 4/3/02
Last Saved Time: 10:17:27 AM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: (none)
Seismic Coefficient: (none)



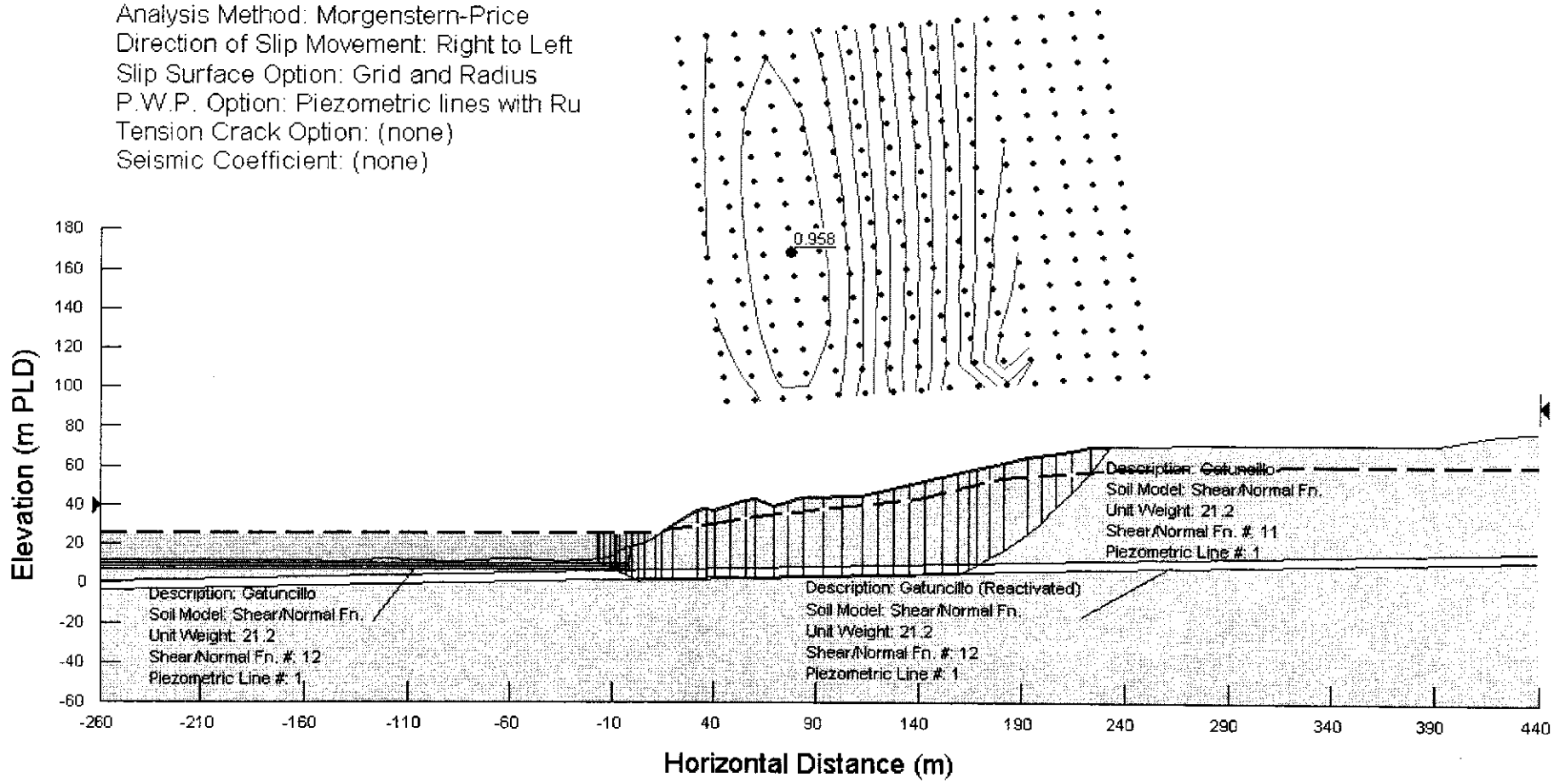


Case 4.2, Channel bottom = 27 ft, Design (& dry excavation)



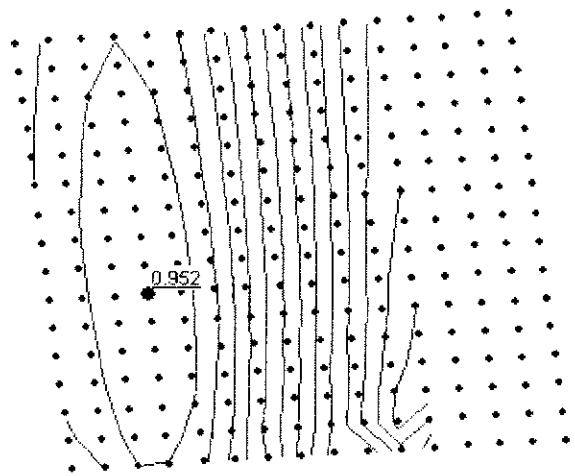
Case 5, Channel bottom = 22 ft, Blasted material only

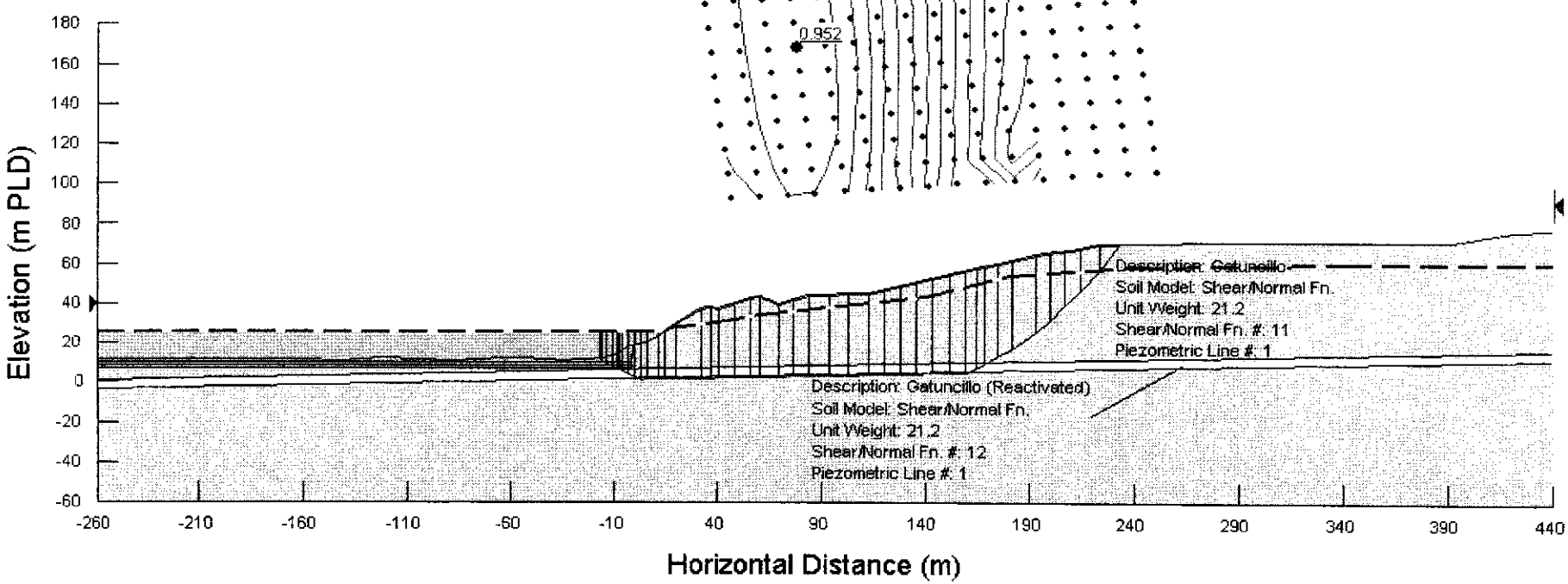
Description: Channel Deepening
Comments: West Bank 57K+820 - Channel Bottom = 22 ft blasted material only (case 5)
File Name: 57K820_5.slz
Last Saved Date: 3/30/02
Last Saved Time: 2:59:37 PM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: (none)
Seismic Coefficient: (none)



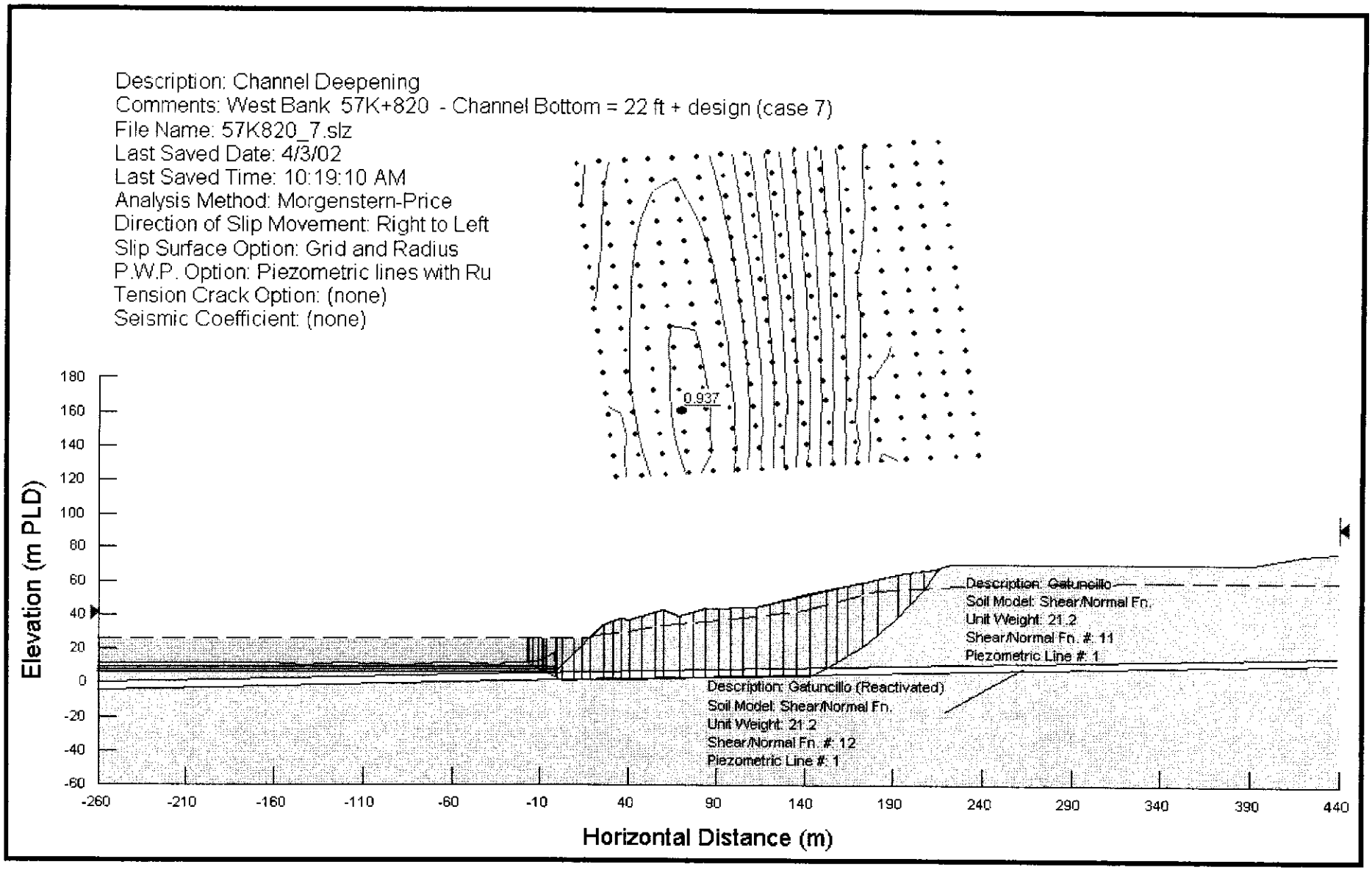
Case 6, Channel bottom = 22 ft, Blasted & removed

Description: Channel Deepening
Comments: West Bank 57K+820 - Channel Bottom = 22 ft blasted & removed (case 6)
File Name: 57K820_6.slz
Last Saved Date: 3/30/02
Last Saved Time: 3:00:23 PM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: (none)
Seismic Coefficient: (none)

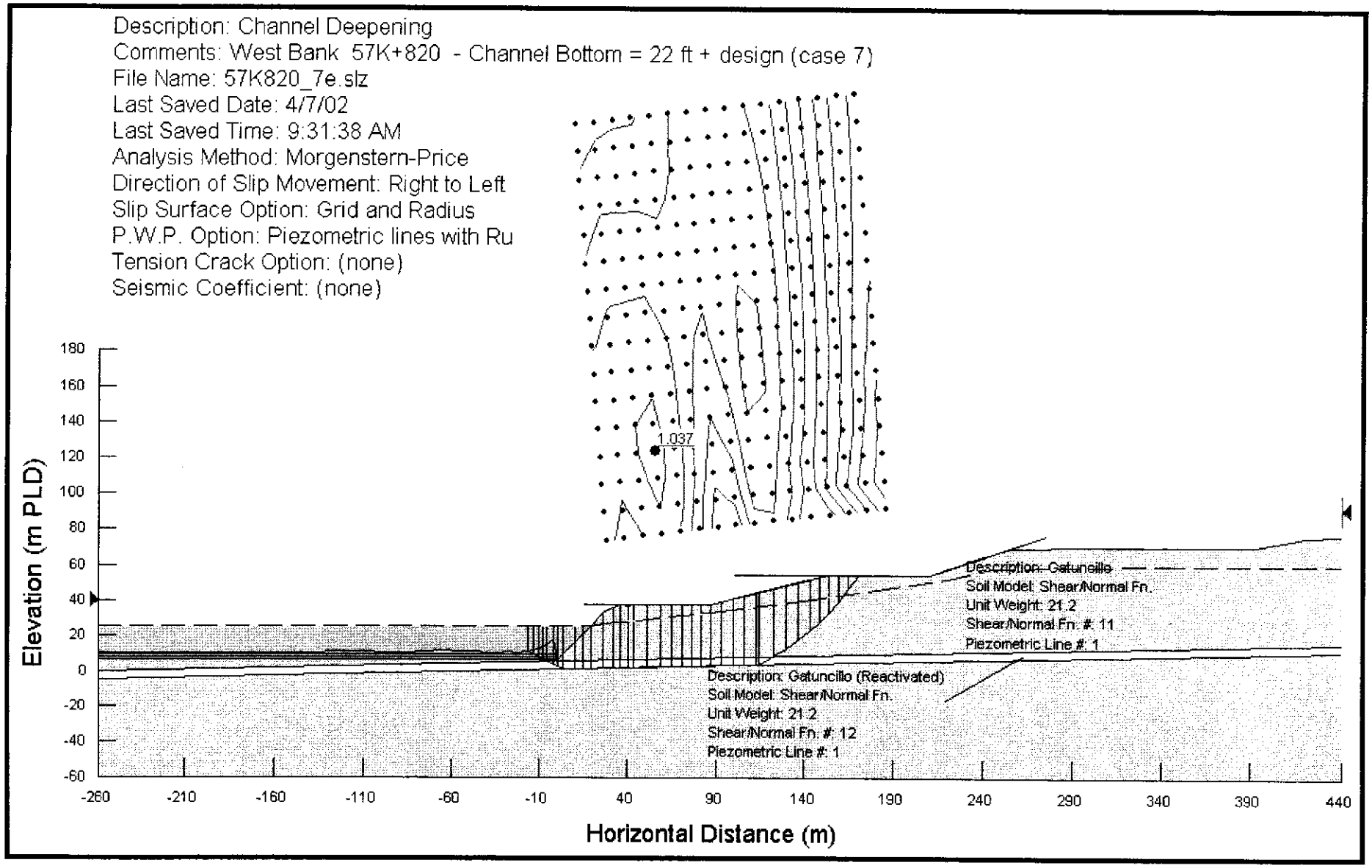




Case 7.1, Channel bottom = 27 ft, Design (underwater slope)

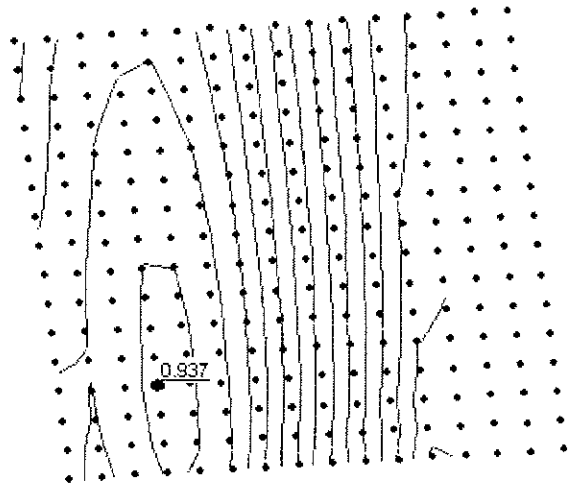


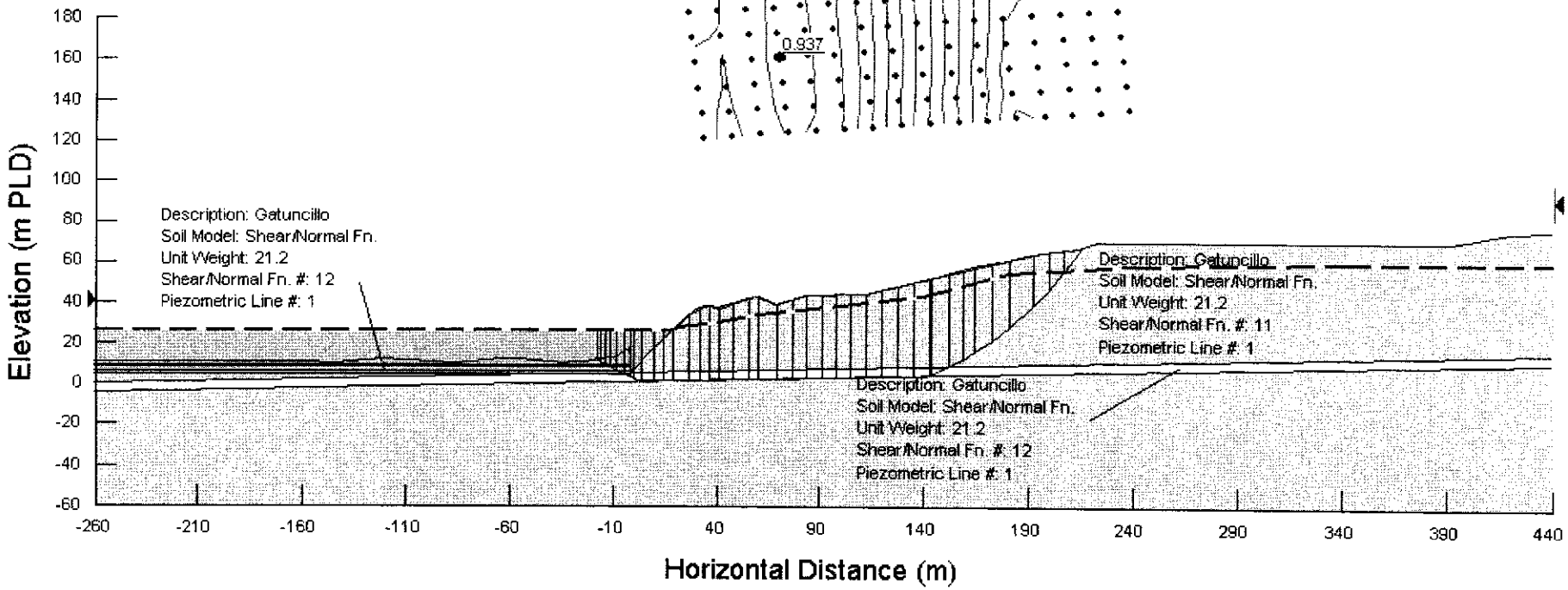
Case 7.2, Channel bottom = 27 ft, Design (& dry excavation)



Case 8, Channel bottom = 16 ft, Blasted

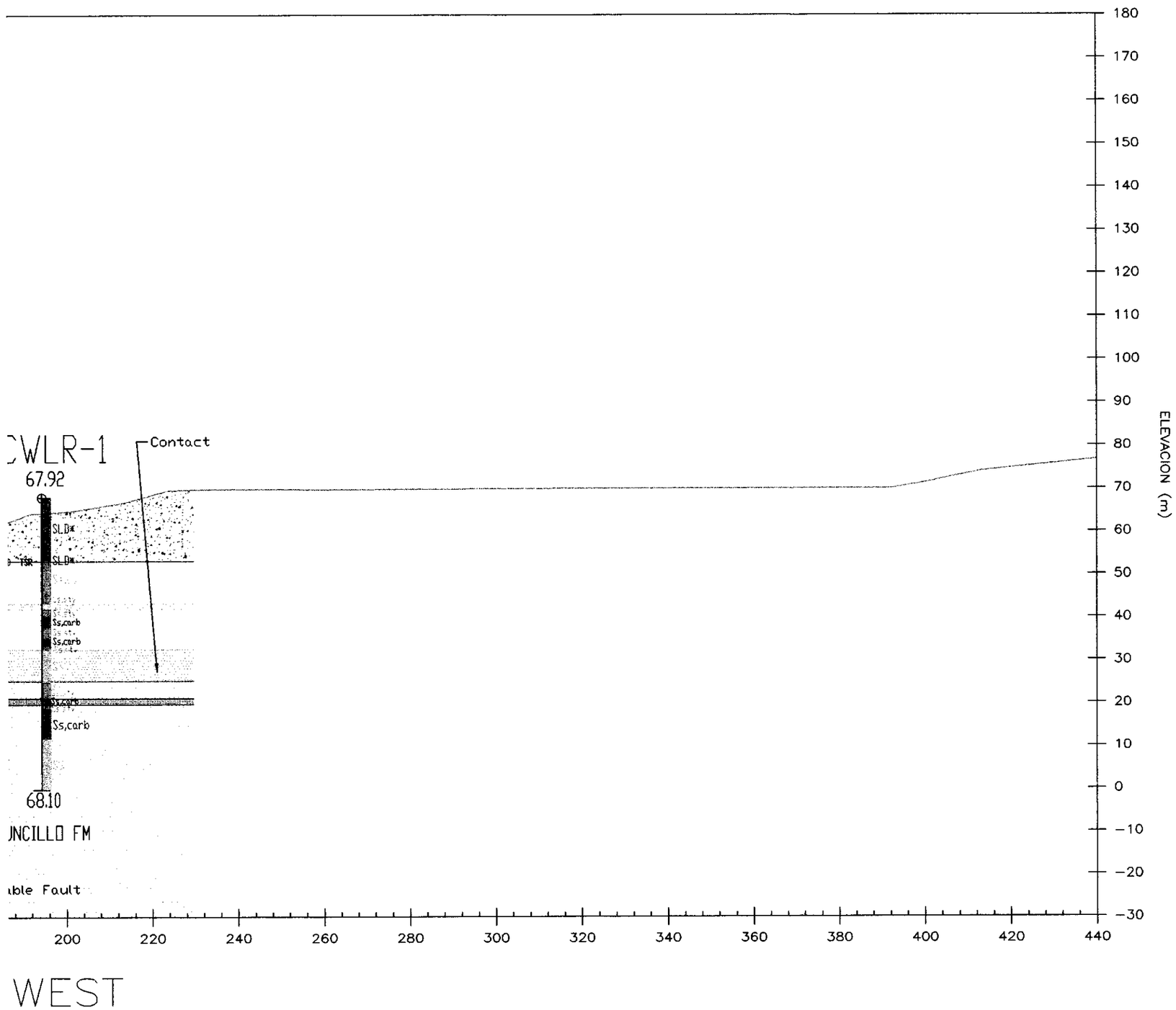
Description: Channel Deepening
Comments: West Bank 57K+820 - Channel Bottom = 22 ft + design + blasted 16 ft (case 8)
File Name: 57K820_8.slz
Last Saved Date: 4/7/02
Last Saved Time: 2:28:37 PM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: (none)
Seismic Coefficient: (none)





Summary, 57k + 820 (1897 + 00)

General Description	Range of stations:	57k + 475 to 57k + 925			
	Sector:	Lirio			
	Maximum height (m):	60			
	Cotangent of slope angle (cot. β):	4.33			
History	Last slide event:	June 2, 2000 (West Lirio Slide)			
Geology	Formation:	Culebra / Gatuncillo			
	Lithology:	Sandstone / Siltstone			
	Critical stratum at toe:	Siltstone Carbonaceous			
	Apparent dip of bedding:	Near Horizontal			
Stability Analysis	Critical failure mechanism:	Translational			
	Shear strength model:	Residual, Gatuncillo along weak plane / Fully softened			
		Operative average pore pressure ratio (aproximate), Ru:	Factor of Safety	Relative Factor of Safety	Percentage of Change (%)
	Case 1: Channel bottom = 32 ft	0.382	0.971	1.000	0.00
	Case 2: Channel bottom = 27 ft, Blasted material only		0.971	1.000	0.00
	Case 3: Channel bottom = 27 ft, Blasted & removed		0.959	0.988	-1.24
	Case 4.1: Channel bottom = 27 ft, Design (underwater slope)		0.949	0.977	-2.27
	Case 4.2: Channel bottom = 27 ft, Design (& dry excavation)	0.382	1.012	1.042	4.22
	Case 5: Channel bottom = 22 ft, Blasted material only		0.958	0.987	-1.34
	Case 6: Channel bottom = 22 ft, Blasted & removed		0.952	0.980	-1.96
	Case 7.1: Channel bottom = 22 ft, Design (underwater slope)		0.937	0.965	-3.50
	Case 7.2: Channel bottom = 22 ft, Design (& dry excavation)	0.353	1.037	1.068	6.80
	Case 8: Channel bottom = 16 ft, Blasted		0.937	0.965	-3.50
Conclusions:	Stabilization is required for Case 4 and Case 7				



AUTORIDAD DEL CANAL DE PANAMA

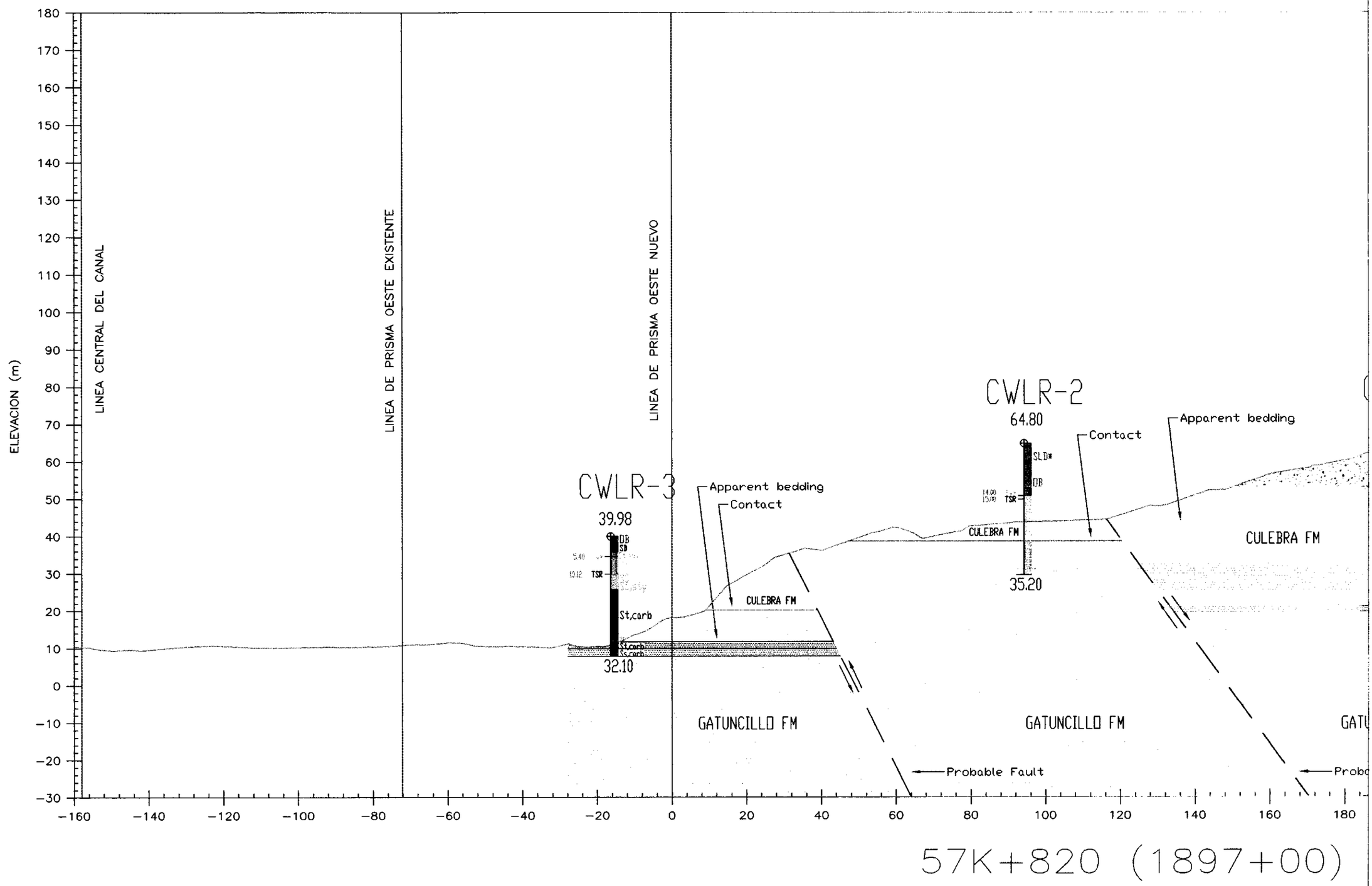
DEPARTAMENTO DE INGENIERIA Y PROYECTOS
DIVISION DE INGENIERIA
ALTOS DE BALBOA, REPUBLICA DE PANAMA

SECCION GEOLOGICA

CORTE GAILLARD

ESTACION 57K+820 (1897+00) OESTE

ESCALA: 1:1000	FECHA: ABRIL 2002
GEOLOGIA POR: J. ARROCHA & P. FRANCESCHI	DIBUJADO POR: J. RAMESCH

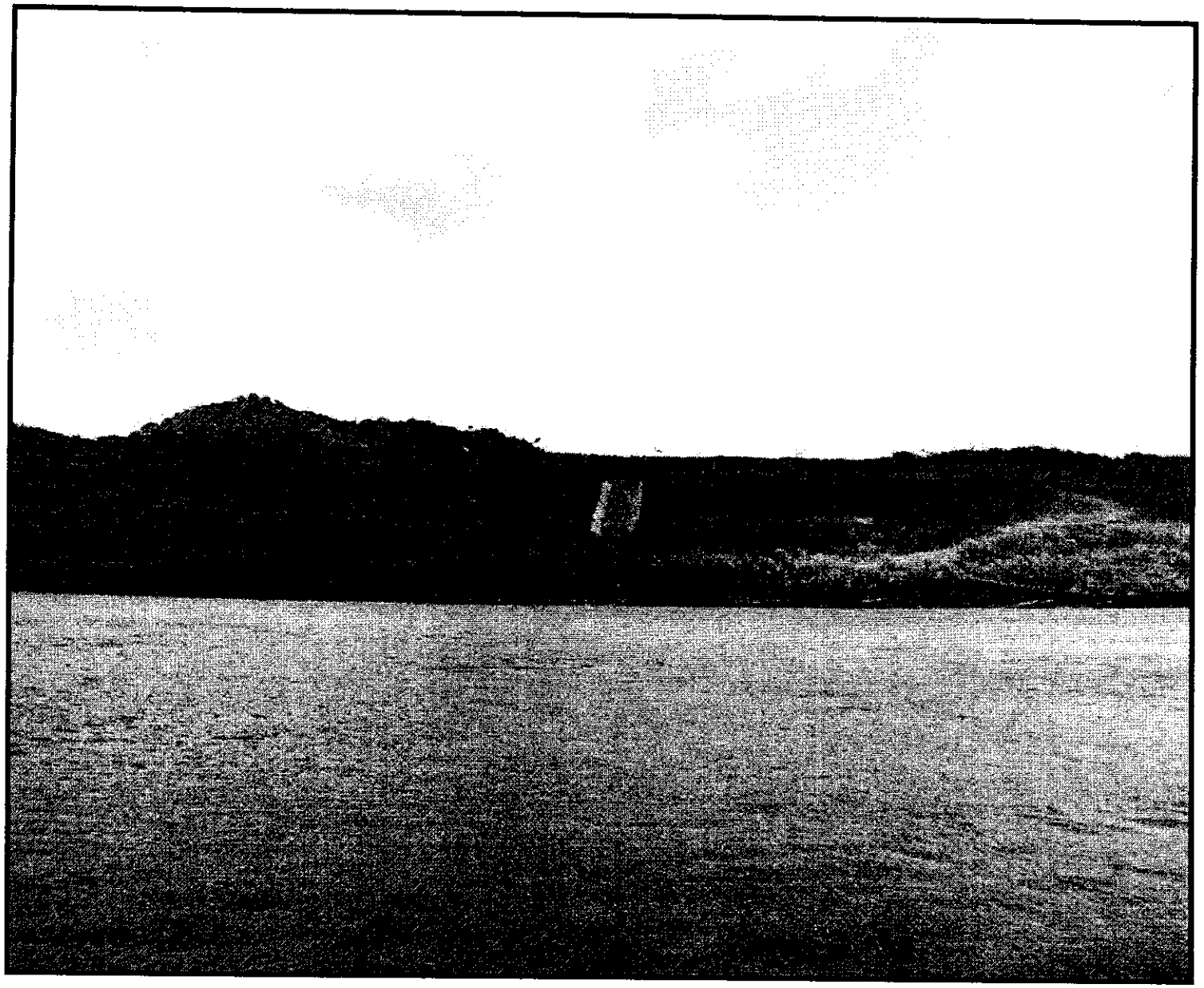

ELEVACION (m)
LINEA CENTRAL DEL CANAL
LINEA DE PRISMA OESTE EXISTENTE
LINEA DE PRISMA OESTE NUEVO
CWLR-3
39.98
DB
SD
TSR
St,carb
32.10
CWLR-2
64.80
SLD
DB
TSR
35.20
Apparent bedding
Contact
CULEBRA FM
GATUNCILLO FM
Probable Fault
57K+820 (1897+00)

station 58k + 120 (1906 + 82)

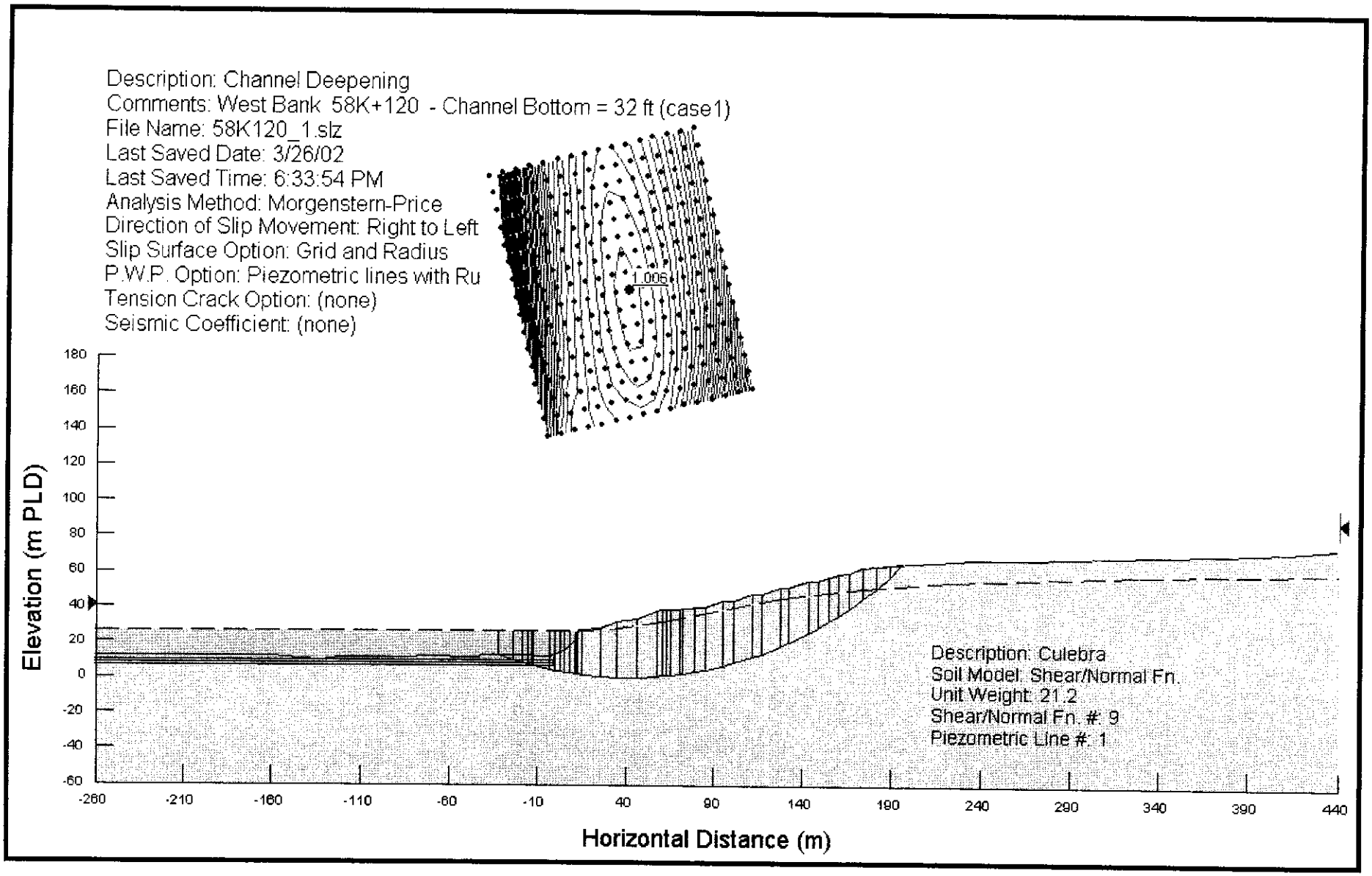
West

Station: 58k + 120 (Lirio)

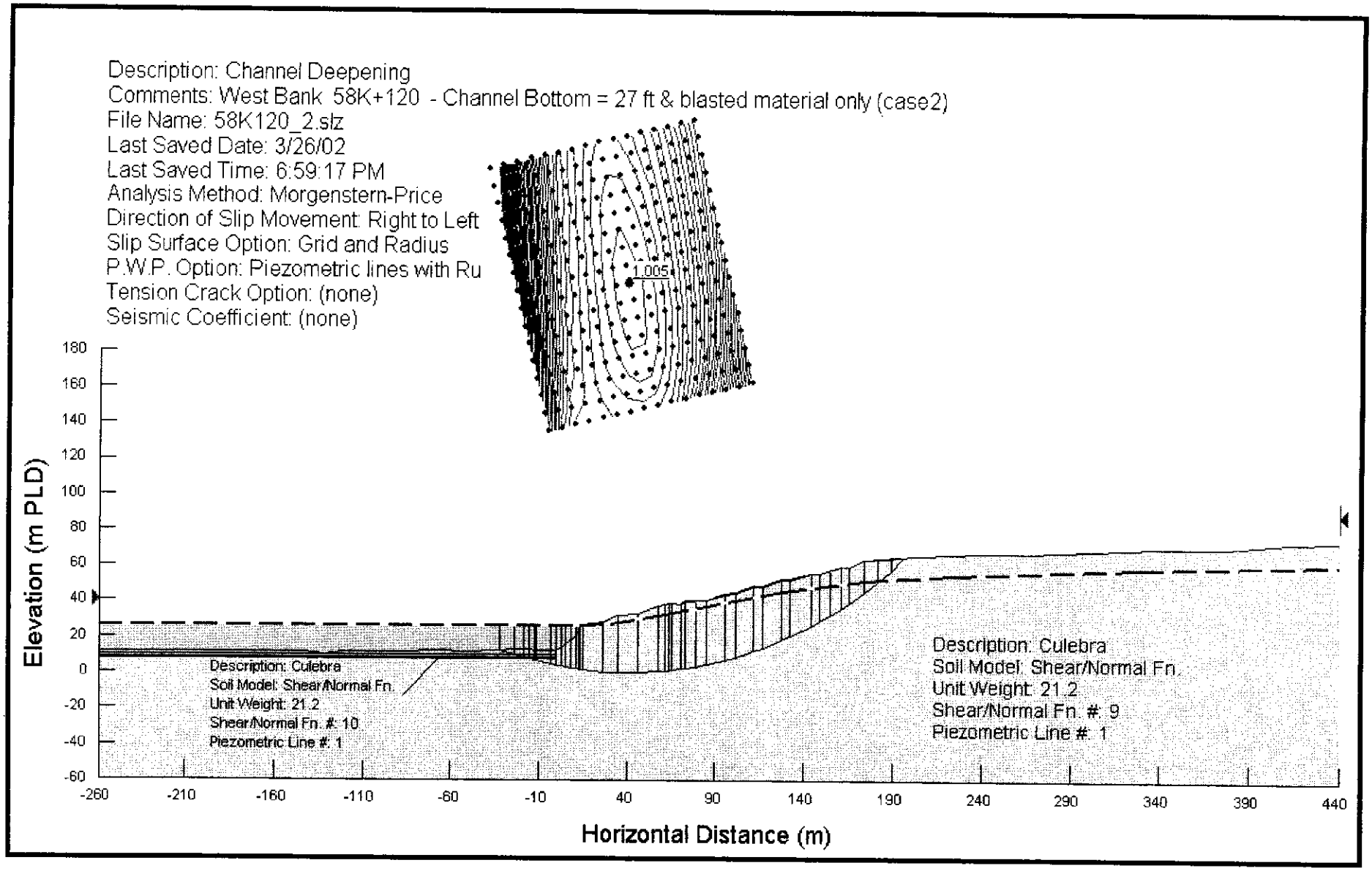
April 16, 2002



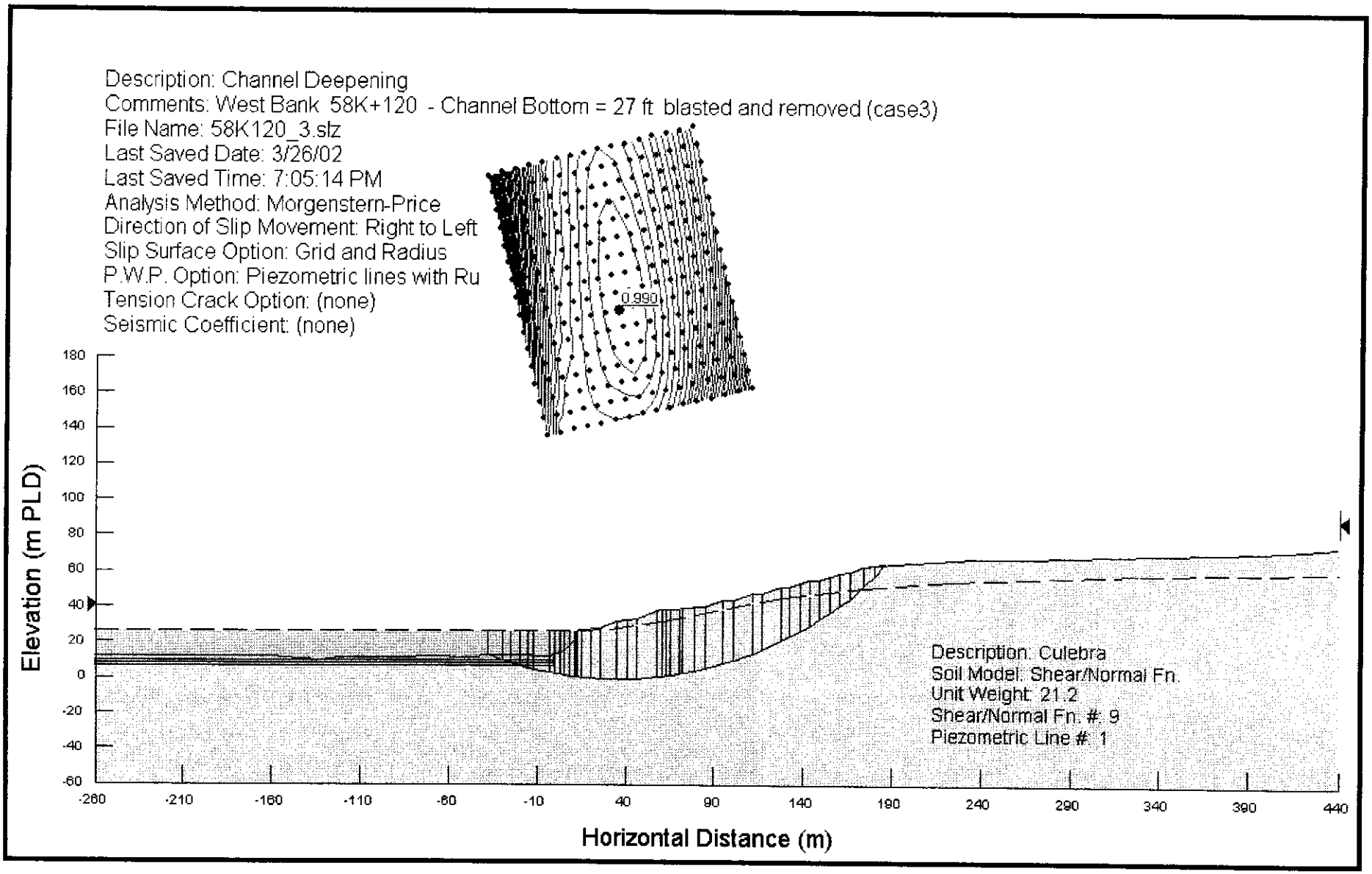
Case 1, Channel bottom = 32 ft



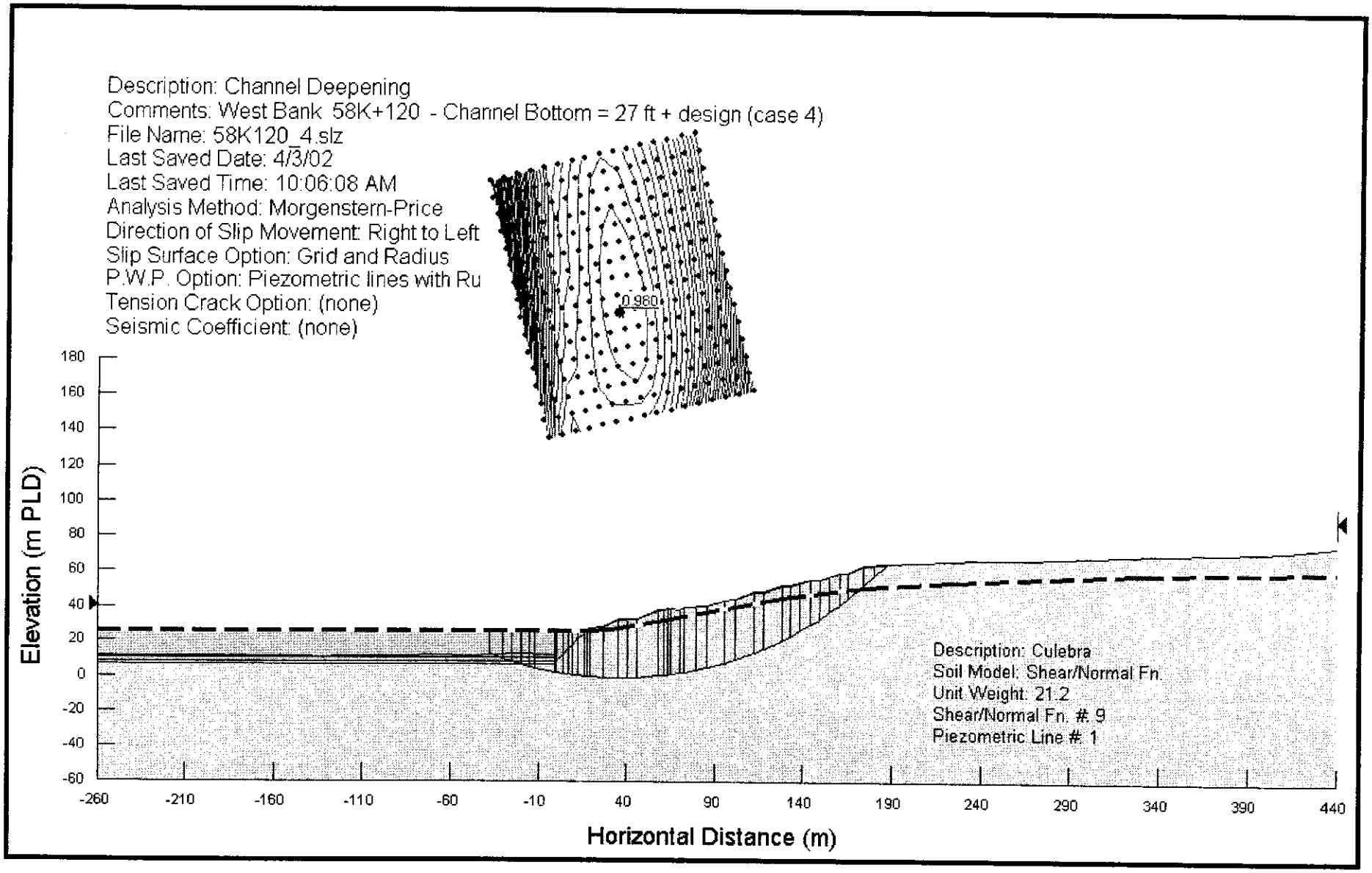
Case 2, Channel bottom = 27 ft, Blasted material only



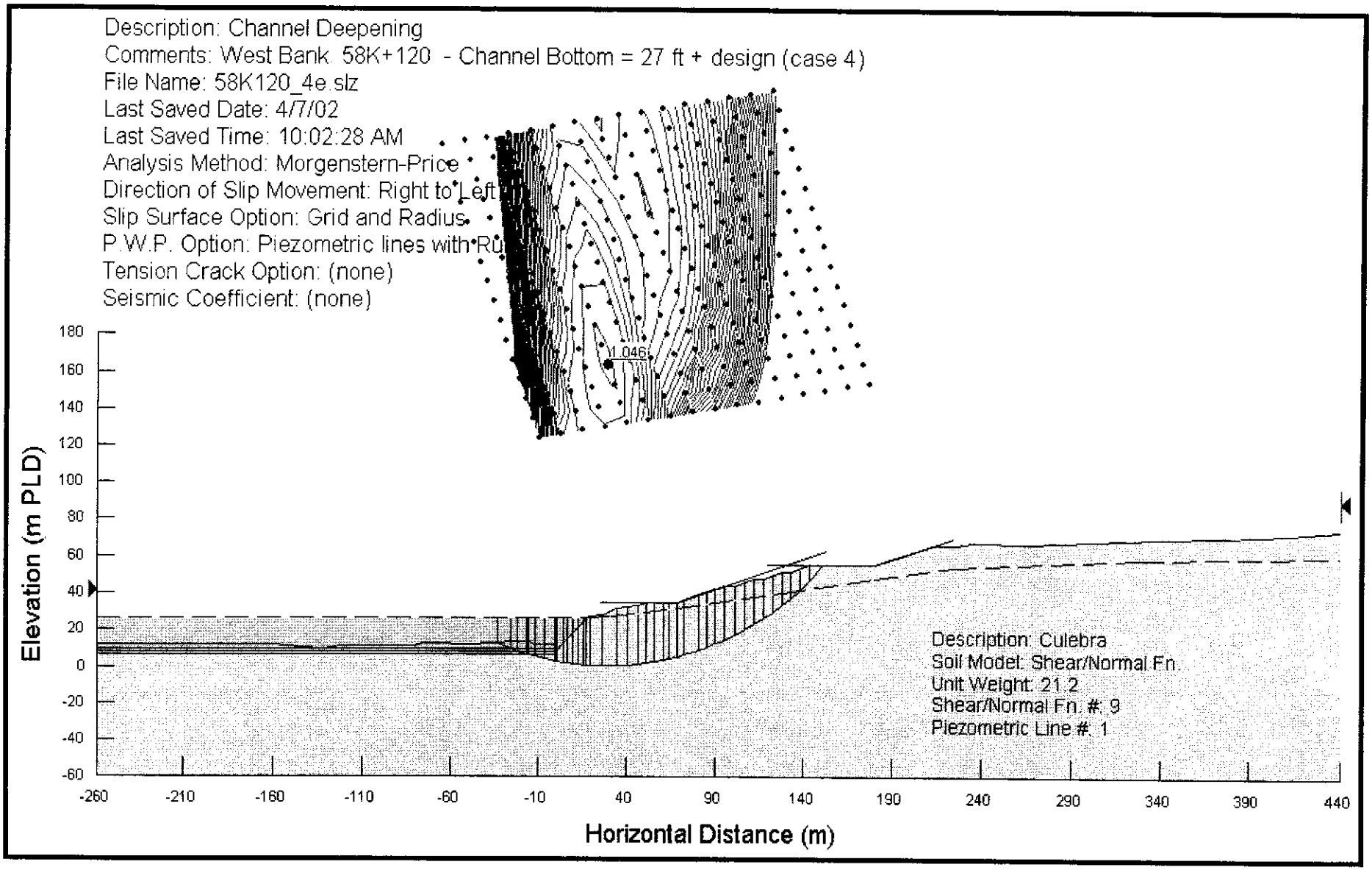
Case 3, Channel bottom = 27 ft, Blasted & removed



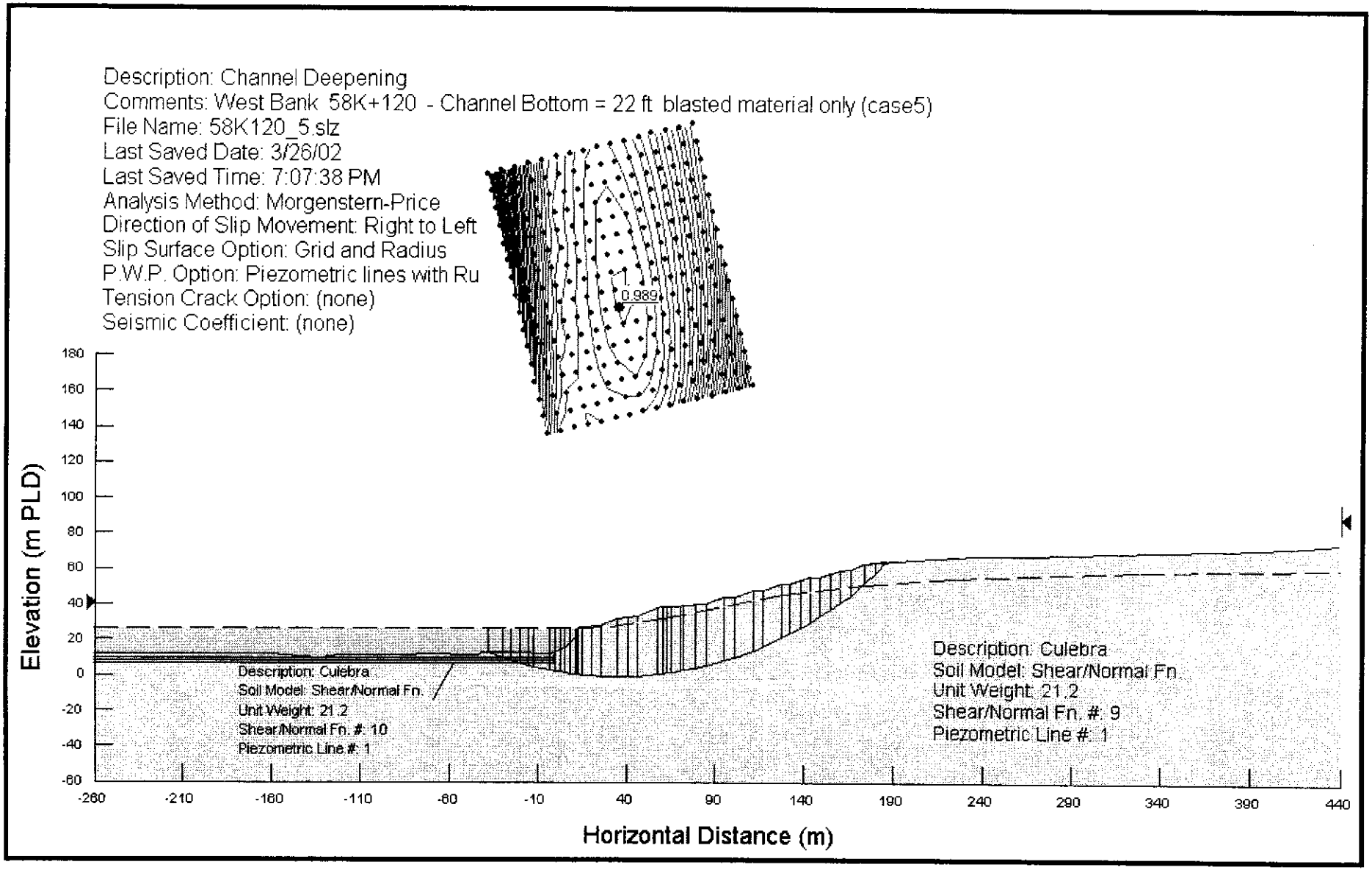
Case 4.1, Channel bottom = 27 ft, Design (underwater slope)



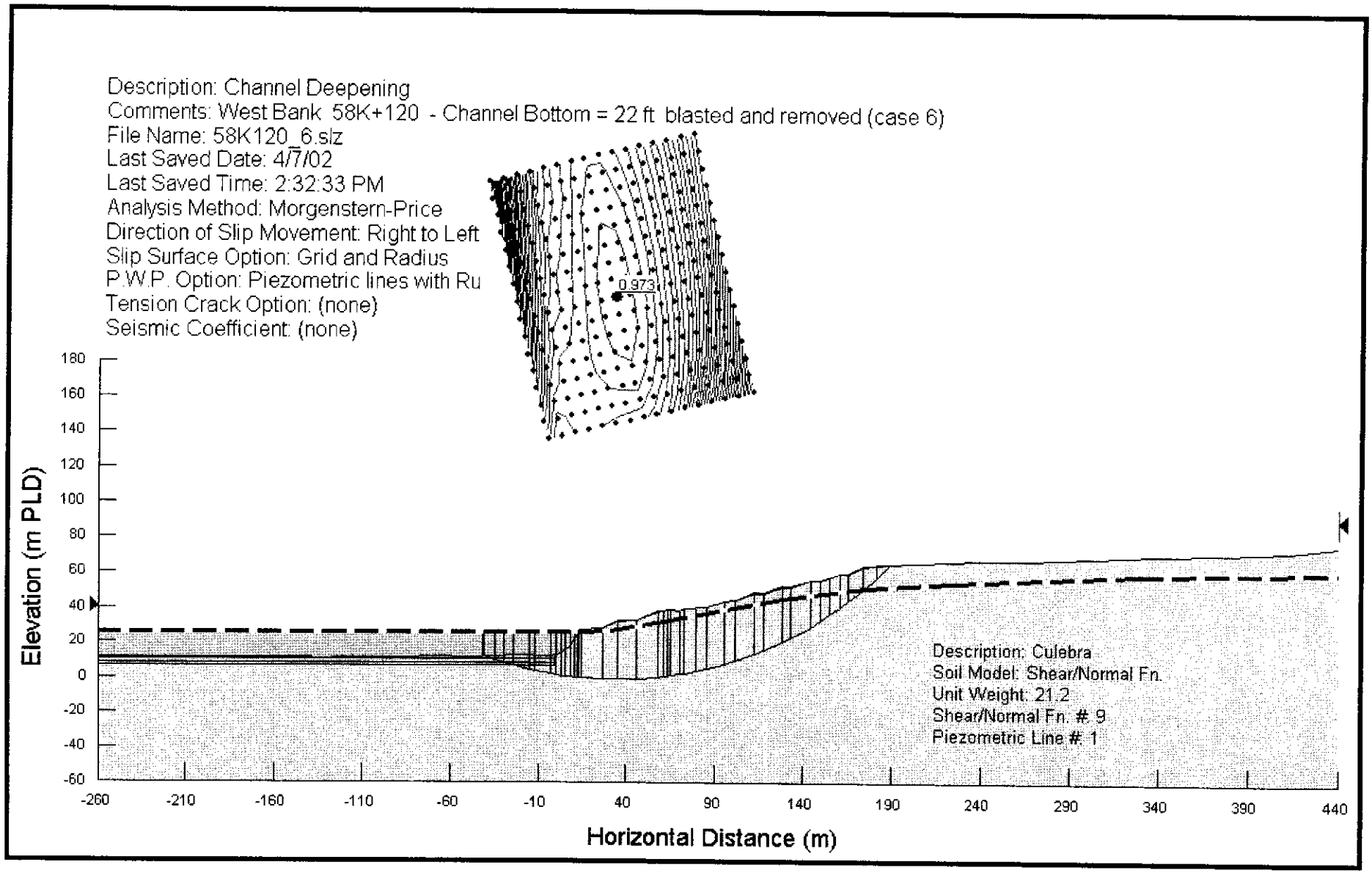
Case 4.2, Channel bottom = 27 ft, Design (& dry excavation)



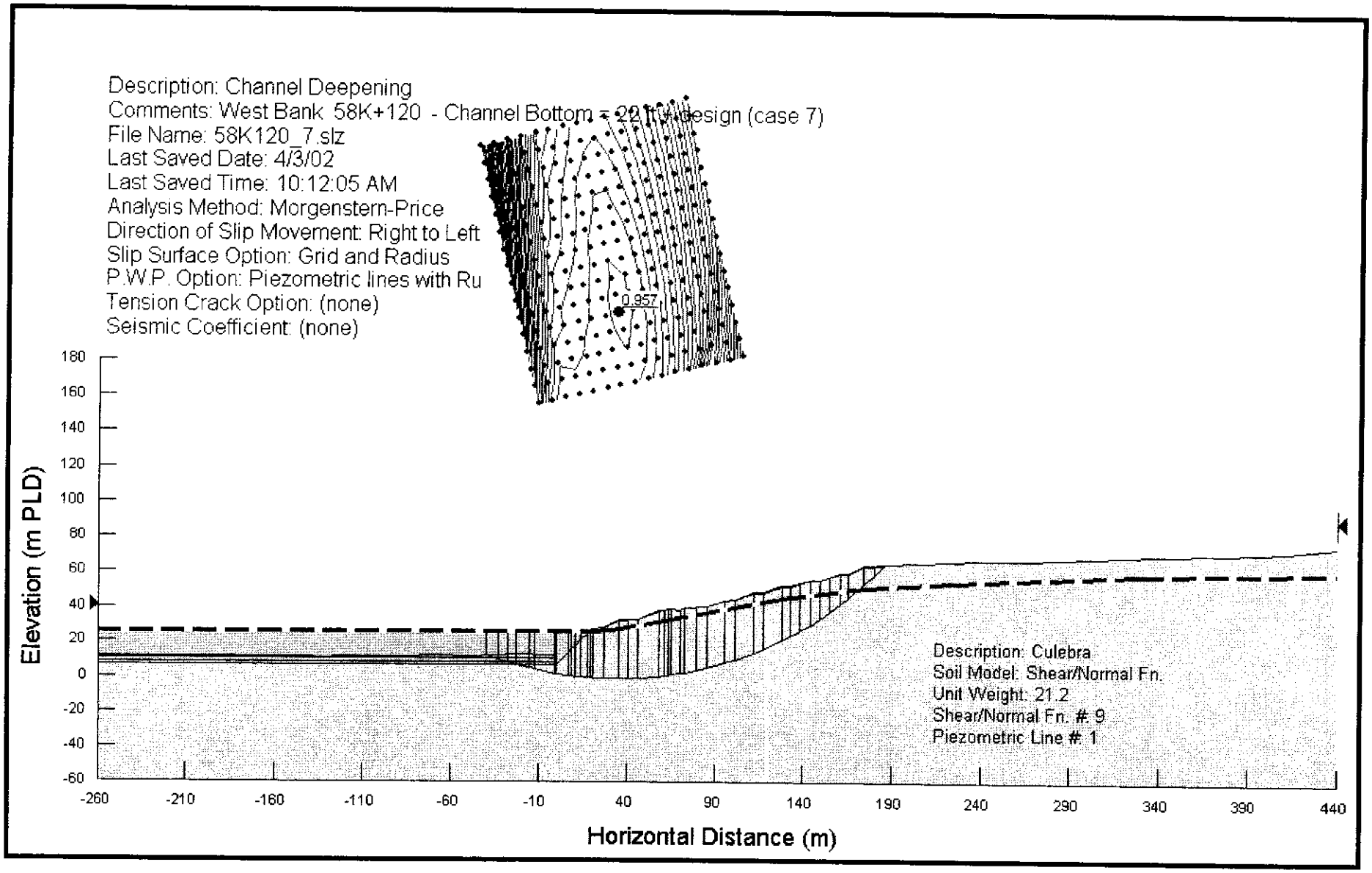
Case 5, Channel bottom = 22 ft, Blasted material only



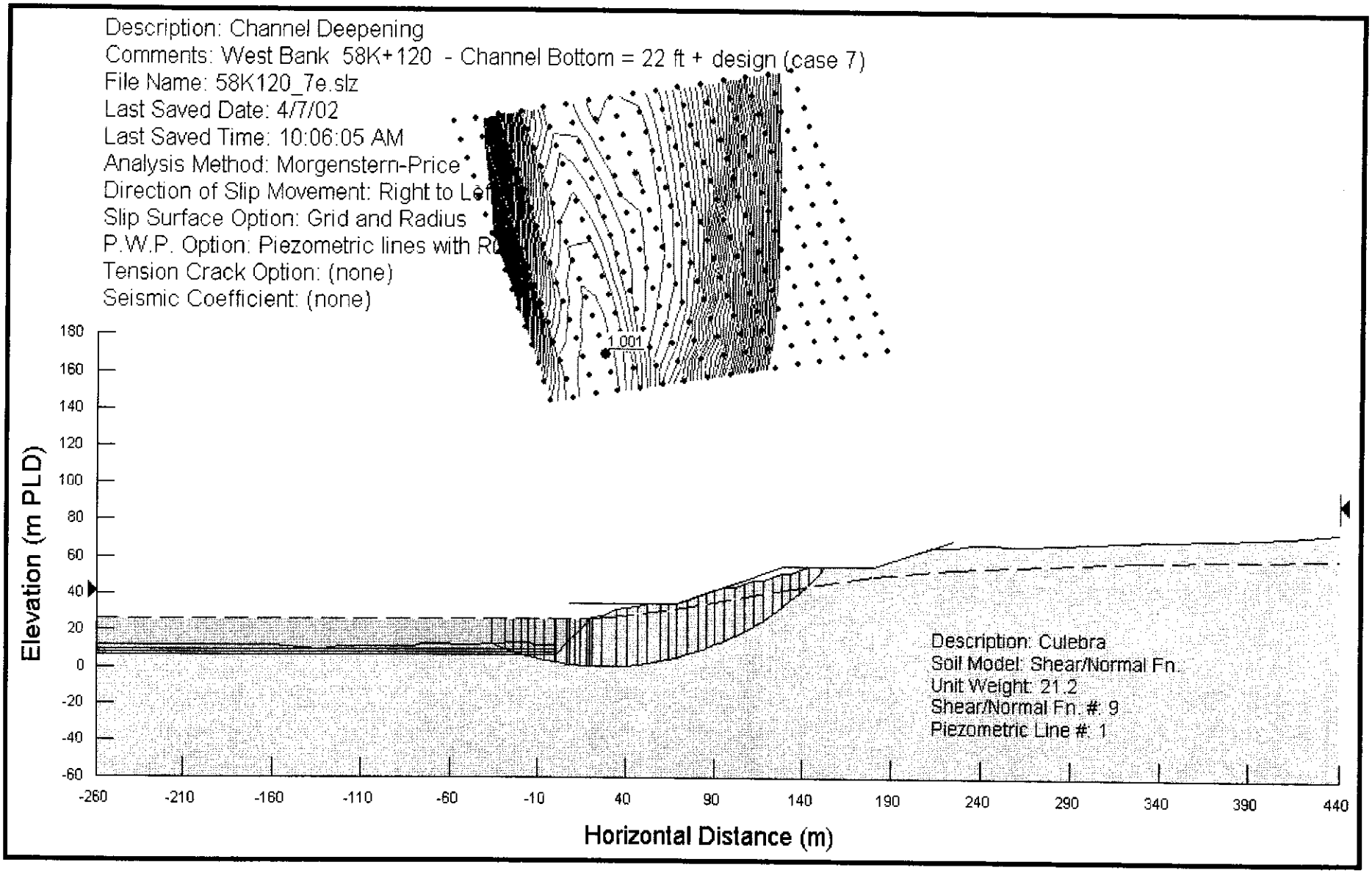
Case 6, Channel bottom = 22 ft, Blasted & removed



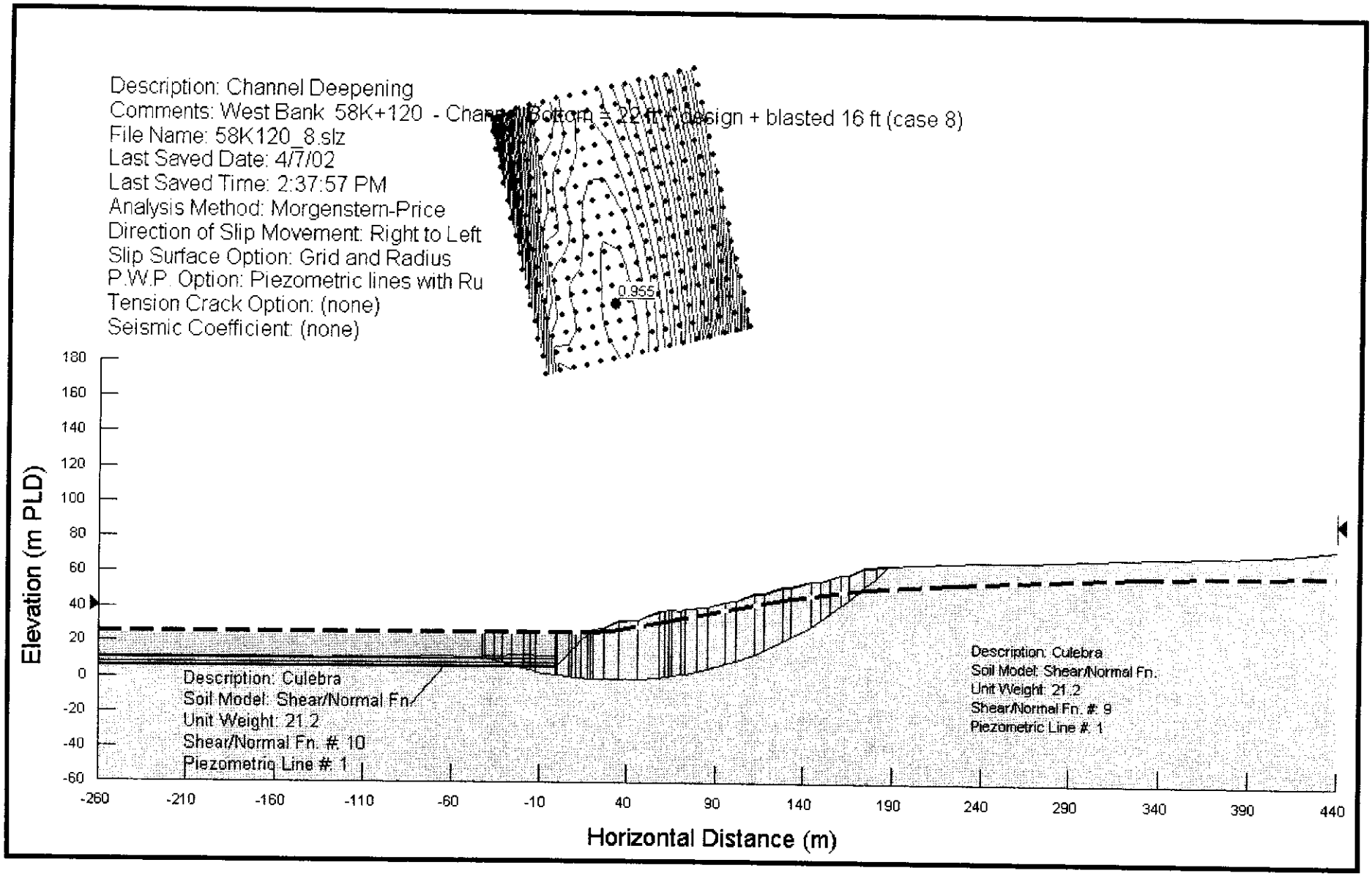
Case 7.1, Channel bottom = 27 ft, Design (underwater slope)



Case 7.2, Channel bottom = 27 ft, Design (& dry excavation)

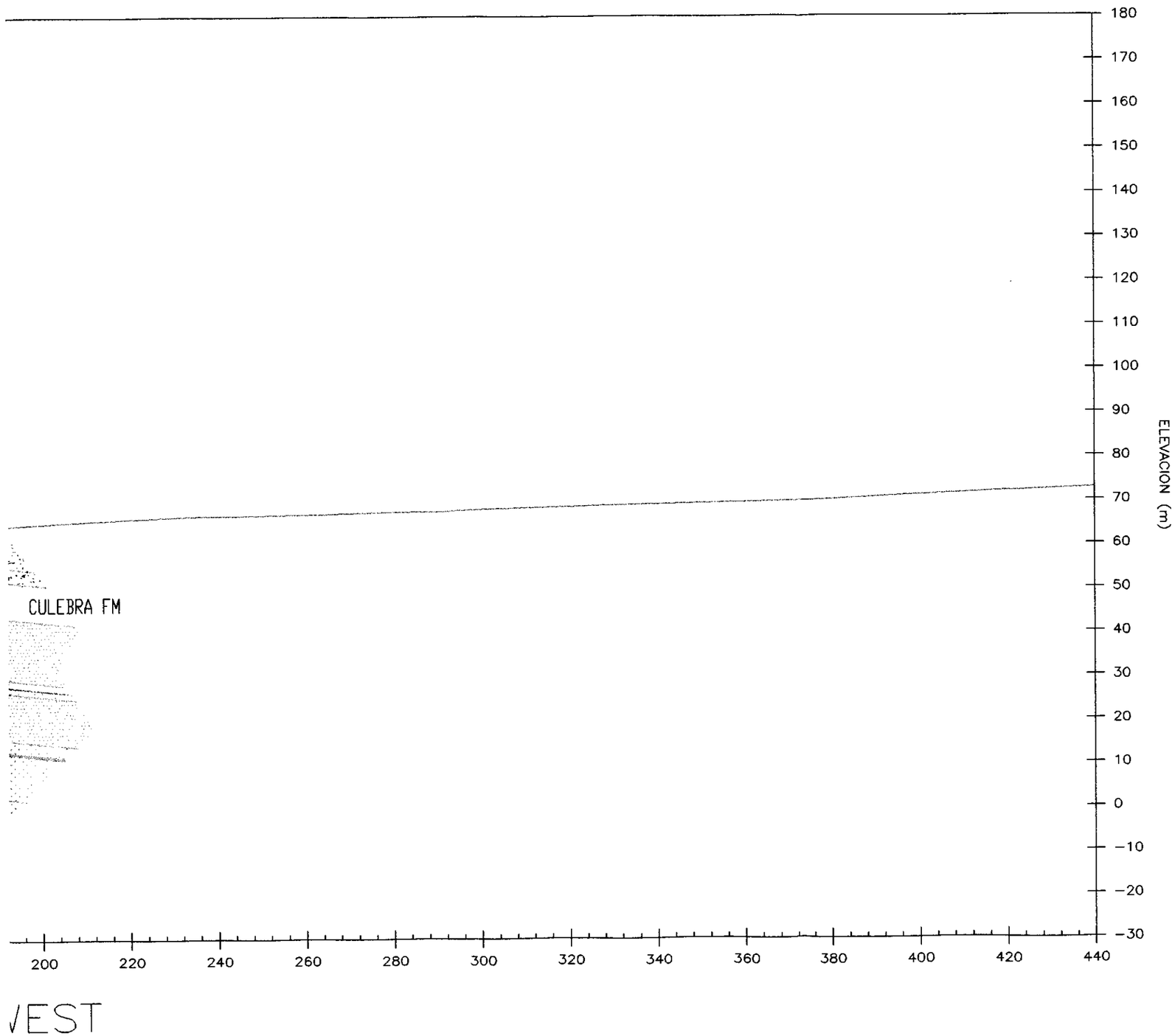


Case 8, Channel bottom = 16 ft, Blasted



Summary, 58k + 120 (1906 + 82)

General Description	Range of stations:	57k + 925 to 58k + 760			
	Sector:	Lirio			
	Maximum height (m):	56			
	Cotangent of slope angle (cot. β):	3.73			
History	Last slide event:	May 22, 2000 (Culebra Village)			
Geology	Formation:	Culebra / Gatuncillo			
	Lithology:	Siltstone / Sandstone / Conglomerate / Shale			
	Critical stratum at toe:	Shale			
	Apparent dip of bedding:	Toward the slope			
Stability Analysis	Critical failure mechanism:	Rotational			
	Shear strength model:	Fully softened Culebra			
		Operative average pore pressure ratio (aproximate), Ru:	Factor of Safety	Relative Factor of Safety	Percentage of Change (%)
	Case 1: Channel bottom = 32 ft	0.372	1.006	1.000	0.00
	Case 2: Channel bottom = 27 ft, Blasted material only		1.005	0.999	-0.10
	Case 3: Channel bottom = 27 ft, Blasted & removed		0.990	0.984	-1.59
	Case 4.1: Channel bottom = 27 ft, Design (underwater slope)		0.980	0.974	-2.58
	Case 4.2: Channel bottom = 27 ft, Design (& dry excavation)	0.363	1.046	1.040	3.98
	Case 5: Channel bottom = 22 ft, Blasted material only		0.989	0.983	-1.69
	Case 6: Channel bottom = 22 ft, Blasted & removed		0.973	0.967	-3.28
	Case 7.1: Channel bottom = 22 ft, Design (underwater slope)		0.957	0.951	-4.87
	Case 7.2: Channel bottom = 22 ft, Design (& dry excavation)	0.368	1.001	0.995	-0.50
	Case 8: Channel bottom = 16 ft, Blasted		0.955	0.949	-5.07
Conclusions:	Stabilization is required for Case 4 and Case 7				



AUTORIDAD DEL CANAL DE PANAMA

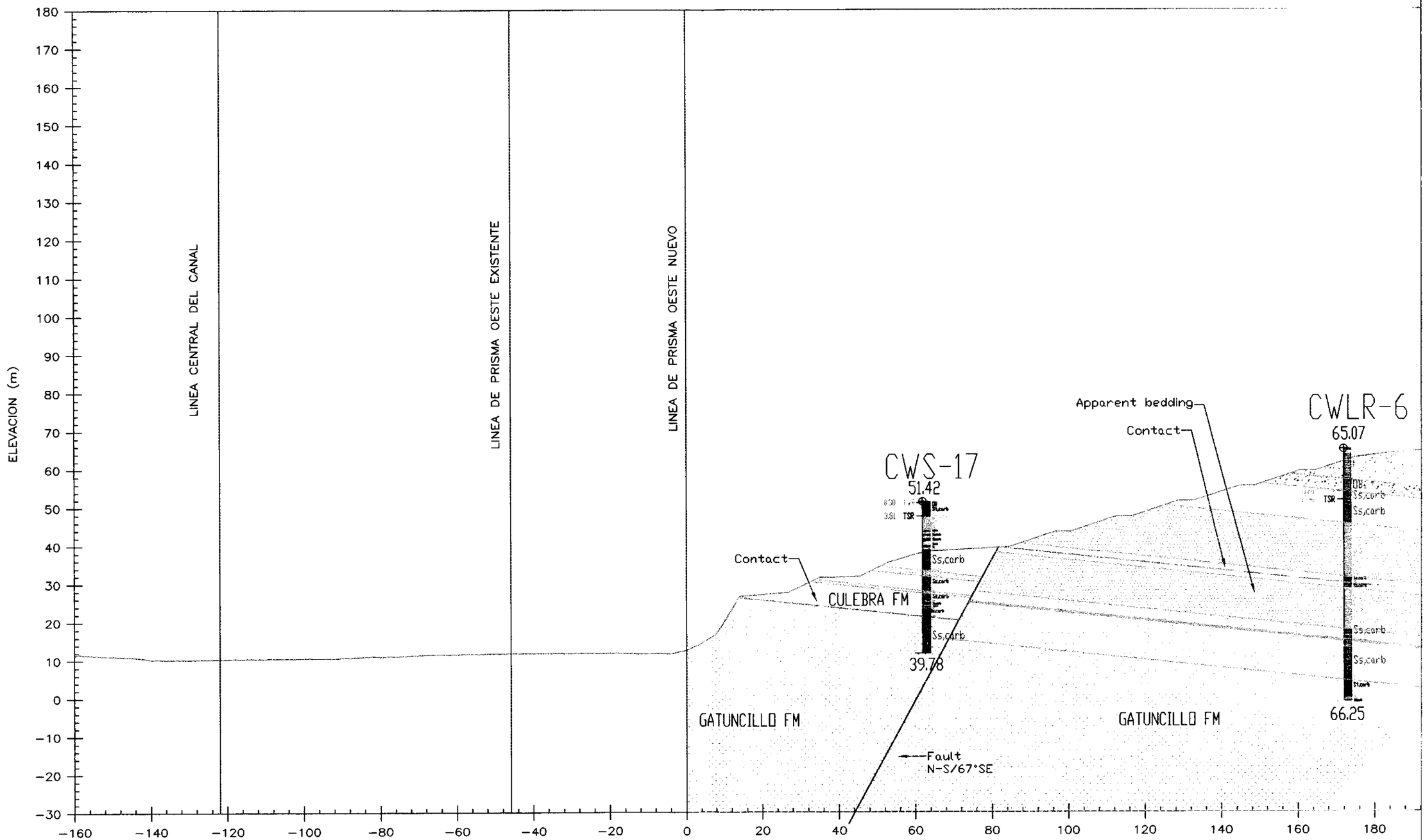
DEPARTAMENTO DE INGENIERIA Y PROYECTOS
DIVISION DE INGENIERIA
ALTOS DE BALBOA, REPUBLICA DE PANAMA

SECCION GEOLOGICA

CORTE GAILLARD

ESTACION 58K+120 (1906+82) OESTE

ESCALA: 1:1000	FECHA: ABRIL 2002
GEOLOGIA POR: J. ARROCHA & P. FRANCESCHI	DIBUJADO POR: J. RAMESCH

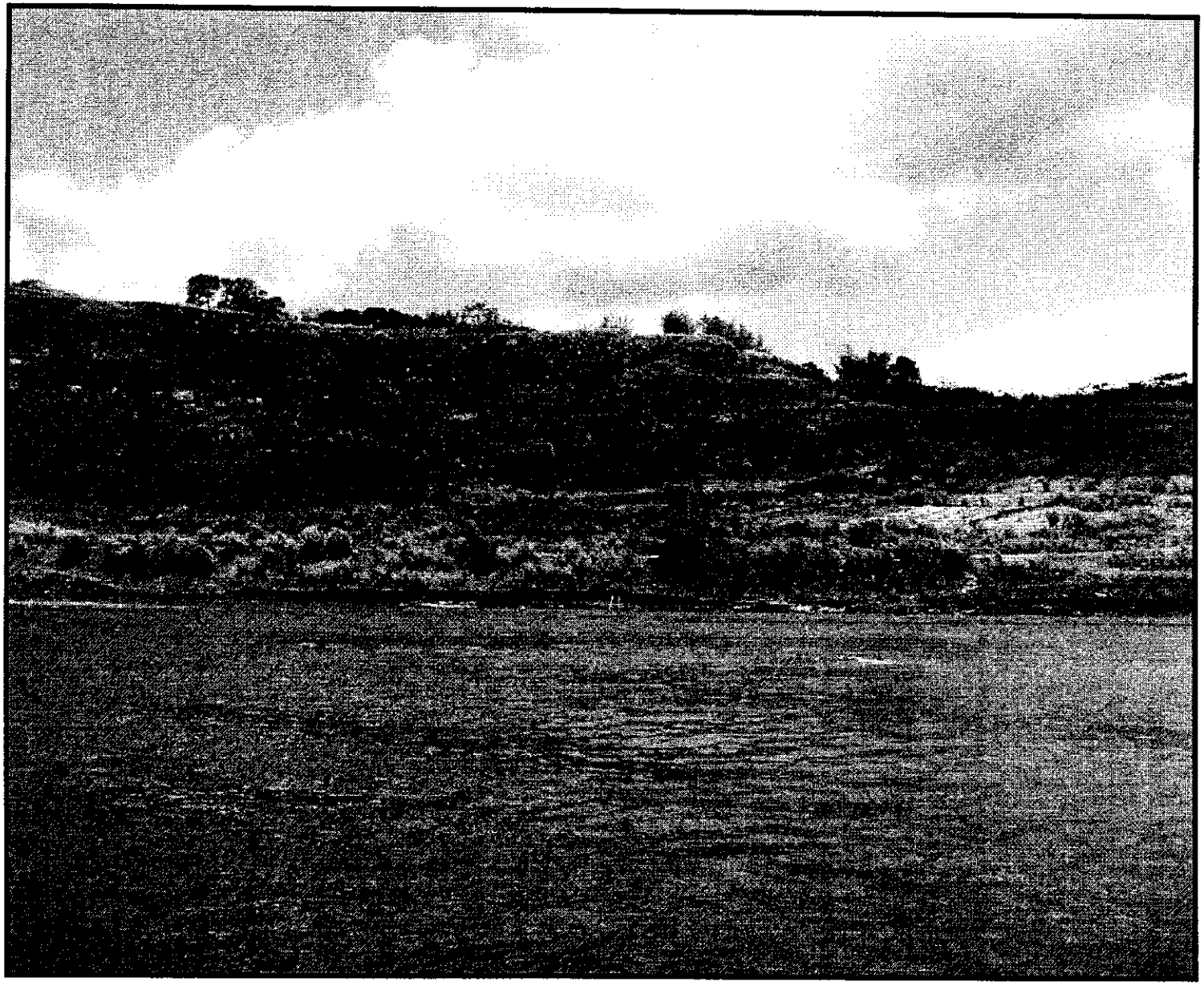

ELEVACION (m)
LINEA CENTRAL DEL CANAL
LINEA DE PRISMA OESTE EXISTENTE
LINEA DE PRISMA OESTE NUEVO
CWS-17
51.42
39.78
CWLR-6
65.07
66.25
Apparent bedding
Contact
Contact
CULEBRA FM
GATUNCILLO FM
GATUNCILLO FM
Fault
N-S/67°SE
Ss,carb
TSR
58K+120 (1906+82) W

station 58k + 887 (1932 + 00)

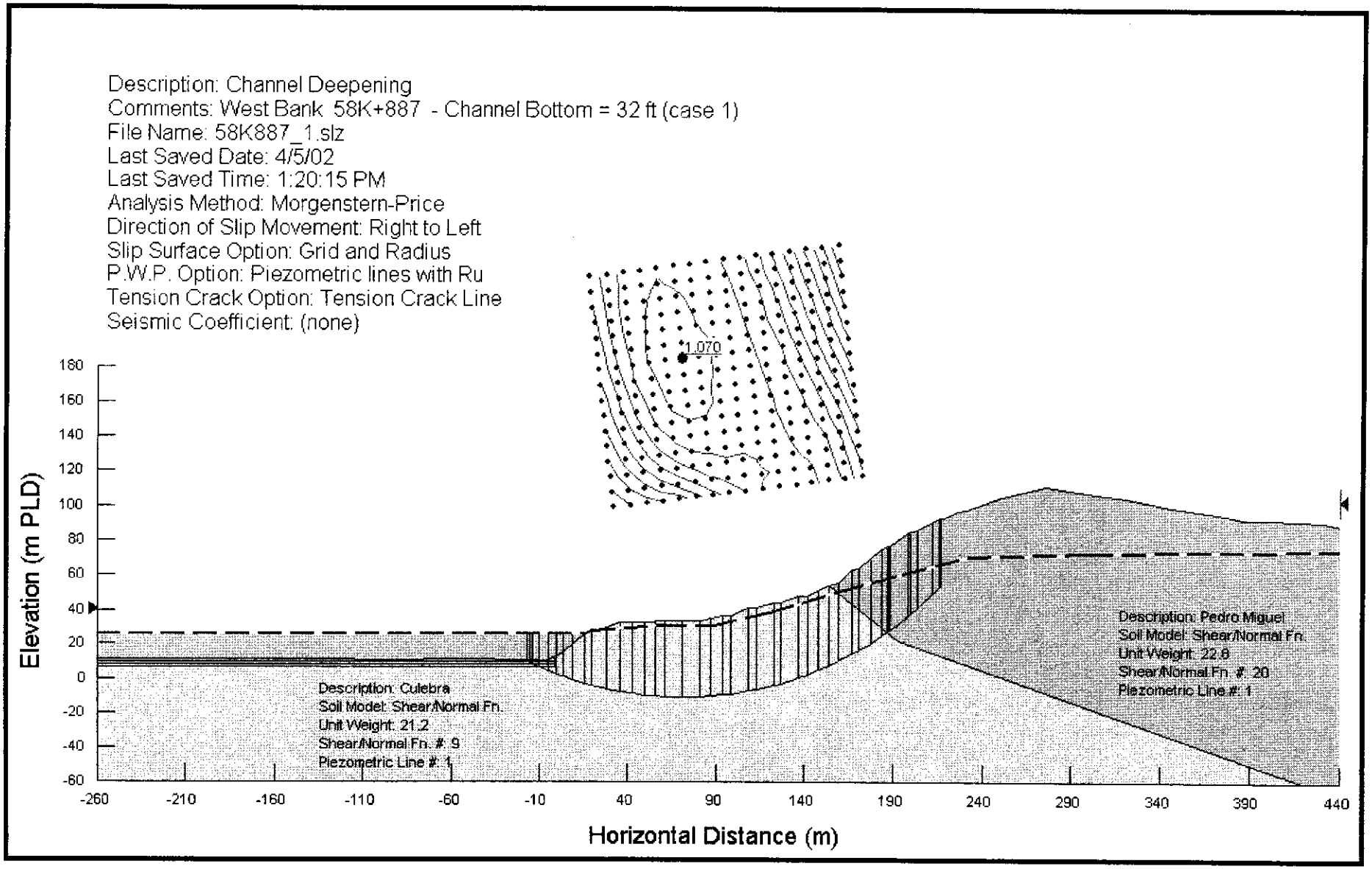
West

Station: 58k + 887 (Hodges)

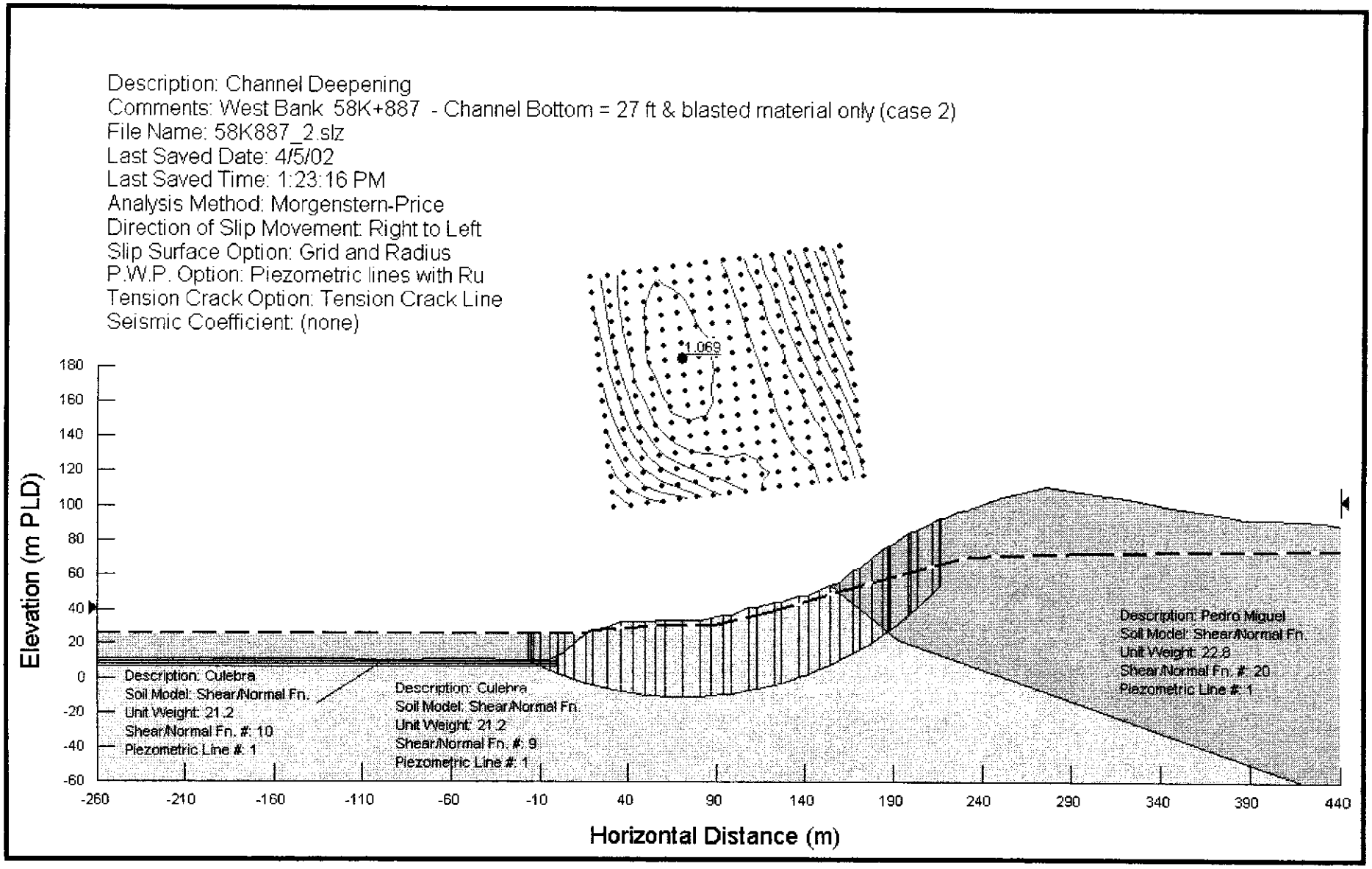
April 16, 2002



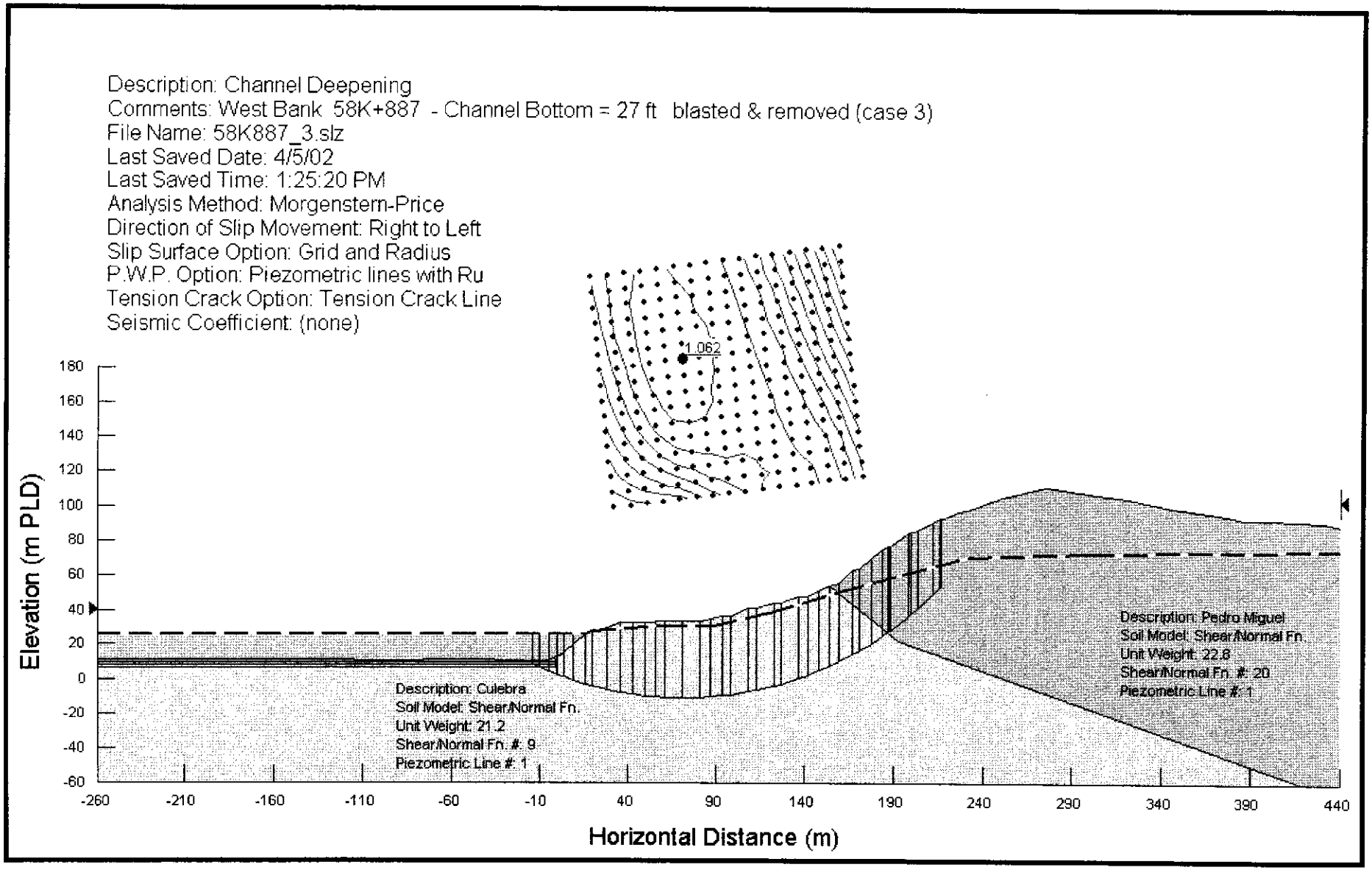
Case 1, Channel bottom = 32 ft



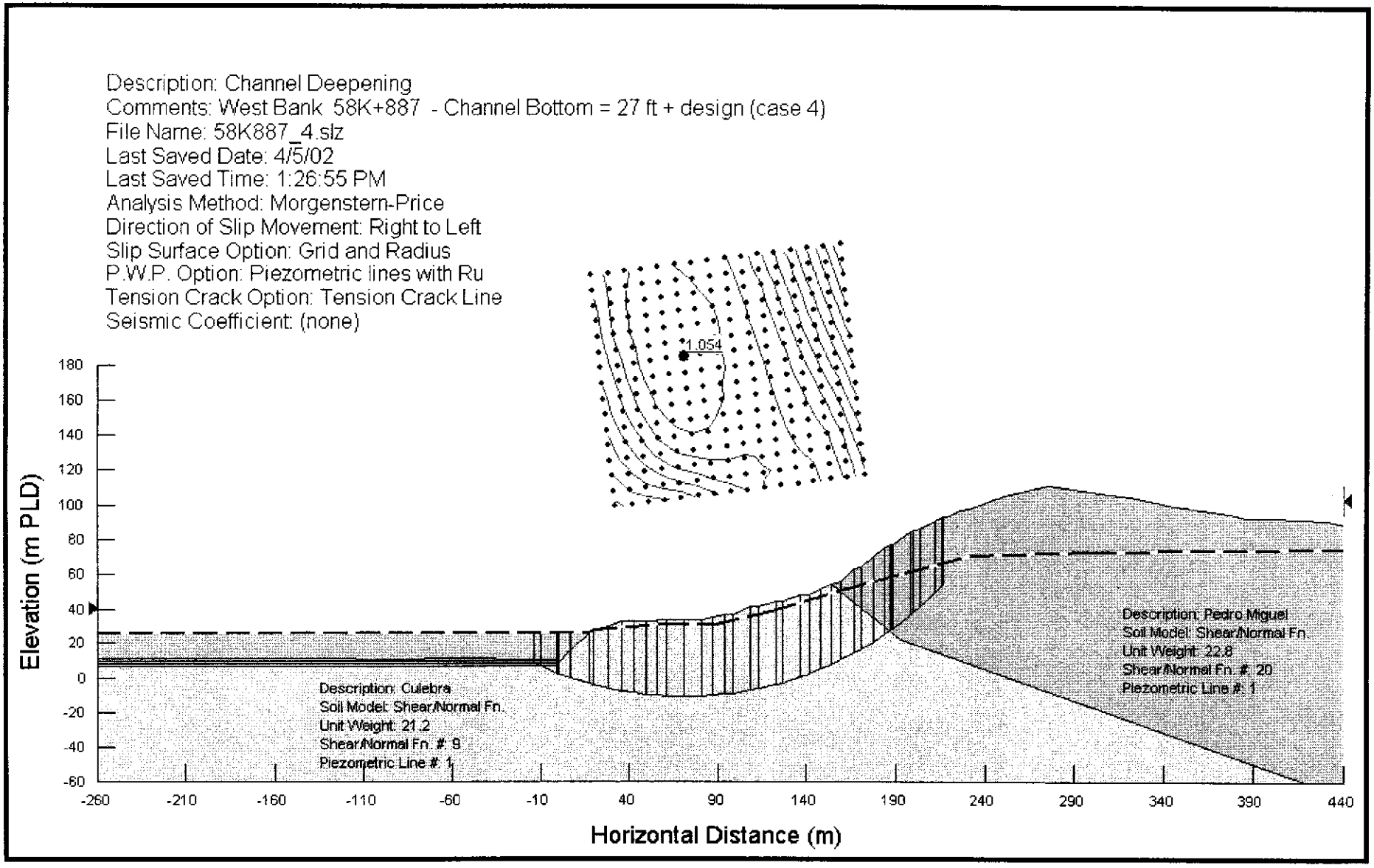
Case 2, Channel bottom = 27 ft, Blasted material only



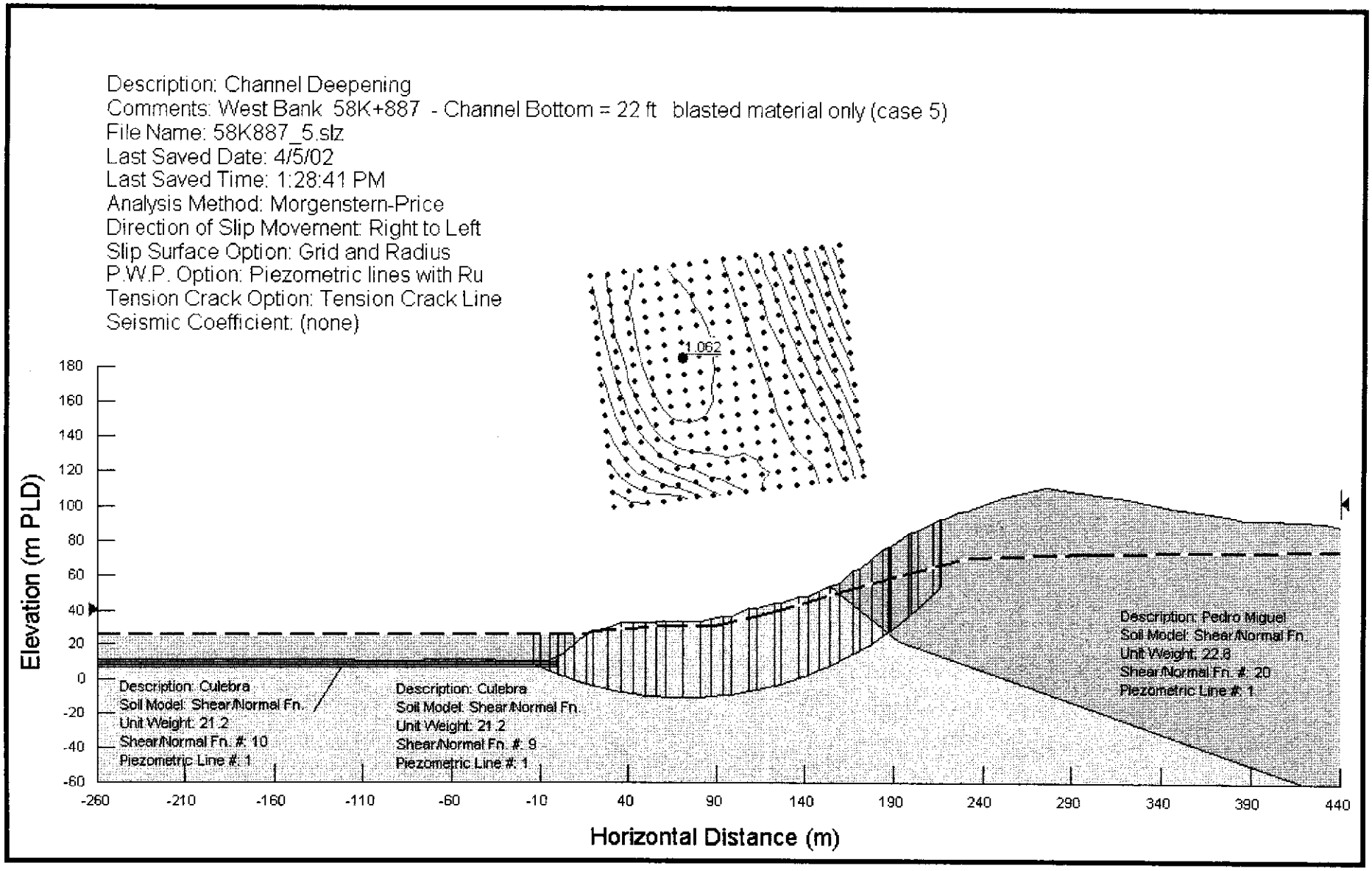
Case 3, Channel bottom = 27 ft, Blasted & removed



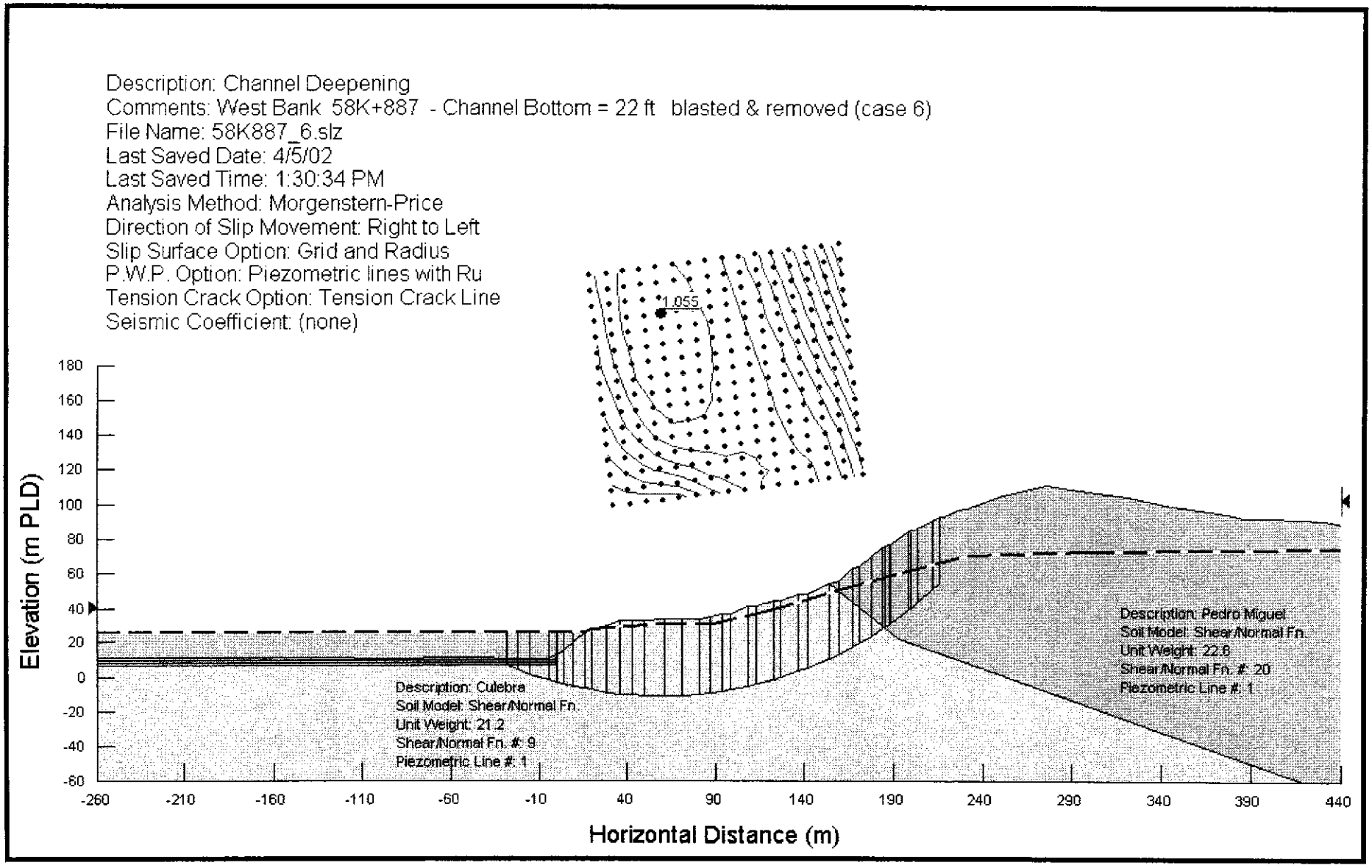
Case 4, Channel bottom = 27 ft, Design (underwater slope)



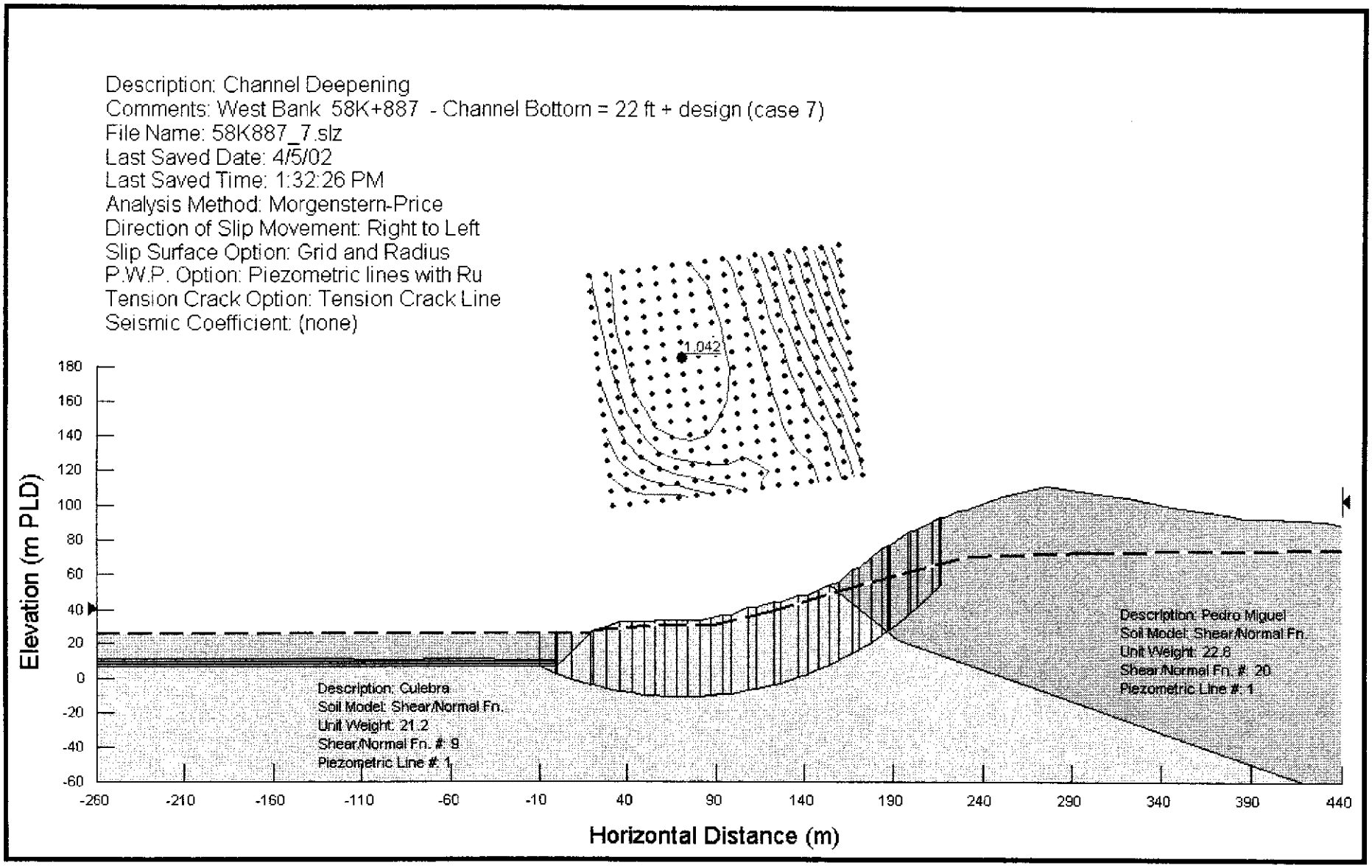
Case 5, Channel bottom = 22 ft, Blasted material only



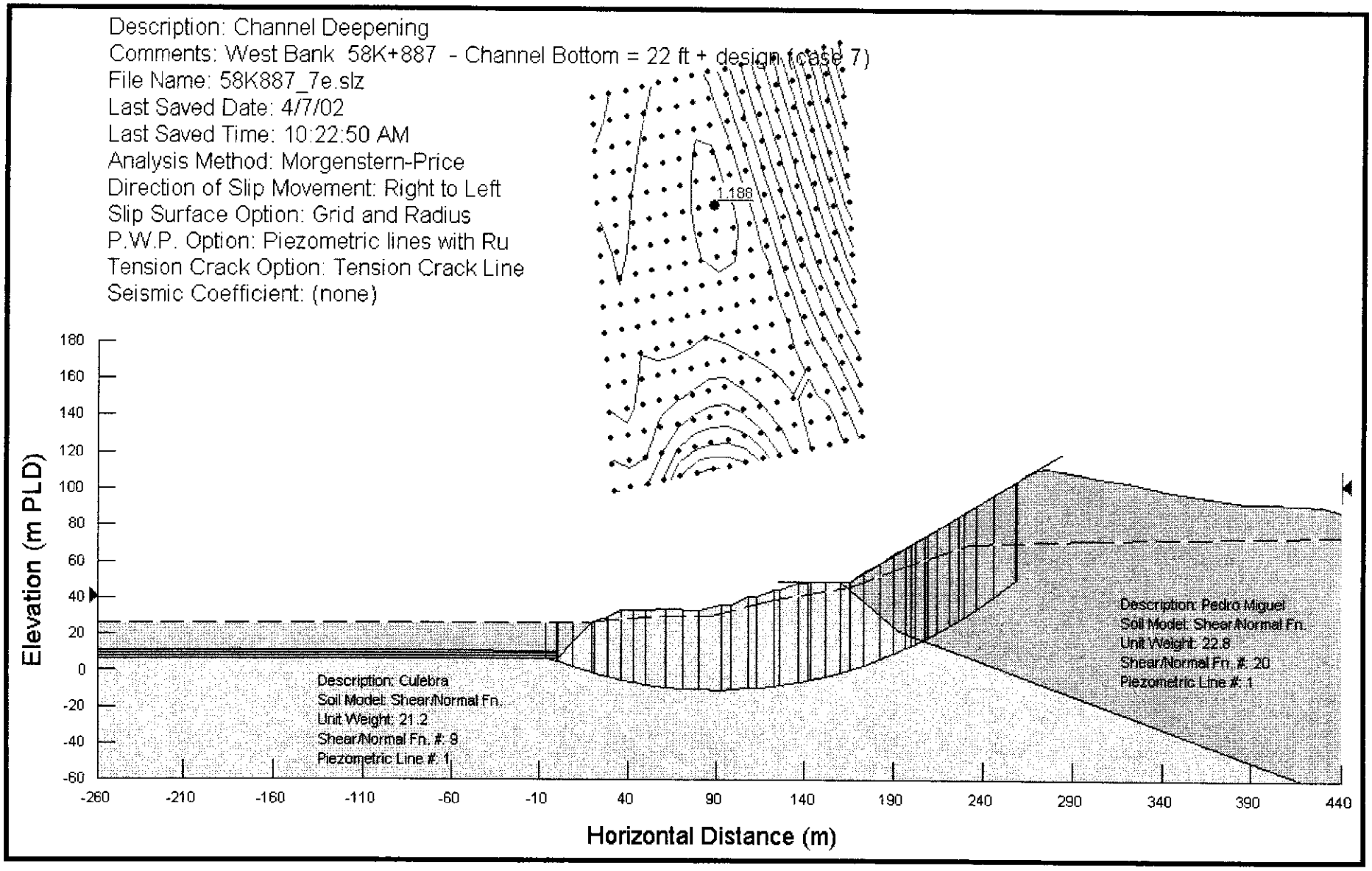
Case 6, Channel bottom = 22 ft, Blasted & removed



Case 7.1, Channel bottom = 27 ft, Design (underwater slope)

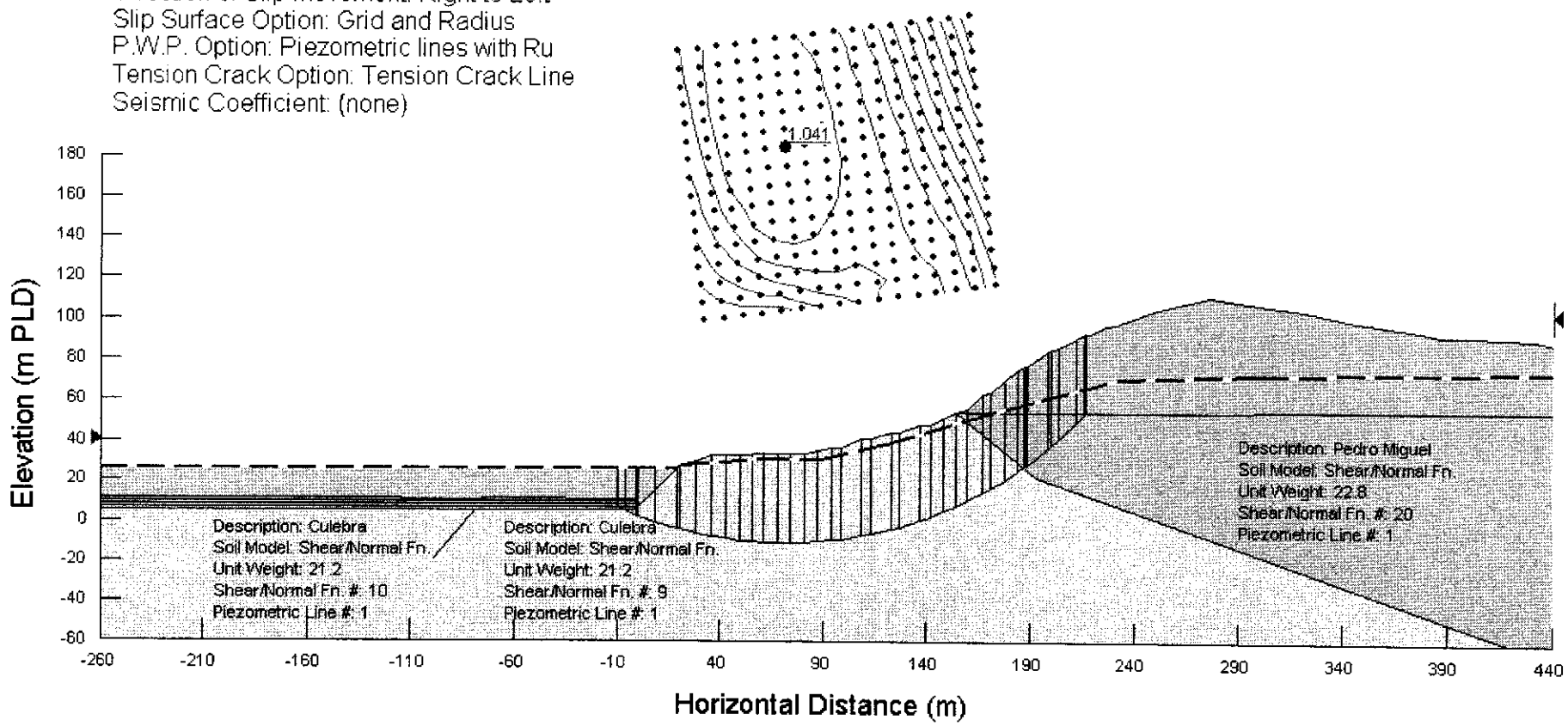


Case 7.2, Channel bottom = 27 ft, Design (& dry excavation)



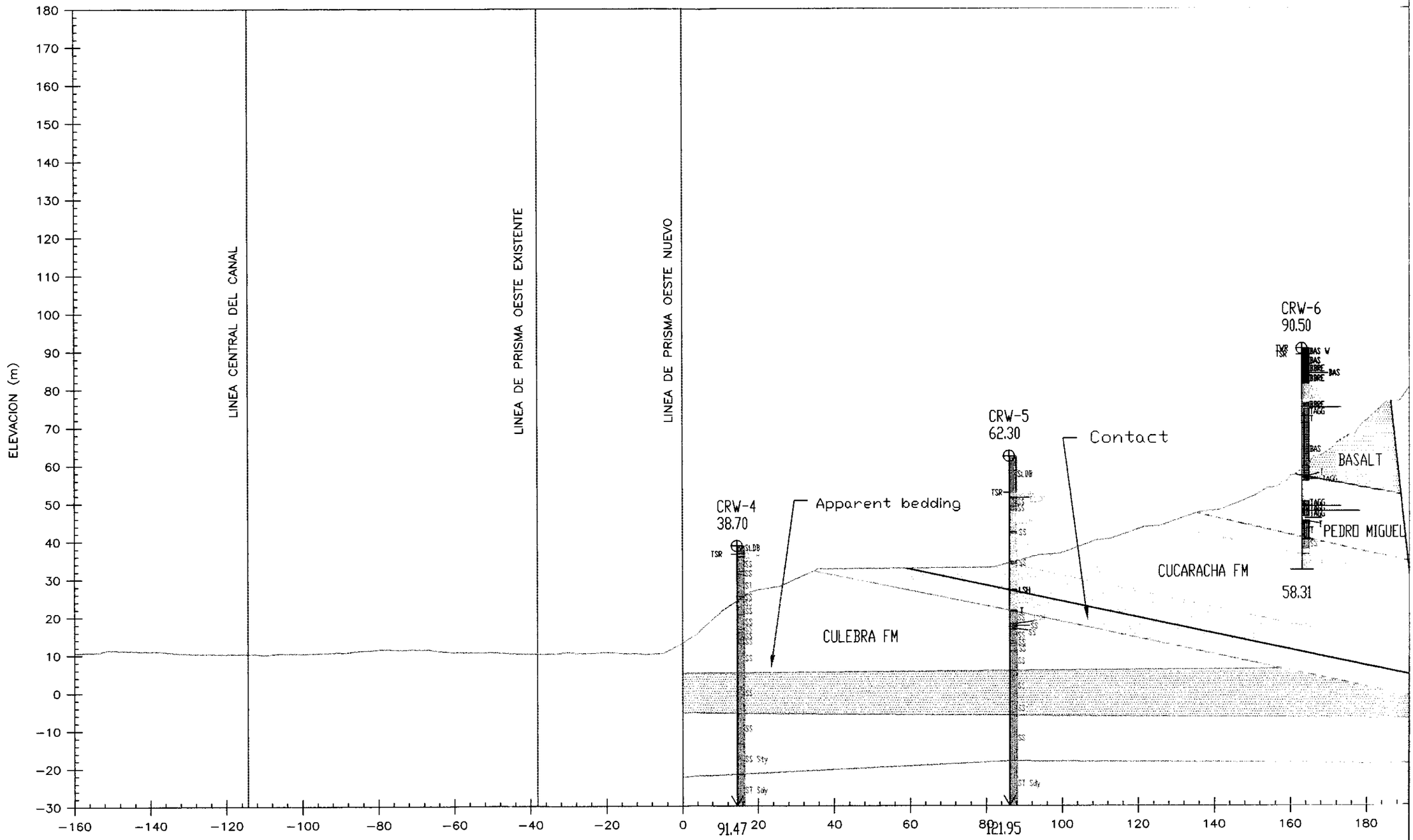
Case 8, Channel bottom = 16 ft, Blasted

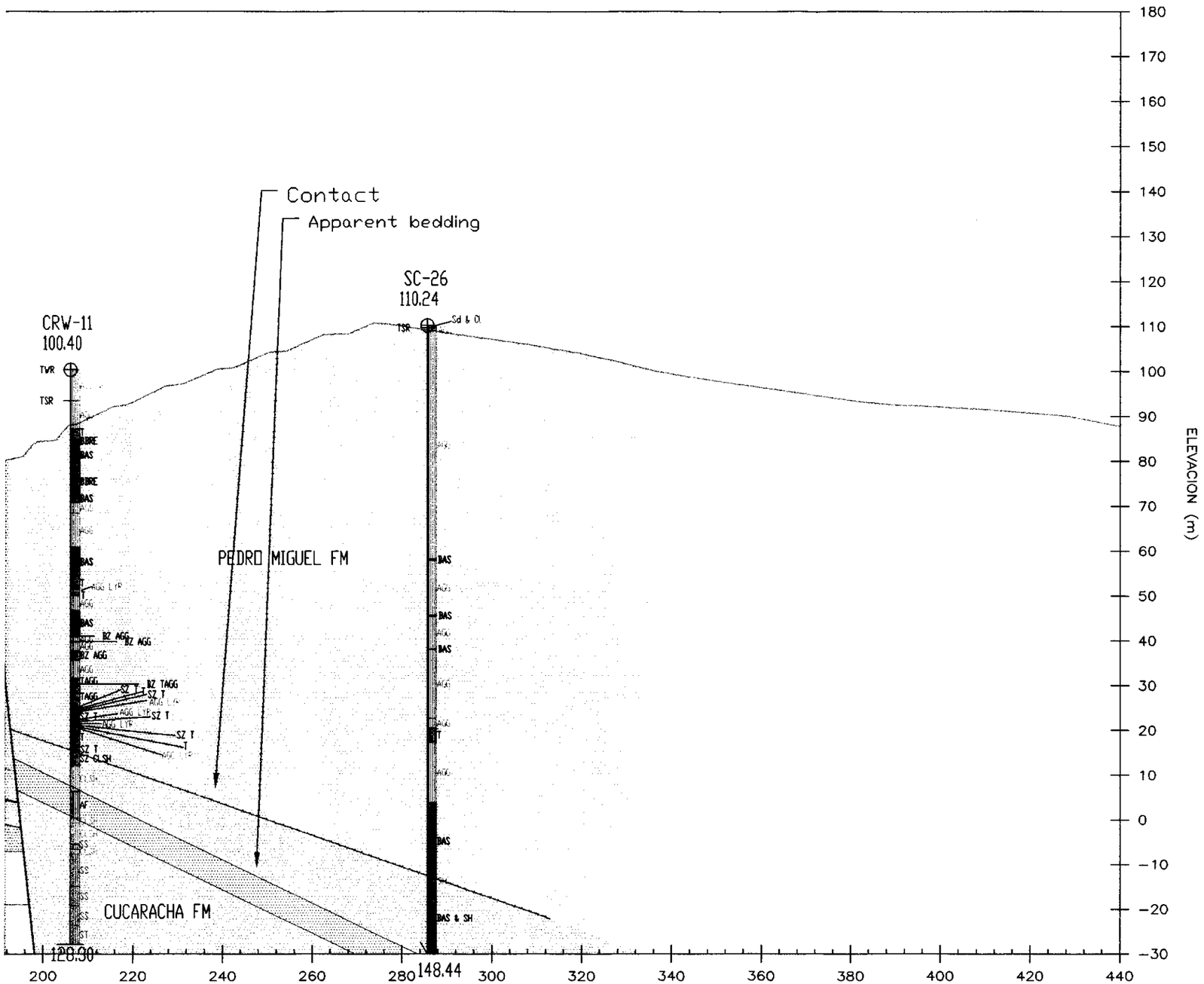
Description: Channel Deepening
Comments: West Bank 58K+887 - Channel Bottom = 22 ft + design + blasted 16 ft (case 8)
File Name: 58K887_8.slz
Last Saved Date: 4/7/02
Last Saved Time: 2:46:51 PM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: Tension Crack Line
Seismic Coefficient: (none)



Summary, 58k + 887 (1932 + 00)

General Description	Range of stations:	58k + 760 to 59k + 000			
	Sector:	Hodges			
	Maximum height (m):	101			
	Cotangent of slope angle (cot. β):	2.9			
History	Last slide event:	July 28, 1997 (Hodges Hill Slide)			
Geology	Formation:	Culebra / Cucaracha / Basalt / Pedro Miguel			
	Lithology:	Agglomerate / Basalt / Siltstone / Sandstone / Clayshale			
	Critical stratum at toe:	Carbonaceous Siltstone / SAndstone			
	Apparent dip of bedding:	Toward the slope, but very gently			
Stability Analysis	Critical failure mechanism:	Rotational and Tension crack			
	Shear strength model:	Fully softened Culebra / First time Pedro Miguel Agglomerate			
		Operative average pore pressure ratio (aproximate), Ru:	Factor of Safety	Relative Factor of Safety	Percentage of Change (%)
	Case 1: Channel bottom = 32 ft	0.384	1.070	1.000	0.00
	Case 2: Channel bottom = 27 ft, Blasted material only		1.069	0.999	-0.09
	Case 3: Channel bottom = 27 ft, Blasted & removed		1.062	0.993	-0.75
	Case 4.1: Channel bottom = 27 ft, Design (underwater slope)		1.054	0.985	-1.50
	Case 4.2: Channel bottom = 27 ft, Design (& dry excavation)	0.384	1.054	0.985	-1.50
	Case 5: Channel bottom = 22 ft, Blasted material only		1.062	0.993	-0.75
	Case 6: Channel bottom = 22 ft, Blasted & removed		1.055	0.986	-1.40
	Case 7.1: Channel bottom = 22 ft, Design (underwater slope)		1.042	0.974	-2.62
	Case 7.2: Channel bottom = 22 ft, Design (& dry excavation)	0.385	1.188	1.110	11.03
	Case 8: Channel bottom = 16 ft, Blasted		1.041	0.973	-2.71
Conclusions:	Stabilization is required for Case 7				


ELEVACION (m)
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-160
-140
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
120
140
160
180
LINEA CENTRAL DEL CANAL
LINEA DE PRISMA OESTE EXISTENTE
LINEA DE PRISMA OESTE NUEVO
CRW-4
38.70
CRW-5
62.30
CRW-6
90.50
Apparent bedding
Contact
BASALT
PEDRO MIGUEL
CUCARACHA FM
CULEBRA FM
58.31
91.47
121.95
58K+887 (1932+00)



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DEPARTAMENTO DE INGENIERIA Y PROYECTOS
DIVISION DE INGENIERIA
ALTOS DE BALBOA, REPUBLICA DE PANAMA

SECCION GEOLOGICA

CORTE GAILLARD

ESTACION 58K+887 (1932+00) OESTE

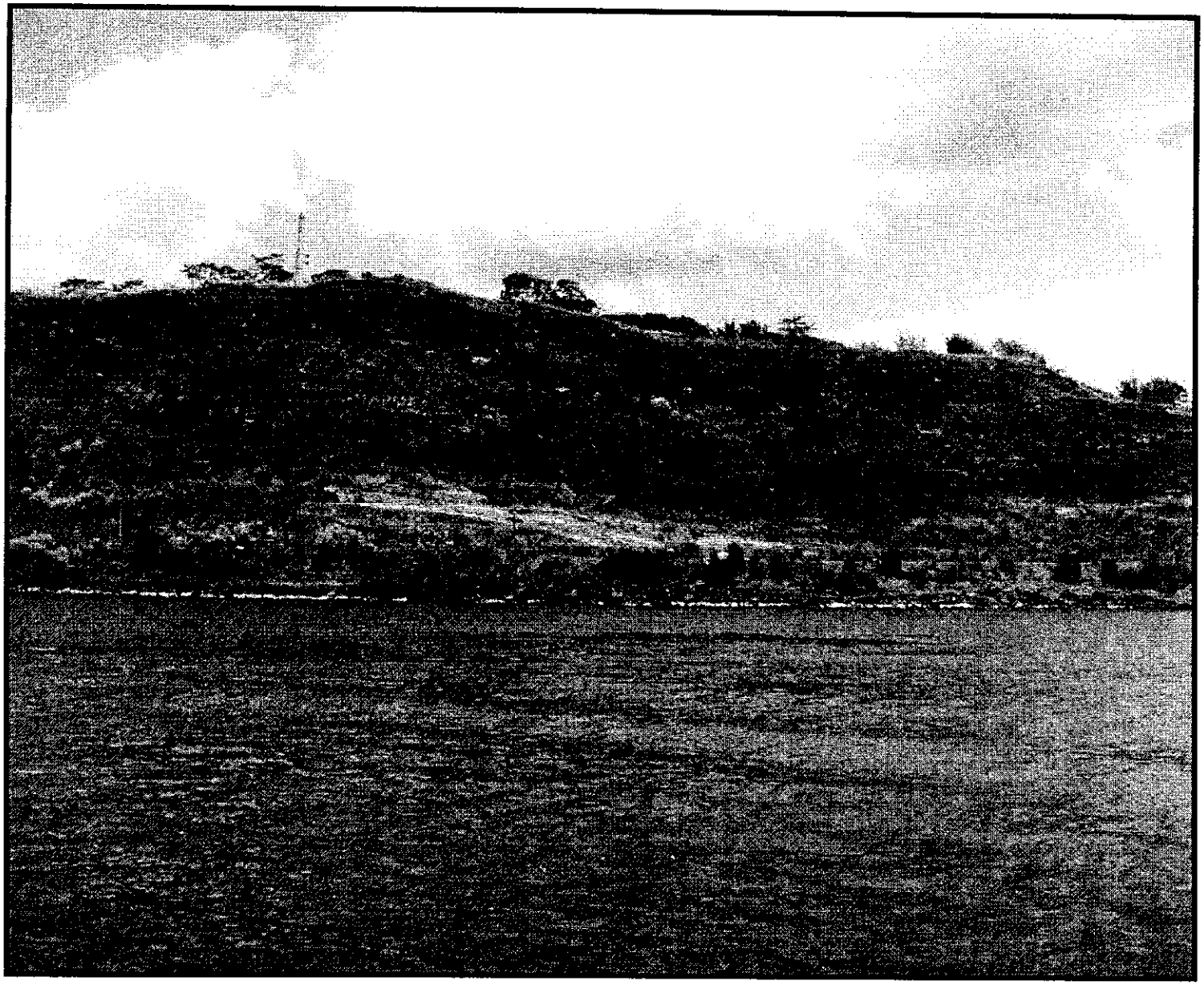
ESCALA: 1:1000	FECHA: ABRIL 2002
GEOLOGIA POR: M. DE PUY	DIBUJADO POR: J. RAMESCH

station 59k + 070 (1938 + 00)

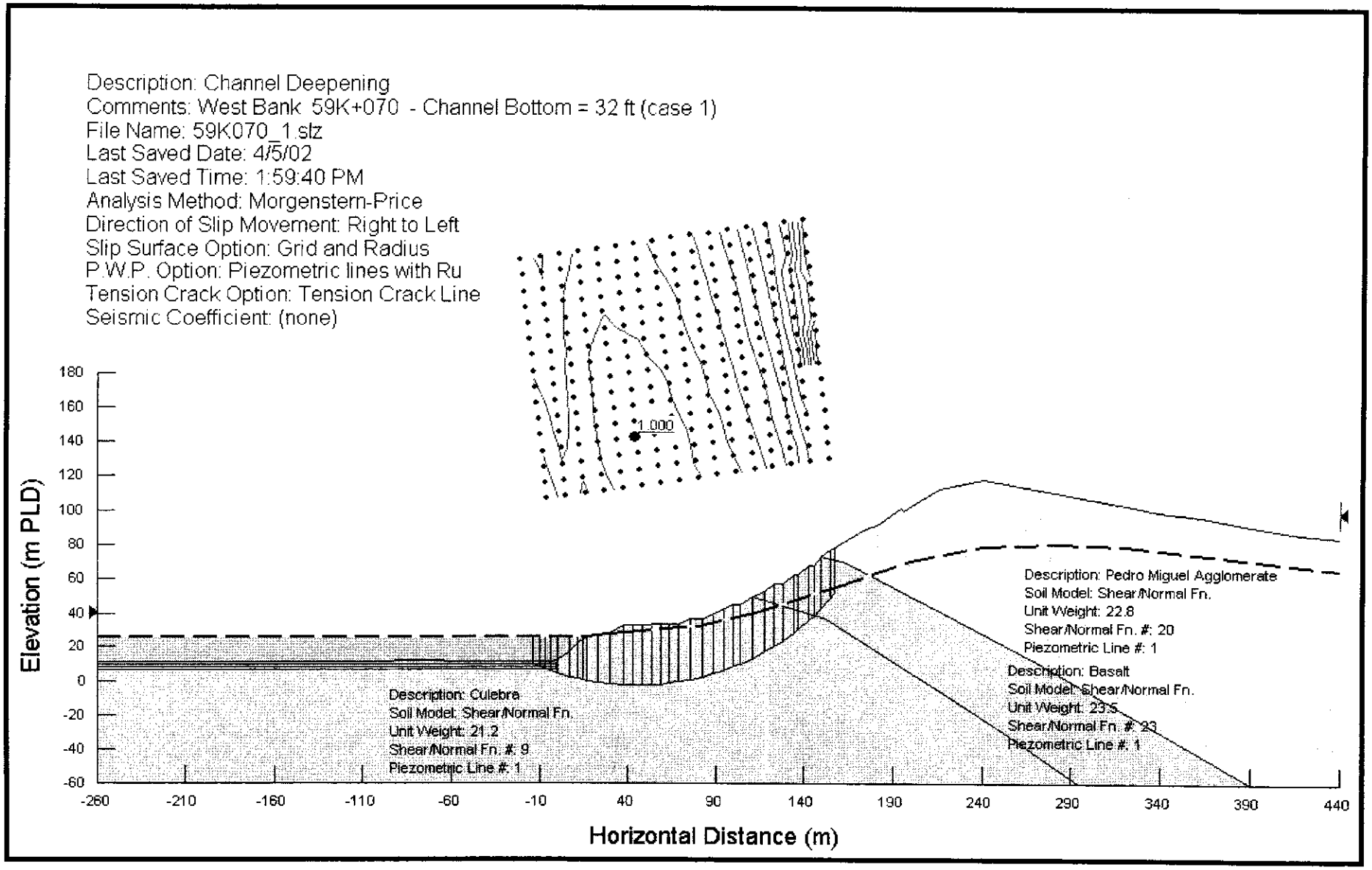
West

Station: 59k + 070 (Hodges)

April 16, 2002

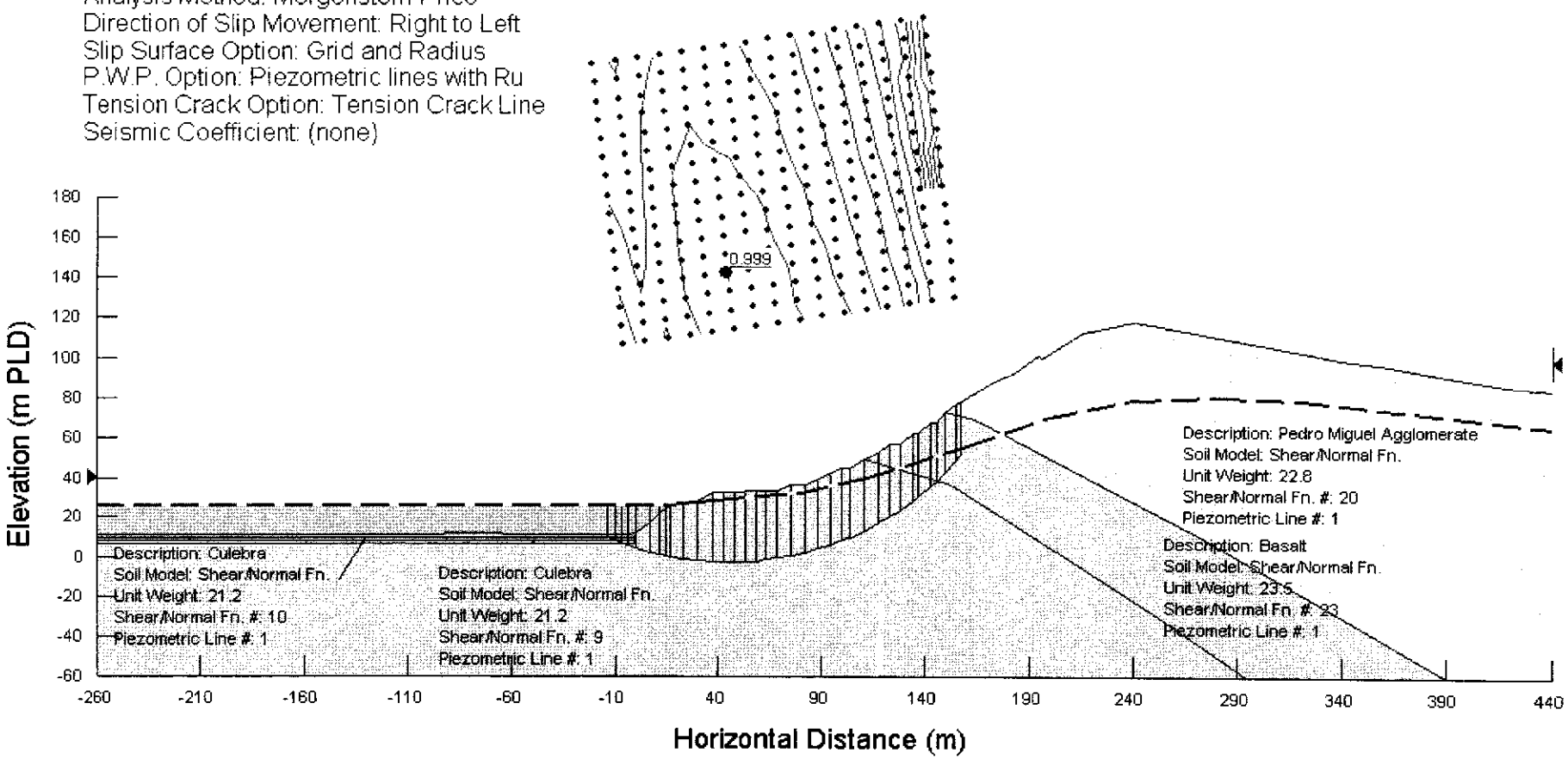


Case 1, Channel bottom = 32 ft

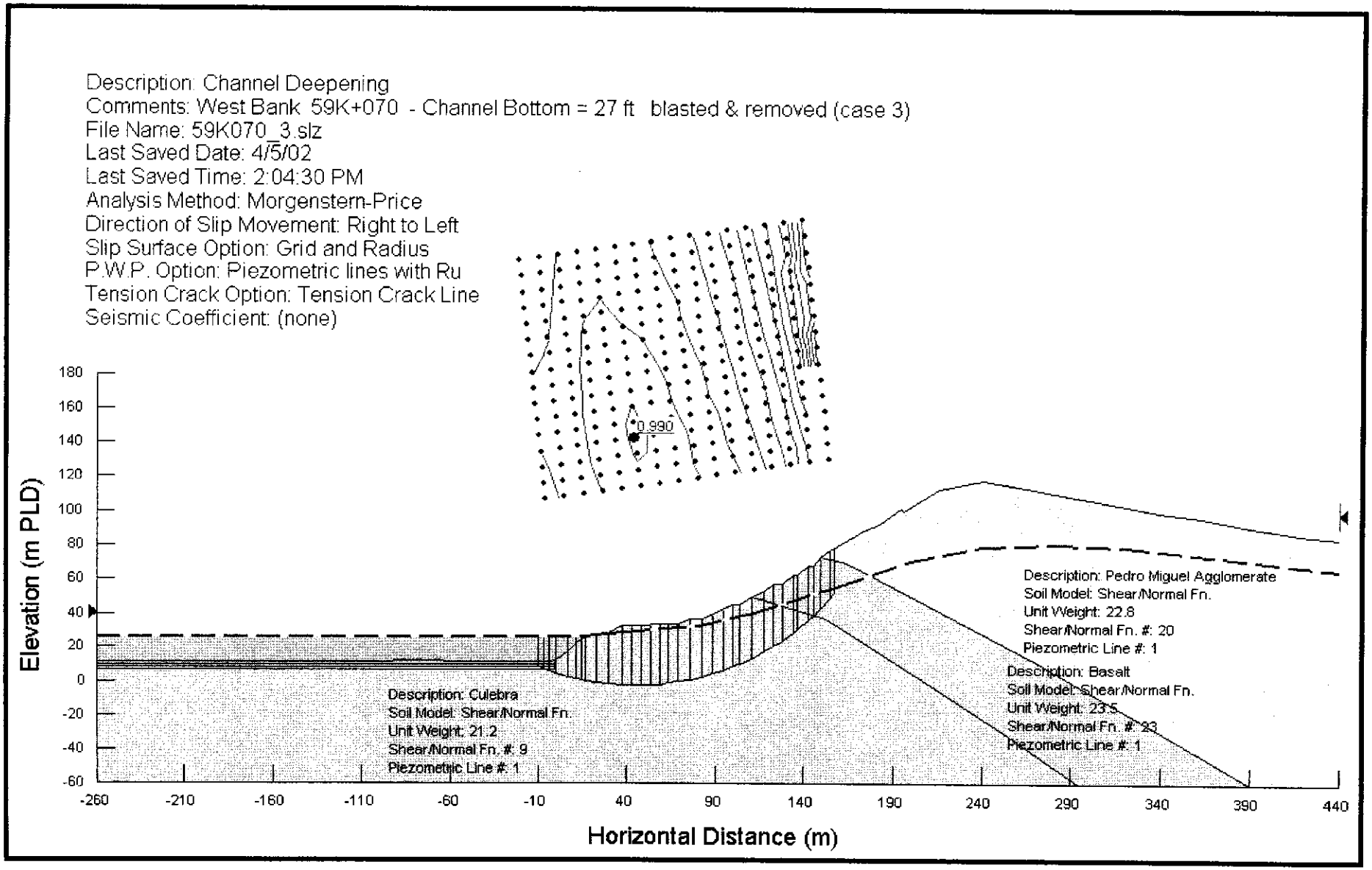


Case 2, Channel bottom = 27 ft, Blasted material only

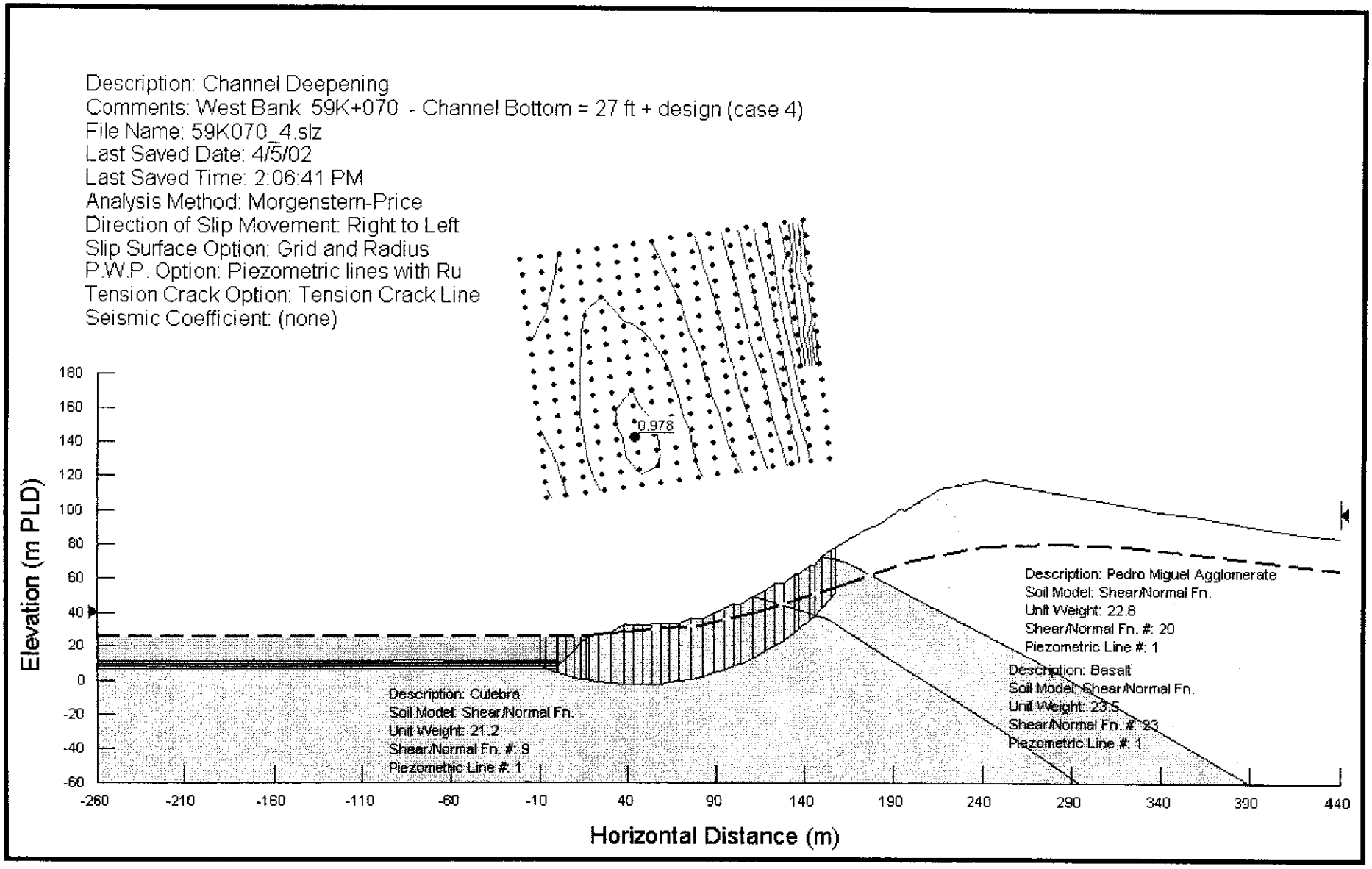
Description: Channel Deepening
Comments: West Bank 59K+070 - Channel Bottom = 27 ft & blasted material only (case 2)
File Name: 59K070_2.slz
Last Saved Date: 4/5/02
Last Saved Time: 2:02:02 PM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: Tension Crack Line
Seismic Coefficient: (none)



Case 3, Channel bottom = 27 ft, Blasted & removed

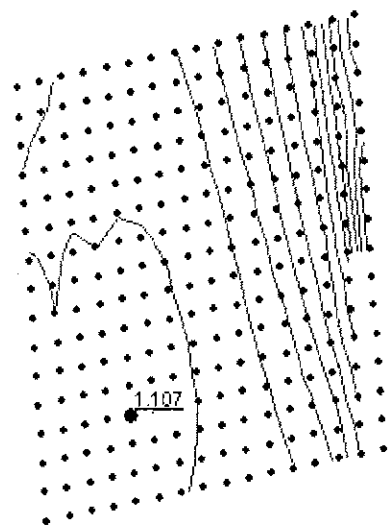


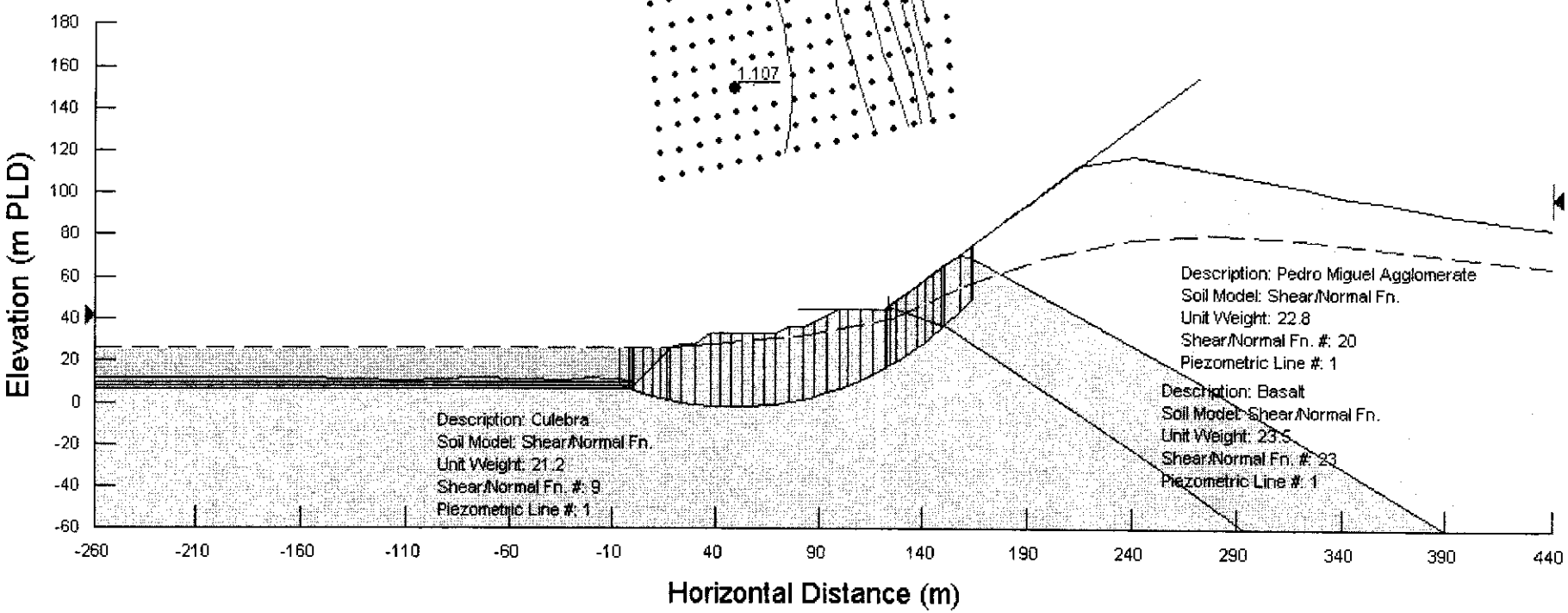
Case 4.1, Channel bottom = 27 ft, Design (underwater slope)



Case 4.2, Channel bottom = 27 ft, Design (& dry excavation)

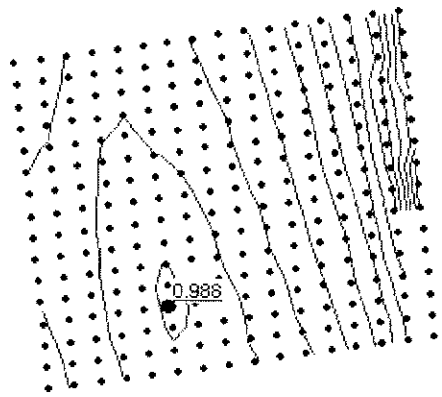
Description: Channel Deepening
Comments: West Bank 59K+070 - Channel Bottom = 27 ft + design (case 4)
File Name: 59K070_4e.slz
Last Saved Date: 4/7/02
Last Saved Time: 11:34:04 AM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: Tension Crack Line
Seismic Coefficient: (none)

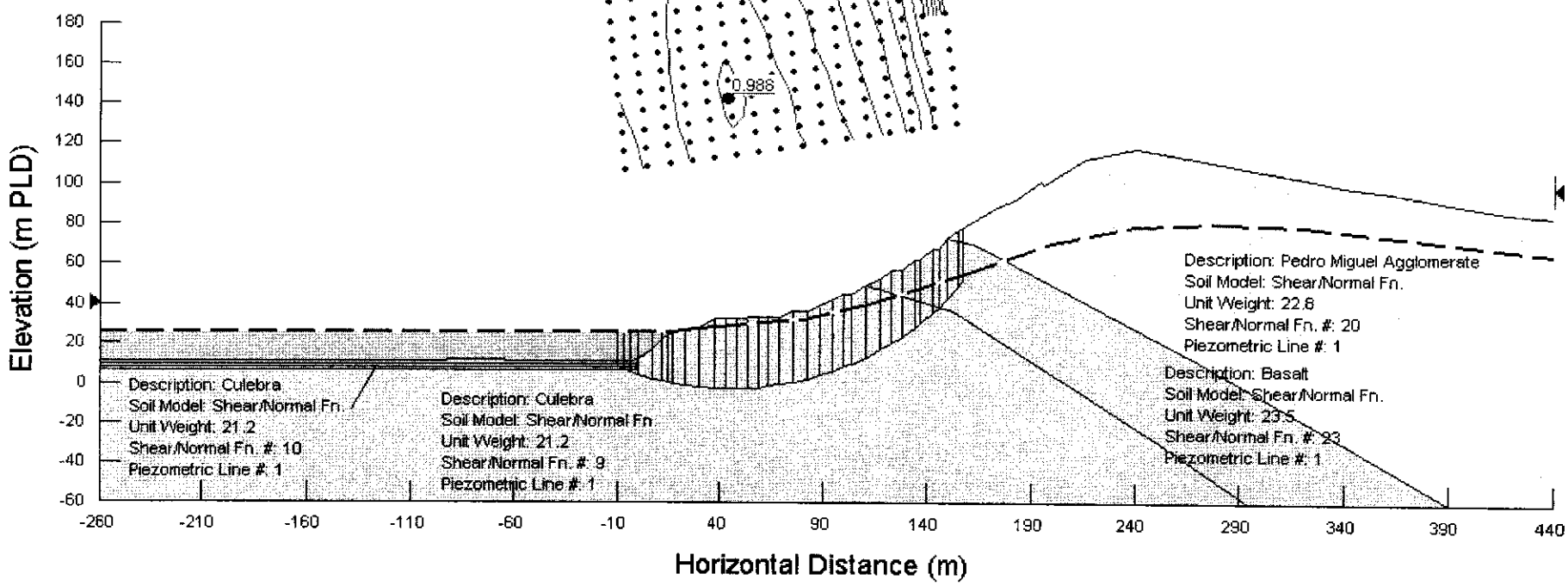




Case 5, Channel bottom = 22 ft, Blasted material only

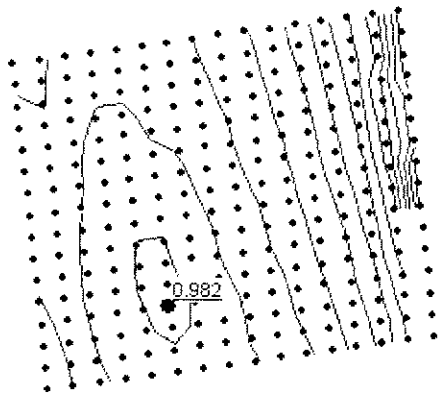
Description: Channel Deepening
Comments: West Bank 59K+070 - Channel Bottom = 22 ft blasted material only (case 5)
File Name: 59K070_5.slz
Last Saved Date: 4/5/02
Last Saved Time: 2:10:34 PM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: Tension Crack Line
Seismic Coefficient: (none)

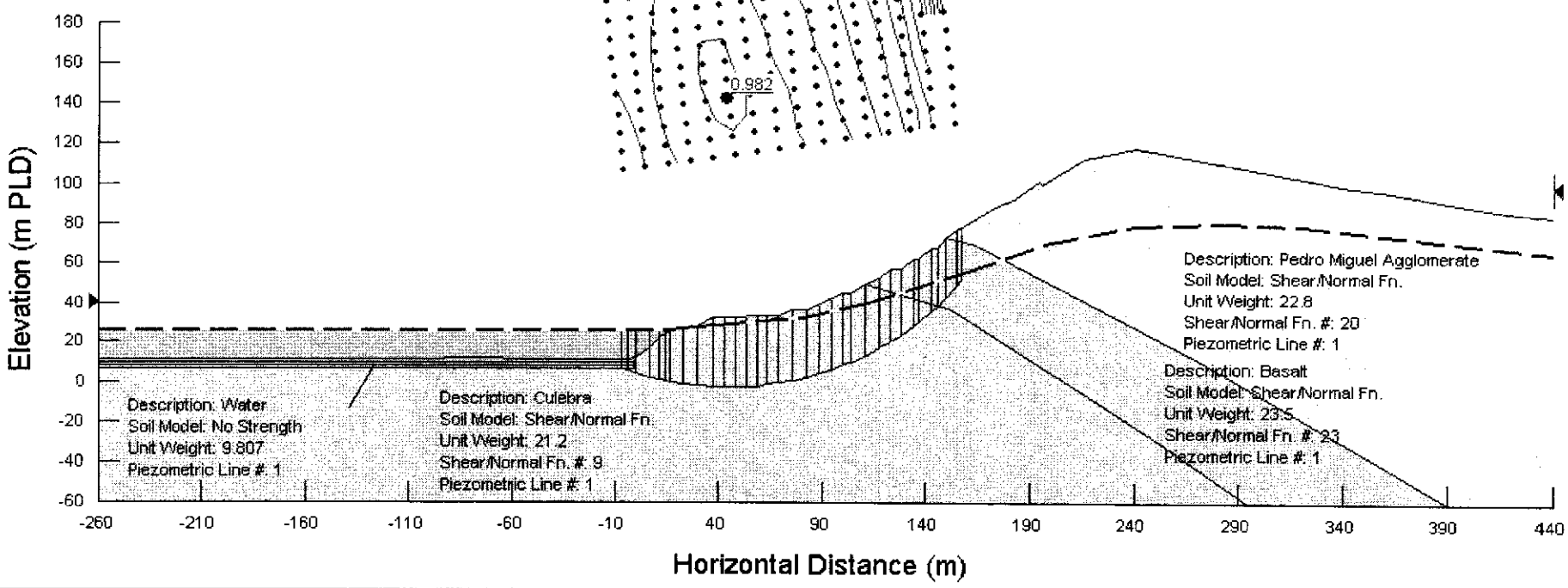




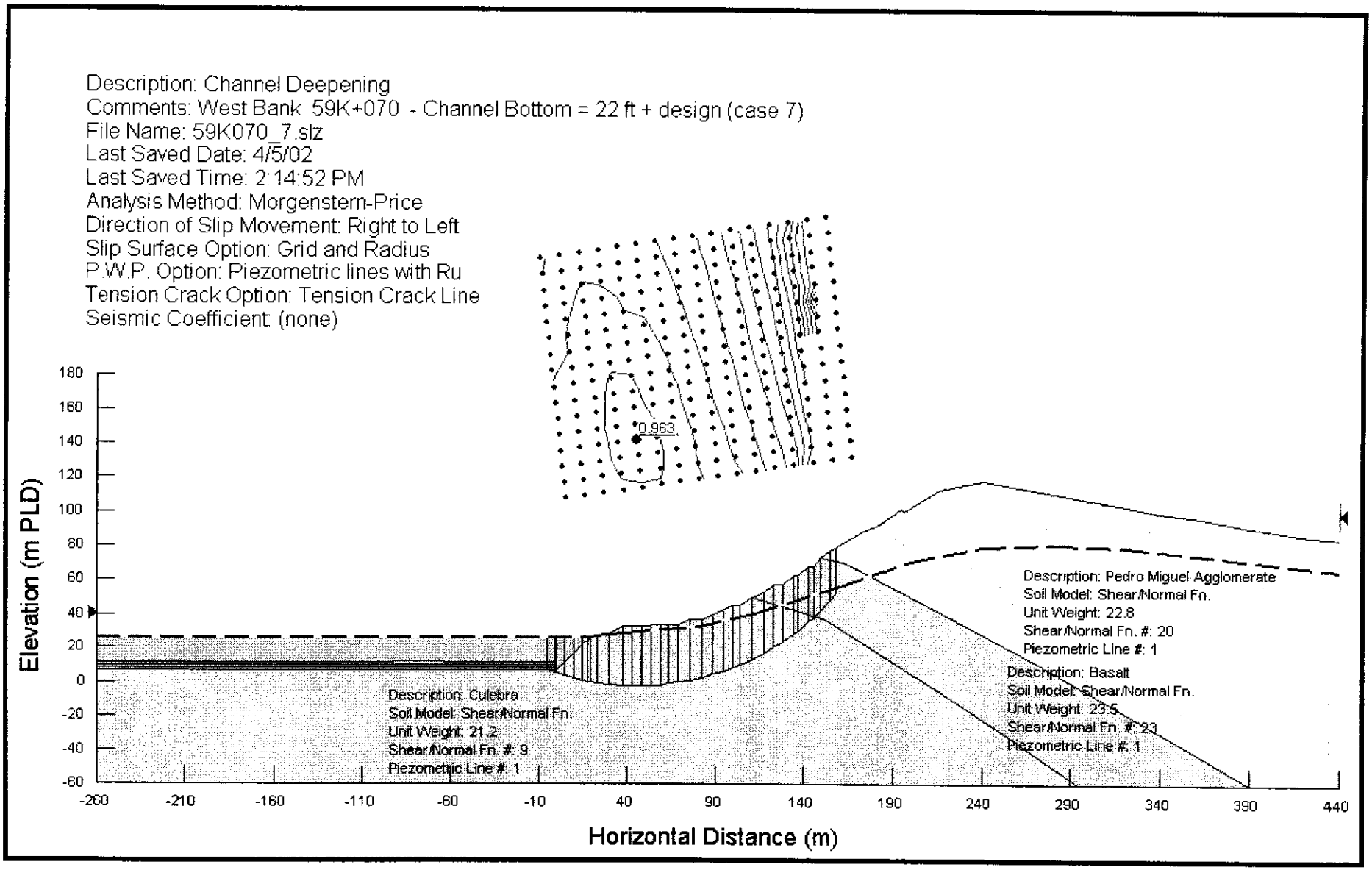
Case 6, Channel bottom = 22 ft, Blasted & removed

Description: Channel Deepening
Comments: West Bank 59K+070 - Channel Bottom = 22 ft blasted & removed (case 6)
File Name: 59K070_6.slz
Last Saved Date: 4/5/02
Last Saved Time: 2:12:23 PM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: Tension Crack Line
Seismic Coefficient: (none)

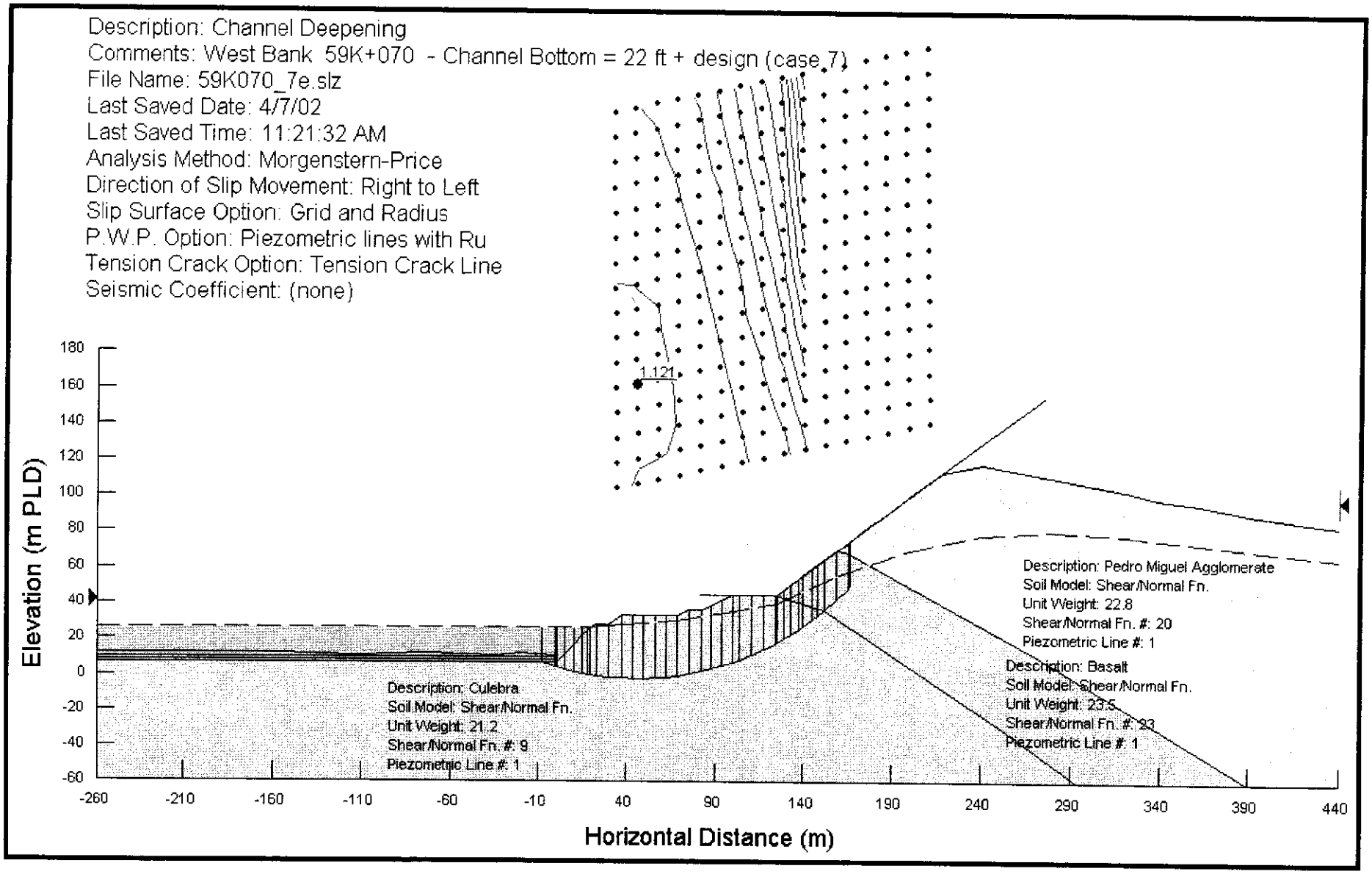




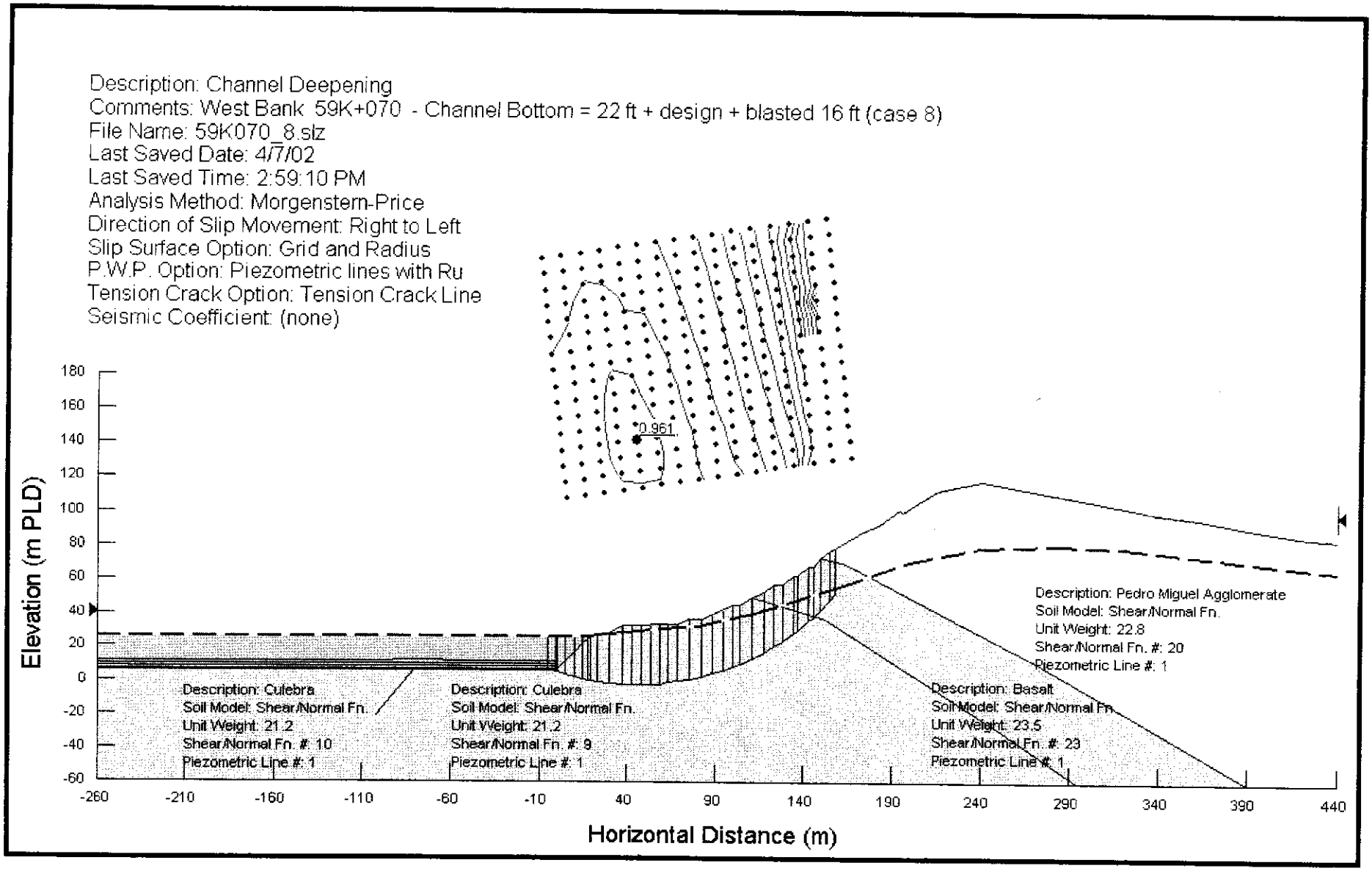
Case 7.1, Channel bottom = 27 ft, Design (underwater slope)



Case 7.2, Channel bottom = 27 ft, Design (& dry excavation)

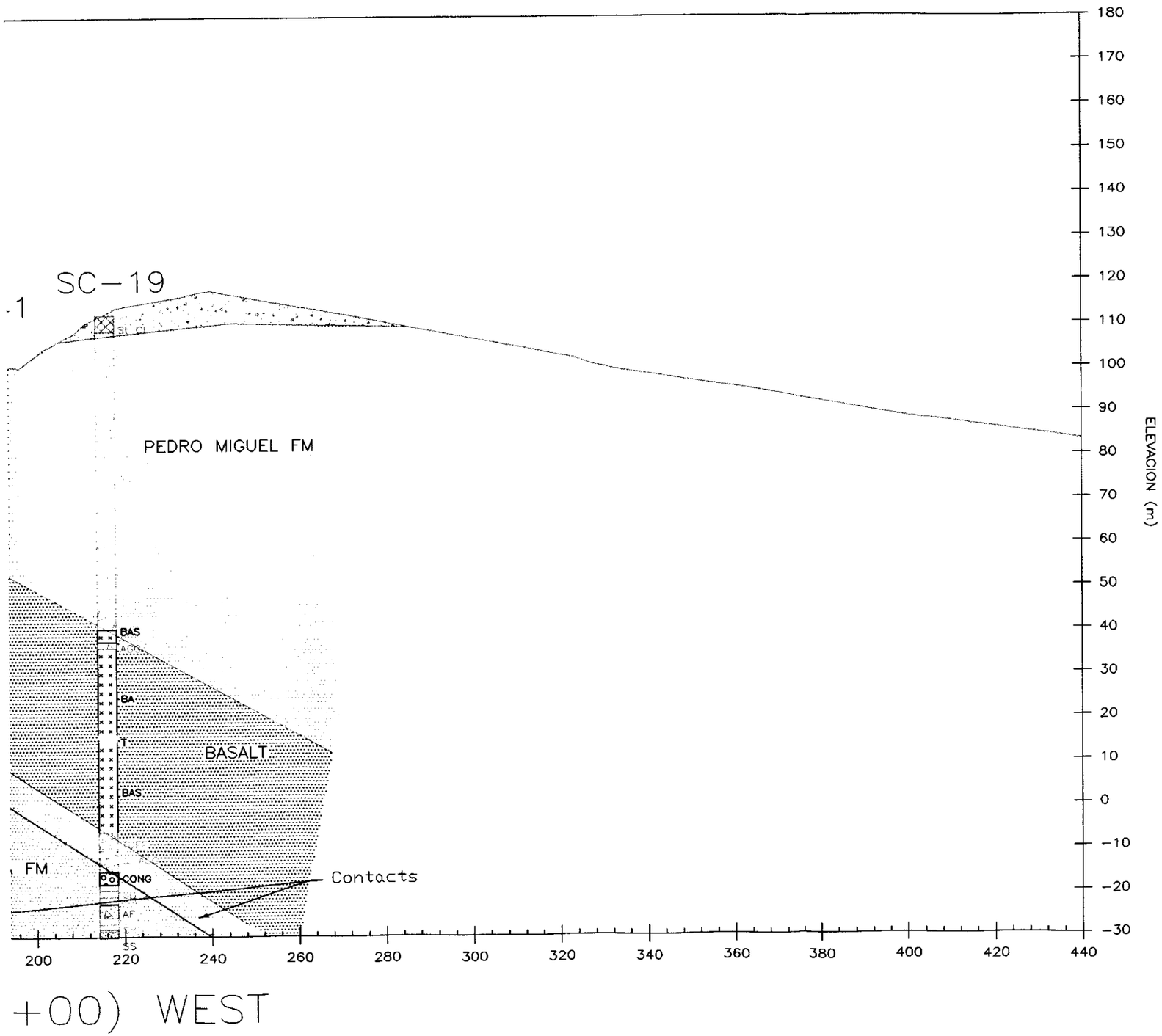


Case 8, Channel bottom = 16 ft, Blasted



Summary, 59k + 070 (1938 + 00)

General Description	Range of stations:	59k + 000 to 59k + 260			
	Sector:	Hodges			
	Maximum height (m):	108			
	Cotangent of slope angle (cot. β):	2.48			
History	Last slide event:	July 28, 1997 (Hodges Hill Slide)			
Geology	Formation:	Culebra / Cucaracha / Basalt / Pedro Miguel			
	Lithology:	Agglomerate / Clayshale / Basalt / Sandstone / Siltstone			
	Critical stratum at toe:	Carbonaceous Sandstone / Siltstone			
	Apparent dip of bedding:	Toward the slope			
Stability Analysis	Critical failure mechanism:	Rotational & Tension crack			
	Shear strength model:	Fully softened Culebra			
		Operative average pore pressure ratio (aproximate), Ru:	Factor of Safety	Relative Factor of Safety	Percentage of Change (%)
	Case 1: Channel bottom = 32 ft	0.369	1.000	1.000	0.00
	Case 2: Channel bottom = 27 ft, Blasted material only		0.999	0.999	-0.10
	Case 3: Channel bottom = 27 ft, Blasted & removed		0.990	0.990	-1.00
	Case 4.1: Channel bottom = 27 ft, Design (underwater slope)		0.978	0.978	-2.20
	Case 4.2: Channel bottom = 27 ft, Design (& dry excavation)	0.373	1.107	1.107	10.70
	Case 5: Channel bottom = 22 ft, Blasted material only		0.988	0.988	-1.20
	Case 6: Channel bottom = 22 ft, Blasted & removed		0.982	0.982	-1.80
	Case 7.1: Channel bottom = 22 ft, Design (underwater slope)		0.963	0.963	-3.70
	Case 7.2: Channel bottom = 22 ft, Design (& dry excavation)	0.375	1.121	1.121	12.10
	Case 8: Channel bottom = 16 ft, Blasted		0.961	0.961	-3.90
Conclusions:	Stabilization is required for Case 4 and Case 7				



AUTORIDAD DEL CANAL DE PANAMA

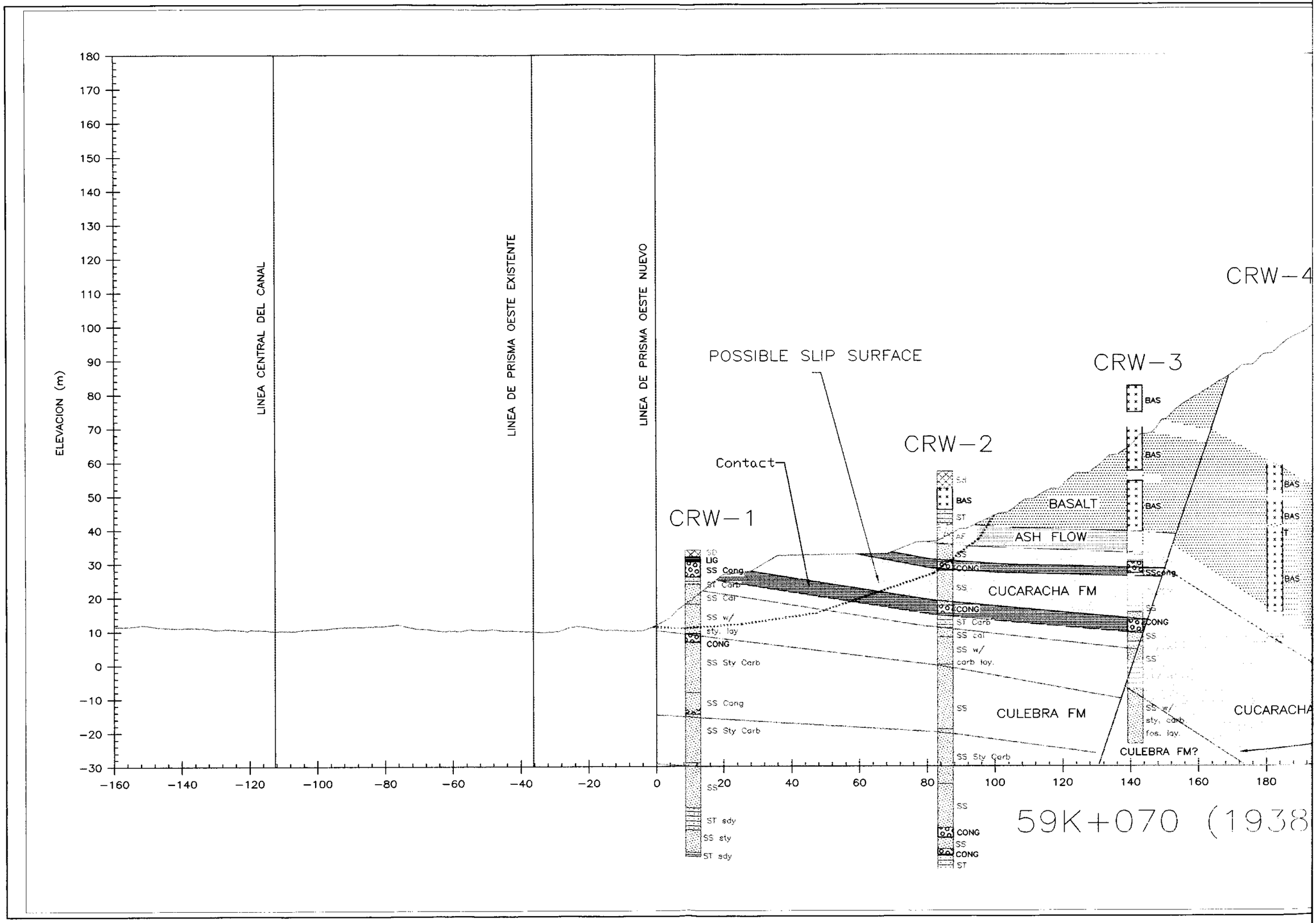
DEPARTAMENTO DE INGENIERIA Y PROYECTOS
DIVISION DE INGENIERIA
ALTOS DE BALBOA, REPUBLICA DE PANAMA

SECCION GEOLOGICA

CORTE GAILLARD

ESTACION 59K+070 (1938+00) OESTE

ESCALA: 1:1000	FECHA: ABRIL 2002
GEOLOGIA POR: M. DE PUY	DIBUJADO POR: J. RAMESCH & M. DE PUY


ELEVACION (m)
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−10
−20
−30
−160
−140
−120
−100
−80
−60
−40
−20
0
20
40
60
80
100
120
140
160
180
LINEA CENTRAL DEL CANAL
LINEA DE PRISMA OESTE EXISTENTE
LINEA DE PRISMA OESTE NUEVO
POSSIBLE SLIP SURFACE
Contact
CRW−1
CRW−2
CRW−3
CRW−4
BASALT
ASH FLOW
CUCARACHA FM
CULEBRA FM
CULEBRA FM?
CUCARACHA
BAS
SD
LIG
SS Cong
ST Carb
SS Car
SS w/
sty. lay
CONG
SS Sty Carb
SS Cong
SS Sty Carb
SS
ST sdy
SS sty
ST sdy
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CONG
SS
CONG
ST Carb
SS Car
SS w/
carb lay.
SS
CONG
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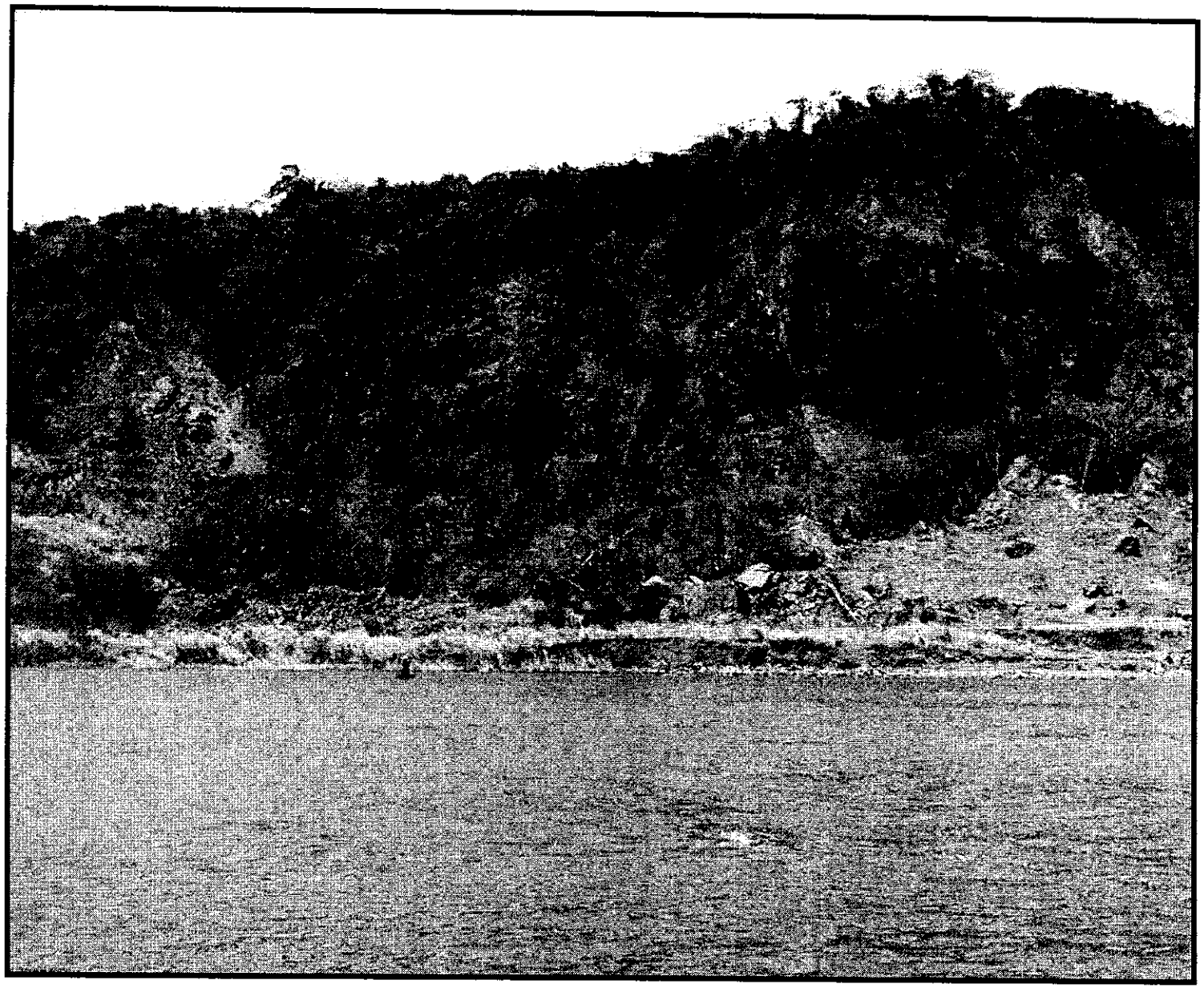
SS w/
sty. carb
fos. lay.
SS Sty Carb
59K+070 (1938

station 59k + 485 (1951 + 60)

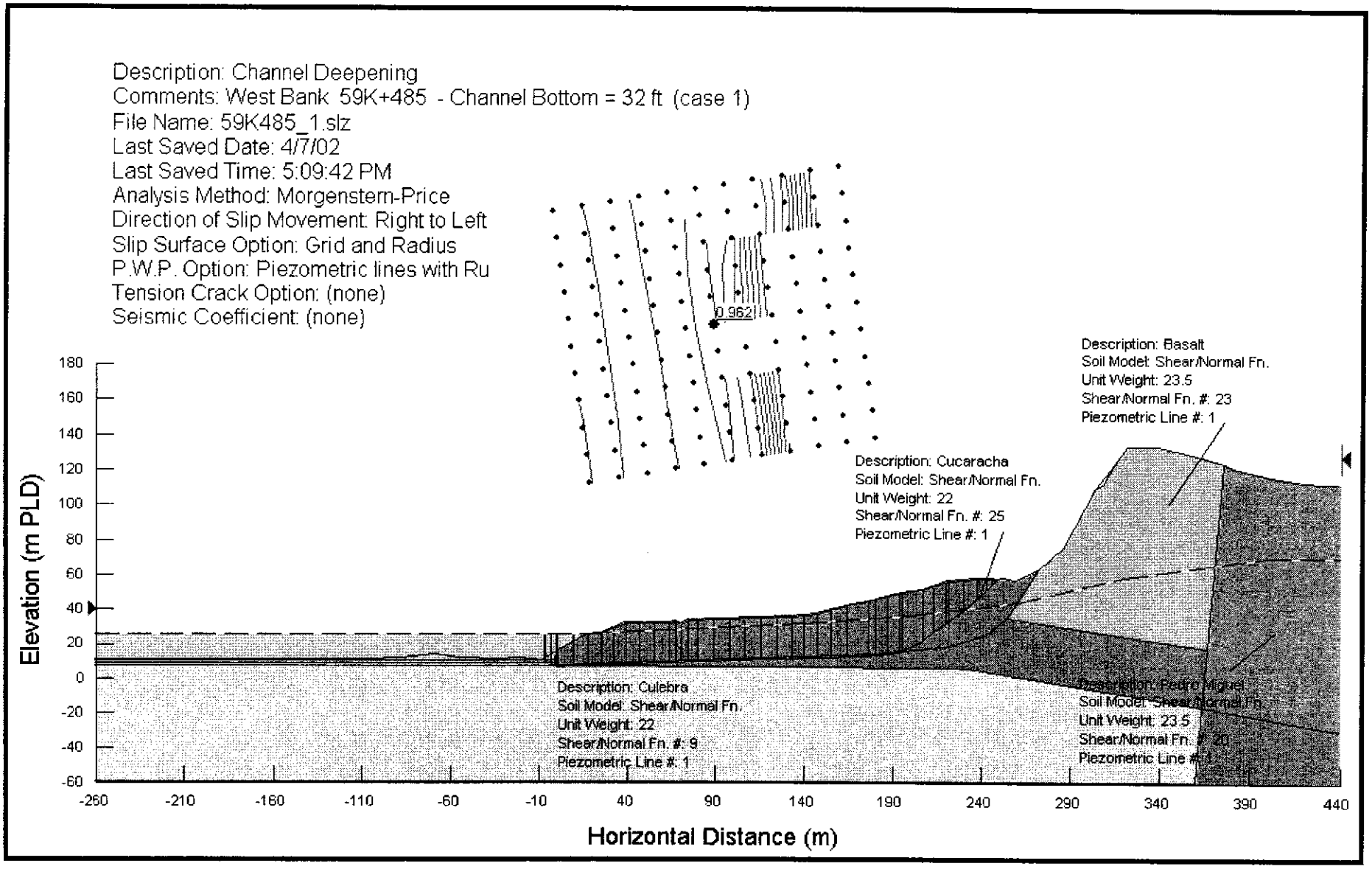
West

Station: 59k + 485 (Model)

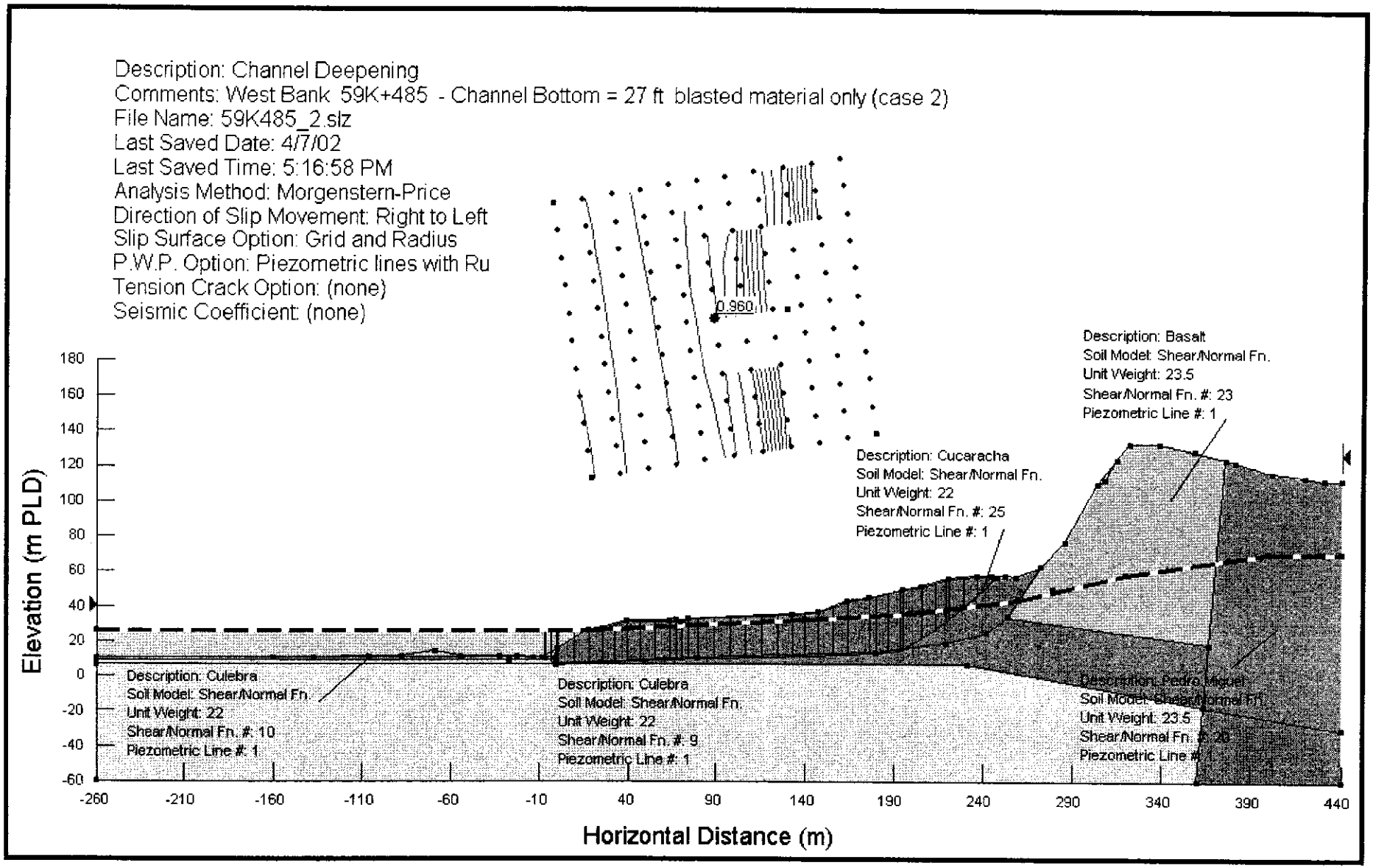
April 16, 2002



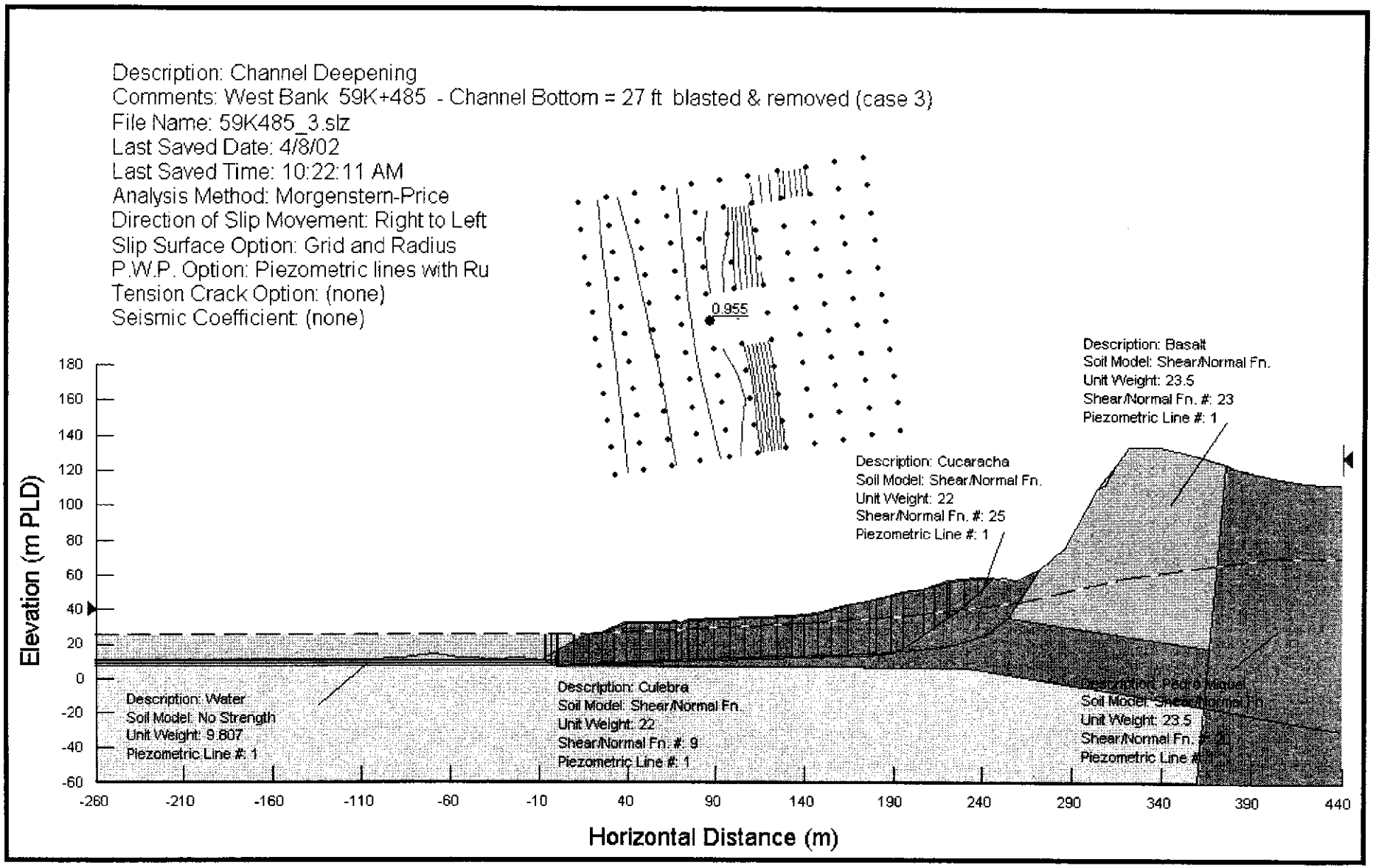
Case 1, Channel bottom = 32 ft



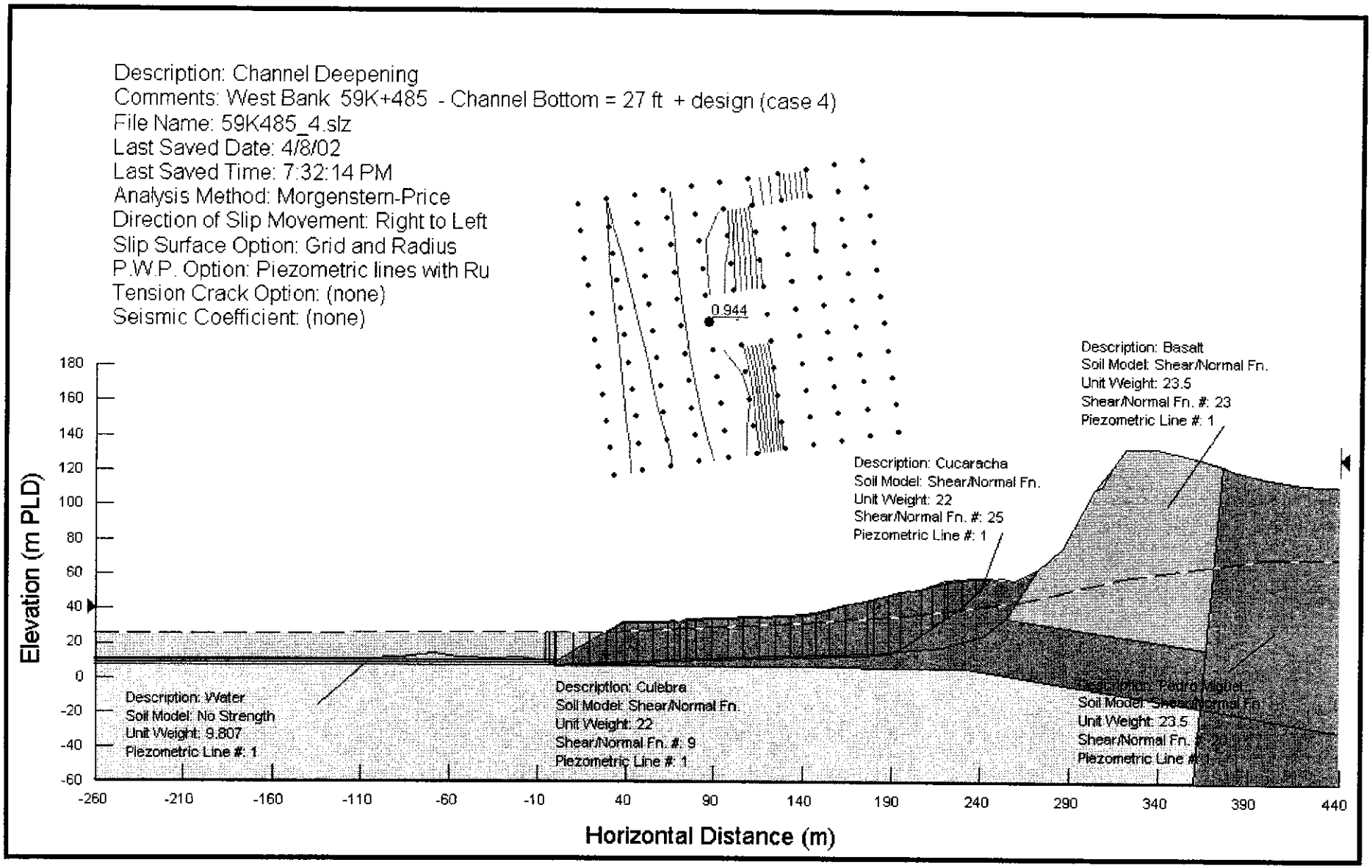
Case 2, Channel bottom = 27 ft, Blasted material only



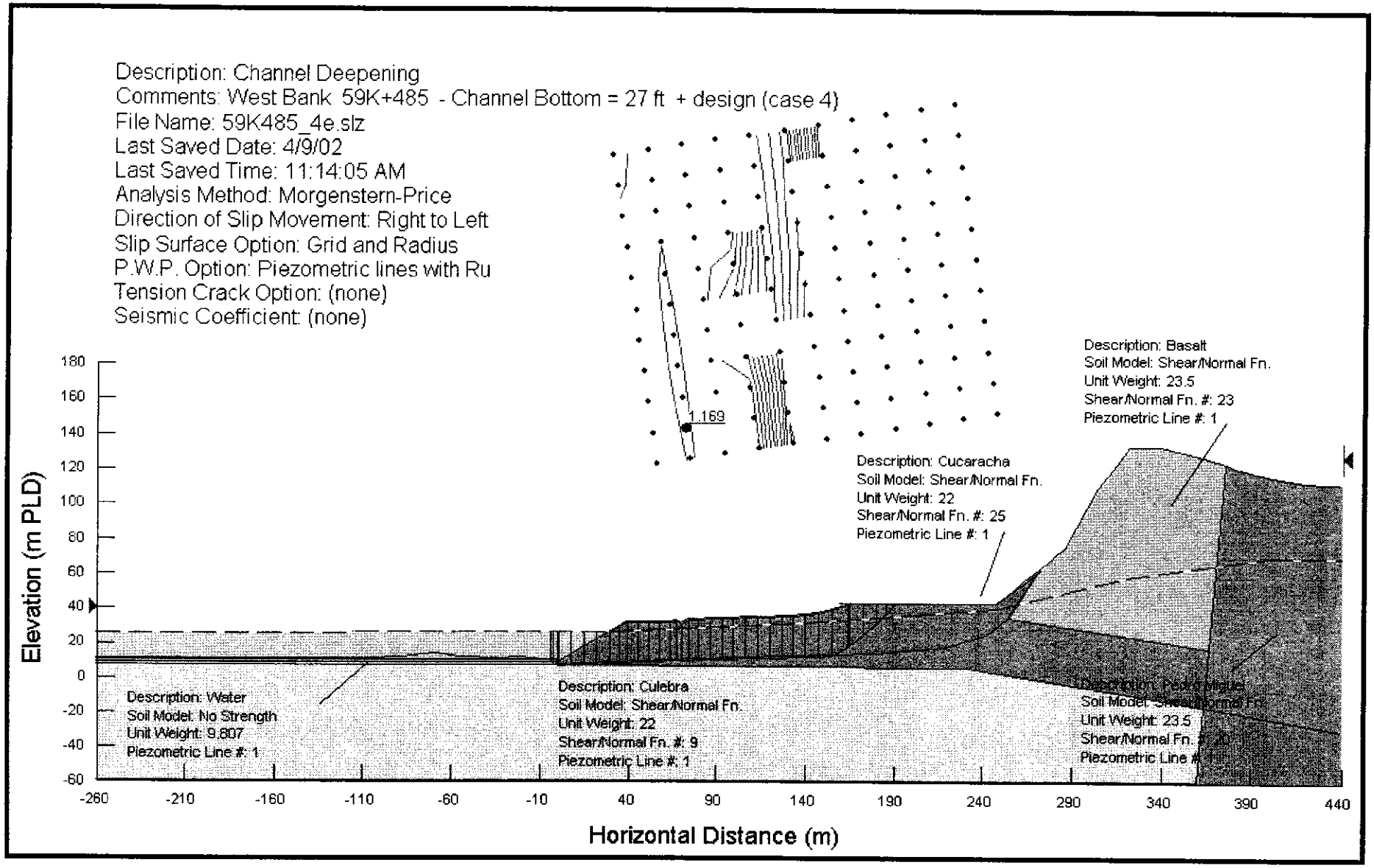
Case 3, Channel bottom = 27 ft, Blasted & removed



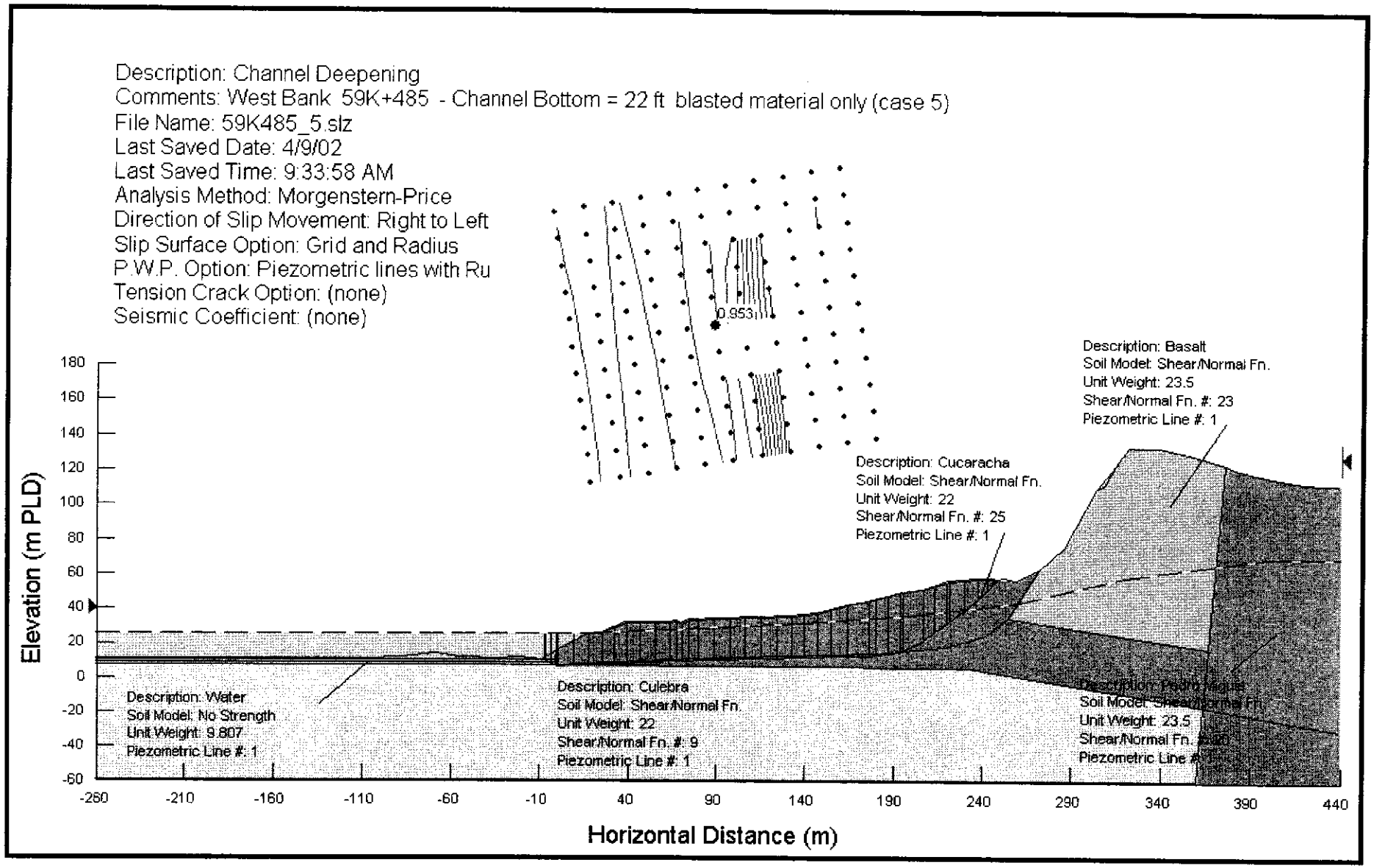
Case 4.1, Channel bottom = 27 ft, Design (underwater slope)



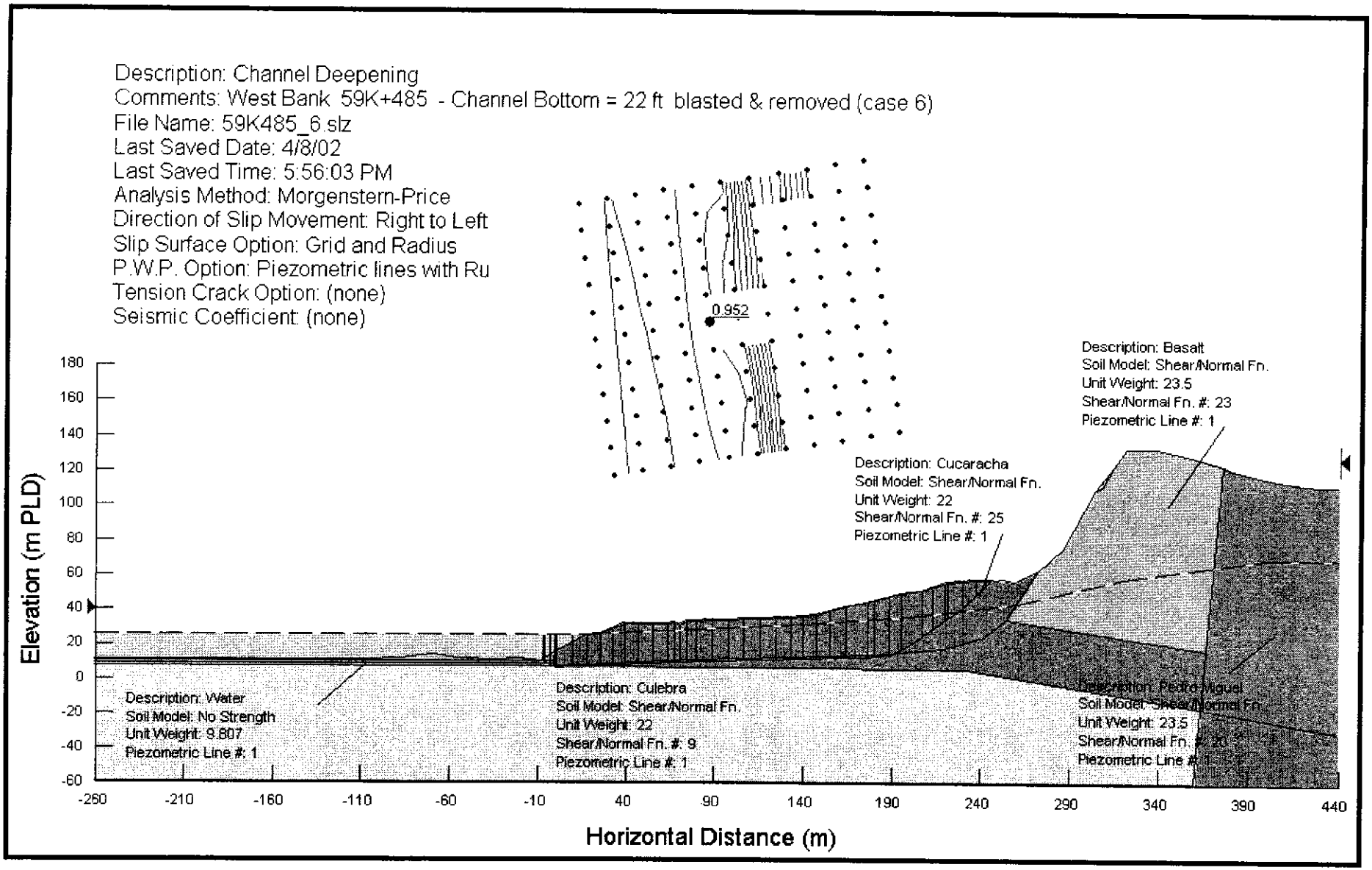
Case 4.2, Channel bottom = 27 ft, Design (& dry excavation)



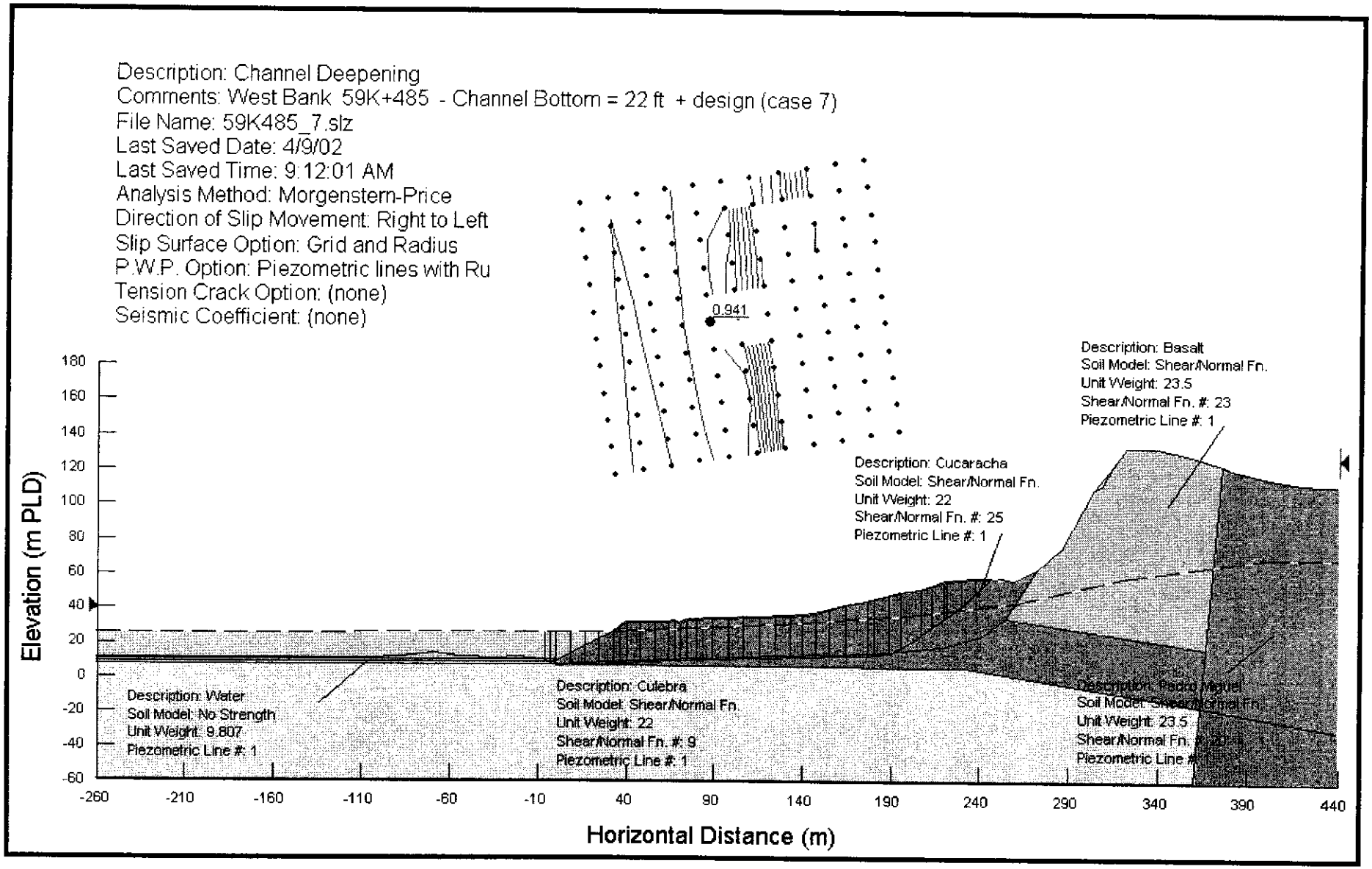
Case 5, Channel bottom = 22 ft, Blasted material only



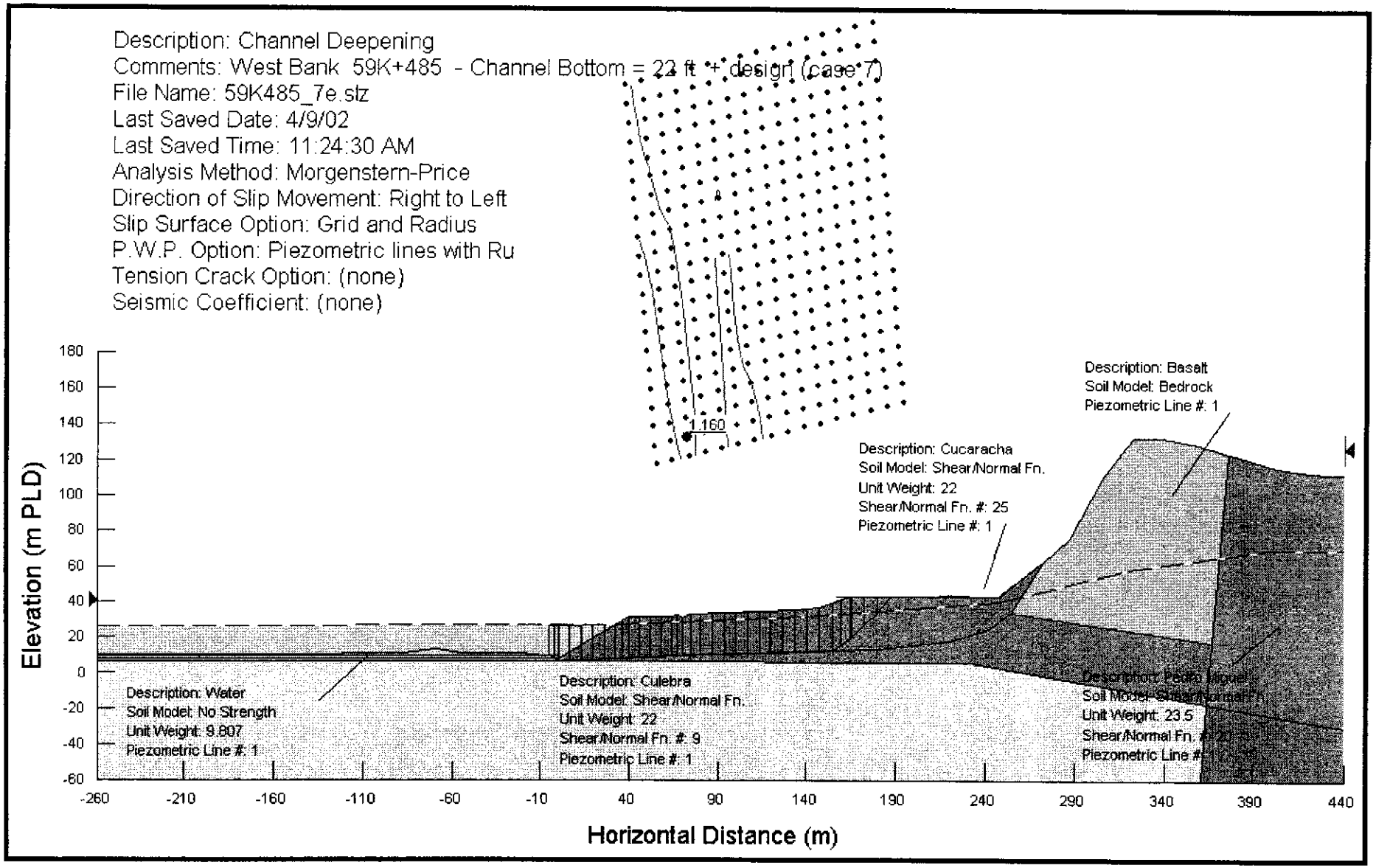
Case 6, Channel bottom = 22 ft, Blasted & removed



Case 7.1, Channel bottom = 27 ft, Design (underwater slope)

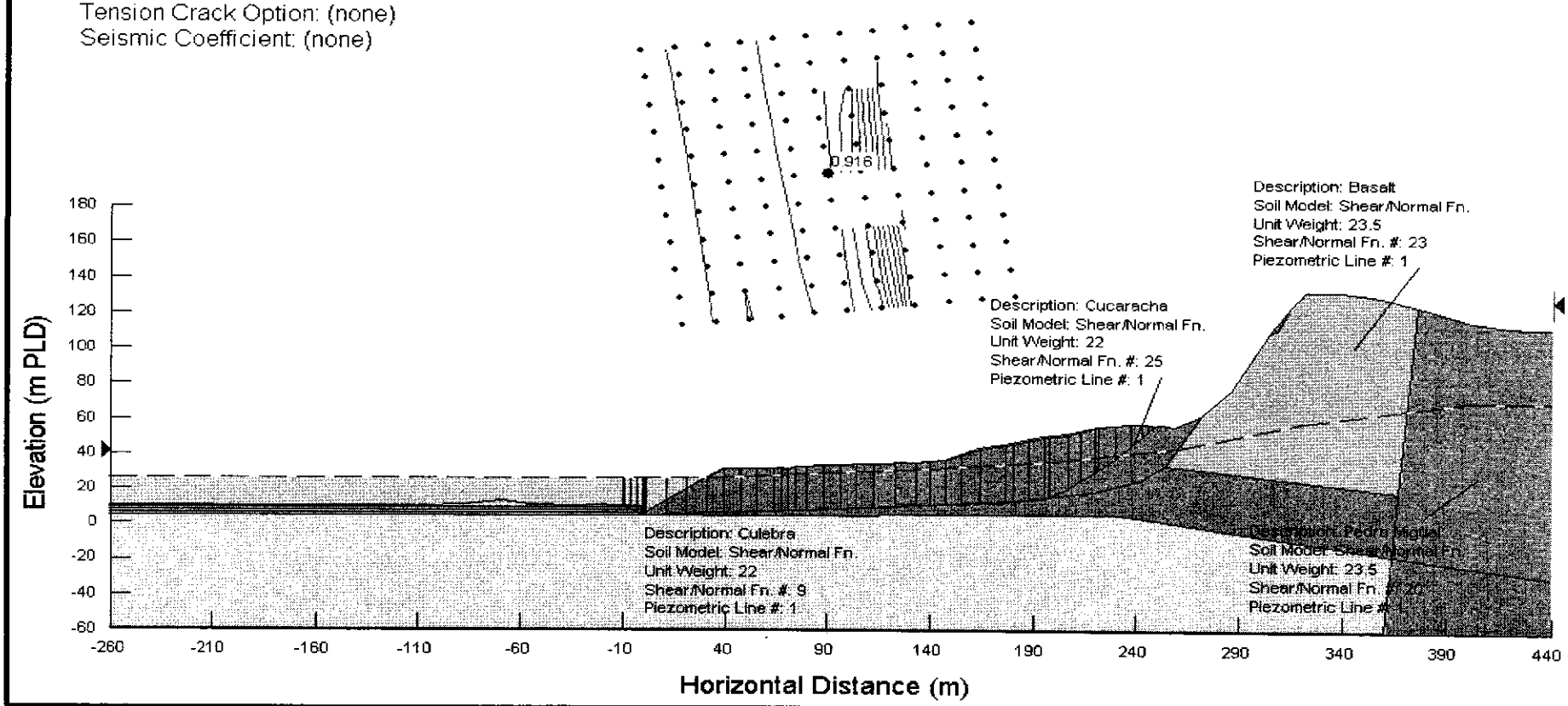


Case 7.2, Channel bottom = 27 ft, Design (& dry excavation)



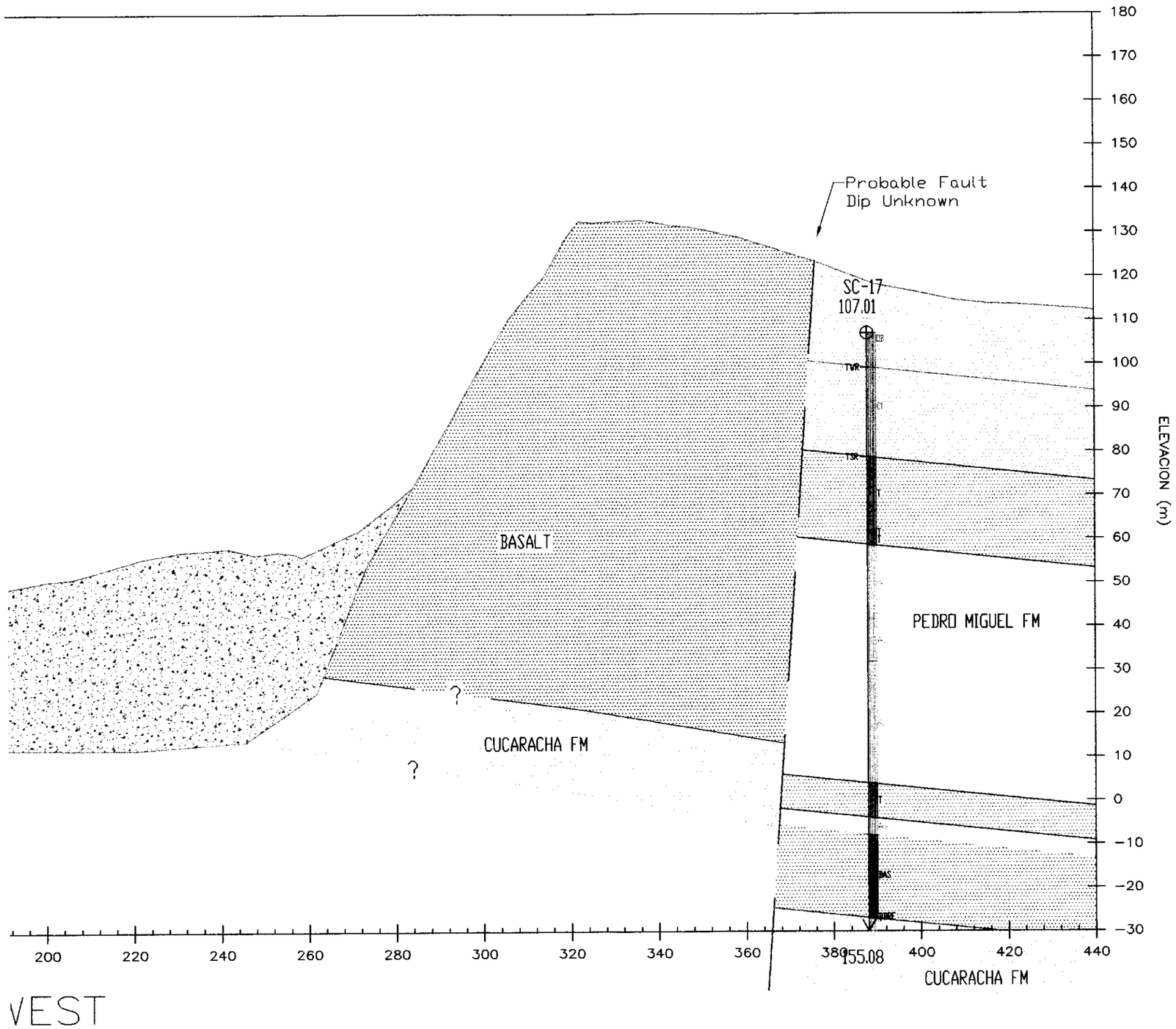
Case 8, Channel bottom = 16 ft, Blasted

Description: Channel Deepening
Comments: West Bank 59K+485 - Channel Bottom = 22 ft + design + blasted 16 ft (case 8)
File Name: 59K485_8.slz
Last Saved Date: 4/8/02
Last Saved Time: 7:15:09 PM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: (none)
Seismic Coefficient: (none)



Summary, 59k + 485 (1951 + 60)

General Description	Range of stations:	59k + 260 to 59k + 780			
	Sector:	Model (West Culebra)			
	Maximum height (m):	122.0 @ Zion Hill / 50.0 @ Scarp			
	Cotangent of slope angle (cot. β):	1.88 @ Zion Hill / 5.4 @ Scarp			
History	Last slide event:	September, 2001 (West Culebra reactivation)			
Geology	Formation:	Basalt / Cucaracha			
	Lithology:	Clayshale			
	Critical stratum at toe:	Clayshale			
	Apparent dip of bedding:	Toward the Canal			
Stability Analysis	Critical failure mechanism:	Translational			
	Shear strength model:	Residual - Cucaracha			
		Operative average pore pressure ratio (aproximate), Ru:	Factor of Safety	Relative Factor of Safety	Percentage of Change (%)
	Case 1: Channel bottom = 32 ft	0.336	0.962	1.000	0.00
	Case 2: Channel bottom = 27 ft, Blasted material only		0.960	0.998	-0.21
	Case 3: Channel bottom = 27 ft, Blasted & removed		0.955	0.993	-0.73
	Case 4.1: Channel bottom = 27 ft, Design (underwater slope)		0.944	0.981	-1.87
	Case 4.2: Channel bottom = 27 ft, Design (& dry excavation)	0.370	1.169	1.215	21.52
	Case 5: Channel bottom = 22 ft, Blasted material only		0.953	0.991	-0.94
	Case 6: Channel bottom = 22 ft, Blasted & removed		0.952	0.990	-1.04
	Case 7.1: Channel bottom = 22 ft, Design (underwater slope)		0.941	0.978	-2.18
	Case 7.2: Channel bottom = 22 ft, Design (& dry excavation)	0.380	1.160	1.206	20.58
	Case 8: Channel bottom = 16 ft, Blasted		0.916	0.952	-4.78
Conclusions:	Stabilization is required for Case 4 and Case 7				



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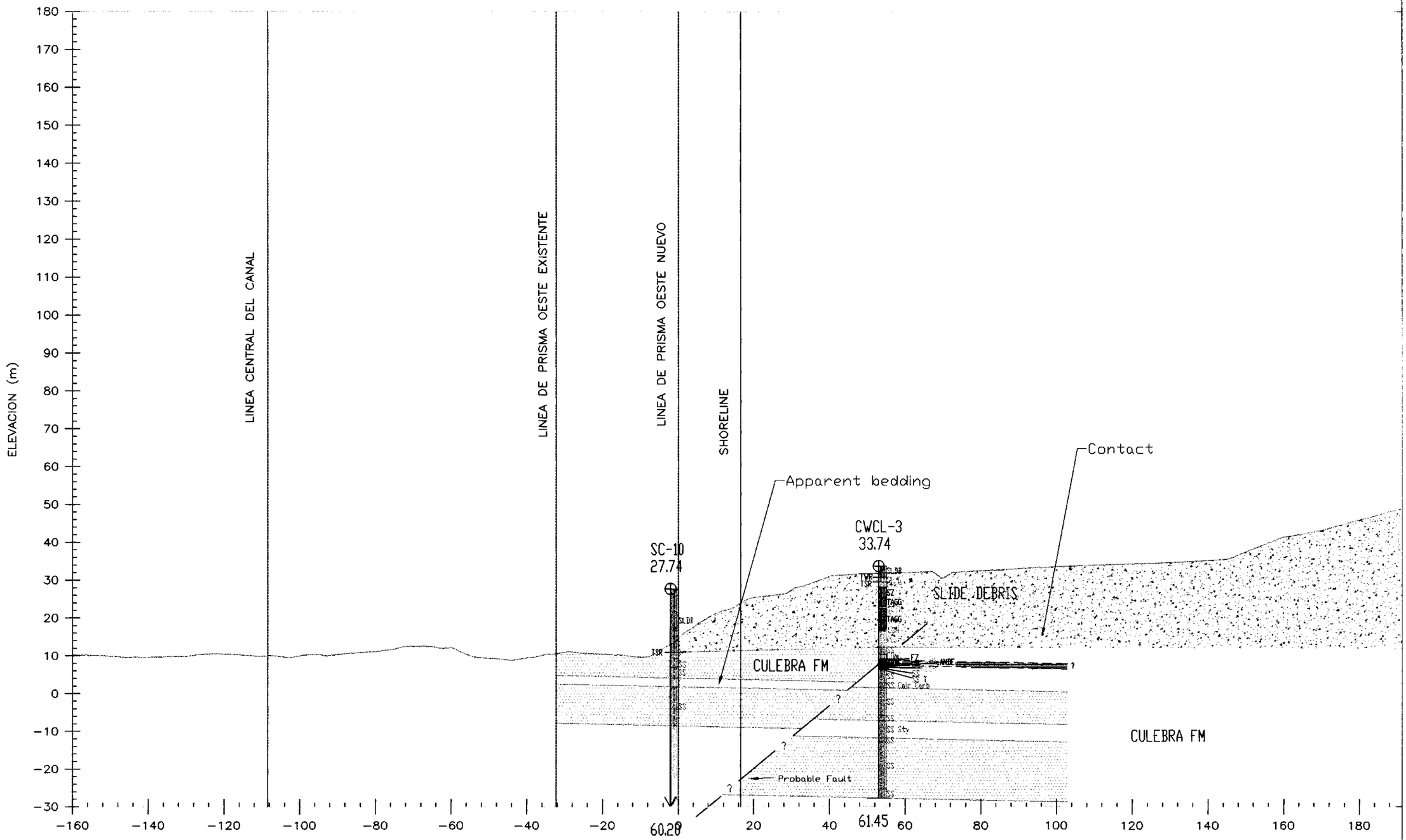
SECCION GEOLOGICA

CORTE GAILLARD

ESTACION 59K+485 (1951+60) OESTE

ESCALA: 1:1000	FECHA: ABRIL 2002
GEOLOGIA POR: M. DE PUY	DIBUJADO POR: J. RAMESCH


ELEVACION (m)
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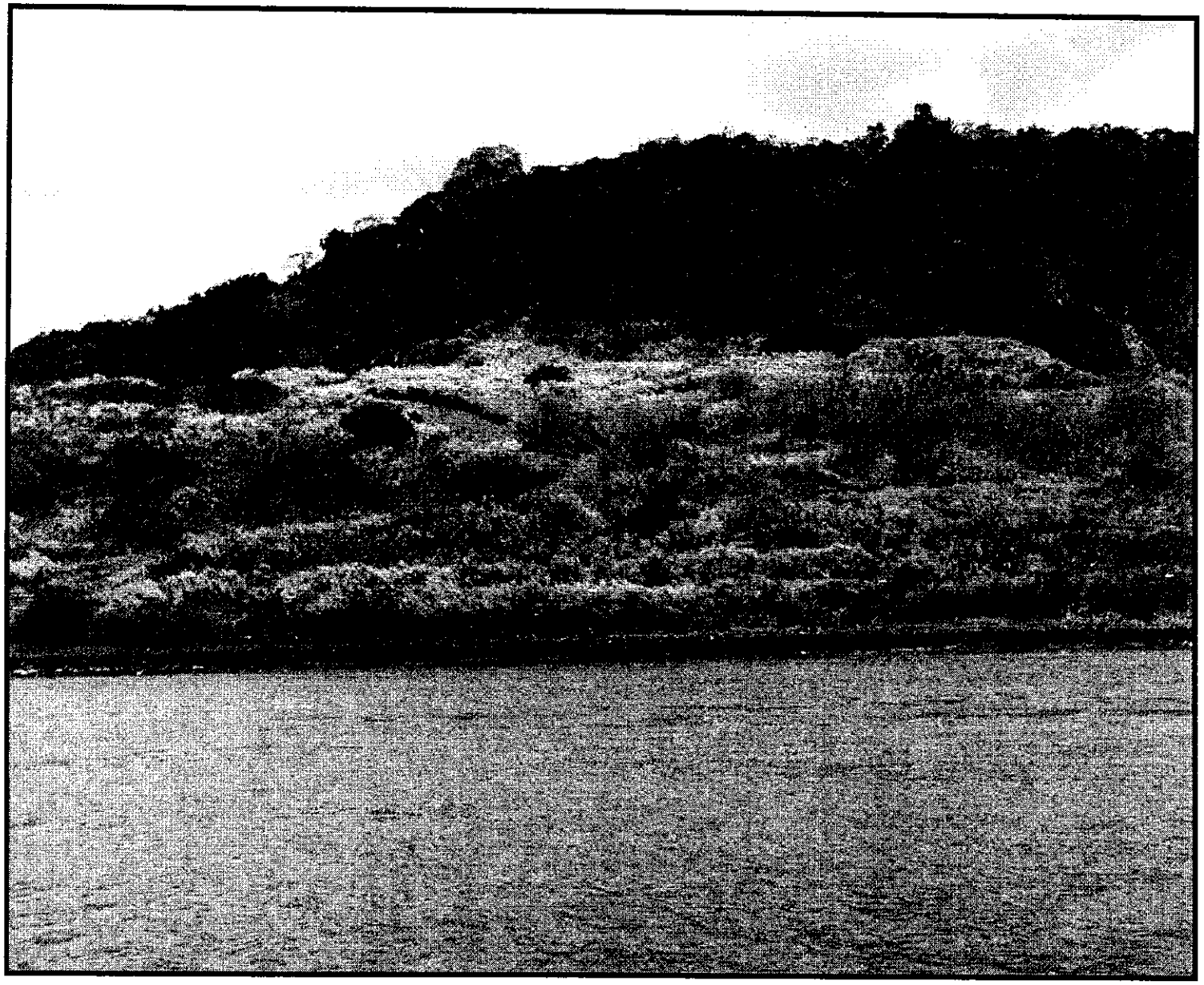
140
160
180
LINEA CENTRAL DEL CANAL
LINEA DE PRISMA OESTE EXISTENTE
LINEA DE PRISMA OESTE NUEVO
SHORELINE
Apparent bedding
Contact
SC-10
27.74
CWCL-3
33.74
SLIDE DEBRIS
CULEBRA FM
CULEBRA FM
Probable Fault
60.20
61.45
59K+485 (1951+60) W

station 59k + 881 (1964 + 00)

West

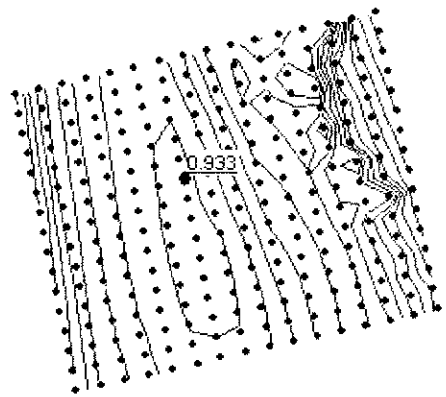
Station: 59k + 881 (Model)

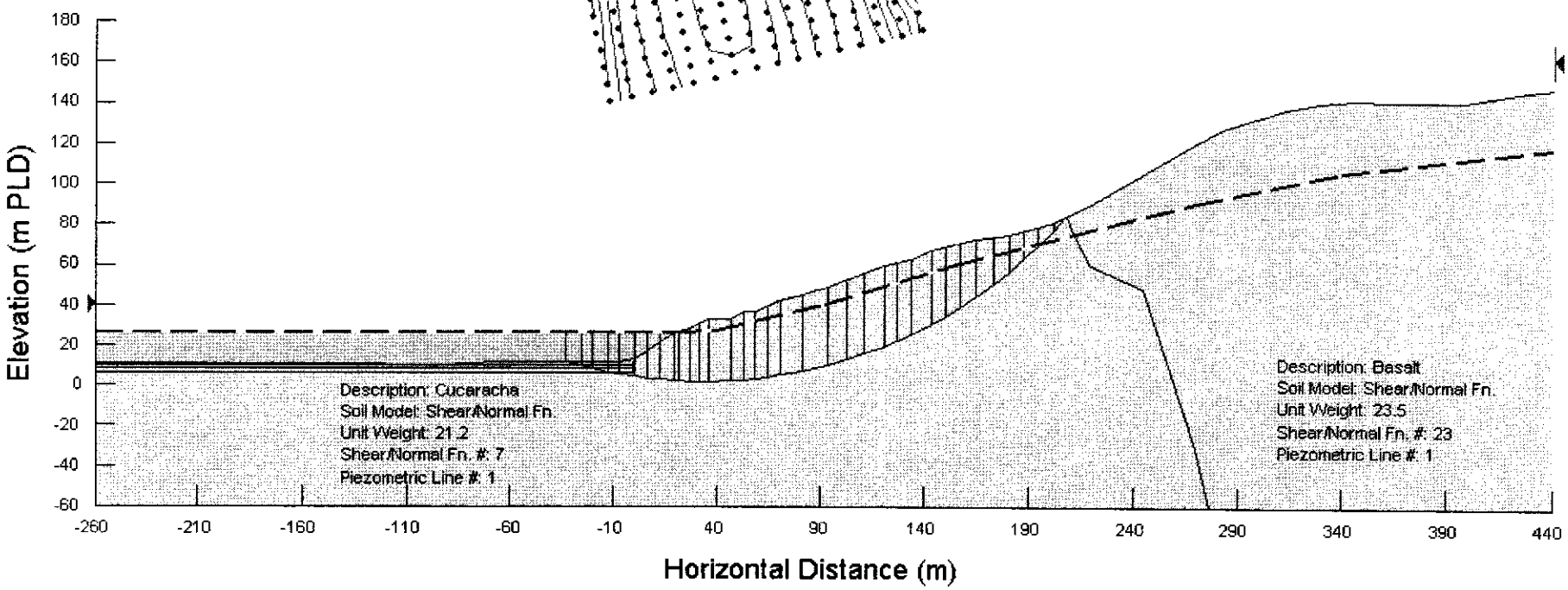
April 16, 2002



Case 1, Channel bottom = 32 ft

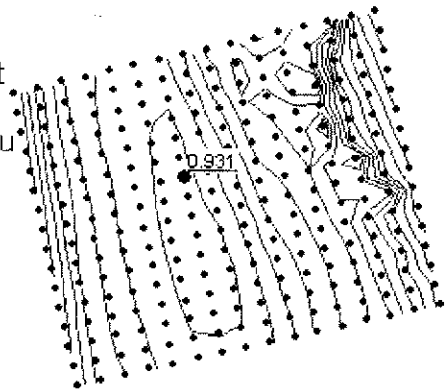
Description: Channel Deepening
Comments: West Bank 59K+881 - Channel Bottom = 32 ft (case 1)
File Name: 59K881_1.slz
Last Saved Date: 3/27/02
Last Saved Time: 10:07:33 AM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: (none)
Seismic Coefficient: (none)

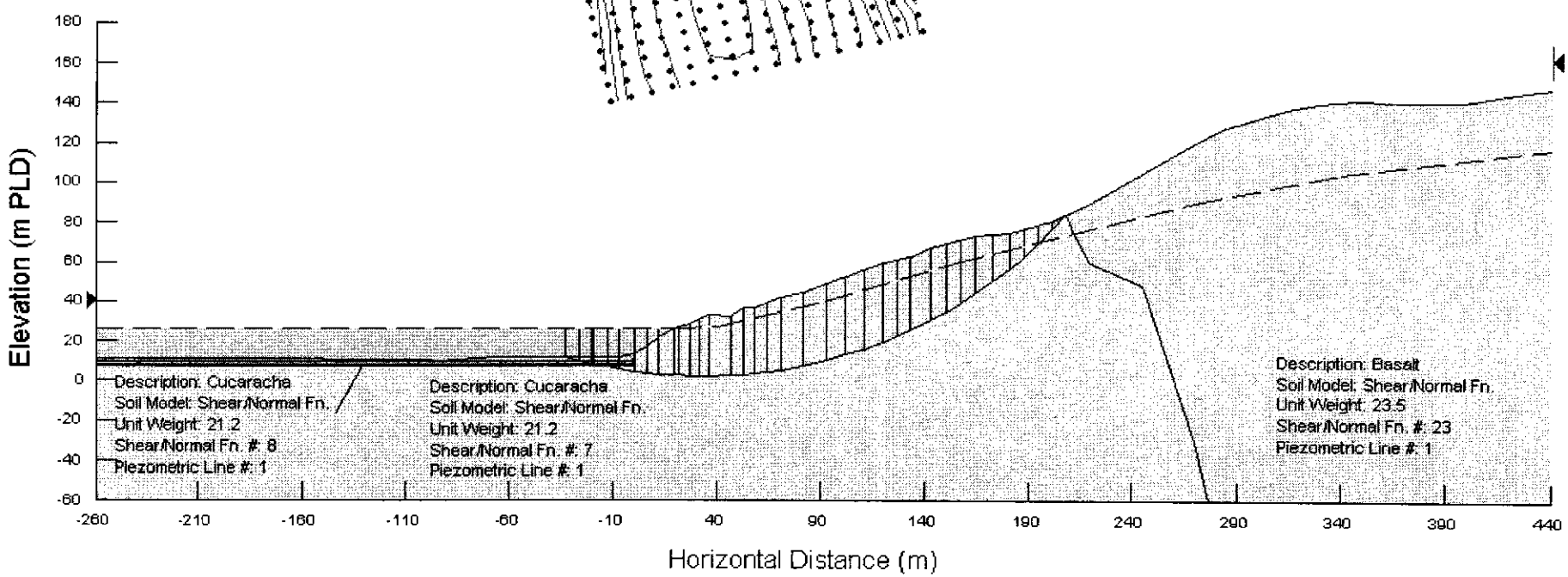




Case 2, Channel bottom = 27 ft, Blasted material only

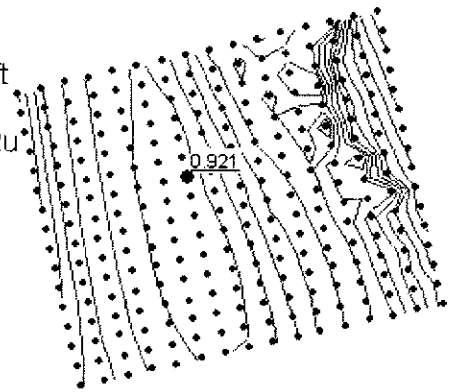
Description: Channel Deepening
Comments: West Bank 59K+881 - Channel Bottom = 27 ft & blasted material only (case 2)
File Name: 59K881_2.slz
Last Saved Date: 3/27/02
Last Saved Time: 10:58:44 AM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: (none)
Seismic Coefficient: (none)

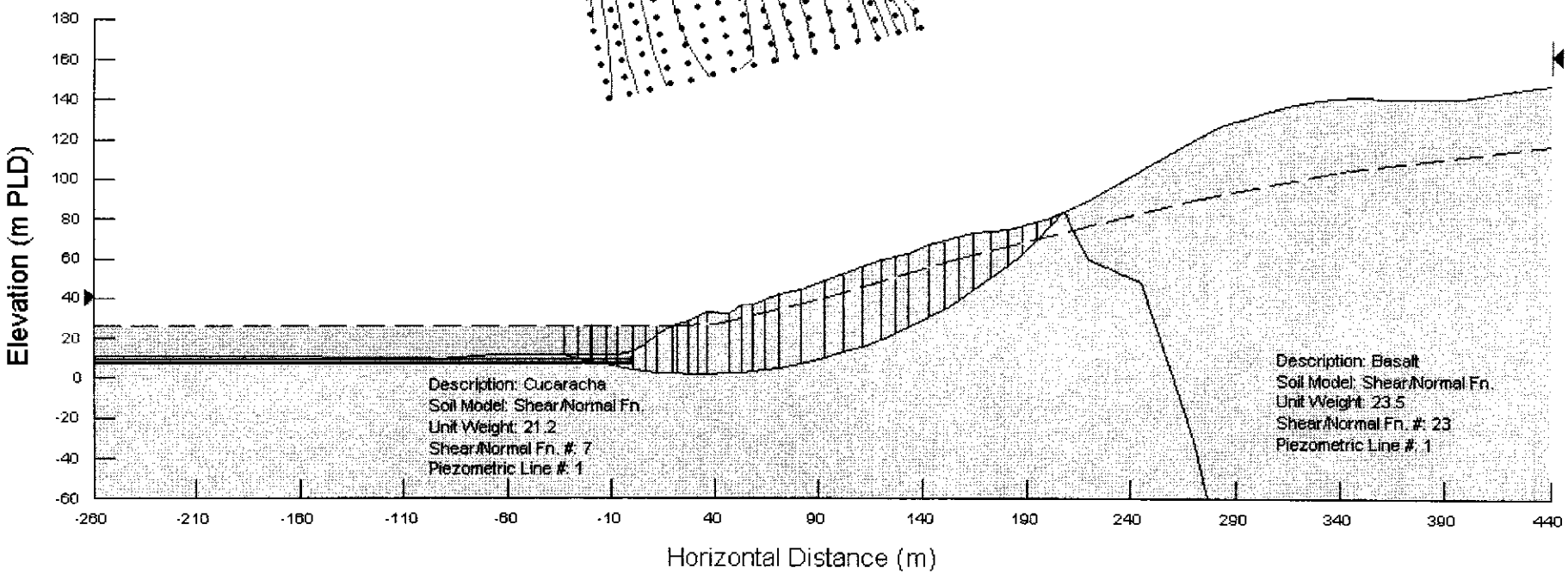




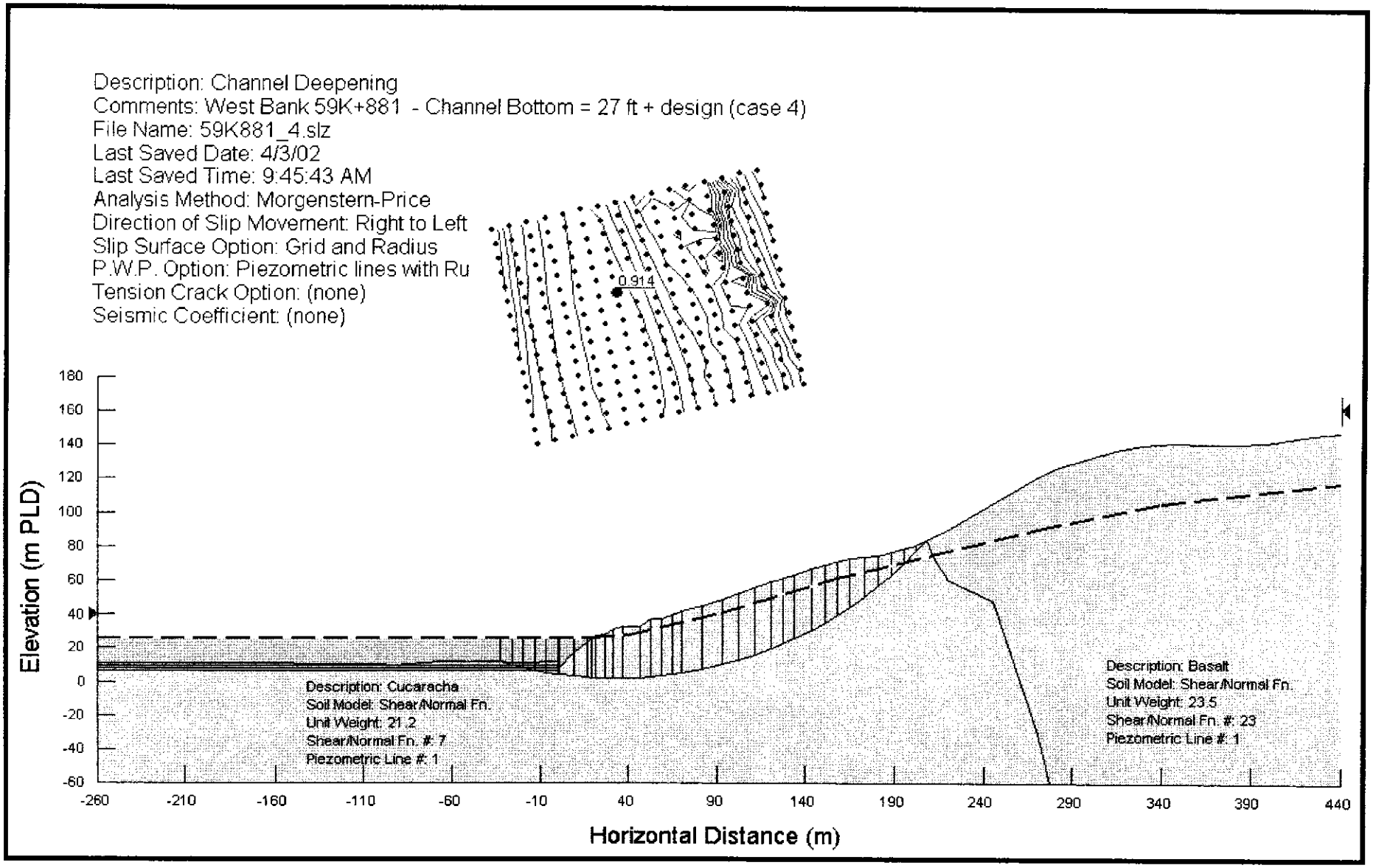
Case 3, Channel bottom = 27 ft, Blasted & removed

Description: Channel Deepening
Comments: West Bank 59K+881 - Channel Bottom = 27 ft & blasted and removed (case 3)
File Name: 59K881_3.slz
Last Saved Date: 3/27/02
Last Saved Time: 11:04:29 AM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: (none)
Seismic Coefficient: (none)

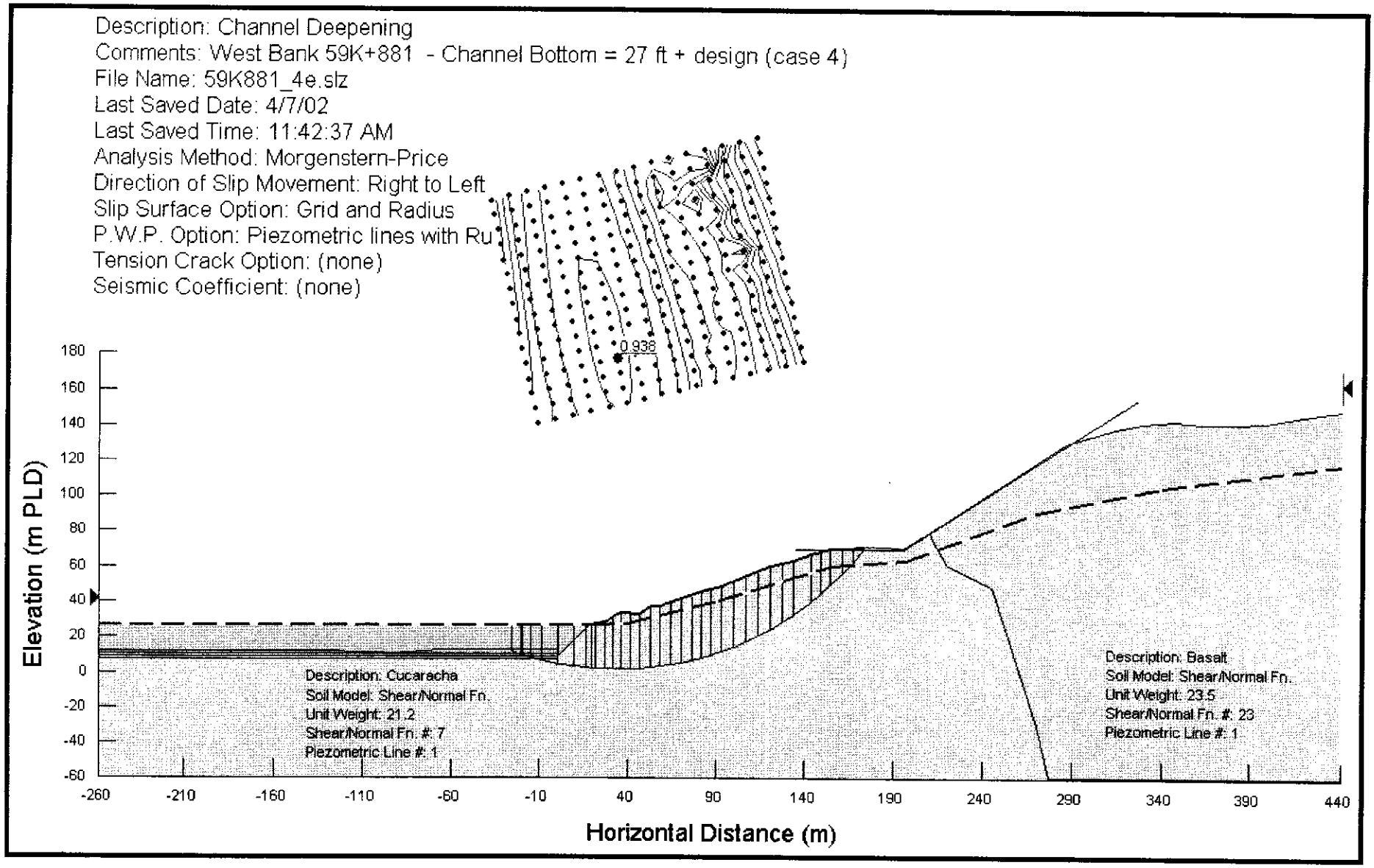




Case 4.1, Channel bottom = 27 ft, Design (underwater slope)

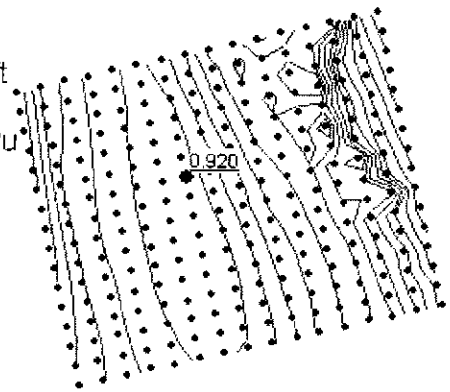


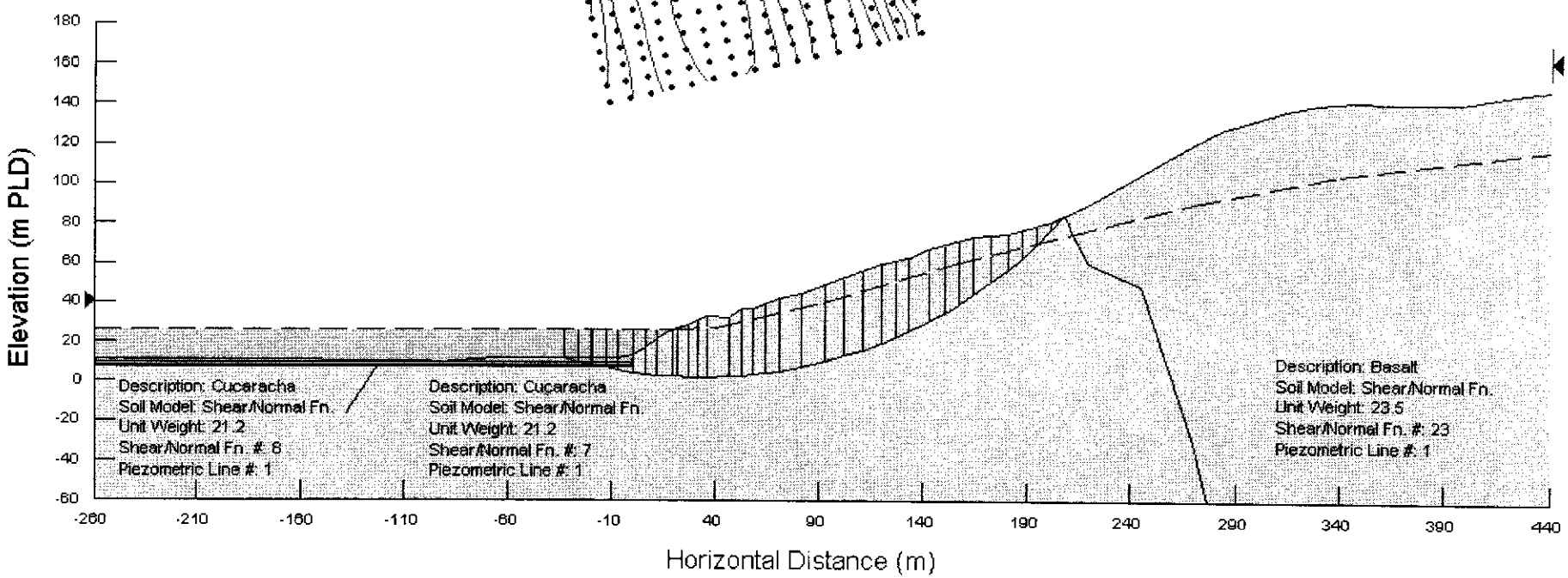
Case 4.2, Channel bottom = 27 ft, Design (& dry excavation)



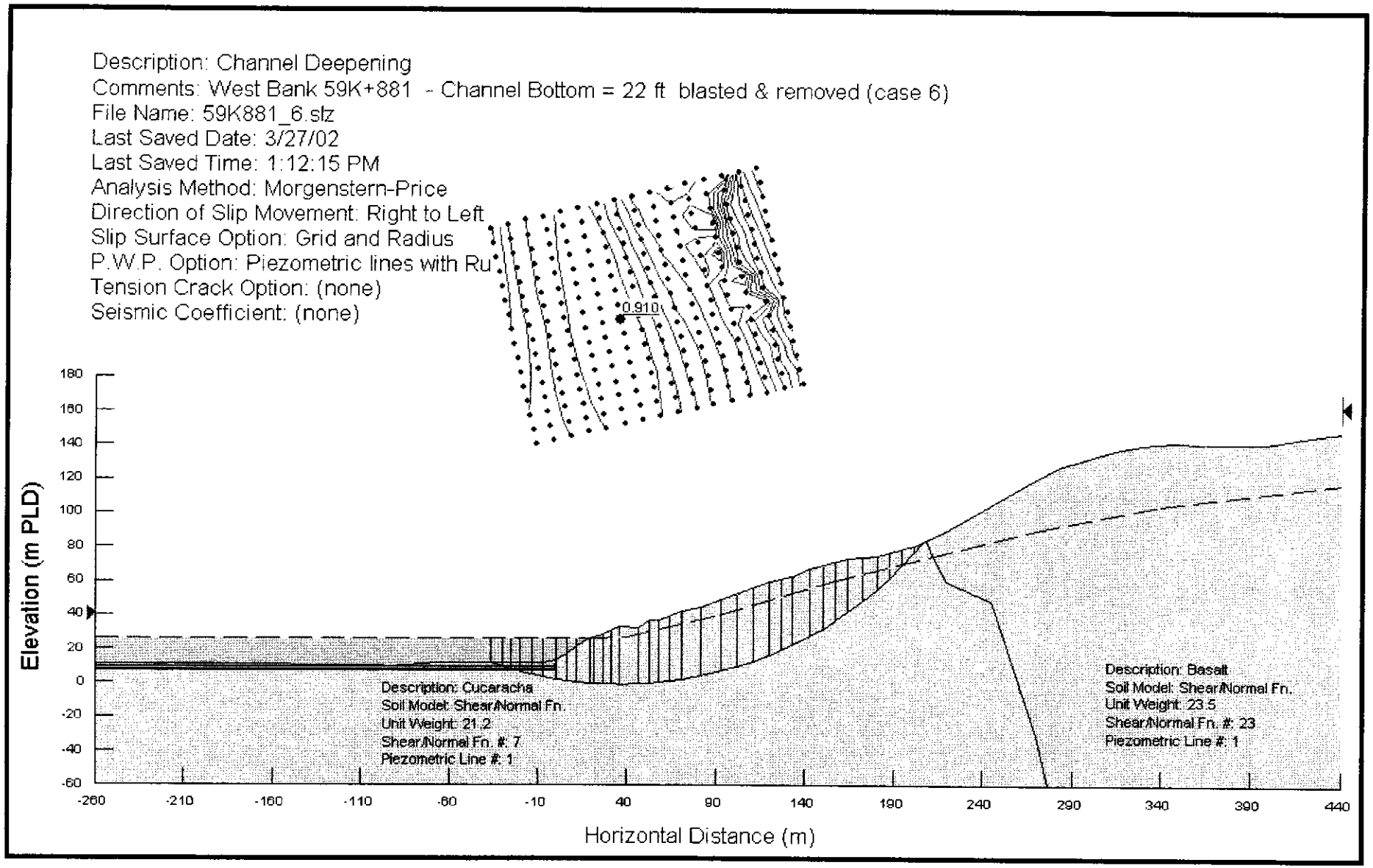
Case 5, Channel bottom = 22 ft, Blasted material only

Description: Channel Deepening
Comments: West Bank 59K+881 - Channel Bottom = 22 ft blasted material only (case 5)
File Name: 59K881_5.slz
Last Saved Date: 3/27/02
Last Saved Time: 1:05:06 PM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: (none)
Seismic Coefficient: (none)

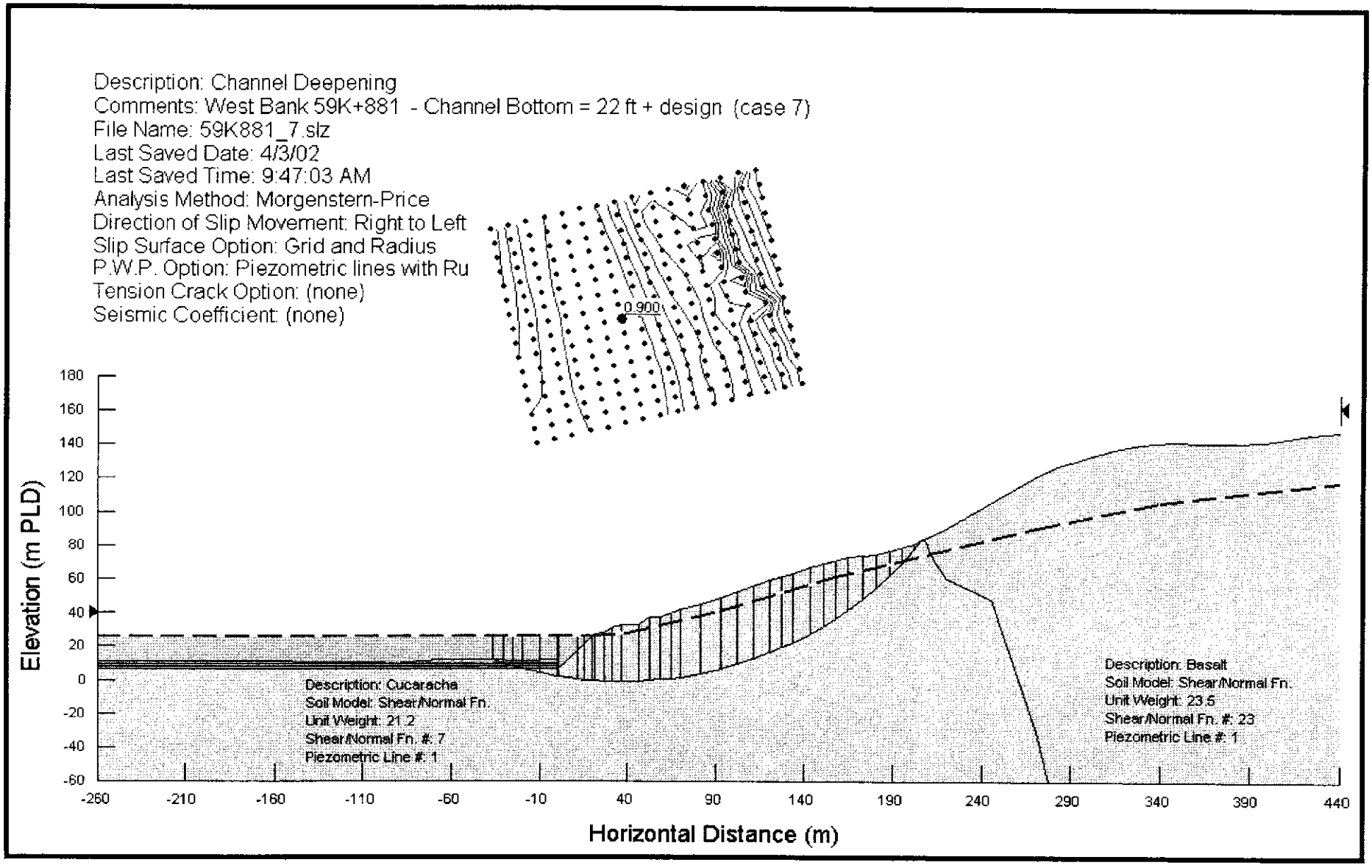




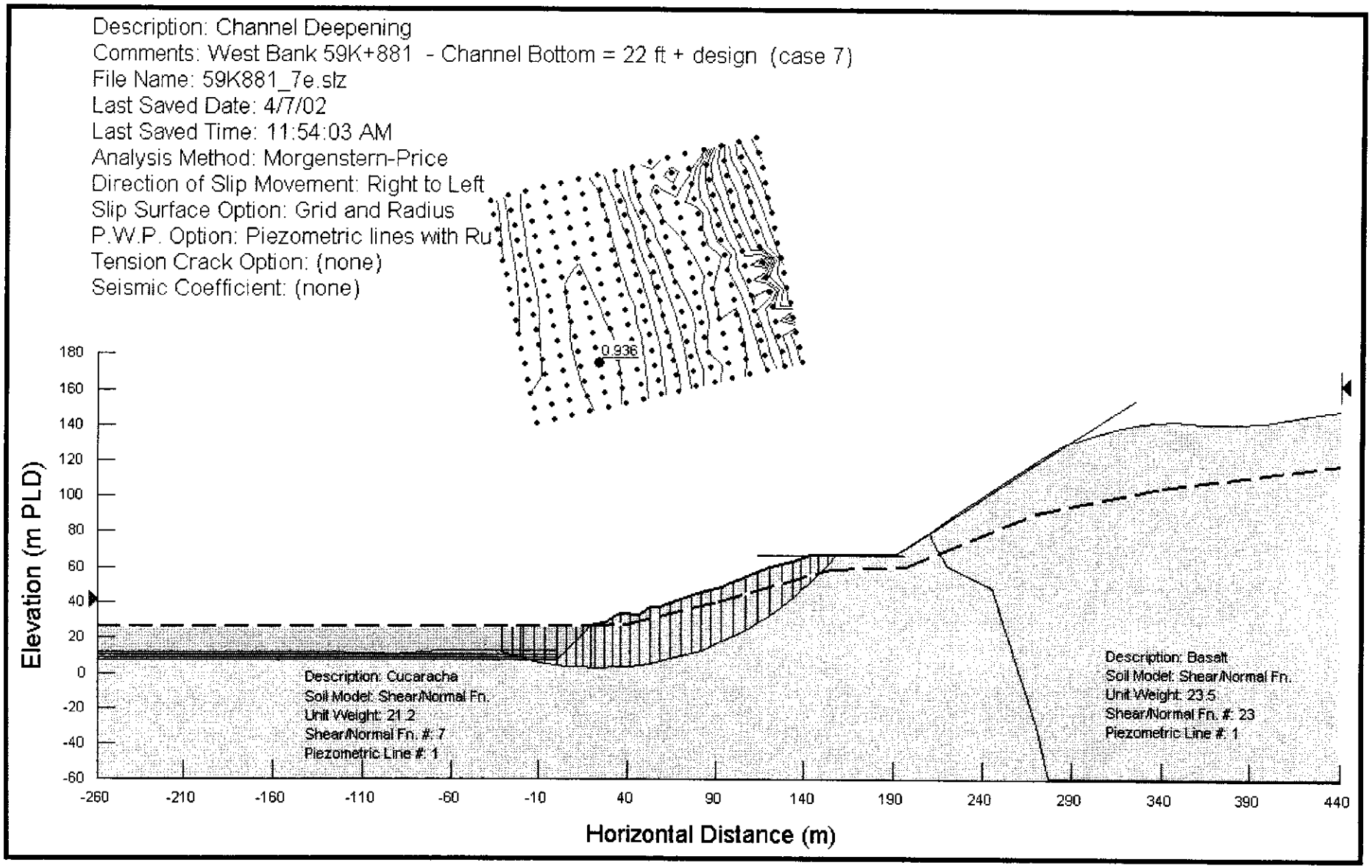
Case 6, Channel bottom = 22 ft, Blasted & removed



Case 7.1, Channel bottom = 27 ft, Design (underwater slope)

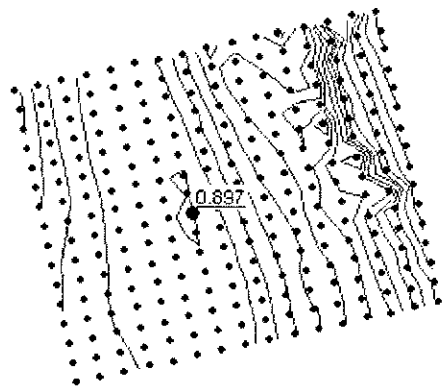


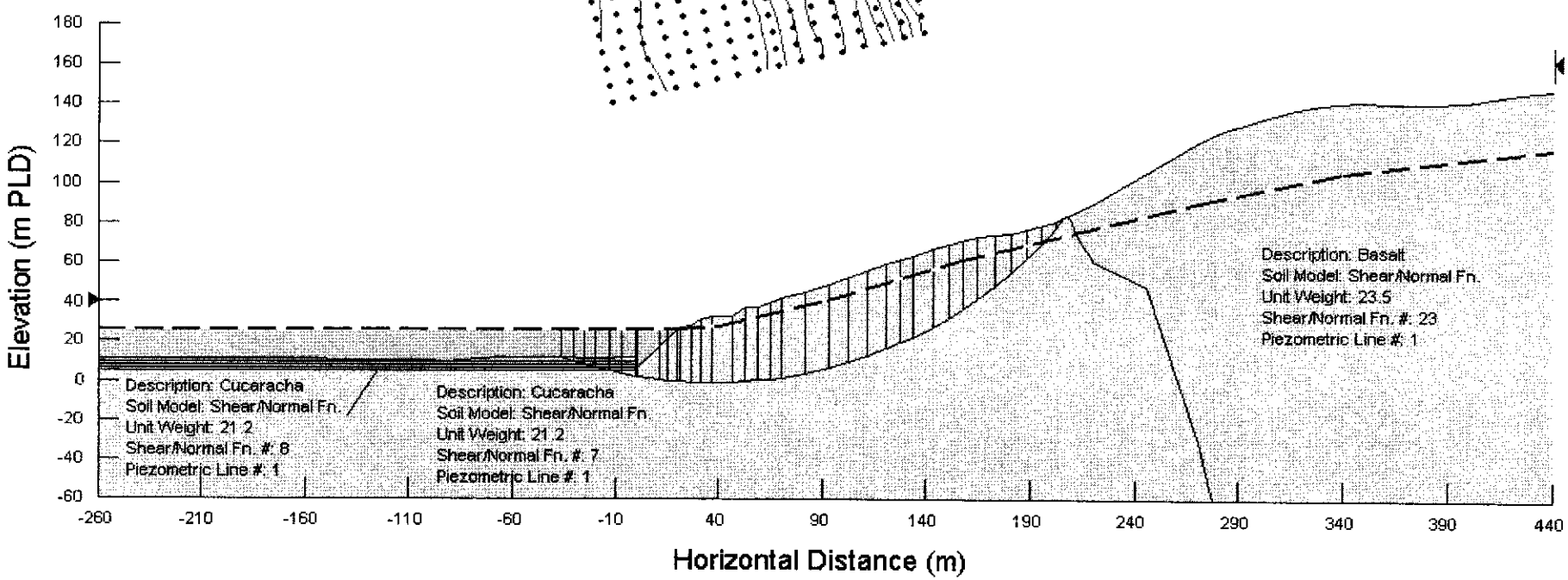
Case 7.2, Channel bottom = 27 ft, Design (& dry excavation)



Case 8, Channel bottom = 16 ft, Basalt

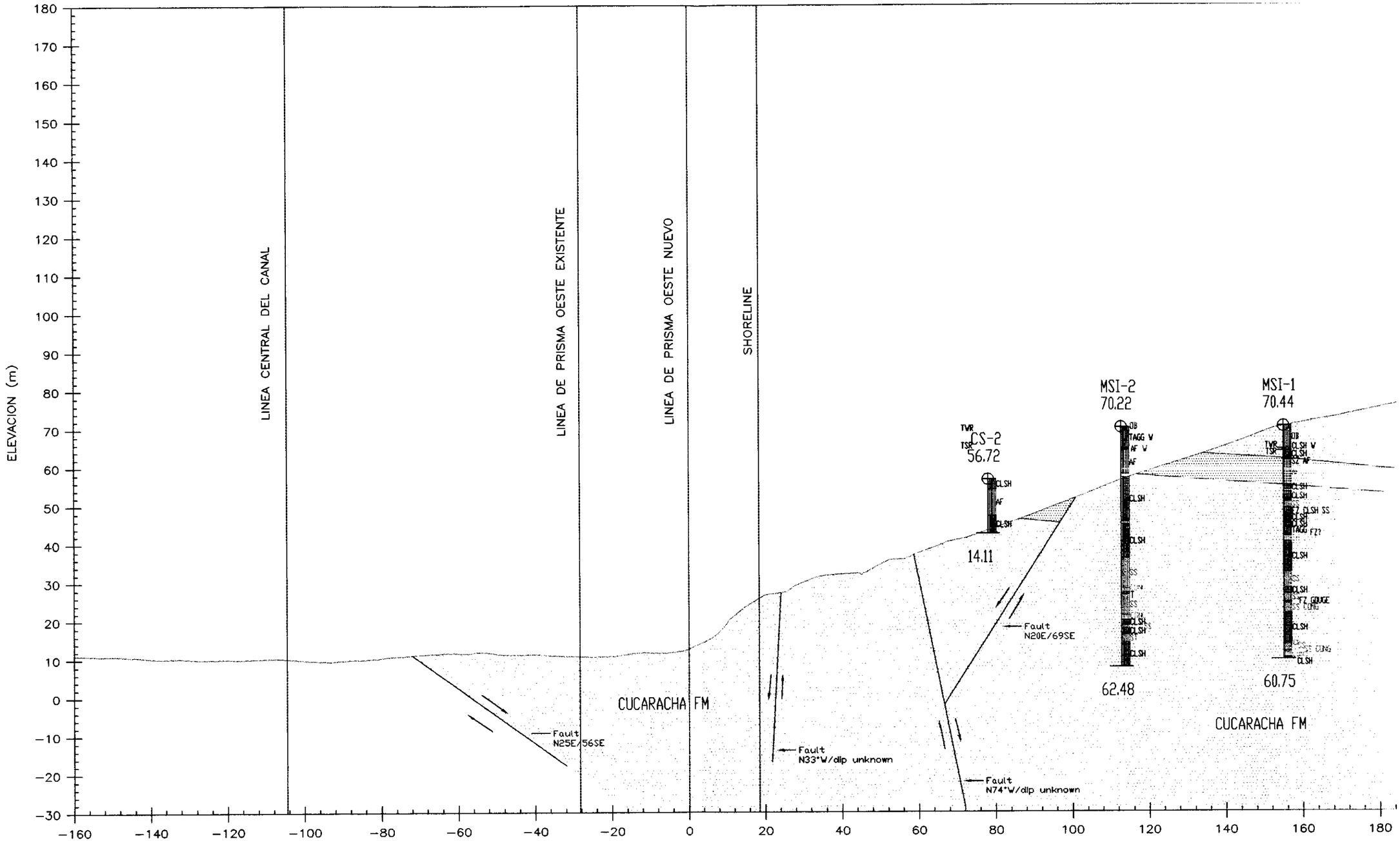
Description: Channel Deepening
Comments: West Bank 59K+881 - Channel Bottom = 22 ft + design + blasted 16 ft (case 8)
File Name: 59K881_8.slz
Last Saved Date: 4/7/02
Last Saved Time: 3:45:29 PM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: (none)
Seismic Coefficient: (none)



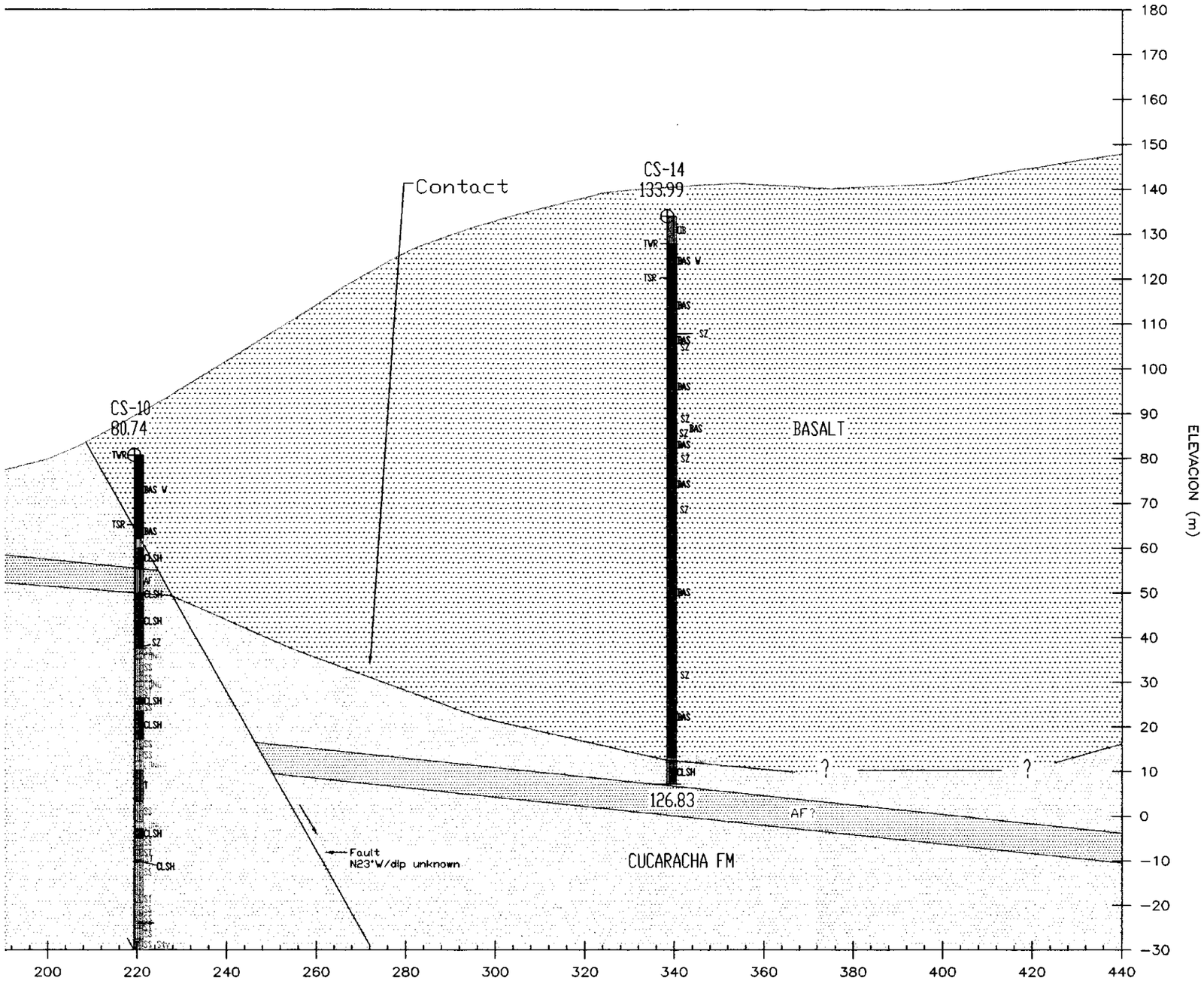


Summary, 59k + 881 (1964 + 00)

General Description	Range of stations:	59k + 780 to 60k + 050			
	Sector:	Model (Model Slope)			
	Maximum height (m):	130			
	Cotangent of slope angle (cot. β):	2.6			
History	Last slide event:	Model Slope Cracks (1997)			
Geology	Formation:	Basalt / Cucaracha			
	Lithology:	Clayshale / Ashflow / Sandstone / Conglomerate / Basalt			
	Critical stratum at toe:	Clayshale			
	Apparent dip of bedding:	Toward slope but very gentle			
Stability Analysis	Critical failure mechanism:	Rotational			
	Shear strength model:	Fully softened Cucaracha			
		Operative average pore pressure ratio (aproximate), Ru:	Factor of Safety	Relative Factor of Safety	Percentage of Change (%)
	Case 1: Channel bottom = 32 ft	0.353	0.933	1.000	0.00
	Case 2: Channel bottom = 27 ft, Blasted material only		0.931	0.998	-0.21
	Case 3: Channel bottom = 27 ft, Blasted & removed		0.921	0.987	-1.29
	Case 4.1: Channel bottom = 27 ft, Design (underwater slope)		0.914	0.980	-2.04
	Case 4.2: Channel bottom = 27 ft, Design (& dry excavation)	0.357	0.938	1.005	0.54
	Case 5: Channel bottom = 22 ft, Blasted material only		0.920	0.986	-1.39
	Case 6: Channel bottom = 22 ft, Blasted & removed		0.910	0.975	-2.47
	Case 7.1: Channel bottom = 22 ft, Design (underwater slope)		0.900	0.965	-3.54
	Case 7.2: Channel bottom = 22 ft, Design (& dry excavation)	0.335	0.936	1.003	0.32
	Case 8: Channel bottom = 16 ft, Blasted		0.897	0.961	-3.86
Conclusions:	Stabilization is required for Case 4 and Case 7				



59K+881 (1964+60)



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SECCION GEOLOGICA

CORTE GAILLARD

ESTACION 59K+881 (1964+60) OESTE

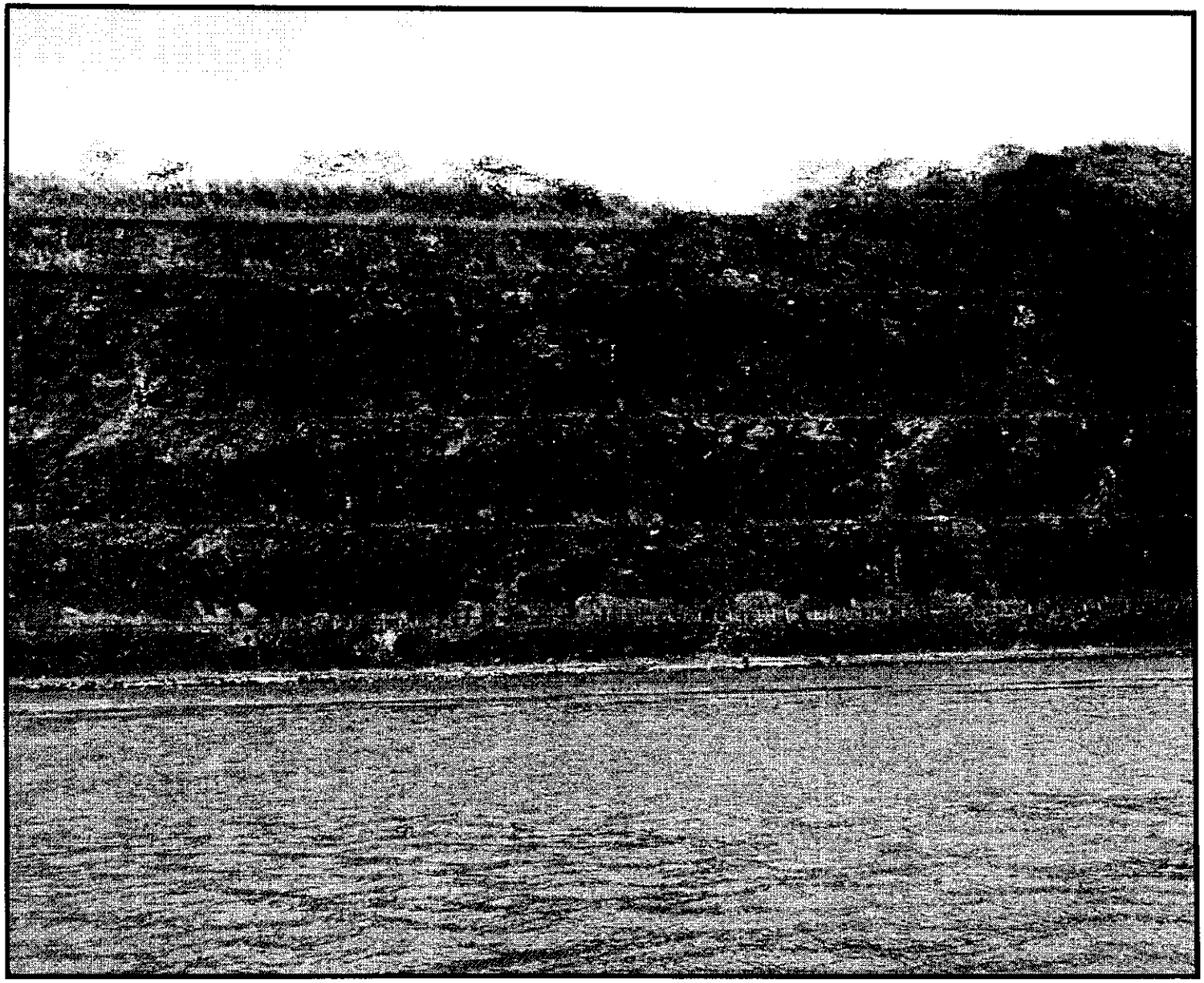
ESCALA: 1:1000	FECHA: ABRIL 2002
GEOLOGIA POR: P. FRANCESCHI & J. RAMESCH	DIBUJADO POR: J. RAMESCH

station 60k + 240 (1976 + 37)

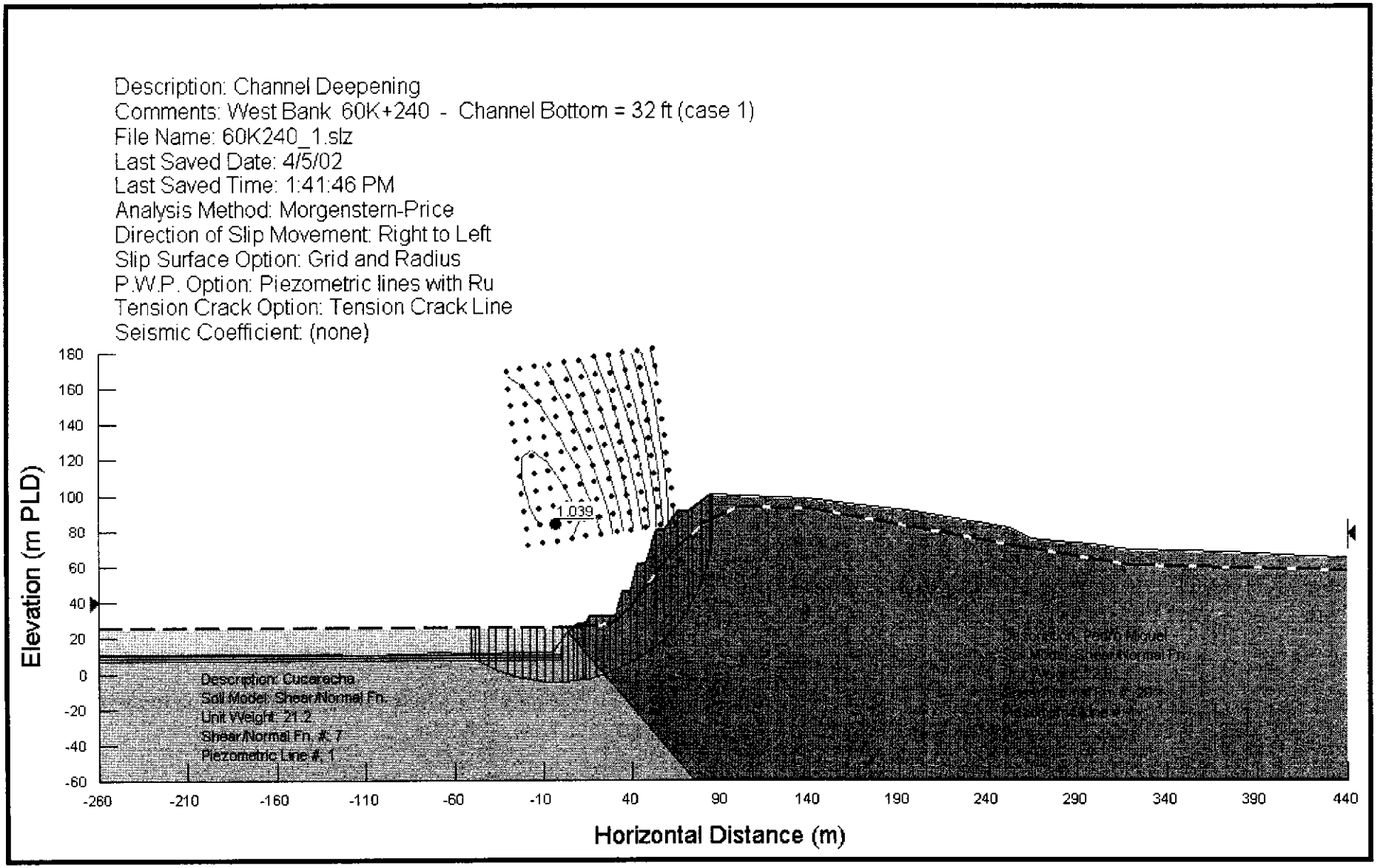
West

Station: 60k + 240 (Contractor)

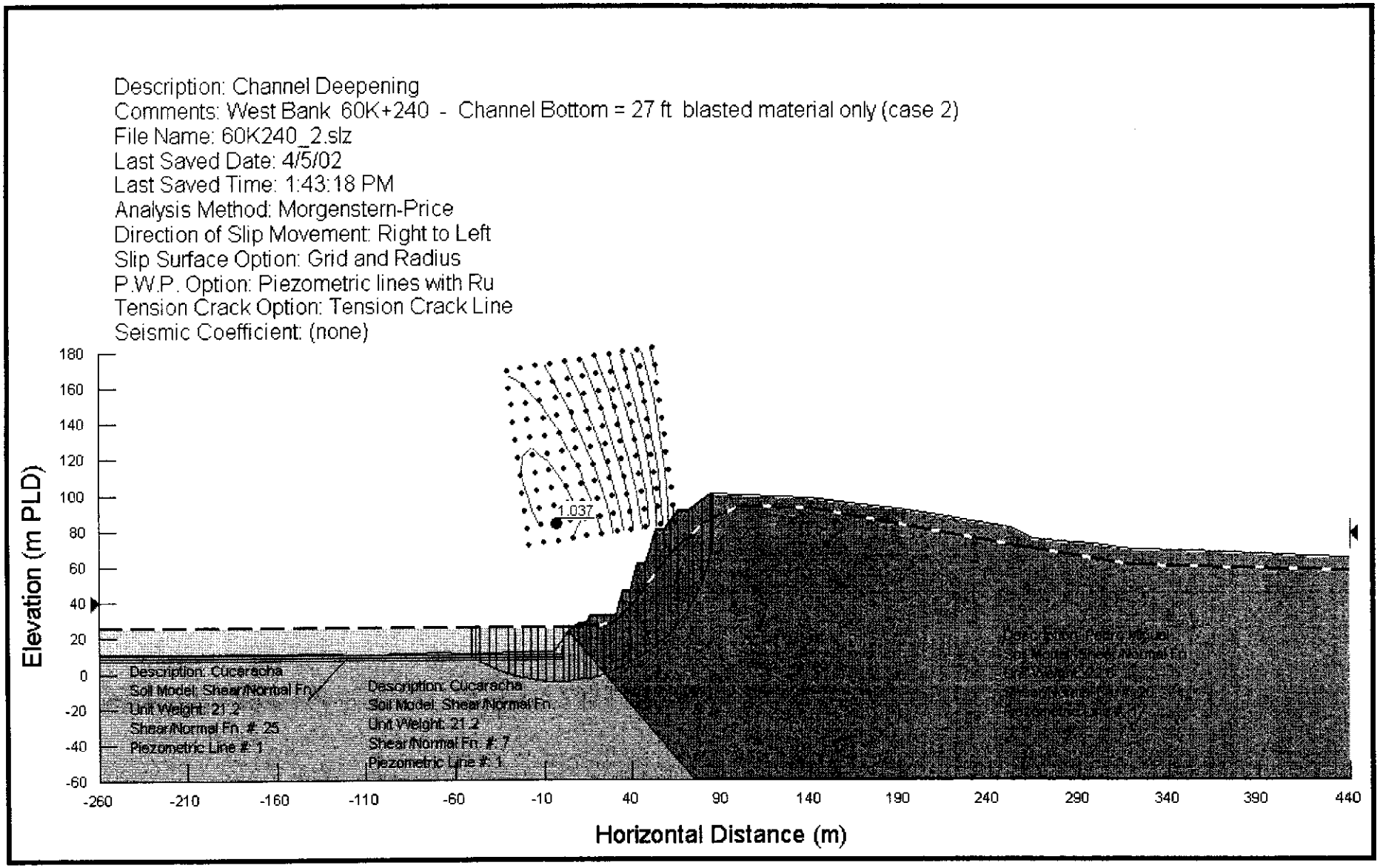
April 16, 2002



Case 1, Channel bottom = 32 ft

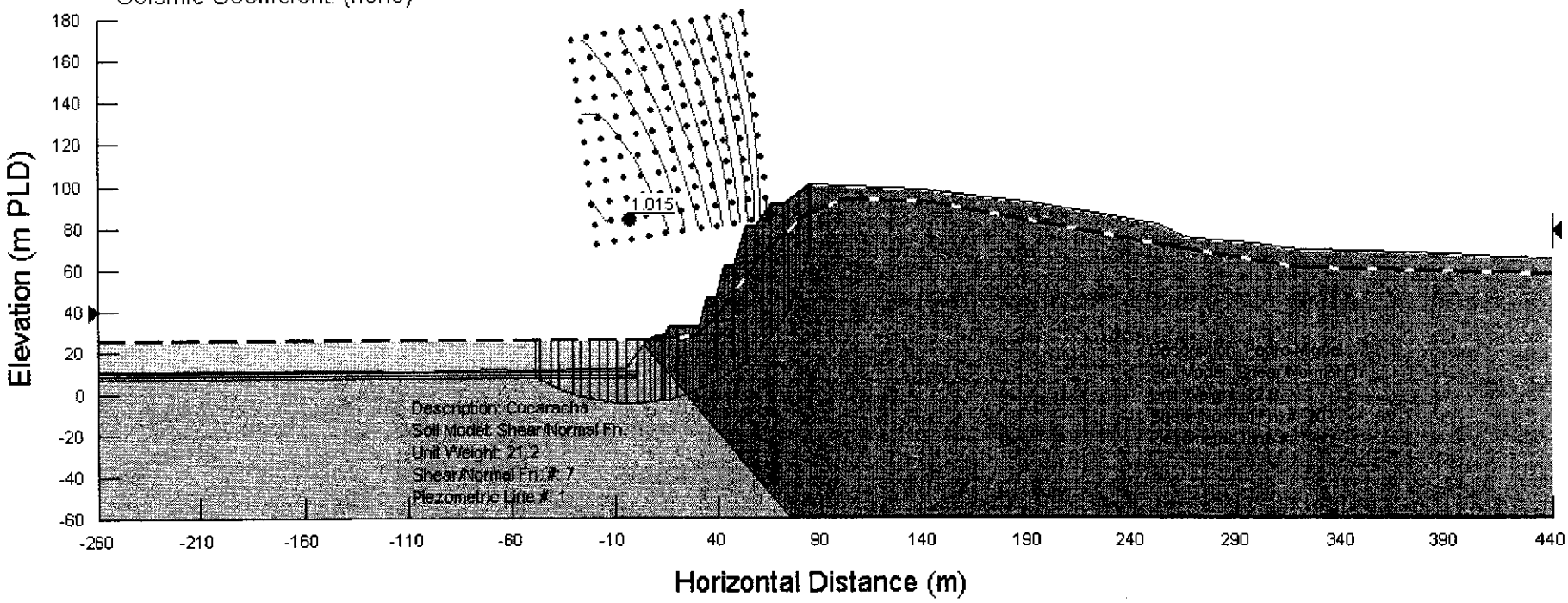


Case 2, Channel bottom = 27 ft, Blasted material only



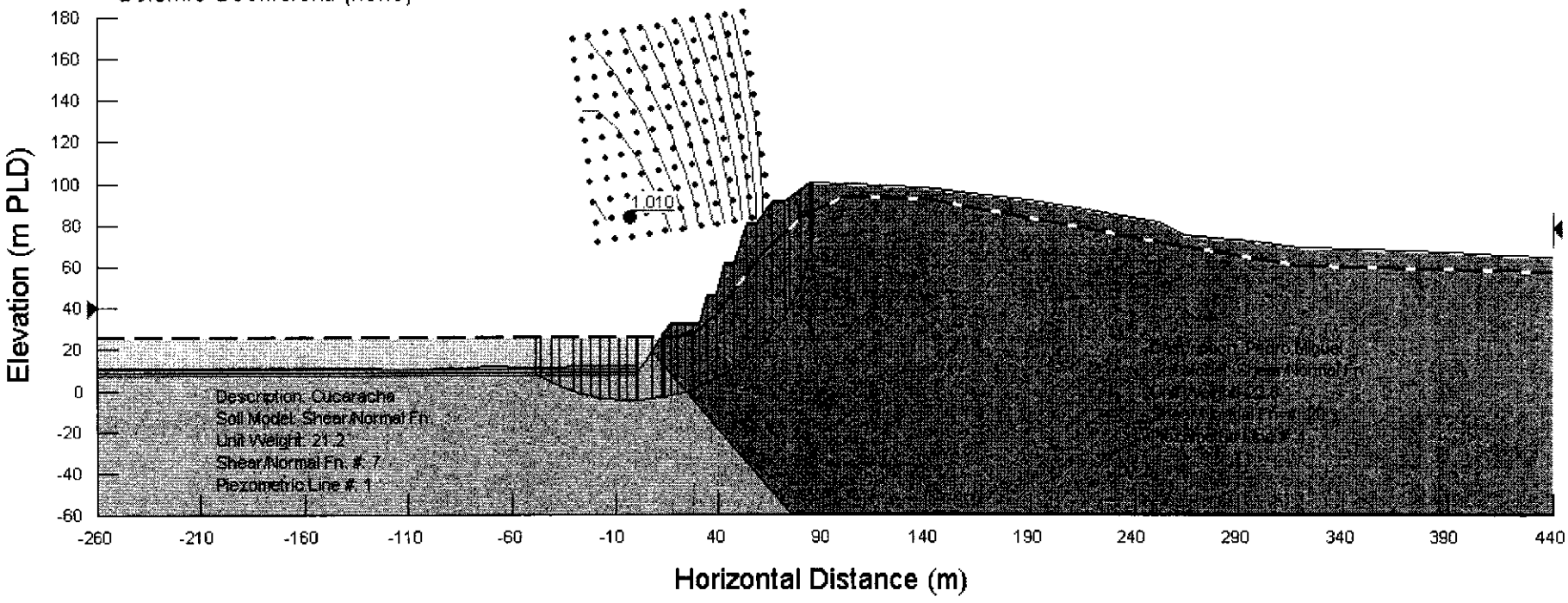
Case 3, Channel bottom = 27 ft, Blasted & removed

Description: Channel Deepening
Comments: West Bank 60K+240 - Channel Bottom = 27 ft blasted & removed (case 3)
File Name: 60K240_3.slz
Last Saved Date: 4/5/02
Last Saved Time: 1:45:06 PM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: Tension Crack Line
Seismic Coefficient: (none)



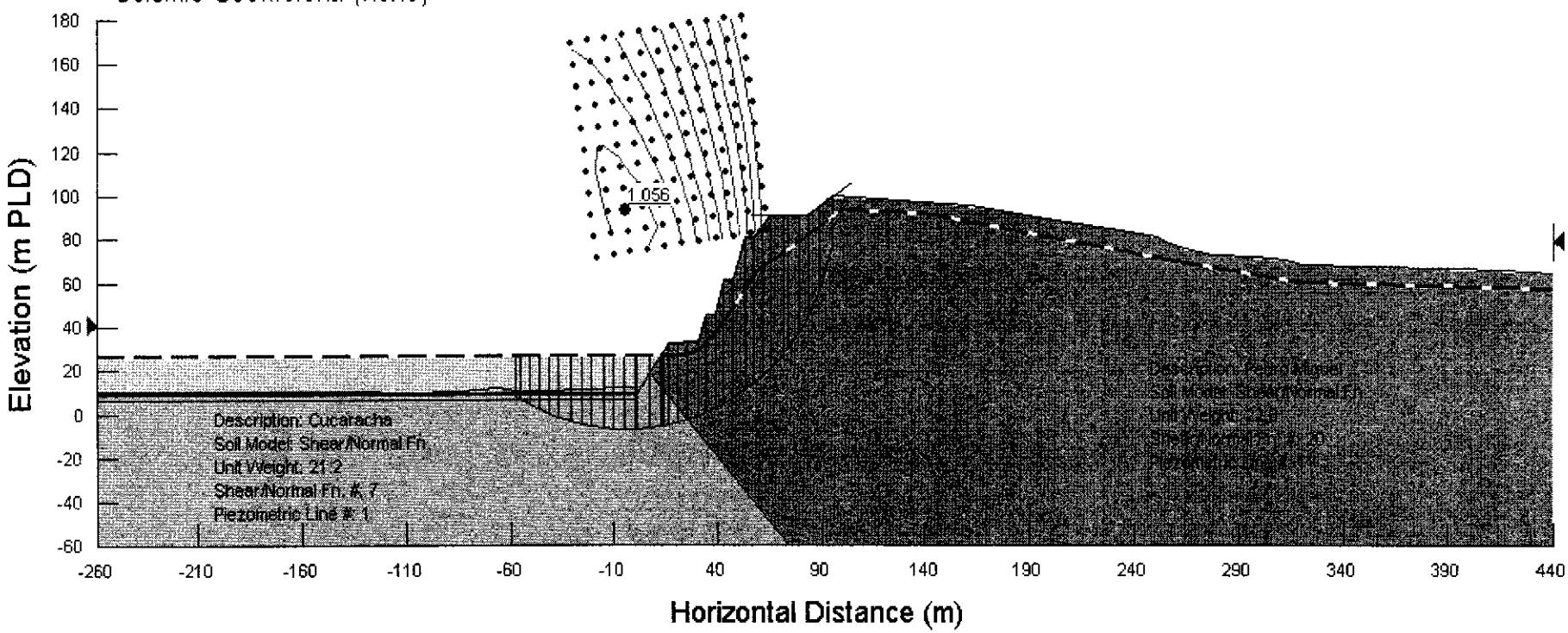
Case 4.1, Channel bottom = 27 ft, Design (underwater slope)

Description: Channel Deepening
Comments: West Bank 60K+240 - Channel Bottom = 27 ft + design (case 4)
File Name: 60K240_4.slz
Last Saved Date: 4/5/02
Last Saved Time: 1:49:51 PM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: Tension Crack Line
Seismic Coefficient: (none)



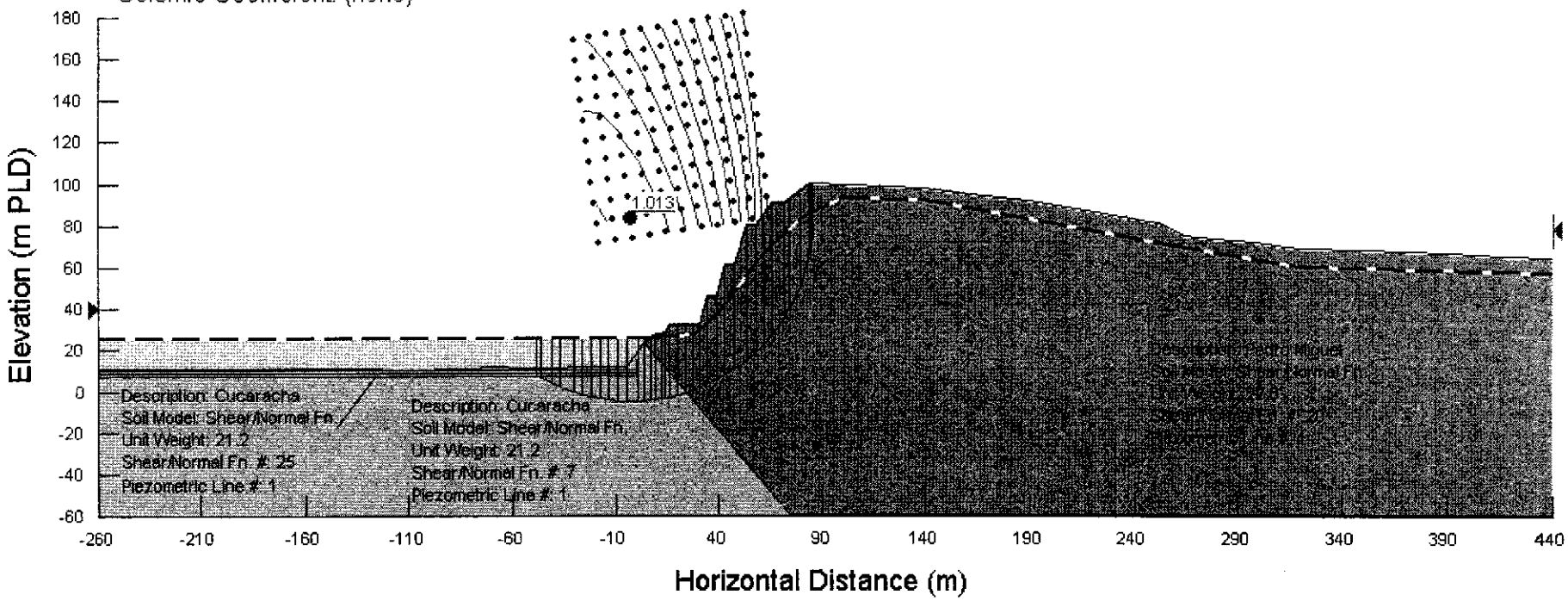
Case 4.2, Channel bottom = 27 ft, Design (& dry excavation)

Description: Channel Deepening
Comments: West Bank 60K+240 - Channel Bottom = 27 ft + design (case 4)
File Name: 60K240_4e.slz
Last Saved Date: 4/7/02
Last Saved Time: 11:59:17 AM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: Tension Crack Line
Seismic Coefficient: (none)



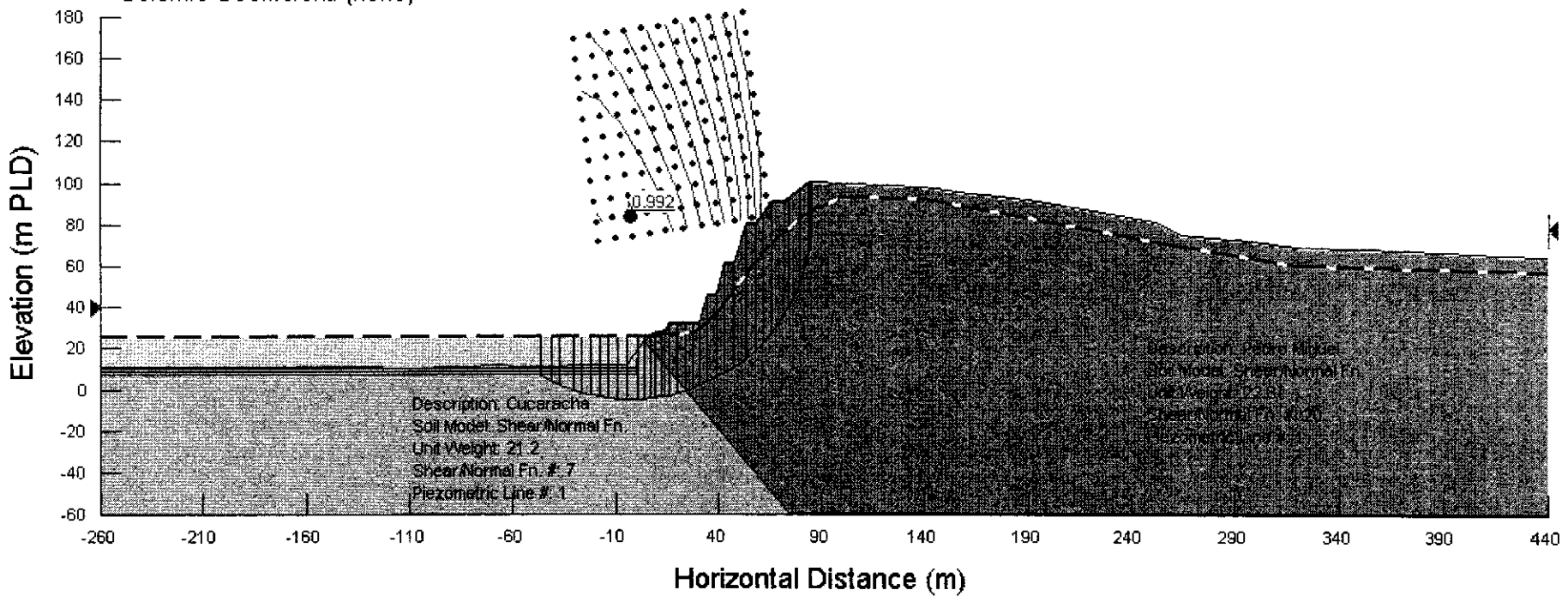
Case 5, Channel bottom = 22 ft, Blasted material only

Description: Channel Deepening
Comments: West Bank 60K+240 - Channel Bottom = 22 ft blasted material only (case 5)
File Name: 60K240_5.slz
Last Saved Date: 4/5/02
Last Saved Time: 1:51:34 PM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: Tension Crack Line
Seismic Coefficient: (none)

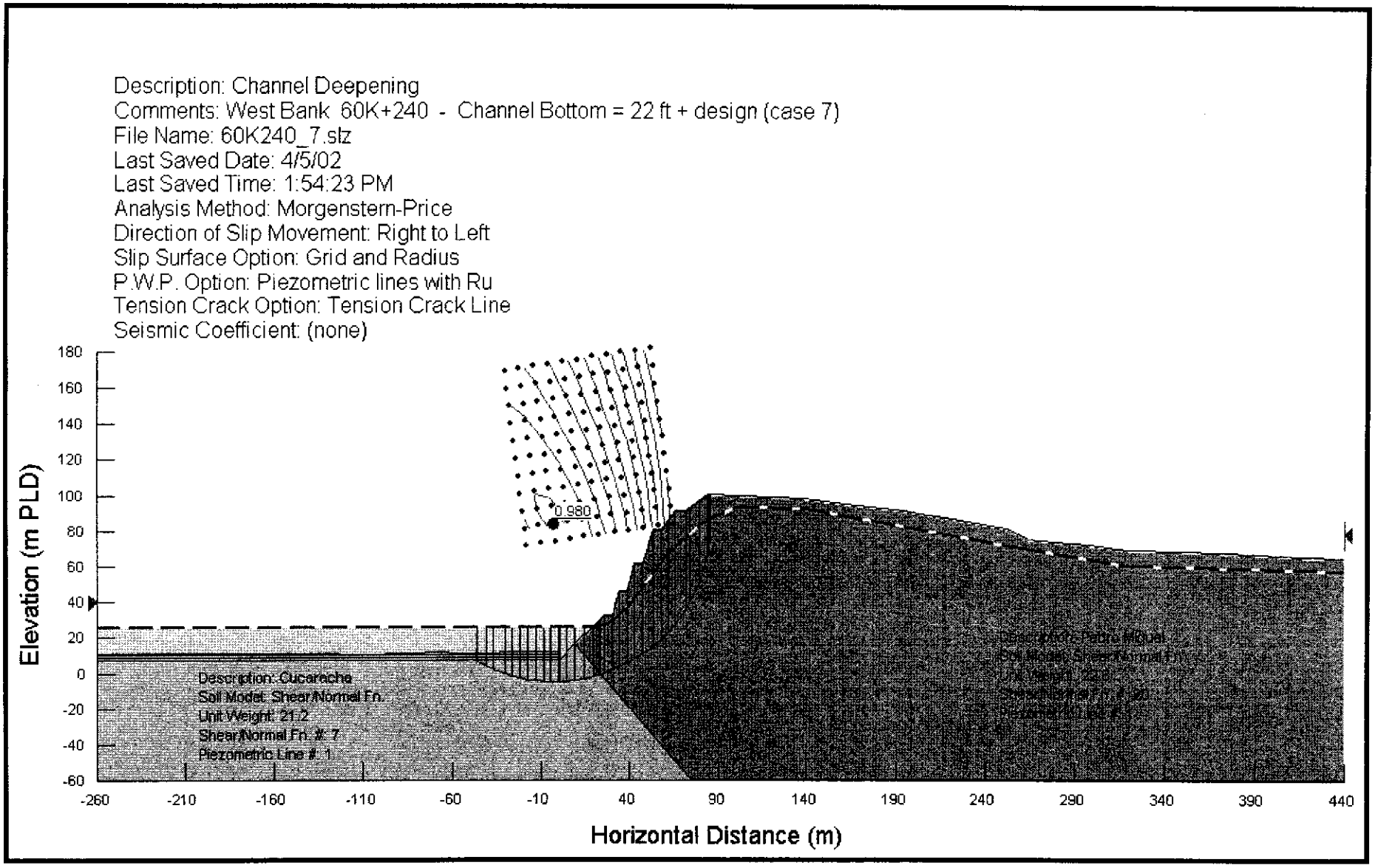


Case 6, Channel bottom = 22 ft, Blasted & removed

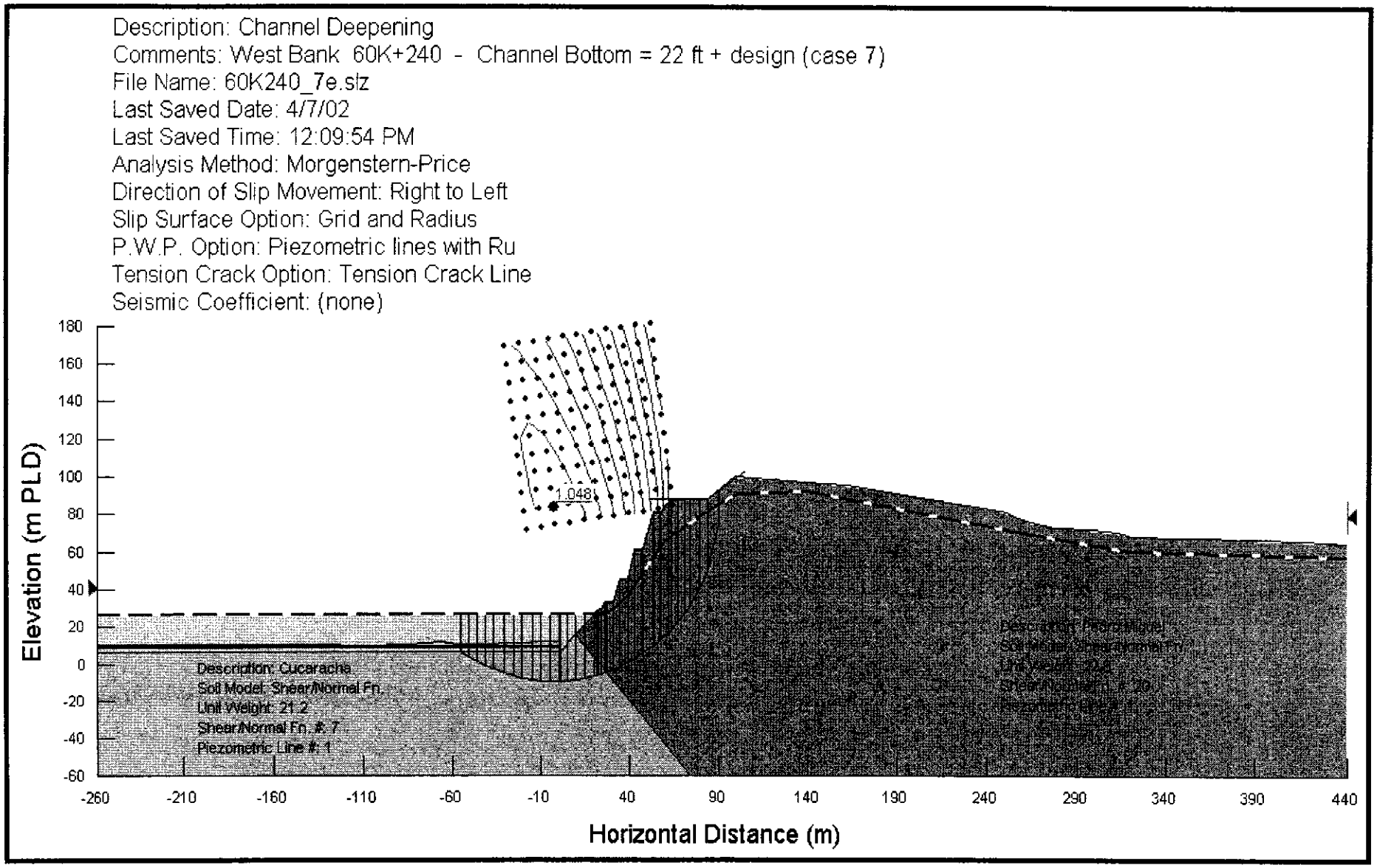
Description: Channel Deepening
Comments: West Bank 60K+240 - Channel Bottom = 22 ft blasted & removed (case 6)
File Name: 60K240_6.slz
Last Saved Date: 4/5/02
Last Saved Time: 1:53:03 PM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: Tension Crack Line
Seismic Coefficient: (none)



Case 7.1, Channel bottom = 27 ft, Design (underwater slope)

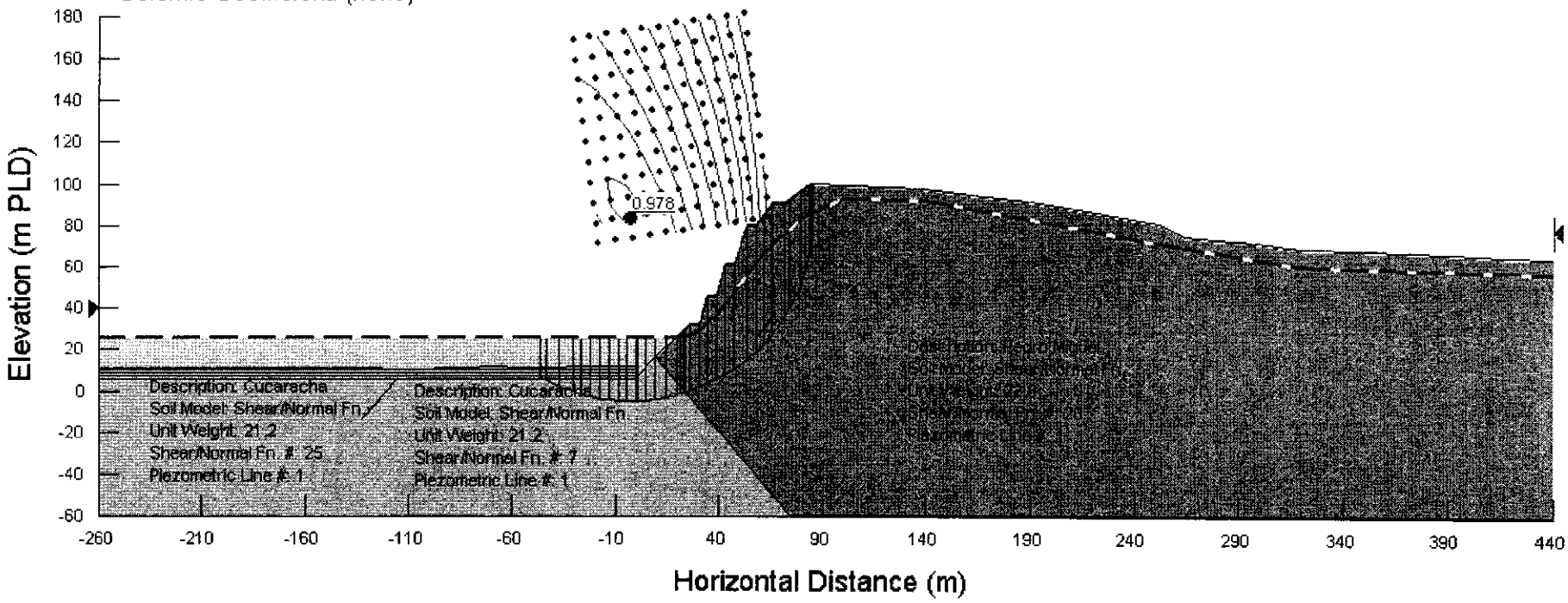


Case 7.2, Channel bottom = 27 ft, Design (& dry excavation)



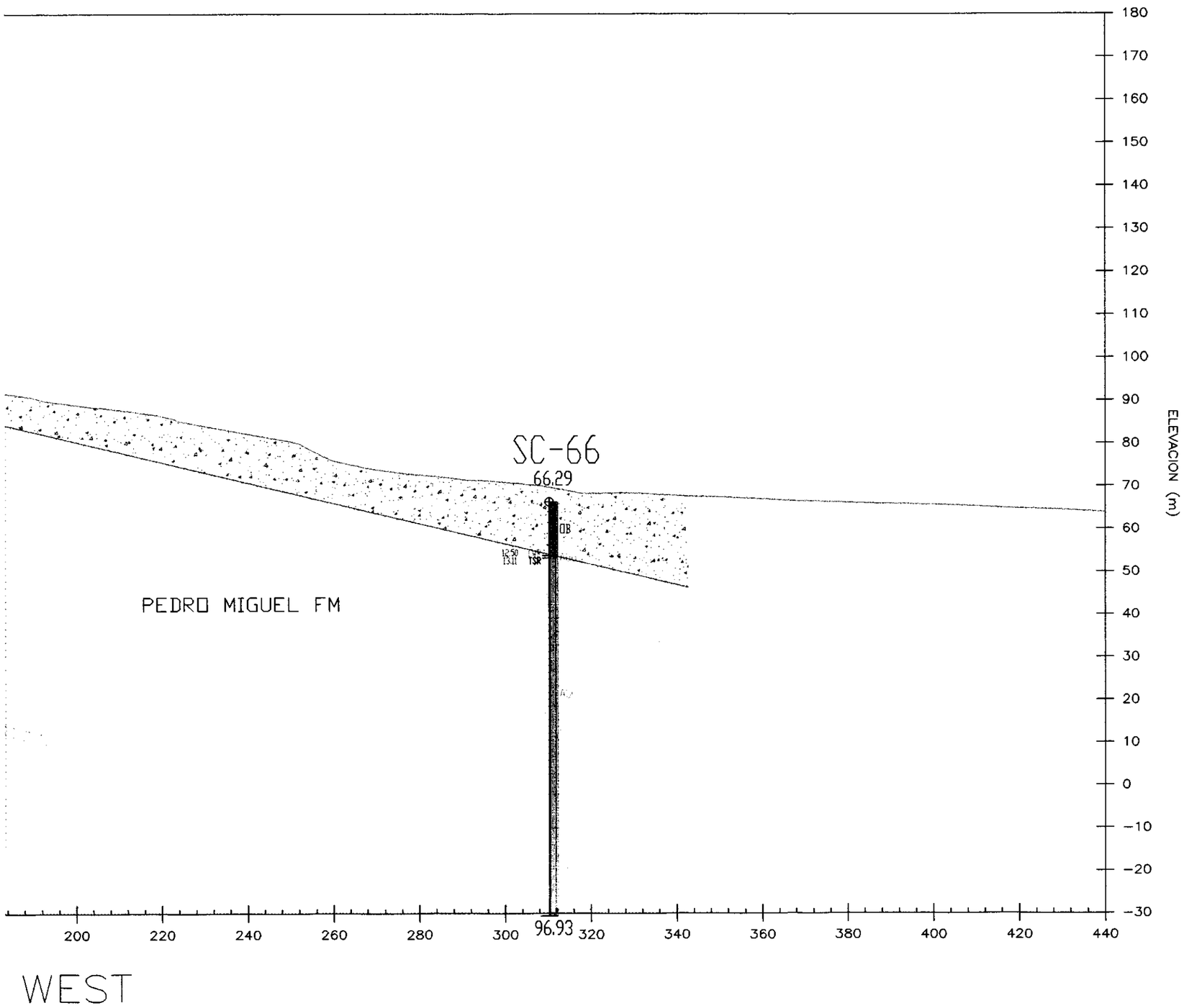
Case 8, Channel bottom = 16 ft, Blasted

Description: Channel Deepening
Comments: West Bank 60K+240 - Channel Bottom = 22 ft + design + blasted 16 ft (case 8)
File Name: 60K240_8.slz
Last Saved Date: 4/7/02
Last Saved Time: 3:59:54 PM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: Tension Crack Line
Seismic Coefficient: (none)



Summary, 60k + 240 (1976 + 37)

General Description	Range of stations:	60k + 050 to 60k + 400			
	Sector:	Contractors			
	Maximum height (m):	90			
	Cotangent of slope angle (cot. β):	0.93			
History	Last slide event:	July 1954, (Large tension cracks during first widening)			
Geology	Formation:	Pedro Miguel / Culebra / Cucaracha			
	Lithology:	Aggregate / Tuff / Clayshale / siltstone			
	Critical stratum at toe:	Clayshale			
	Apparent dip of bedding:	Toward the Slope			
Stability Analysis	Critical failure mechanism:	Rotational and tension cracks			
	Shear strength model:	Fully softened, Cucaracha / First time Pedro Miguel Agglomerate			
		Operative average pore pressure ratio (aproximate), Ru:	Factor of Safety	Relative Factor of Safety	Percentage of Change (%)
	Case 1: Channel bottom = 32 ft	0.358	1.039	1.000	0.00
	Case 2: Channel bottom = 27 ft, Blasted material only		1.037	0.998	-0.19
	Case 3: Channel bottom = 27 ft, Blasted & removed		1.015	0.977	-2.31
	Case 4.1: Channel bottom = 27 ft, Design (underwater slope)		1.010	0.972	-2.79
	Case 4.2: Channel bottom = 27 ft, Design (& dry excavation)	0.366	1.056	1.016	1.64
	Case 5: Channel bottom = 22 ft, Blasted material only		1.013	0.975	-2.50
	Case 6: Channel bottom = 22 ft, Blasted & removed		0.992	0.955	-4.52
	Case 7.1: Channel bottom = 22 ft, Design (underwater slope)		0.980	0.943	-5.68
	Case 7.2: Channel bottom = 22 ft, Design (& dry excavation)	0.374	1.048	1.009	0.87
	Case 8: Channel bottom = 16 ft, Blasted		0.978	0.941	-5.87
Conclusions:	Stabilization is required for Case 4 and Case 7				



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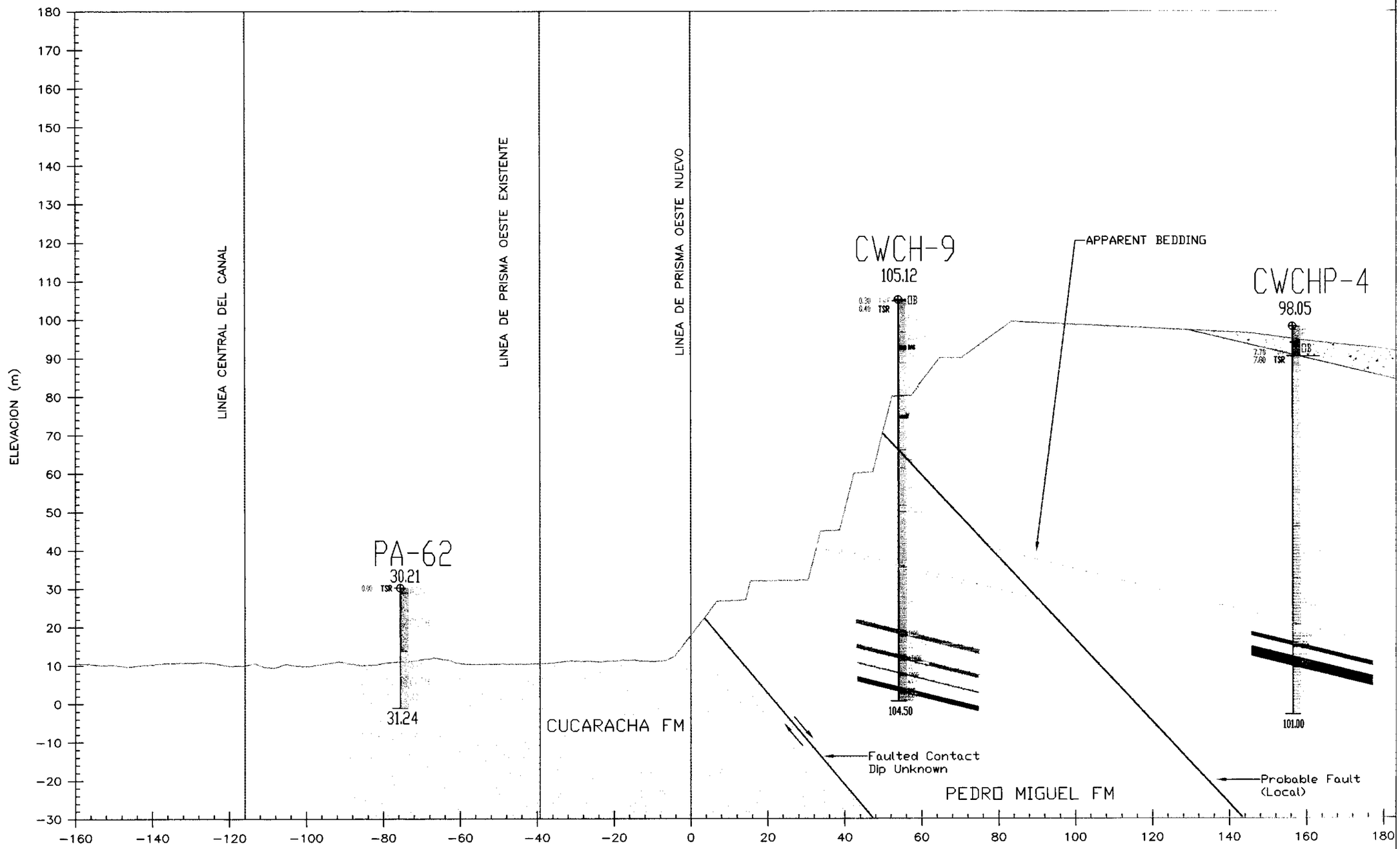
SECCION GEOLOGICA

CORTE GAILLARD

ESTACION 60K+240 (1976+37) OESTE

ESCALA: 1:1000	FECHA: ABRIL 2002
GEOLOGIA POR: J. ARROCHA & P. FRANCESCHI	DIBUJADO POR: J. RAMESCH



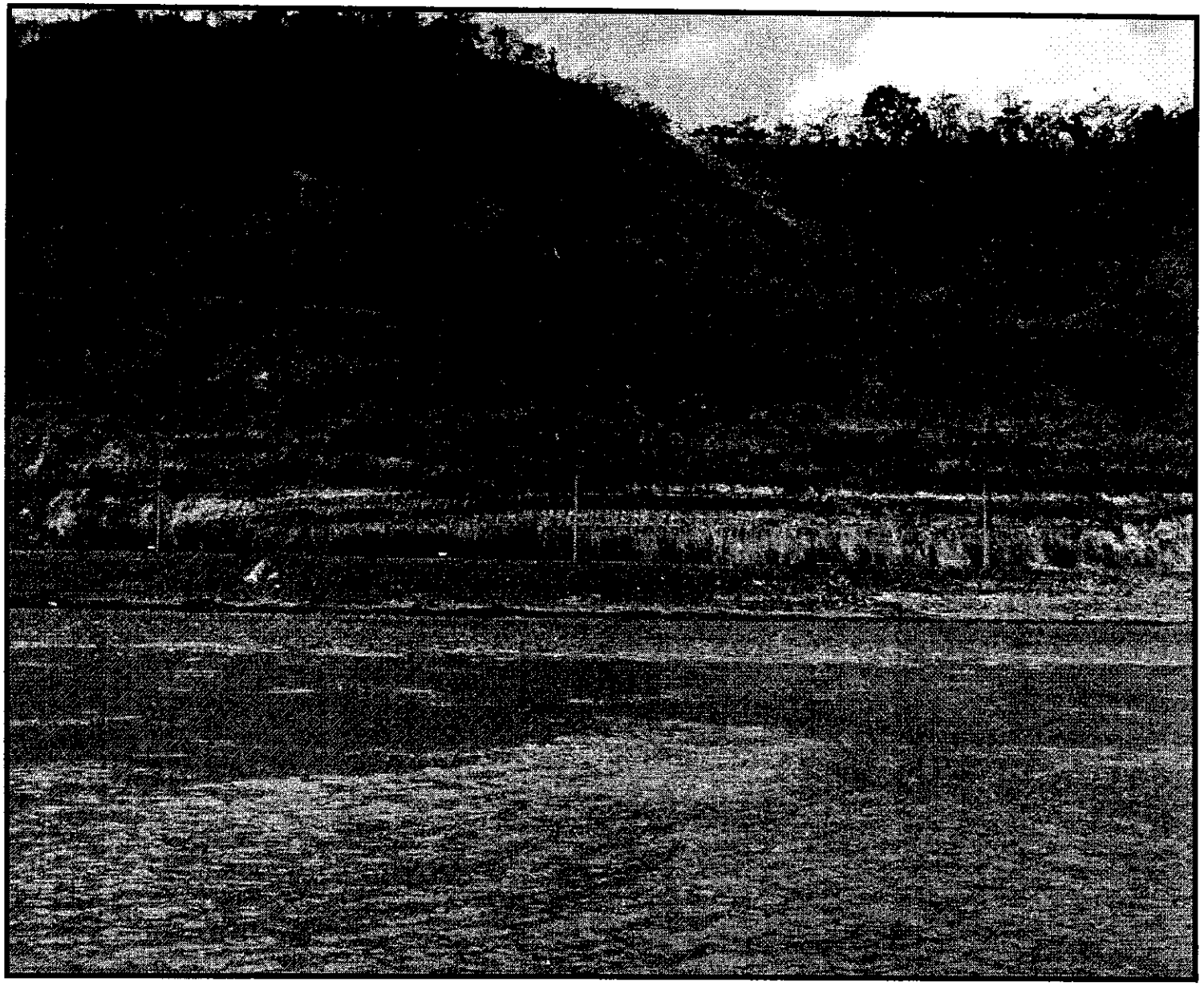
60K+240 (1976+37)

station 60k + 950 (1999 + 61)

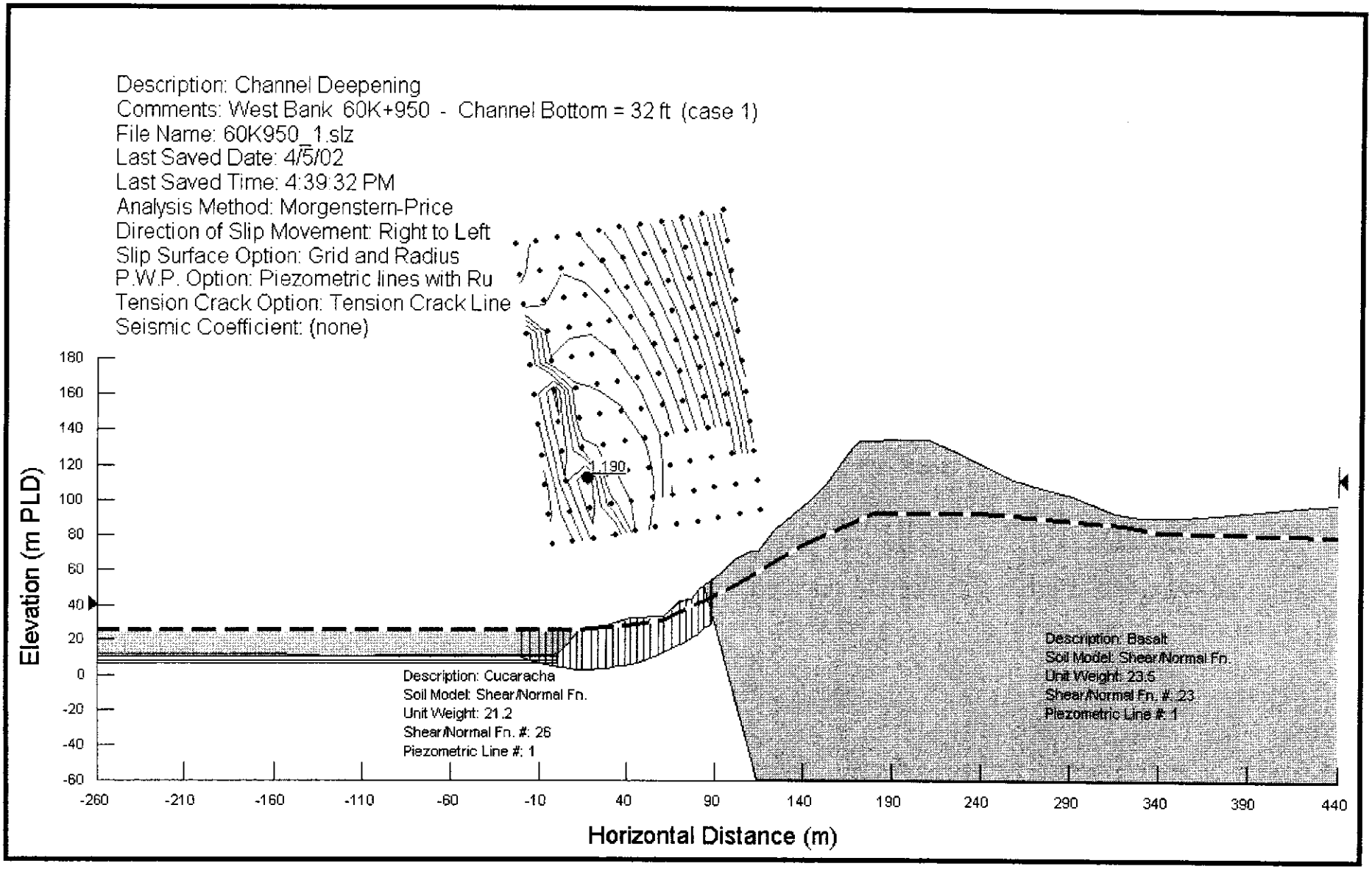
West

Station: 60k + 950 (Escobar)

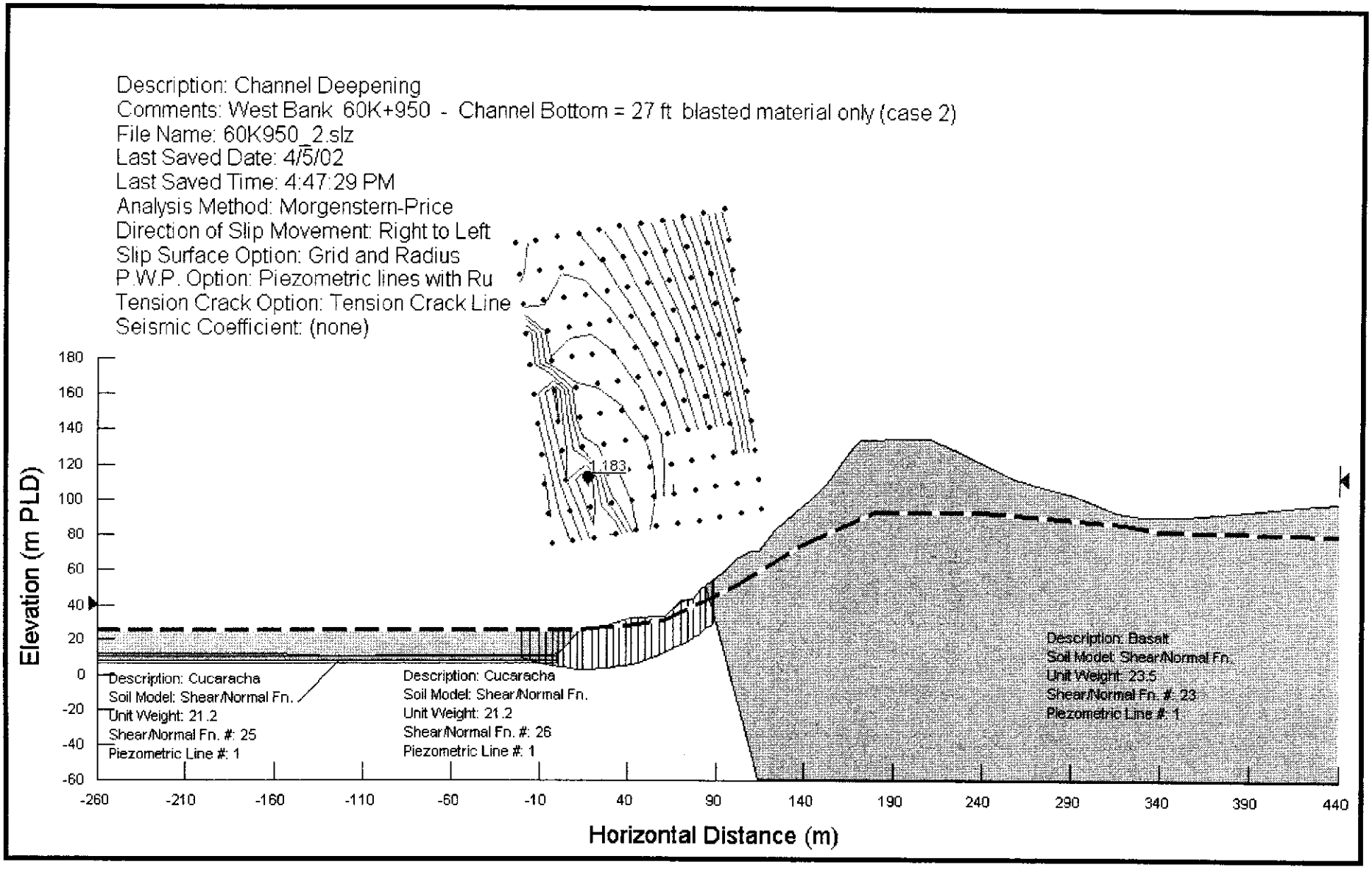
April 16, 2002



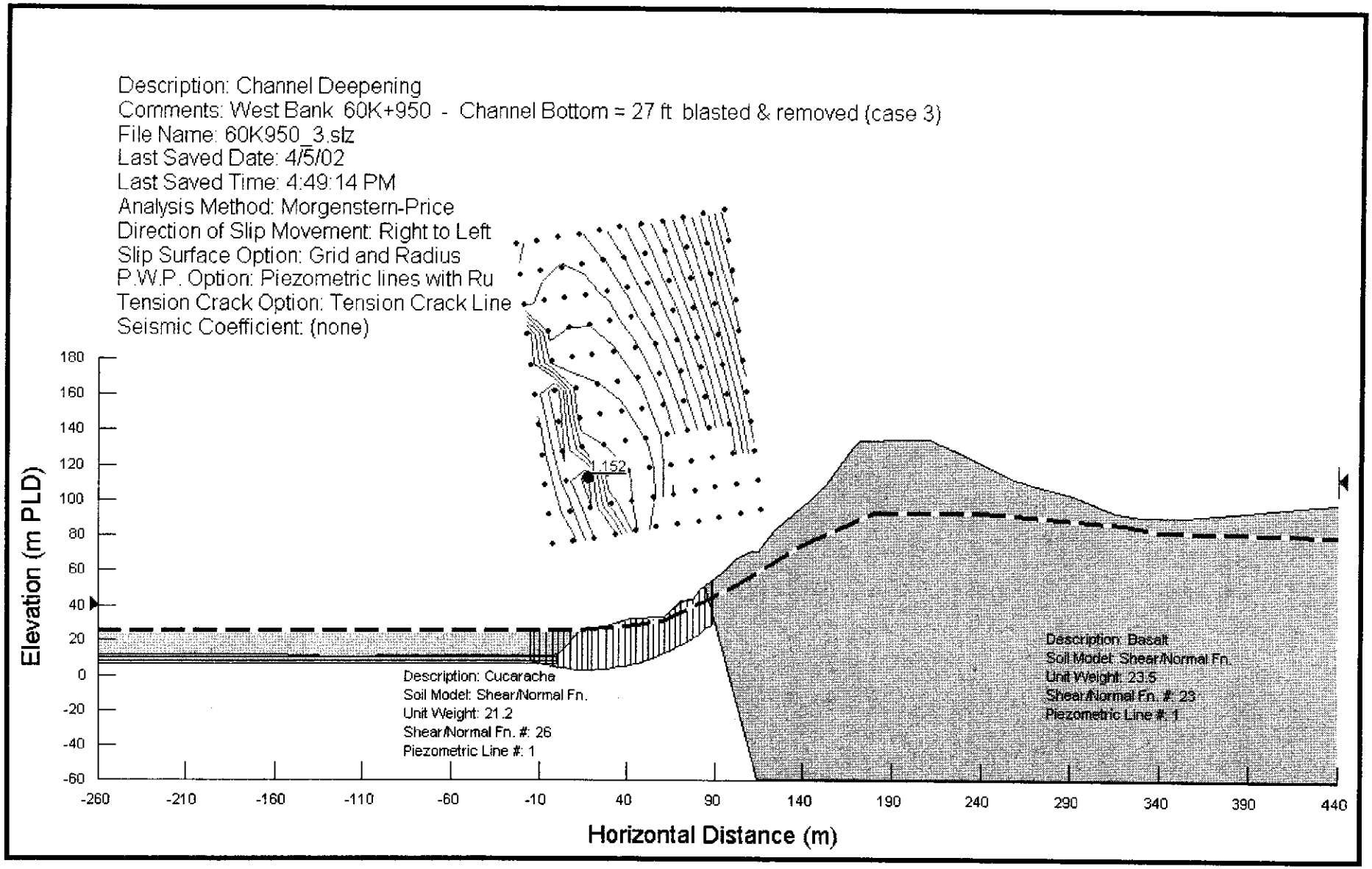
Case 1, Channel bottom = 32 ft



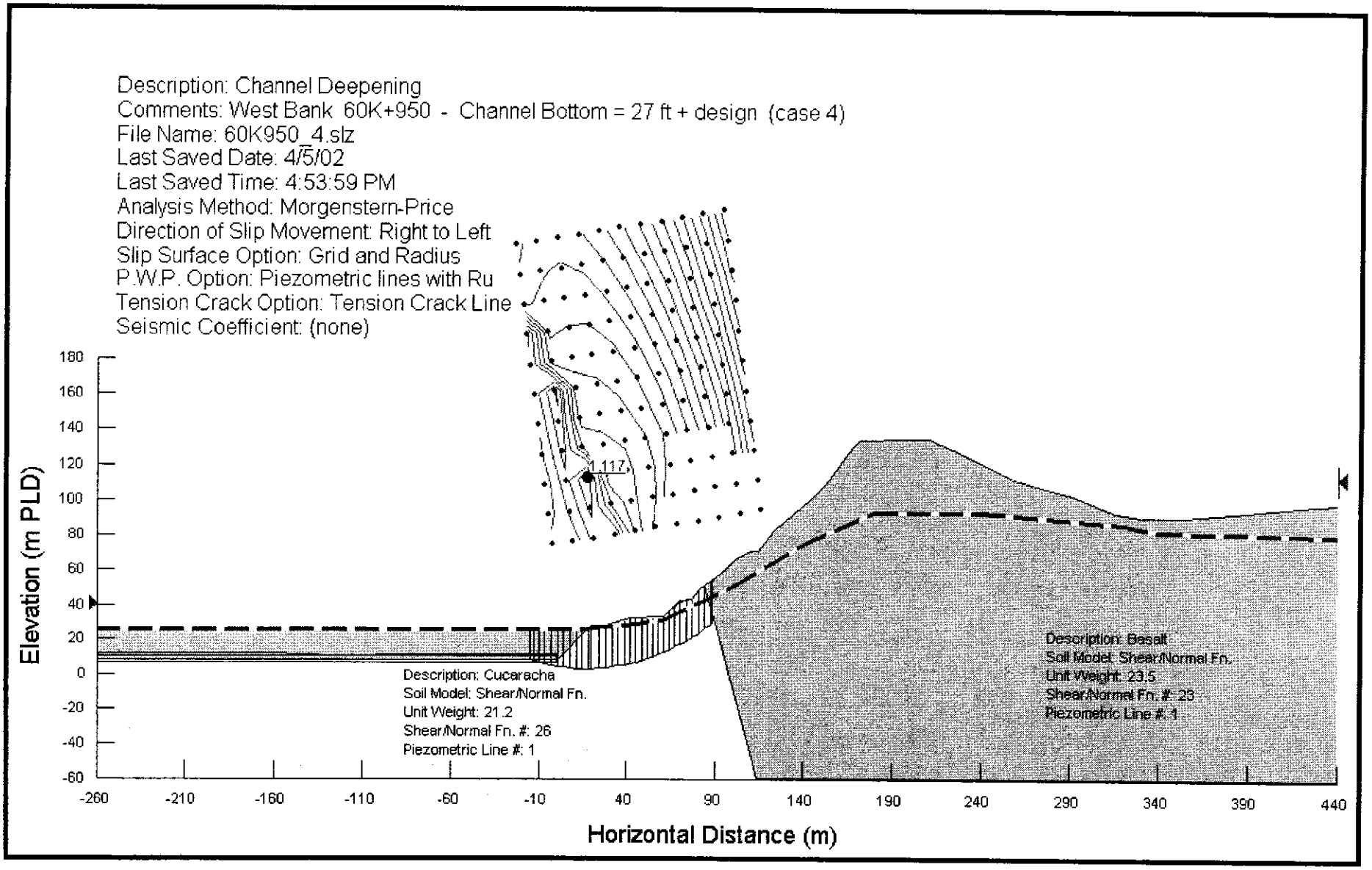
Case 2, Channel bottom = 27 ft, Blasted material only



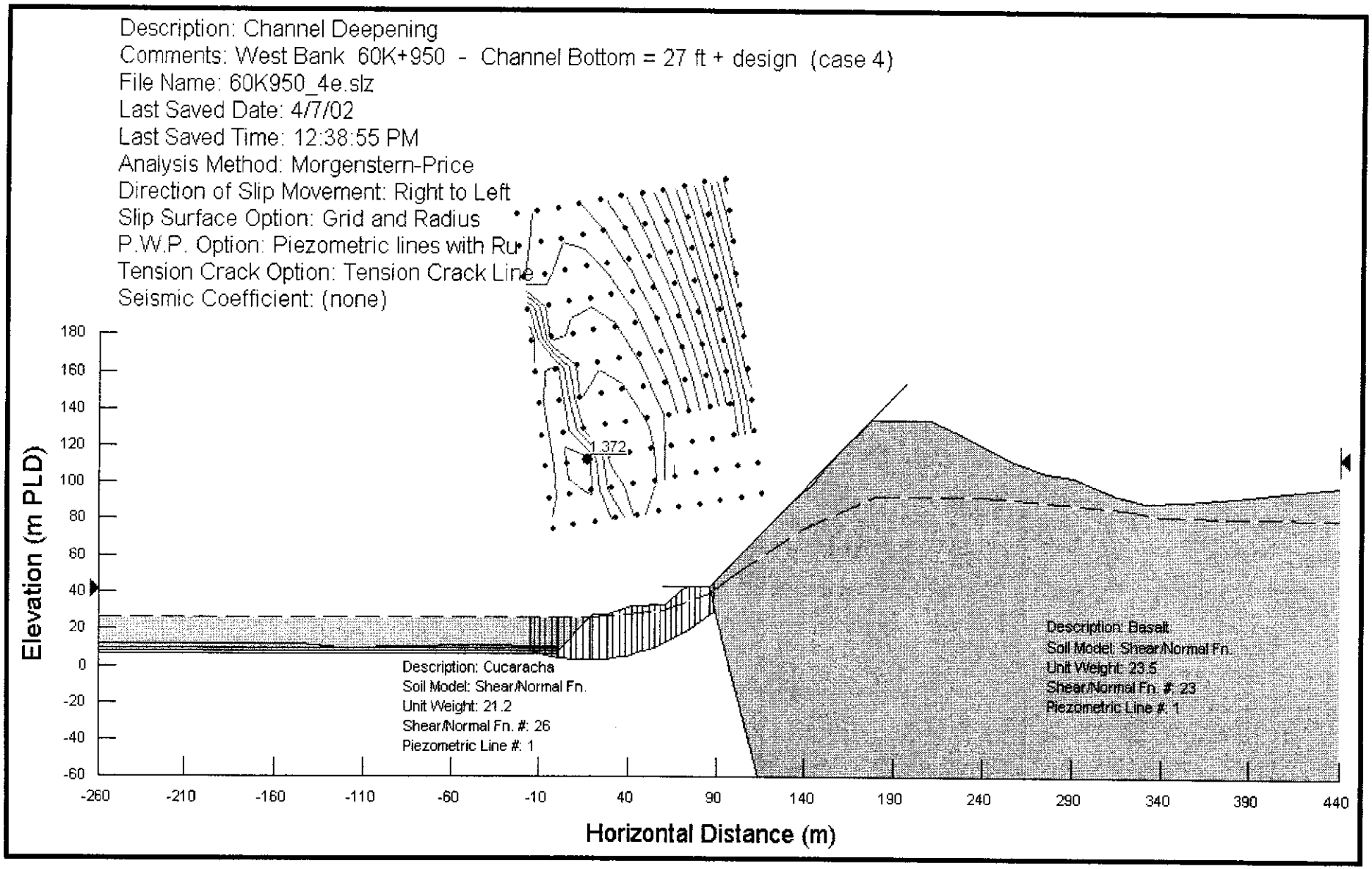
Case 3, Channel bottom = 27 ft, Blasted & removed



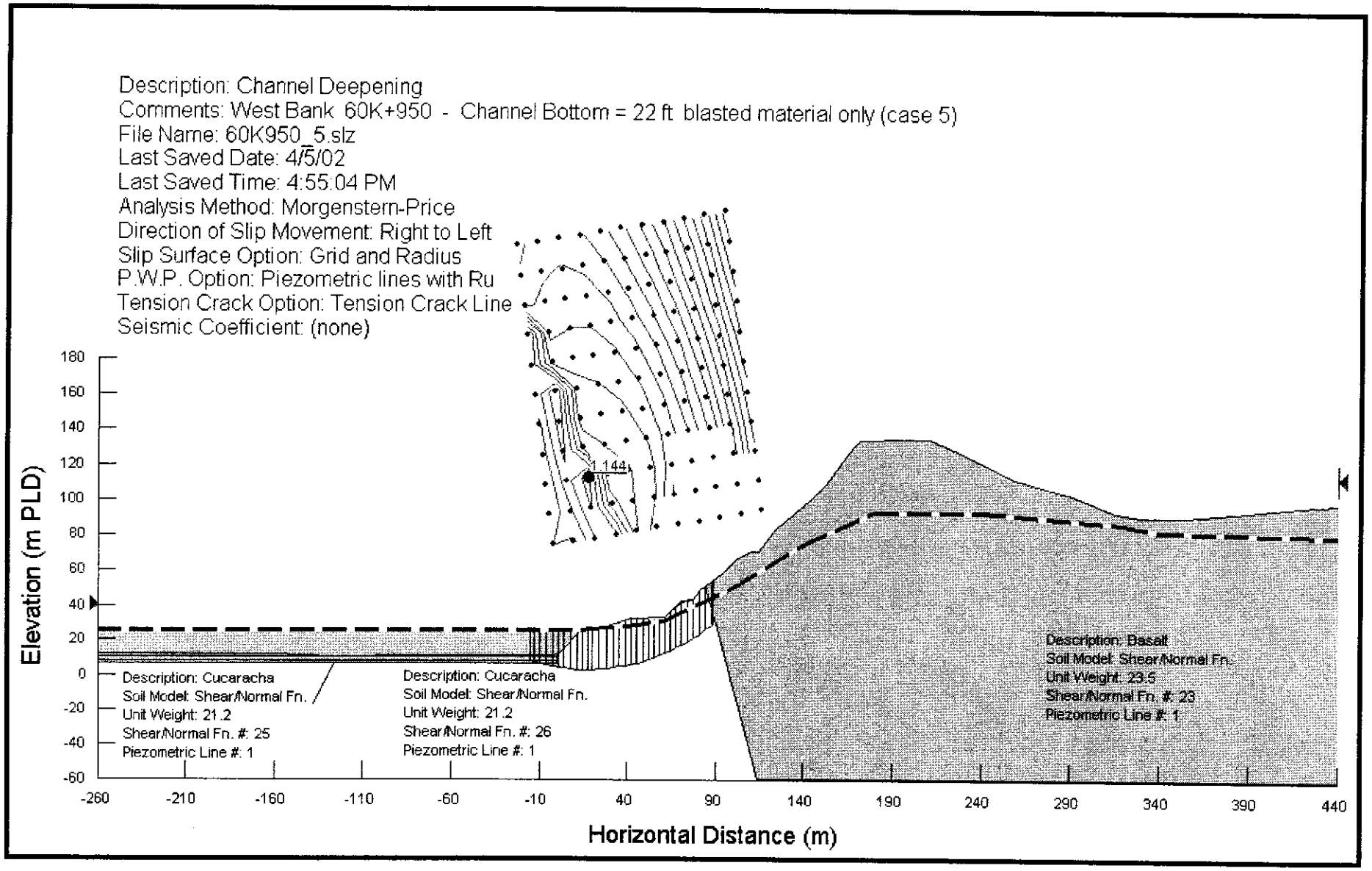
Case 4.1, Channel bottom = 27 ft, Design (underwater slope)



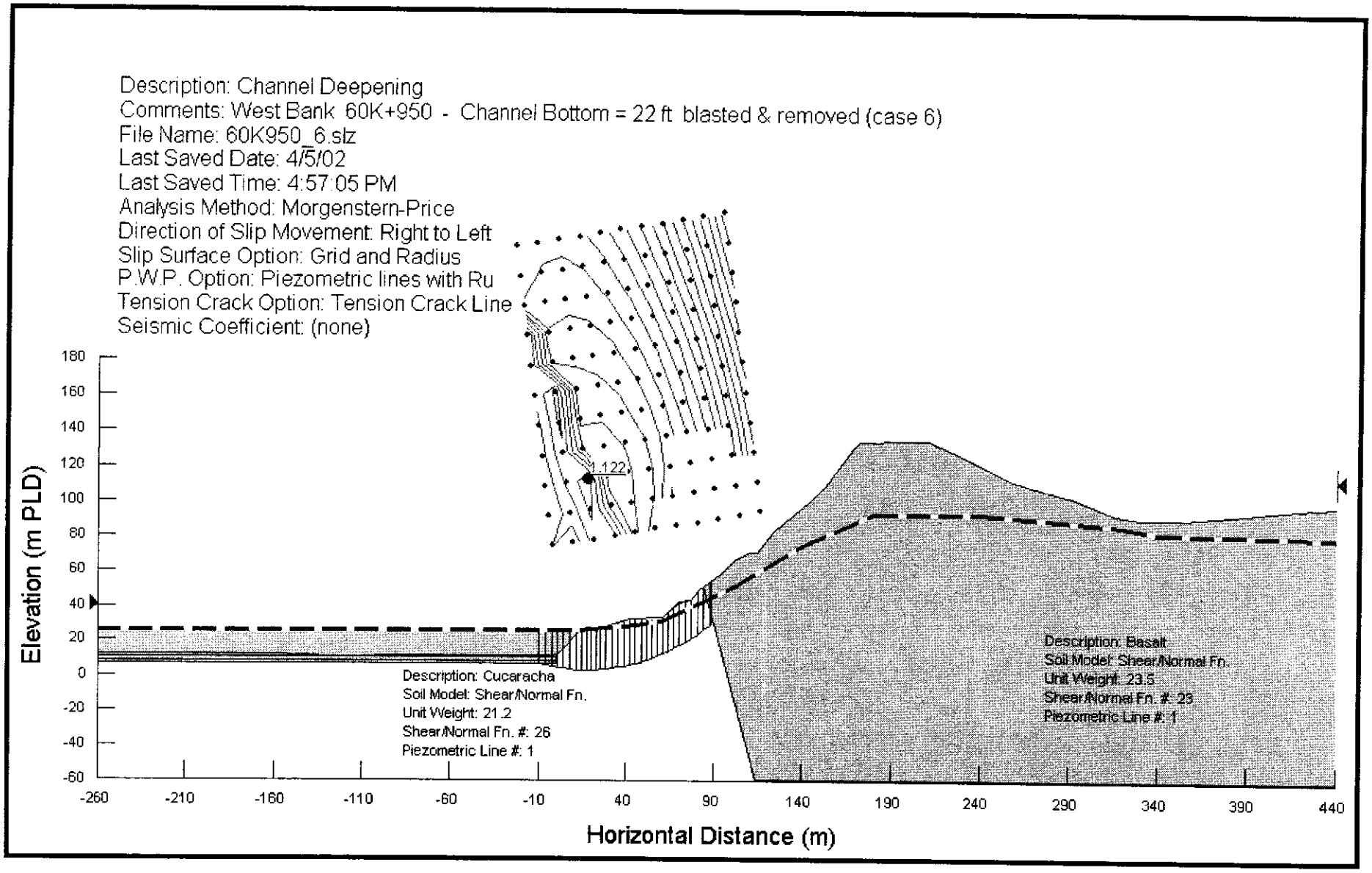
Case 4.2, Channel bottom = 27 ft, Design (& dry excavation)



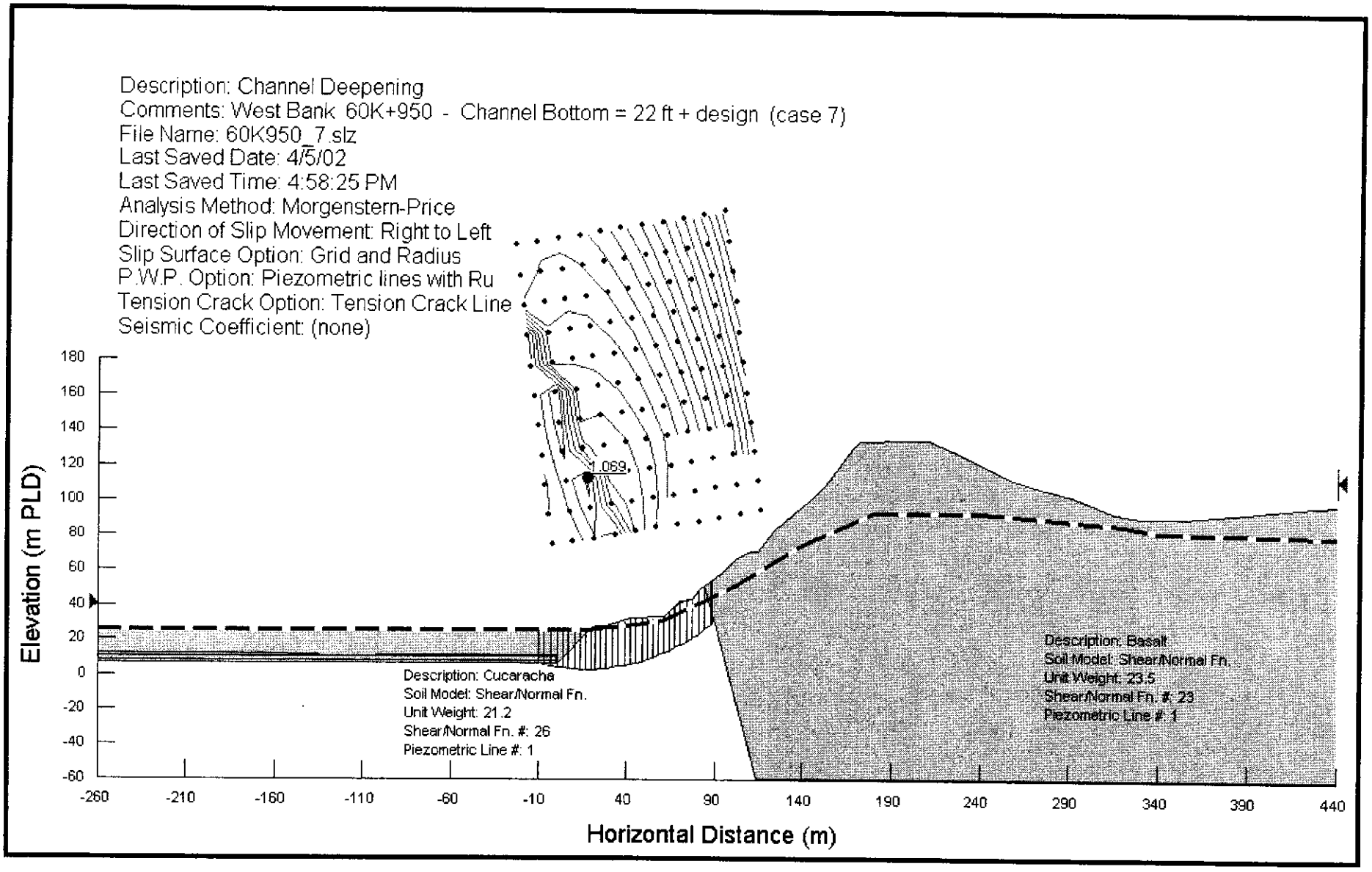
Case 5, Channel bottom = 22 ft, Blasted material only



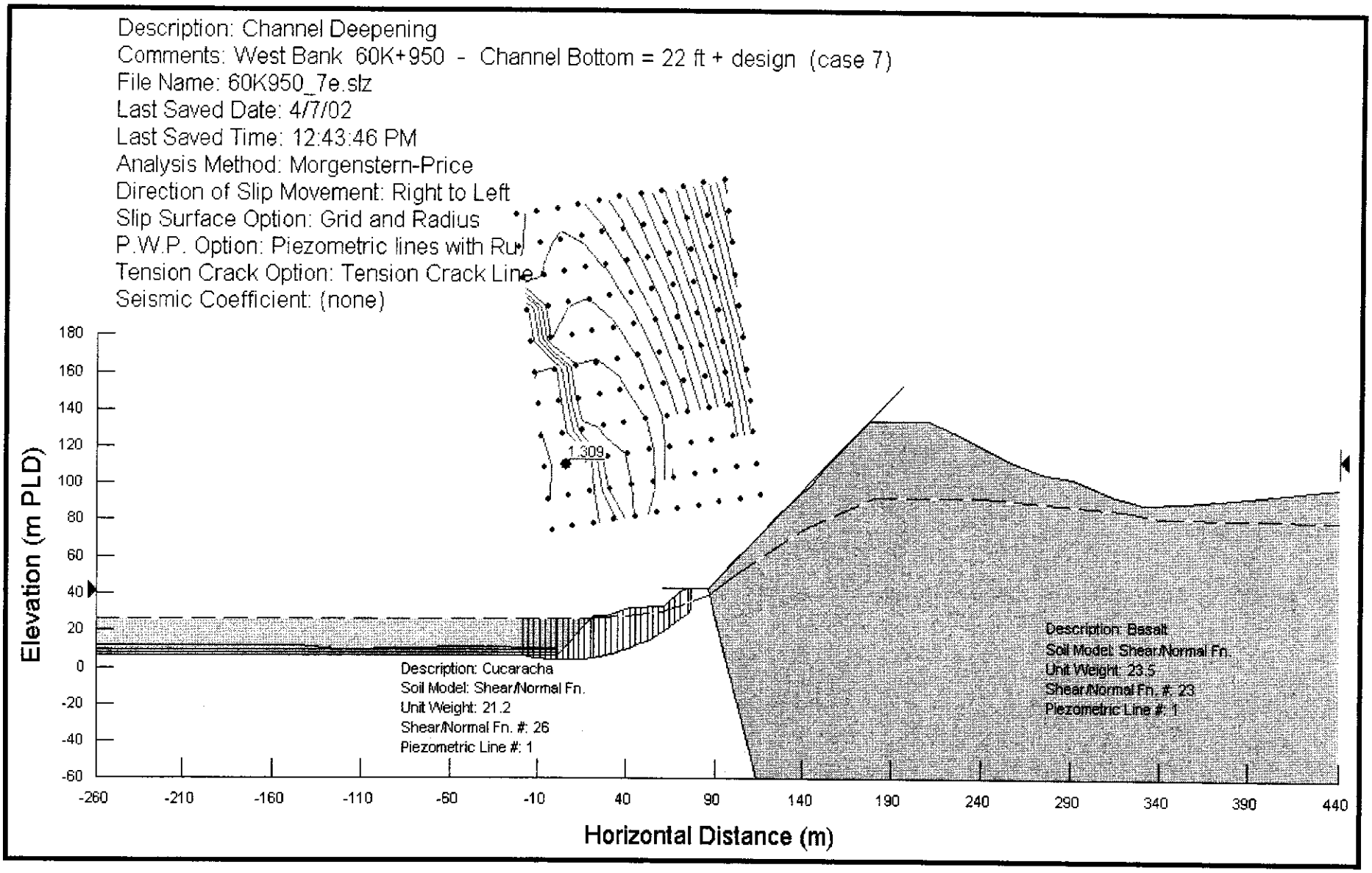
Case 6, Channel bottom = 22 ft, Blasted & removed



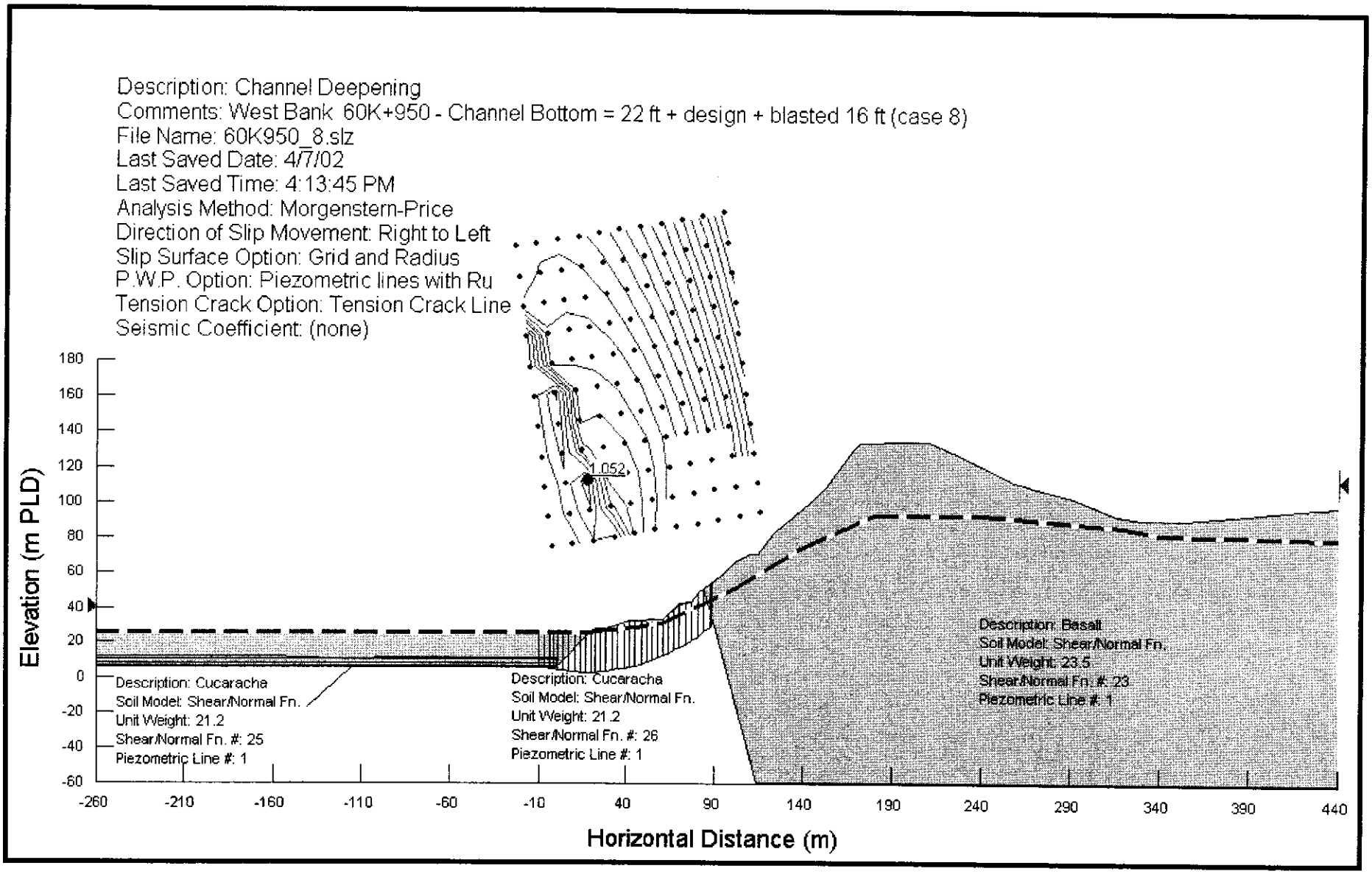
Case 7.1, Channel bottom = 27 ft, Design (underwater slope)



Case 7.2, Channel bottom = 27 ft, Design (& dry excavation)



Case 8, Channel bottom = 27 ft, Blasted

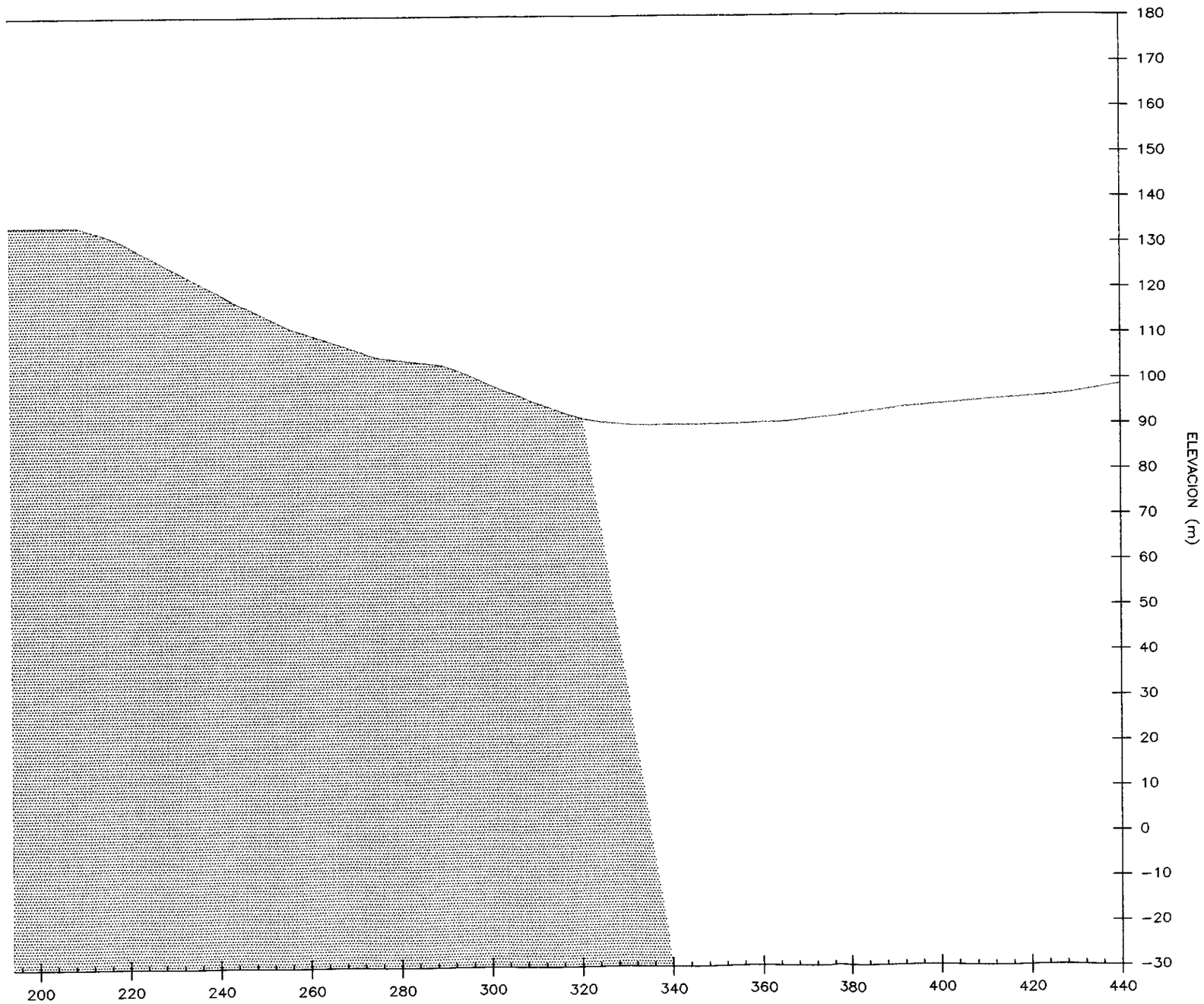


Summary, 60k + 950 (1999 + 61)

General Description	Range of stations:	60k + 400 to 61k + 240
	Sector:	Escobar
	Maximum height (m):	124
	Cotangent of slope angle (cot. β):	1.43
History	Last slide event:	No slide event after widening (Nov. 1931, Cucaracha Signal Station Slid
Geology	Formation:	Basalt / Cucaracha
	Lithology:	Clayshale / Lignitic Shale / Ashflow / Basalt
	Critical stratum at toe:	Clayshale / Ashflow
	Apparent dip of bedding:	Toward the Slope
Stability Analysis	Critical failure mechanism:	Rotational & Tension crack
	Shear strength model:	Fully softened upper bound, Cucaracha / First time, Basalt

	Operative average pore pressure ratio (aproximate), Ru:	Factor of Safety	Relative Factor of Safety	Percentage of Change (%)
Case 1: Channel bottom = 32 ft	0.409	1.190	1.000	0.00
Case 2: Channel bottom = 27 ft, Blasted material only		1.183	0.994	-0.59
Case 3: Channel bottom = 27 ft, Blasted & removed		1.152	0.968	-3.19
Case 4.1: Channel bottom = 27 ft, Design (underwater slope)		1.117	0.939	-6.13
Case 4.2: Channel bottom = 27 ft, Design (& dry excavation)	0.393	1.372	1.153	15.29
Case 5: Channel bottom = 22 ft, Blasted material only		1.144	0.961	-3.87
Case 6: Channel bottom = 22 ft, Blasted & removed		1.122	0.943	-5.71
Case 7.1: Channel bottom = 22 ft, Design (underwater slope)		1.069	0.898	-10.17
Case 7.2: Channel bottom = 22 ft, Design (& dry excavation)	0.387	1.309	1.100	10.00
Case 8: Channel bottom = 16 ft, Blasted		1.052	0.884	-11.60

Conclusions:	Stabilization is required for Case 4 and Case 7



AUTORIDAD DEL CANAL DE PANAMA

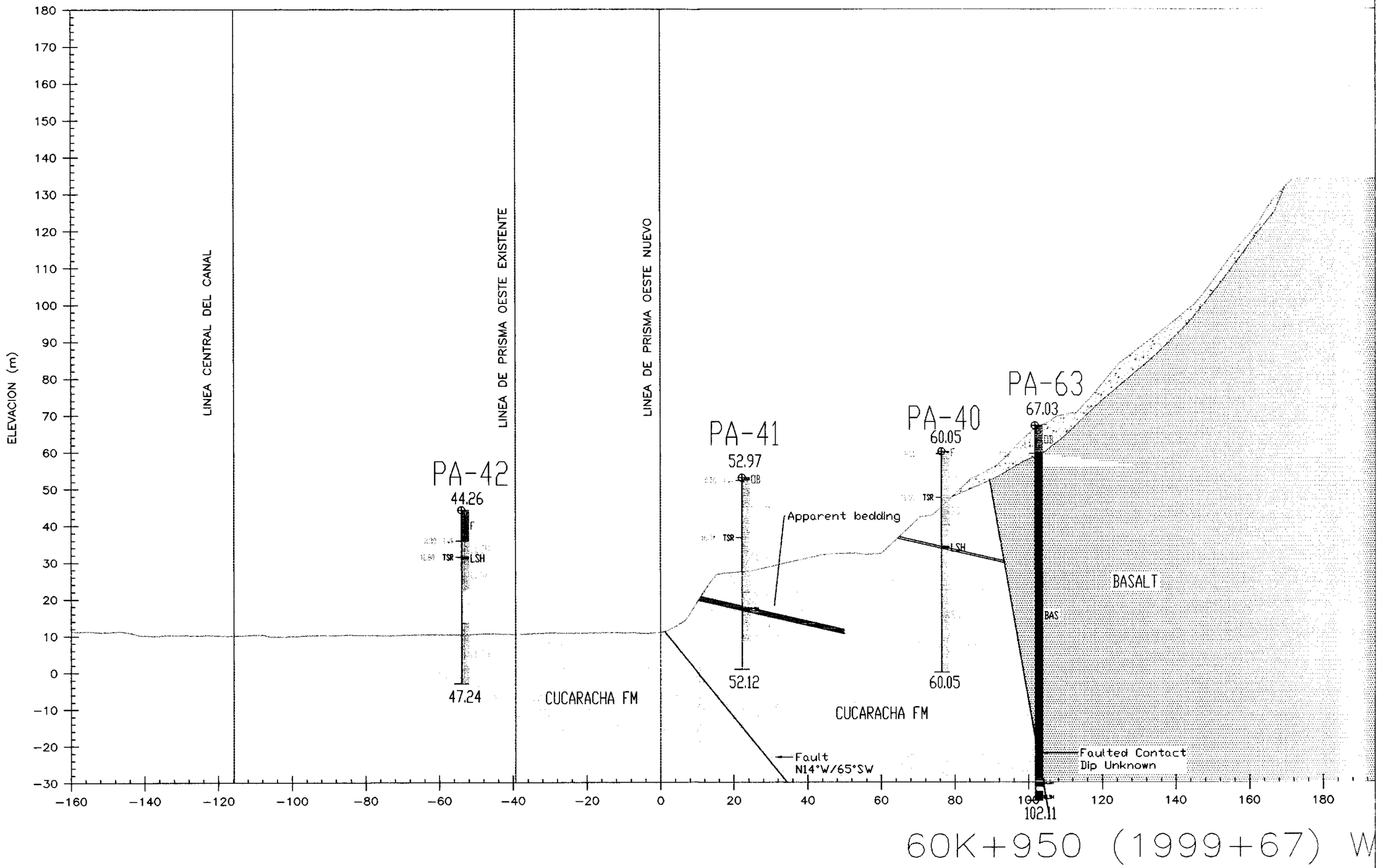
DEPARTAMENTO DE INGENIERIA Y PROYECTOS
DIVISION DE INGENIERIA
ALTOS DE BALBOA, REPUBLICA DE PANAMA

SECCION GEOLOGICA

CORTE GAILLARD

ESTACION 60K+950 (199+67) OESTE

ESCALA: 1:1000	FECHA: ABRIL 2002
GEOLOGIA POR: J. ARROCHA & P. FRANCESCHI	DIBUJADO POR: J. RAMESCH

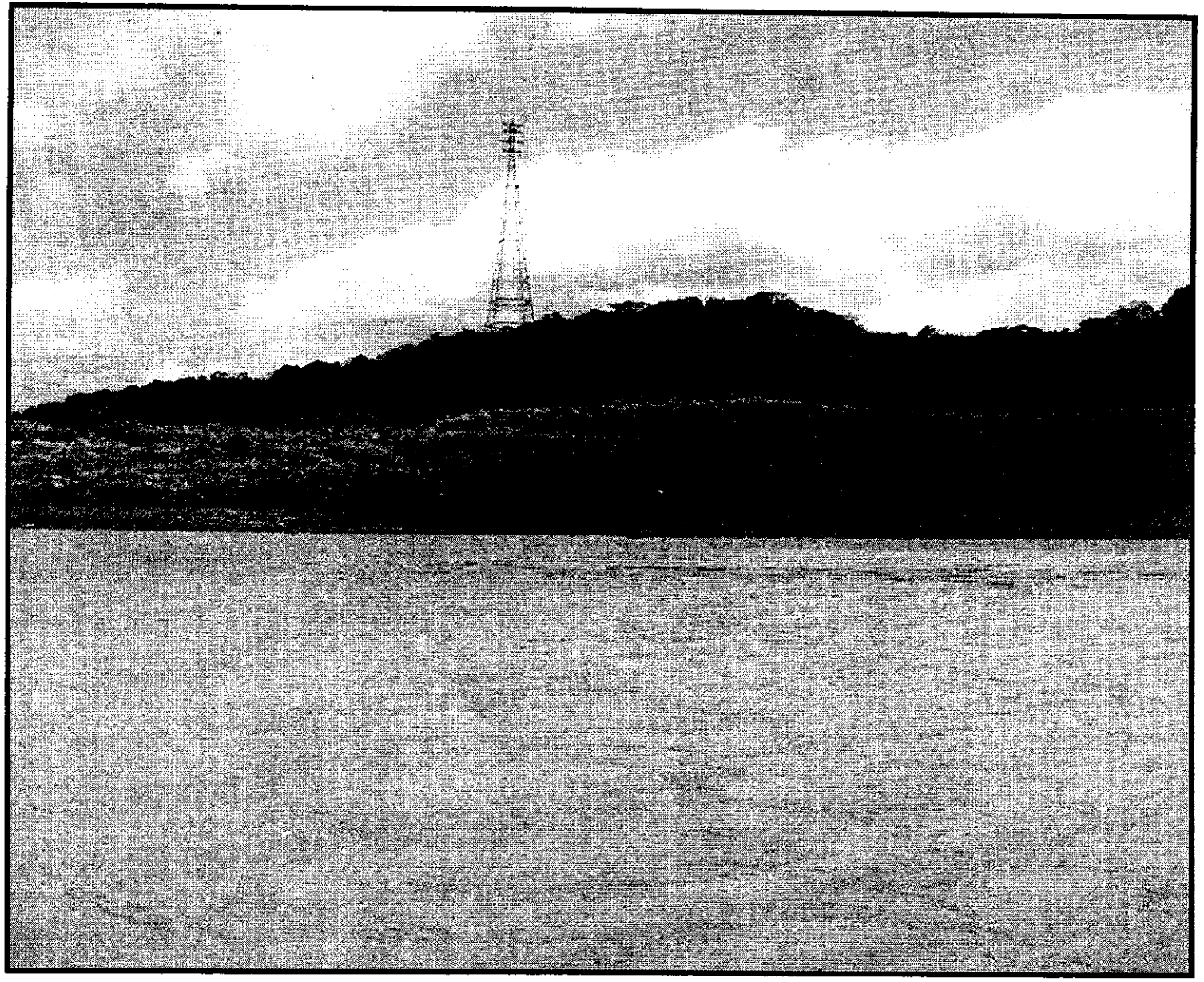

ELEVACION (m)
LINEA CENTRAL DEL CANAL
LINEA DE PRISMA OESTE EXISTENTE
LINEA DE PRISMA OESTE NUEVO
PA-42
44.26
TSR
LSH
47.24
PA-41
52.97
CB
TSR
52.12
PA-40
60.05
TSR
LSH
60.05
PA-63
67.03
CB
BAS
102.11
Apparent bedding
CUCARACHA FM
CUCARACHA FM
BASALT
Fault
N14°W/65°SW
Faulted Contact
Dip Unknown
60K+950 (1999+67) W

station 61k + 600 (2021 + 00)

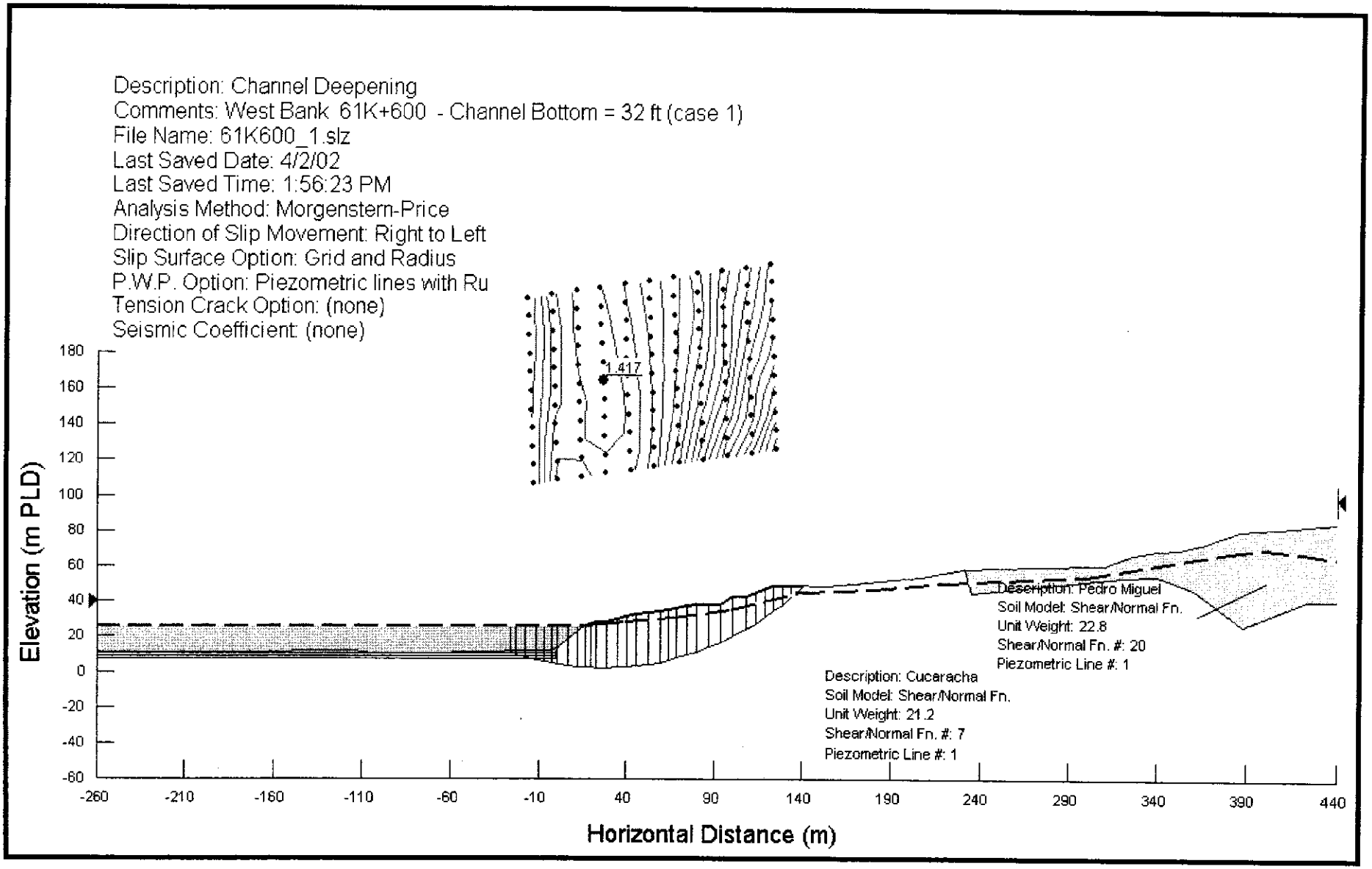
West

Station: 61k + 600 (Escobar)

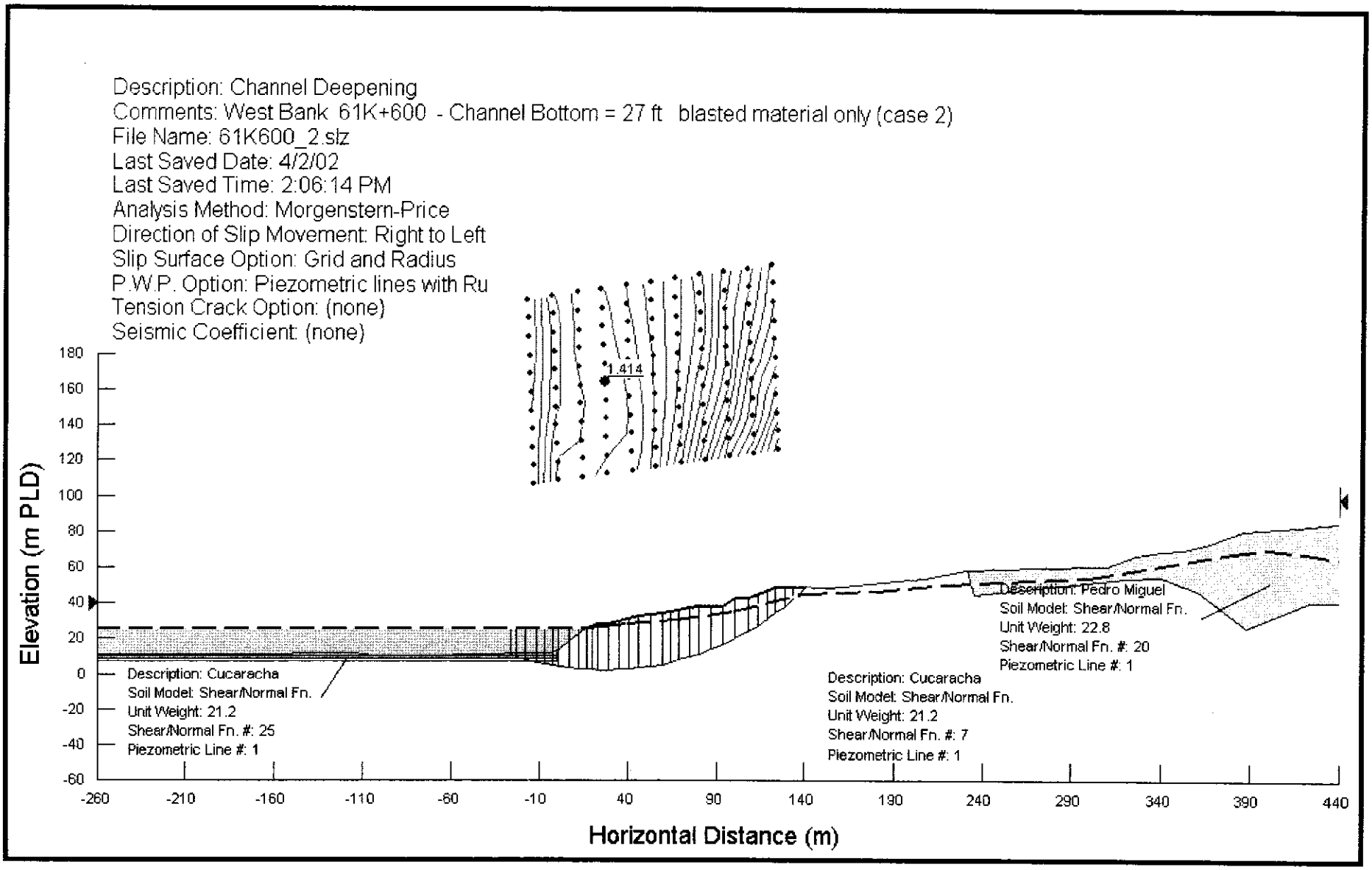
April 16, 2002



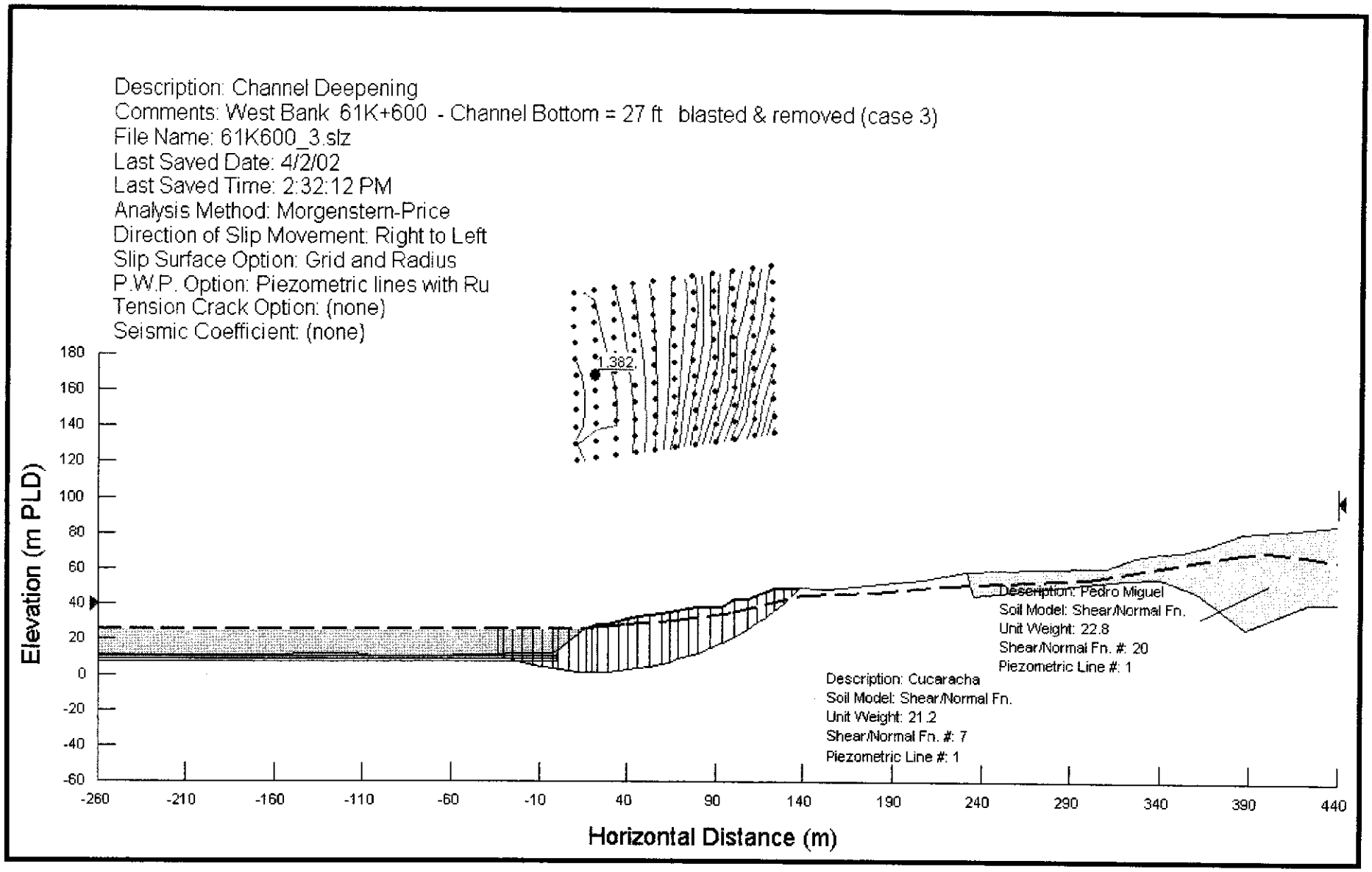
Case 1, Channel bottom = 32 ft



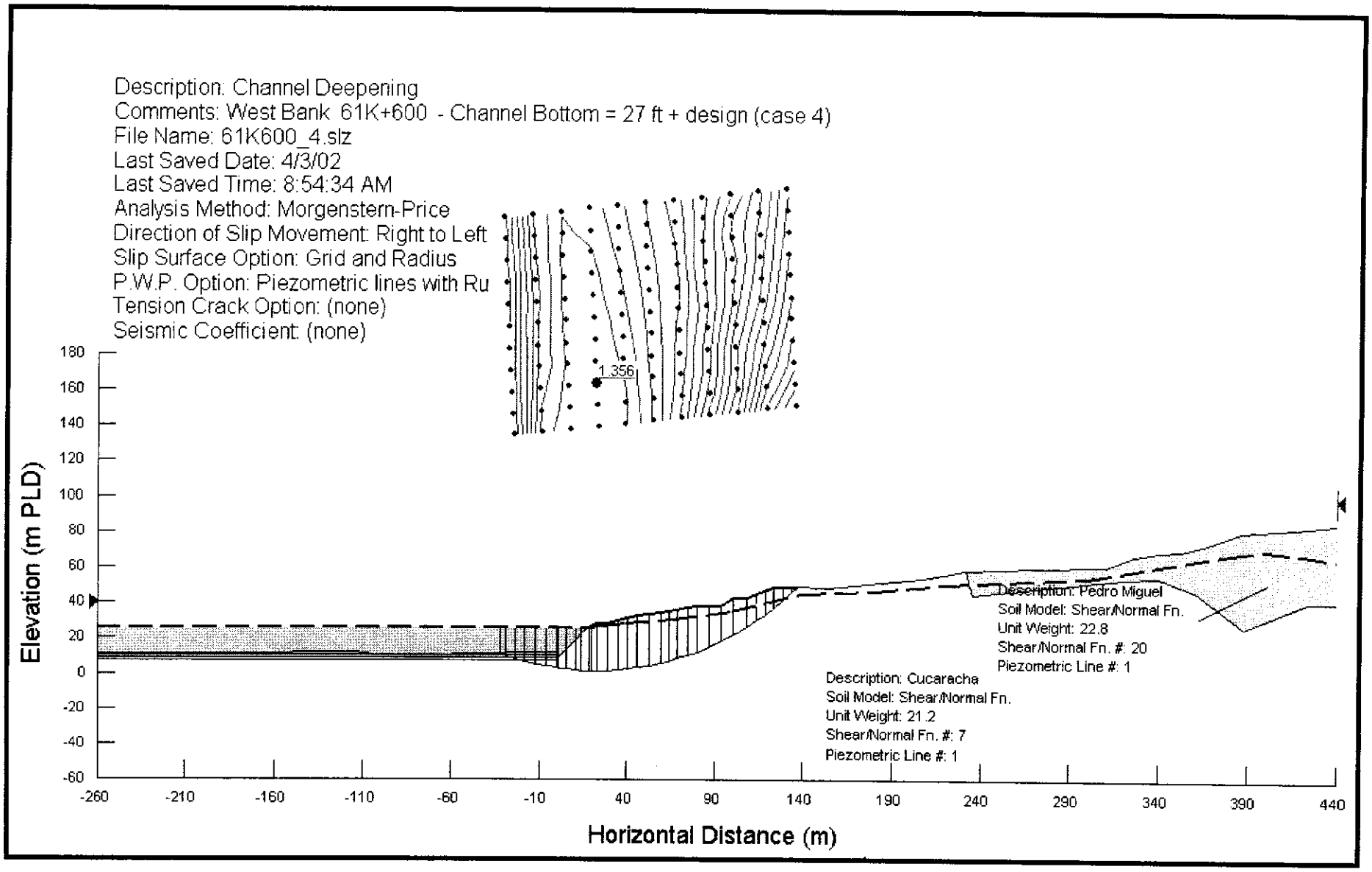
Case 2, Channel bottom = 27 ft, Blasted material only



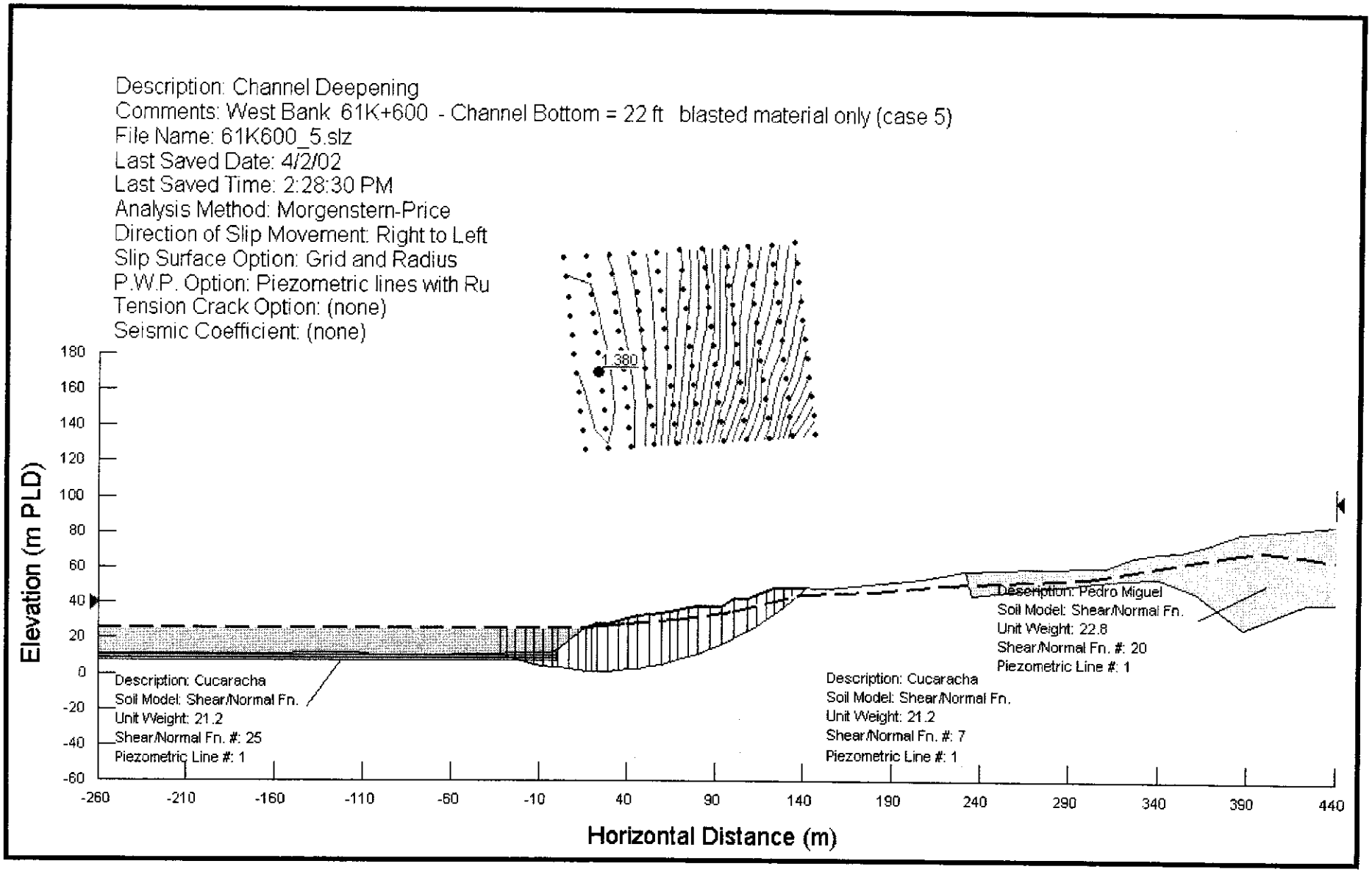
Case 3, Channel bottom = 27 ft, Blasted & removed



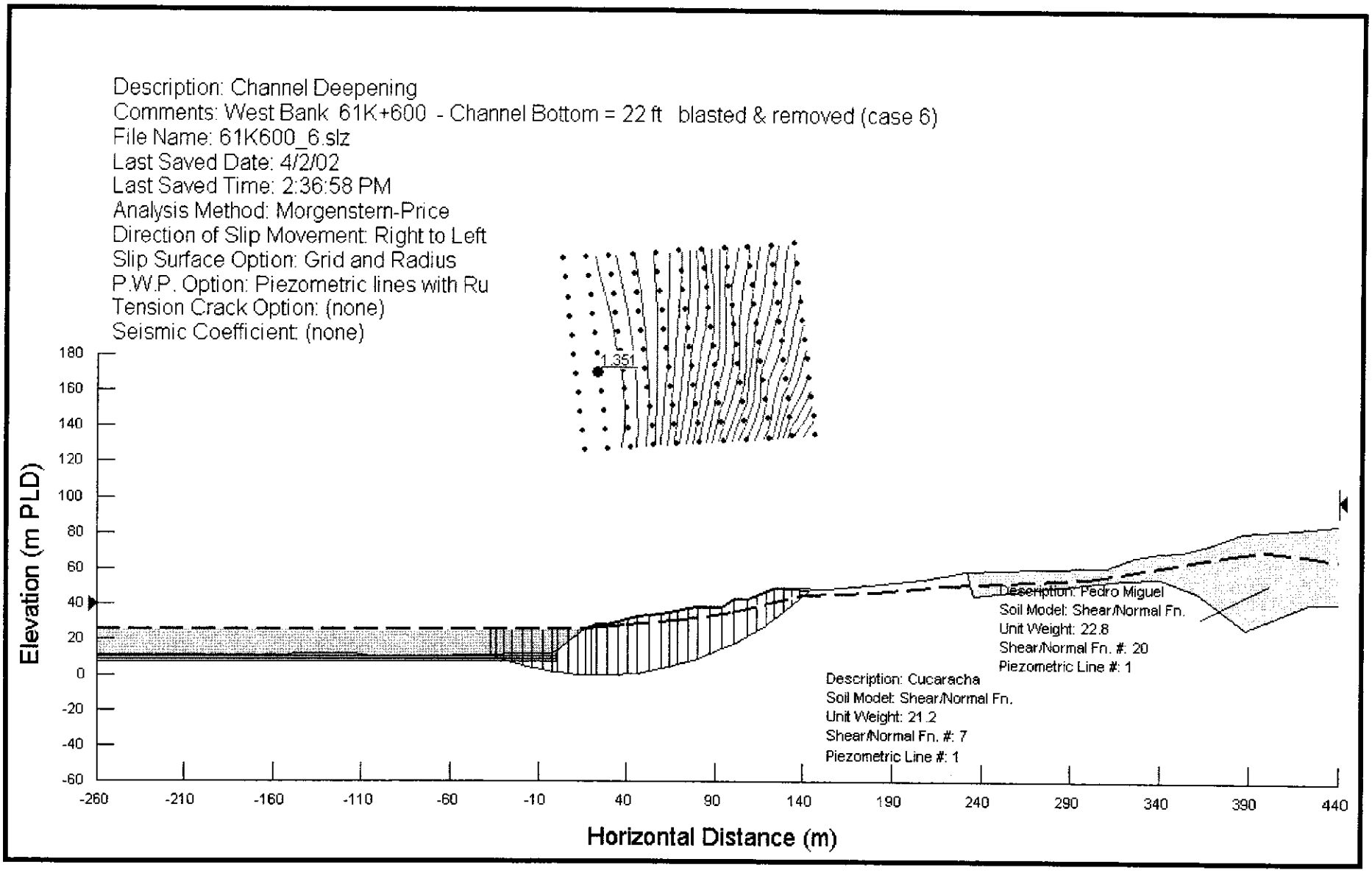
Case 4, Channel bottom = 27 ft, Design (underwater slope)



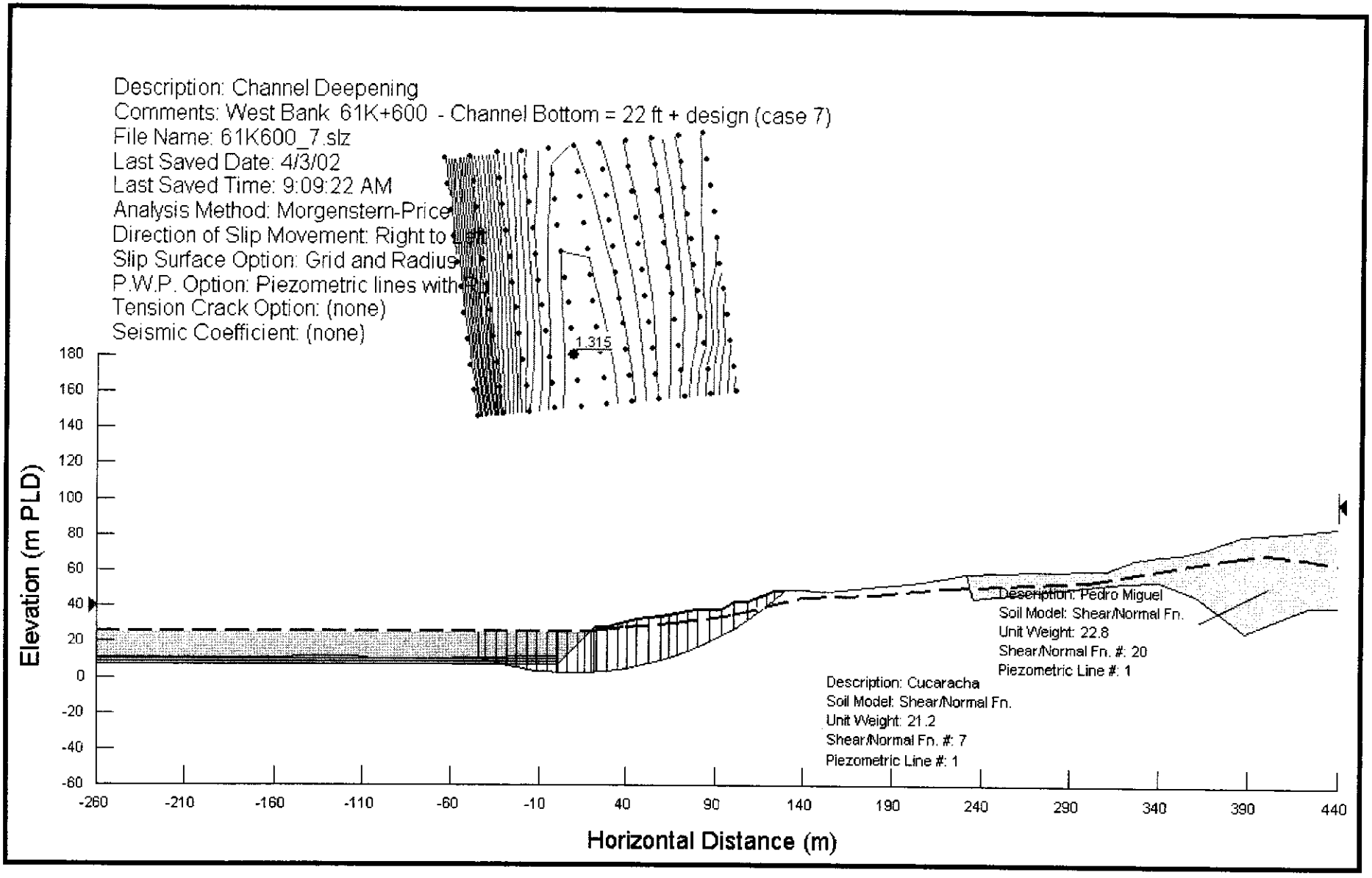
Case 5, Channel bottom = 22 ft, Blasted material only



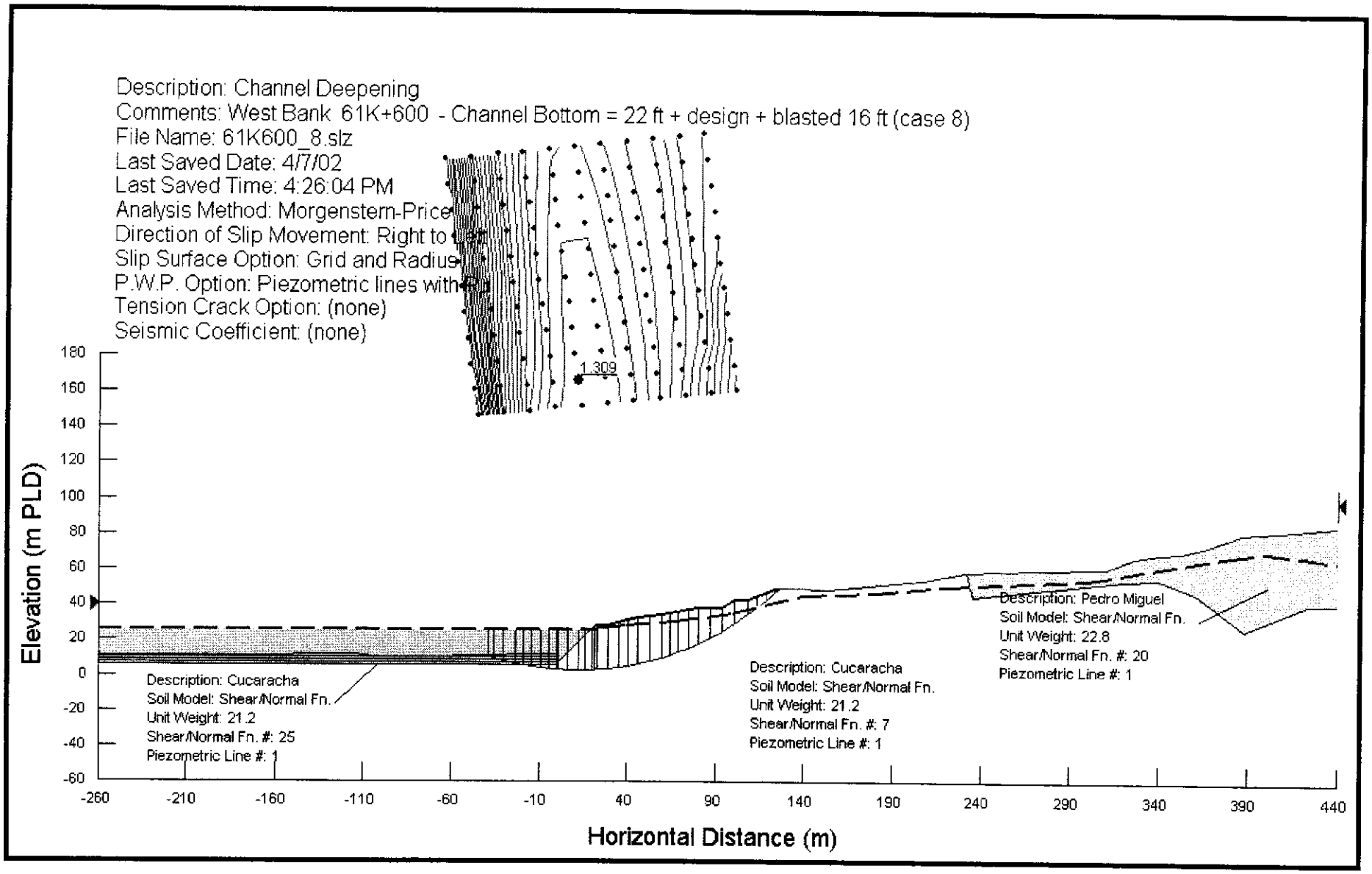
Case 6, Channel bottom = 22 ft, Blasted & removed



Case 7, Channel bottom = 27 ft, Design (underwater slope)

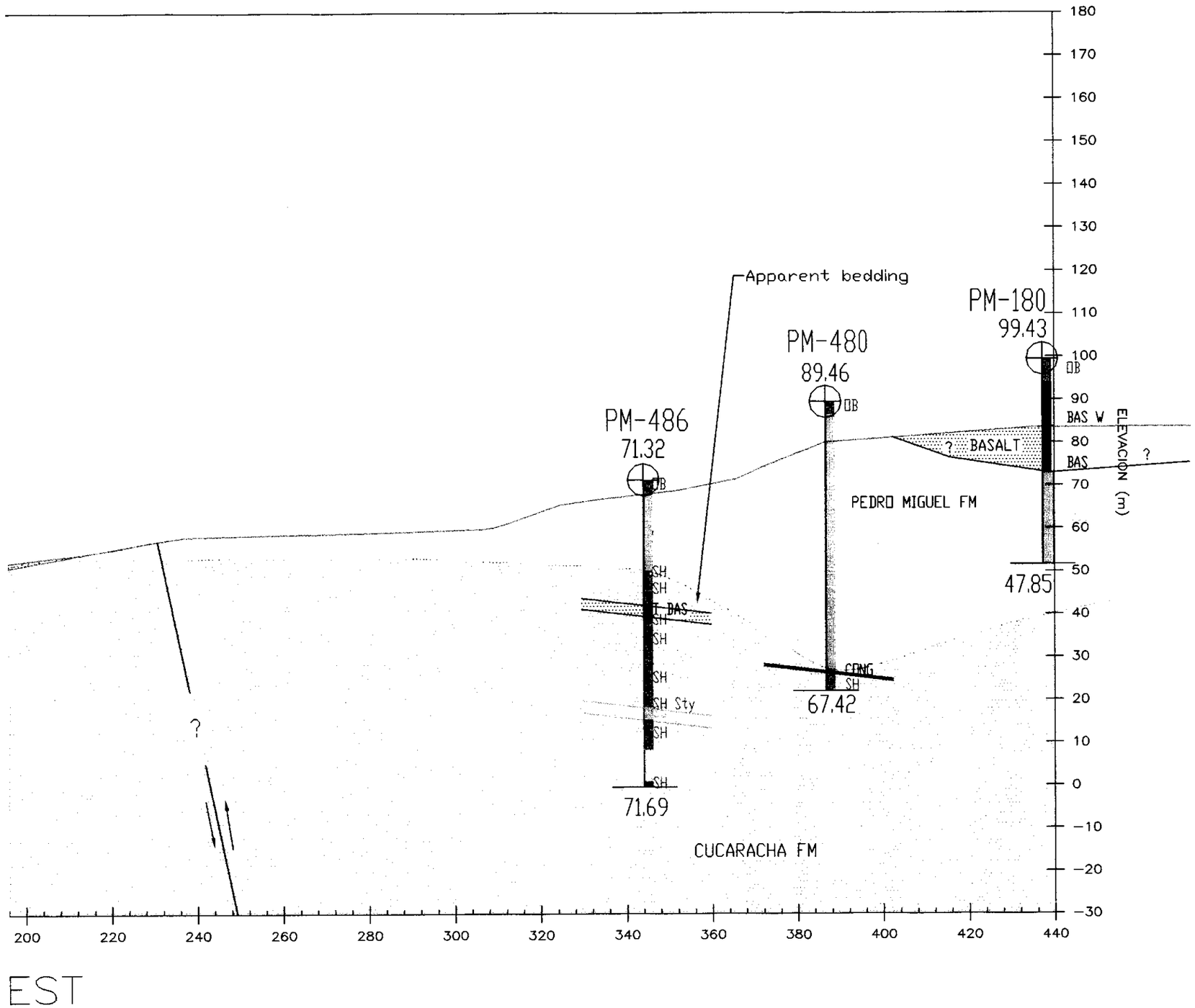


Case 8, Channel bottom = 16 ft, Blasted



Summary, 61k + 600 (2021 + 00)

General Description	Range of stations:	61k + 240 to 61k + 900			
	Sector:	Marieta			
	Maximum height (m):	75			
	Cotangent of slope angle (cot. β):	5.9			
History	Last slide event:	No slide event during widening			
Geology	Formation:	Basalt / Cucaracha			
	Lithology:	Clayshale / Siltstone / Sandstone			
	Critical stratum at toe:	Clayshale			
	Apparent dip of bedding:	Toward the slope			
Stability Analysis	Critical failure mechanism:	Rotational			
	Shear strength model:	Fully softened, Cucaracha			
		Operative average pore pressure ratio (aproximate), Ru:	Factor of Safety	Relative Factor of Safety	Percentage of Change (%)
	Case 1: Channel bottom = 32 ft	0.372	1.417	1.000	0.00
	Case 2: Channel bottom = 27 ft, Blasted material only		1.414	0.998	-0.21
	Case 3: Channel bottom = 27 ft, Blasted & removed		1.382	0.975	-2.47
	Case 4.1: Channel bottom = 27 ft, Design (underwater slope)		1.356	0.957	-4.30
	Case 4.2: Channel bottom = 27 ft, Design (& dry excavation)	0.371	1.356	0.957	-4.30
	Case 5: Channel bottom = 22 ft, Blasted material only		1.380	0.974	-2.61
	Case 6: Channel bottom = 22 ft, Blasted & removed		1.351	0.953	-4.66
	Case 7.1: Channel bottom = 22 ft, Design (underwater slope)		1.315	0.928	-7.20
	Case 7.2: Channel bottom = 22 ft, Design (& dry excavation)	0.363	1.315	0.928	-7.20
	Case 8: Channel bottom = 16 ft, Blasted		1.309	0.924	-7.62
Conclusions:	No stabilization is required				



AUTORIDAD DEL CANAL DE PANAMA

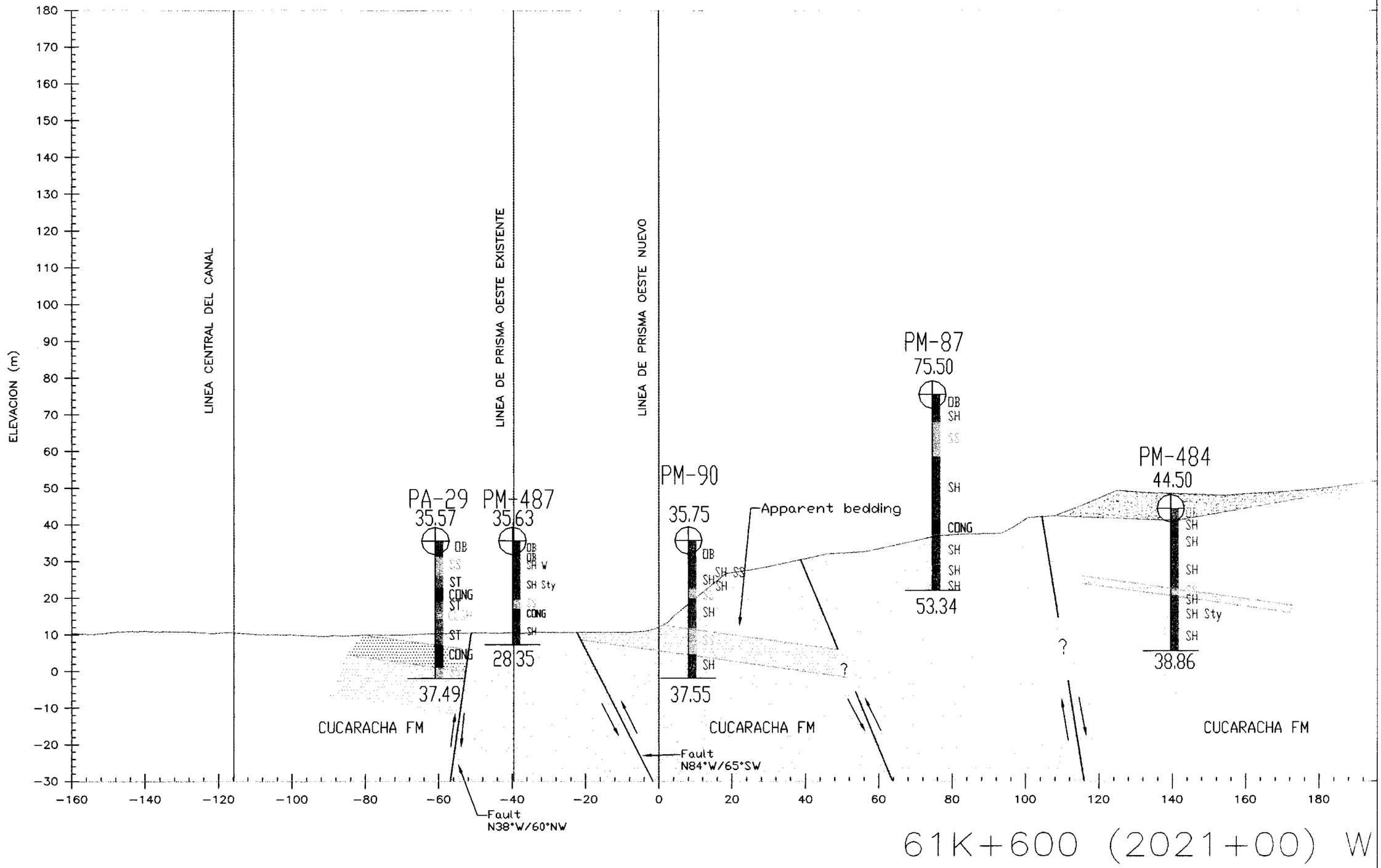
DEPARTAMENTO DE INGENIERIA Y PROYECTOS
DIVISION DE INGENIERIA
ALTOS DE BALBOA, REPUBLICA DE PANAMA

SECCION GEOLOGICA

CORTE GAILLARD

ESTACION 61K+600 (2021+00) OESTE

ESCALA: 1:1000	FECHA: ABRIL 2002
GEOLOGIA POR: P. FRANCESCHI	DIBUJADO POR: J. RAMESCH

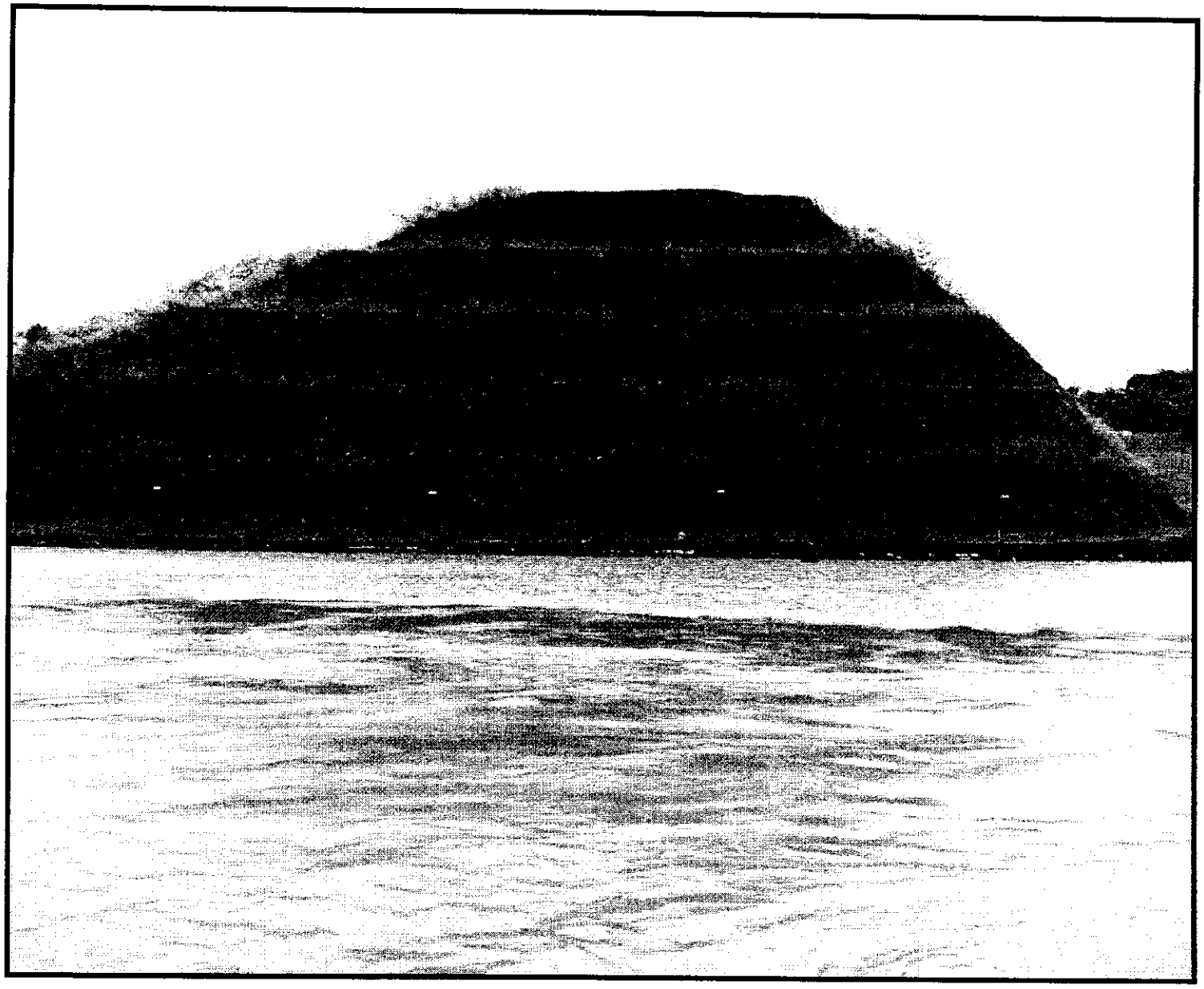

ELEVACION (m)
LINEA CENTRAL DEL CANAL
LINEA DE PRISMA OESTE EXISTENTE
LINEA DE PRISMA OESTE NUEVO
PA-29
35.57
DB
SS
ST
CONG
ST
ST
CONG
37.49
PM-487
35.63
DB
DB
SH W
SH Sty
CONG
SH
28.35
PM-90
35.75
DB
SH
SH SS
SH
SH
SH
37.55
Apparent bedding
PM-87
75.50
DB
SH
SS
SH
CONG
SH
SH
SH
53.34
PM-484
44.50
SH
SH
SH
SH
SH Sty
SH
38.86
CUCARACHA FM
CUCARACHA FM
CUCARACHA FM
Fault
N84°W/65°SW
Fault
N38°W/60°NW
61K+600 (2021+00) W

station 62k + 000 (2034 + 12)

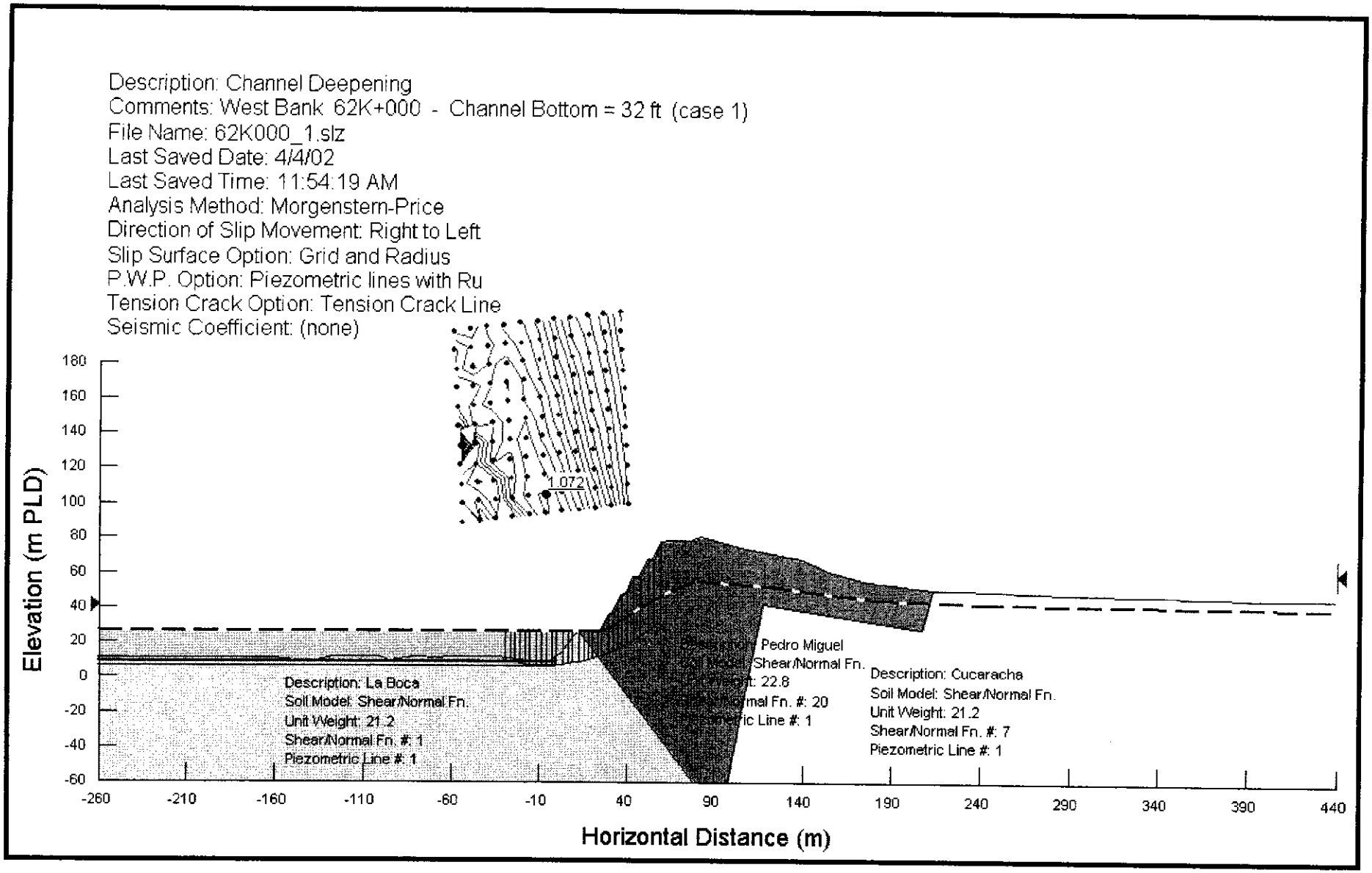
West

Station: 62k + 000 (Marieta)

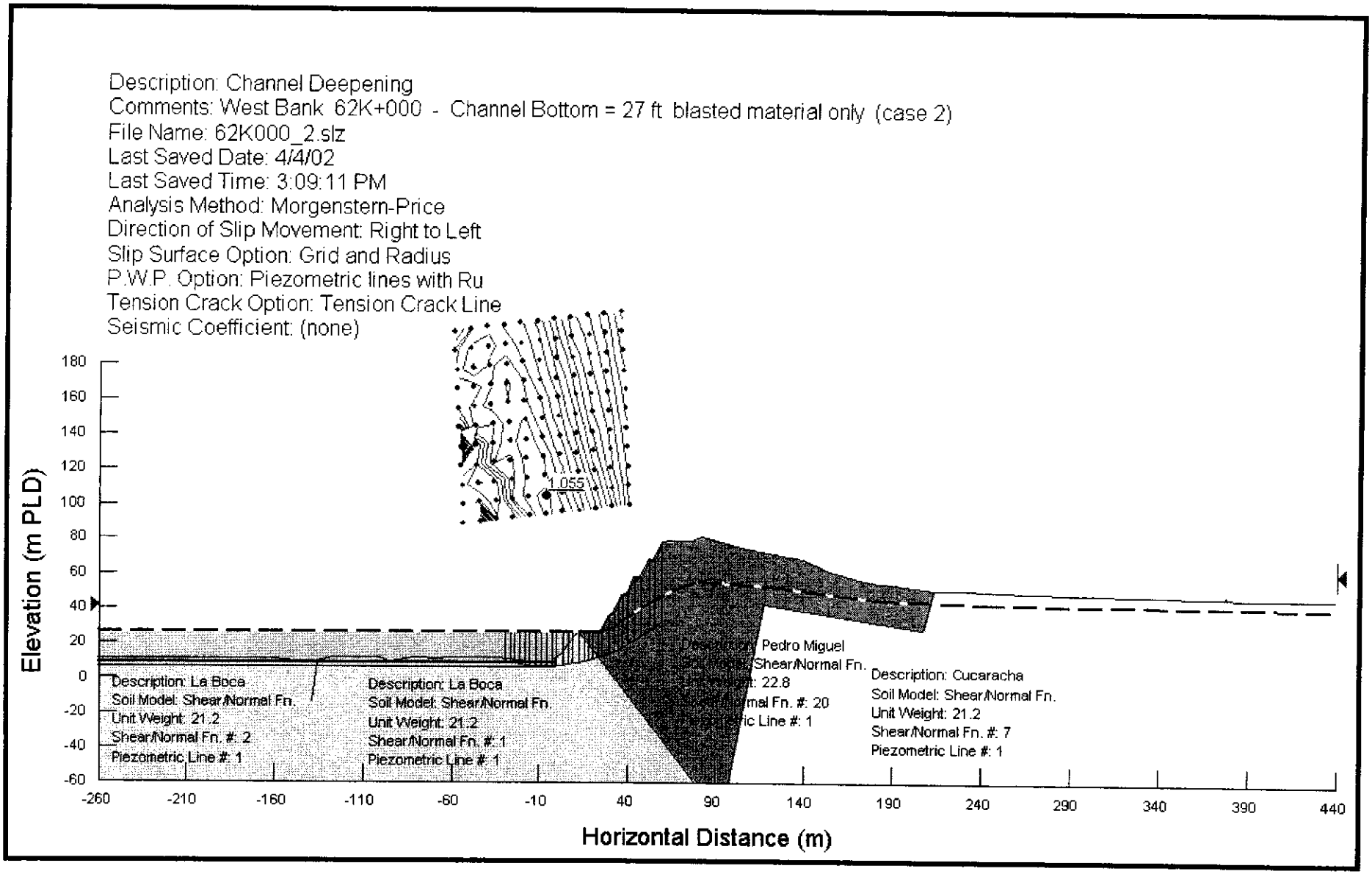
April 16, 2002



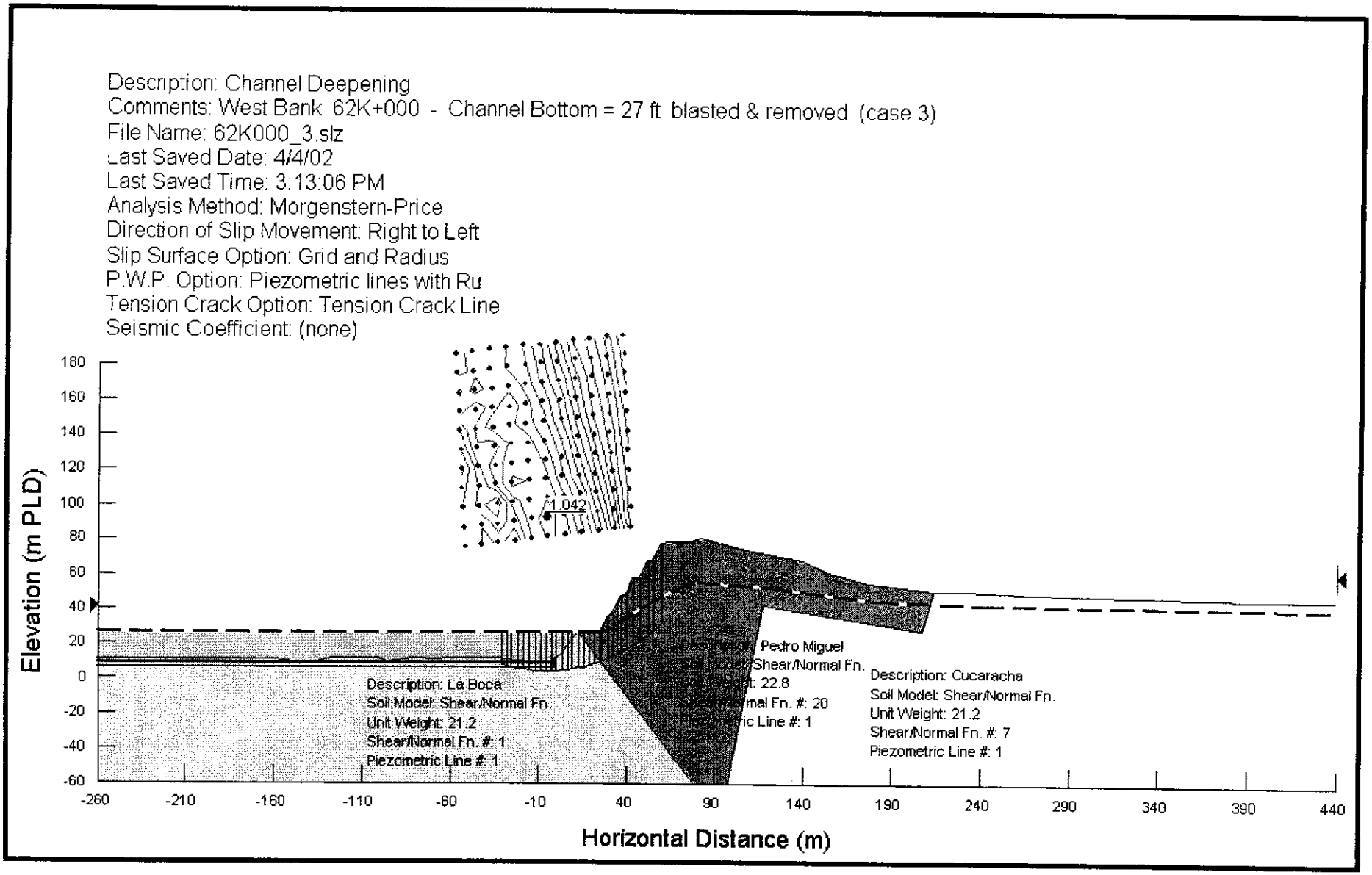
Case 1, Channel bottom = 32 ft



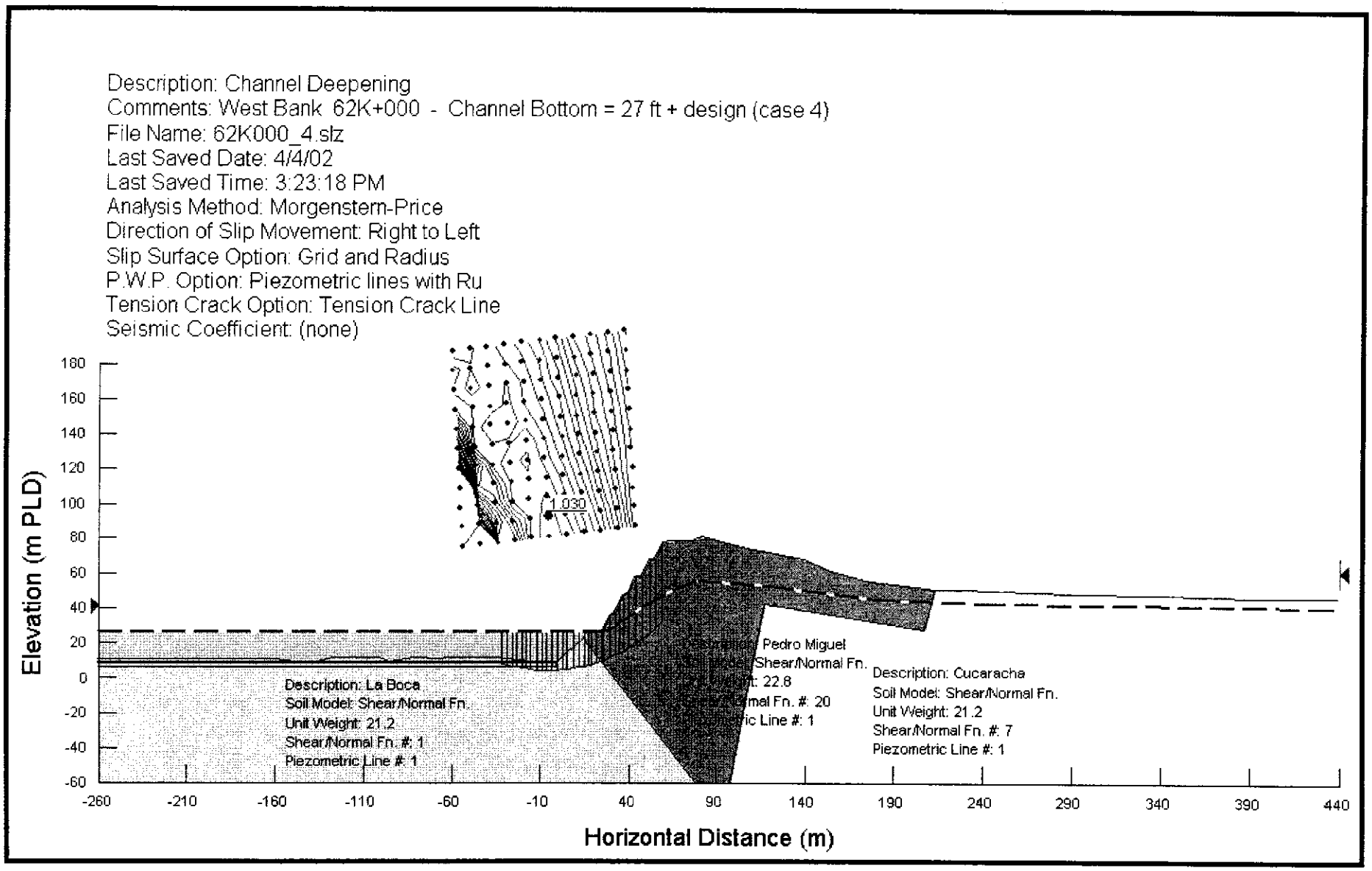
Case 2, Channel bottom = 27 ft, Blasted material only



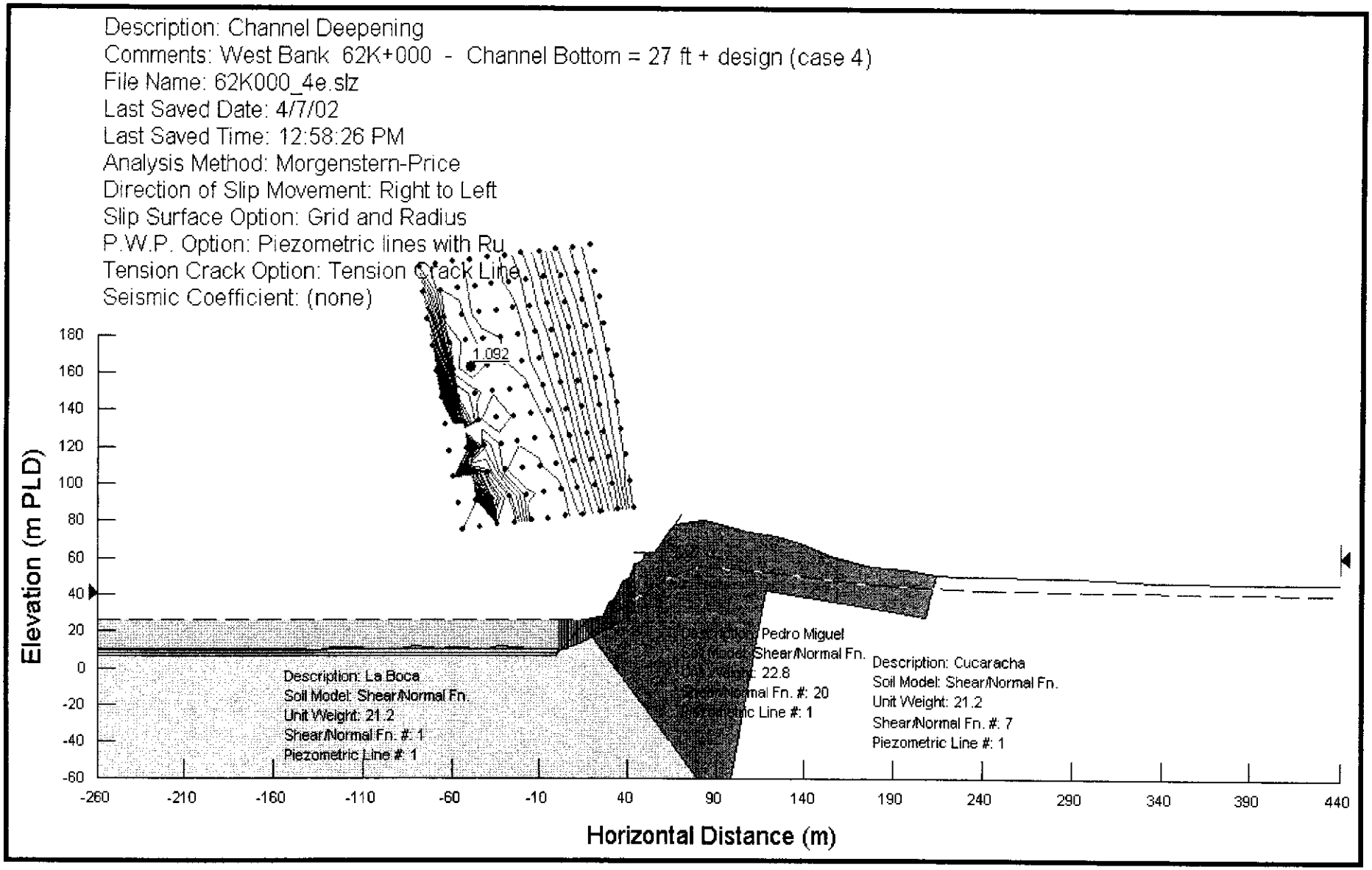
Case 3, Channel bottom = 27 ft, Blasted & removed



Case 4.1, Channel bottom = 27 ft, Design (underwater slope)

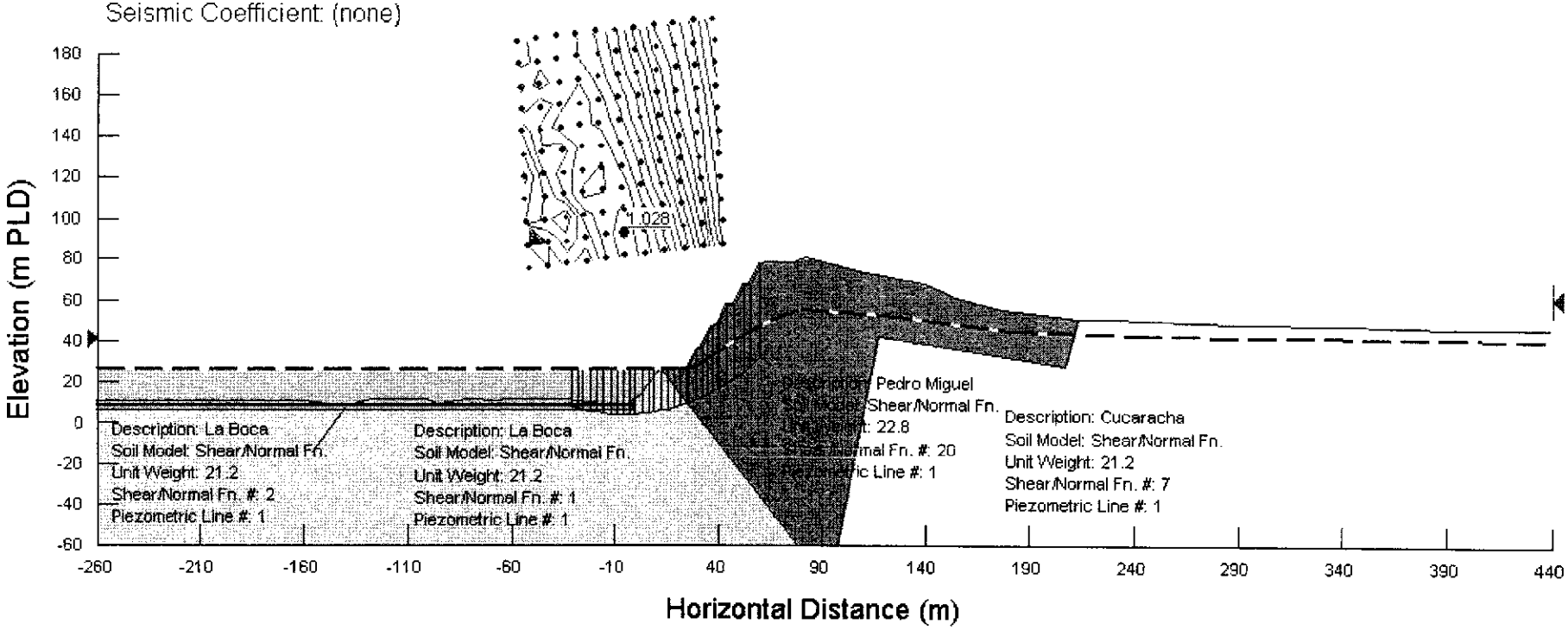


Case 4.2, Channel bottom = 27 ft, Design (& dry excavation)



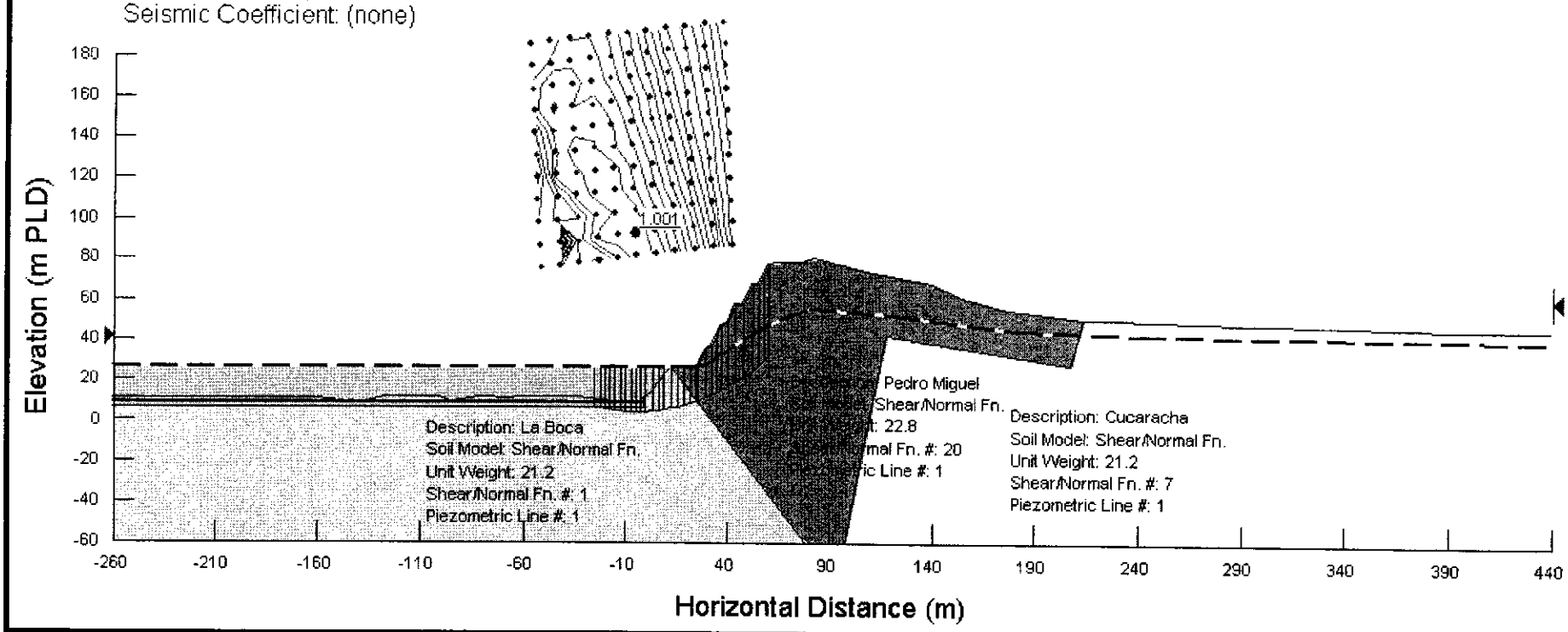
Case 5, Channel bottom = 22 ft, Blasted material only

Description: Channel Deepening
Comments: West Bank 62K+000 - Channel Bottom = 22 ft blasted material only (case 5)
File Name: 62K000_5.slz
Last Saved Date: 4/4/02
Last Saved Time: 3:14:45 PM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: Tension Crack Line
Seismic Coefficient: (none)

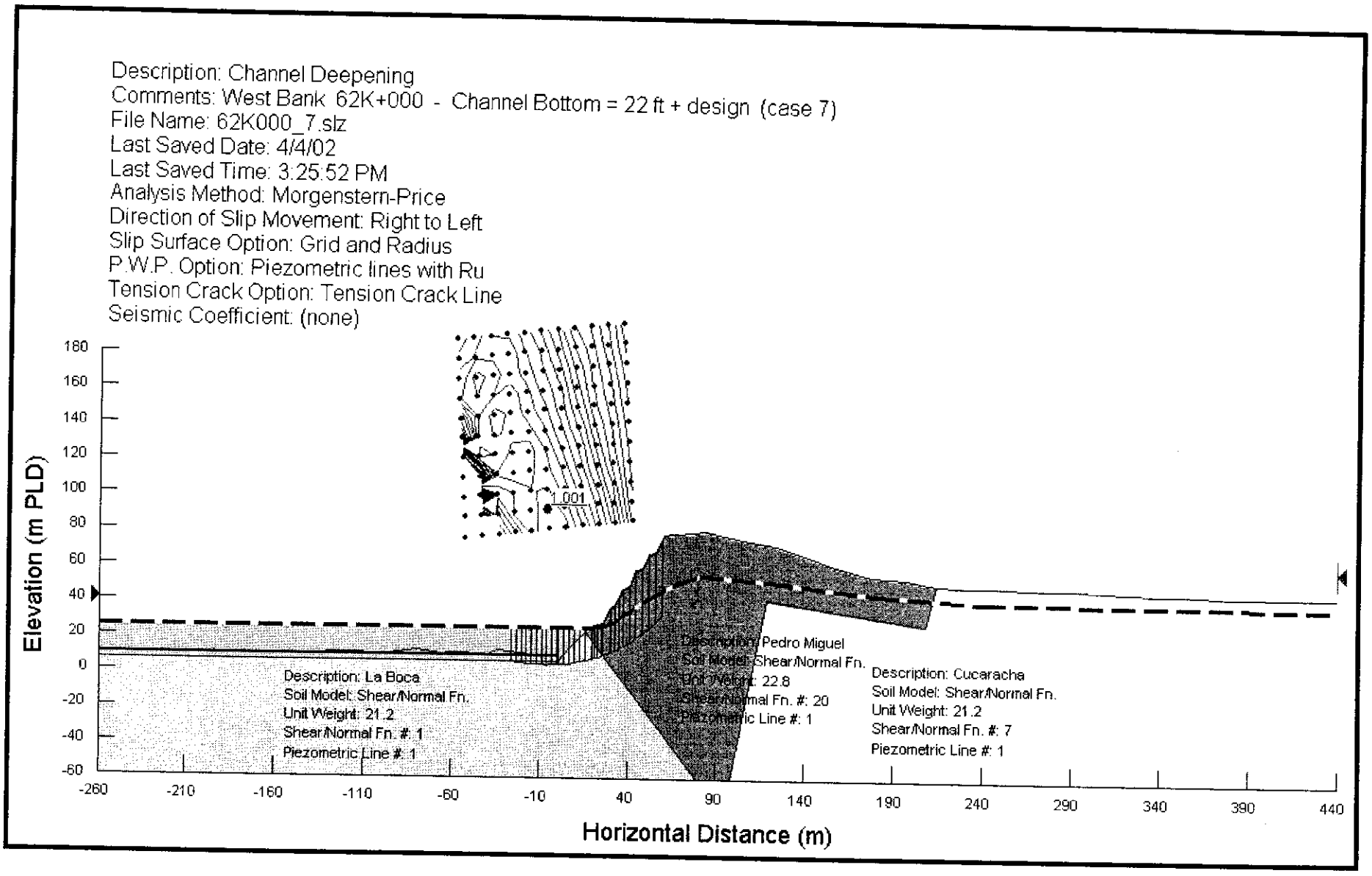


Case 6, Channel bottom = 22 ft, Blasted & removed

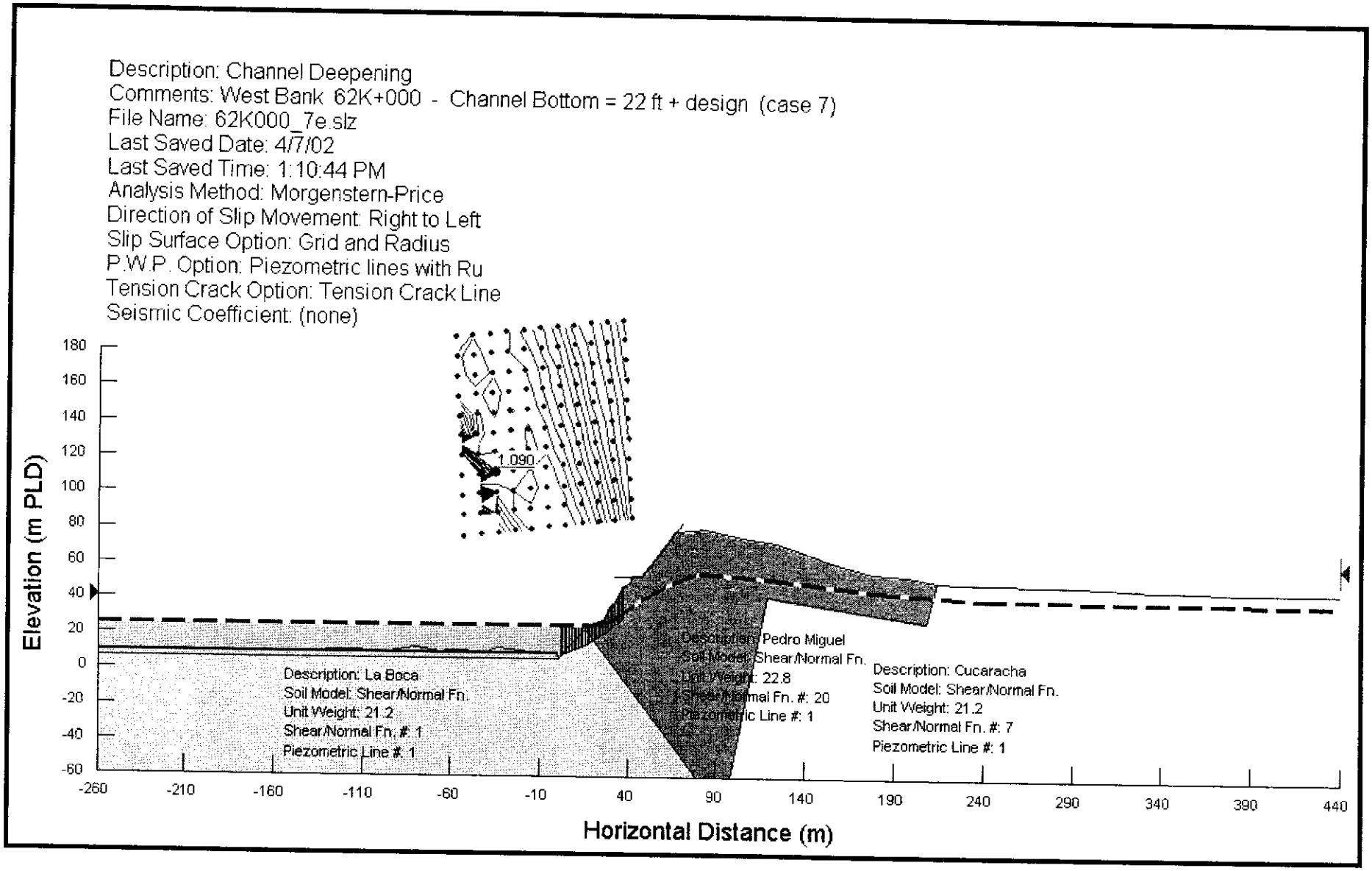
Description: Channel Deepening
Comments: West Bank 62K+000 - Channel Bottom = 22 ft blasted & removed (case 6)
File Name: 62K000_6.slz
Last Saved Date: 4/4/02
Last Saved Time: 3:19:15 PM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: Tension Crack Line
Seismic Coefficient: (none)



Case 7.1, Channel bottom = 27 ft, Design (underwater slope)

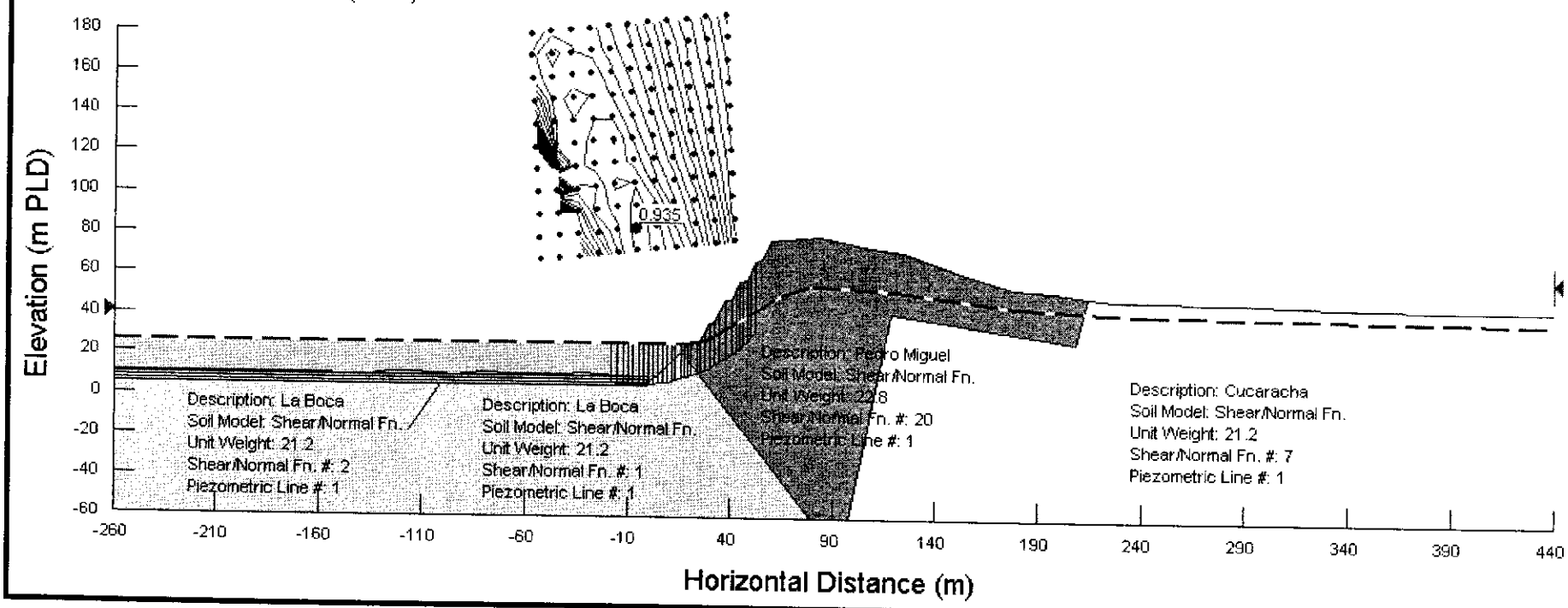


Case 7.2, Channel bottom = 27 ft, Design (& dry excavation)



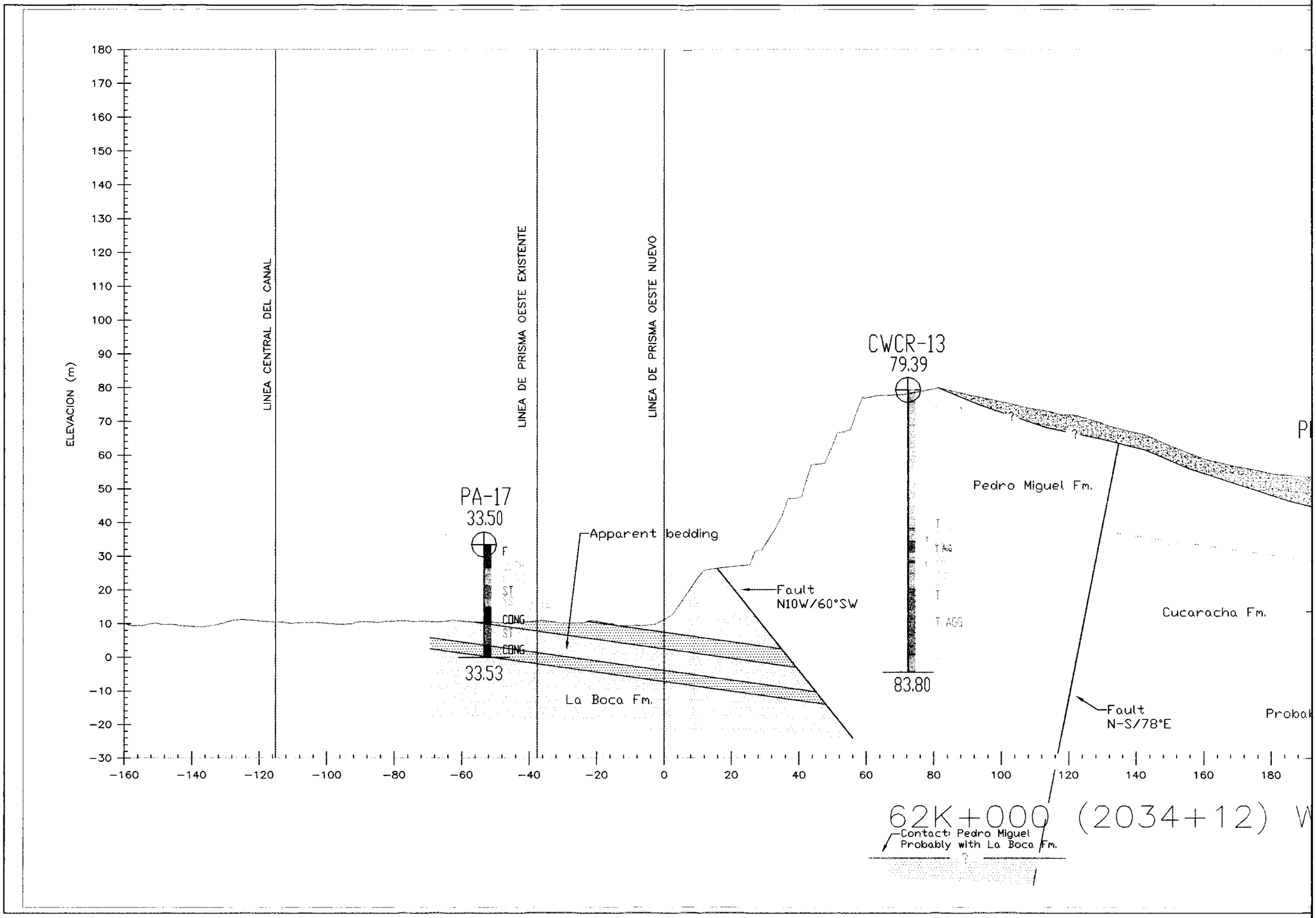
Case 8, Channel bottom = 16 ft, Blasted

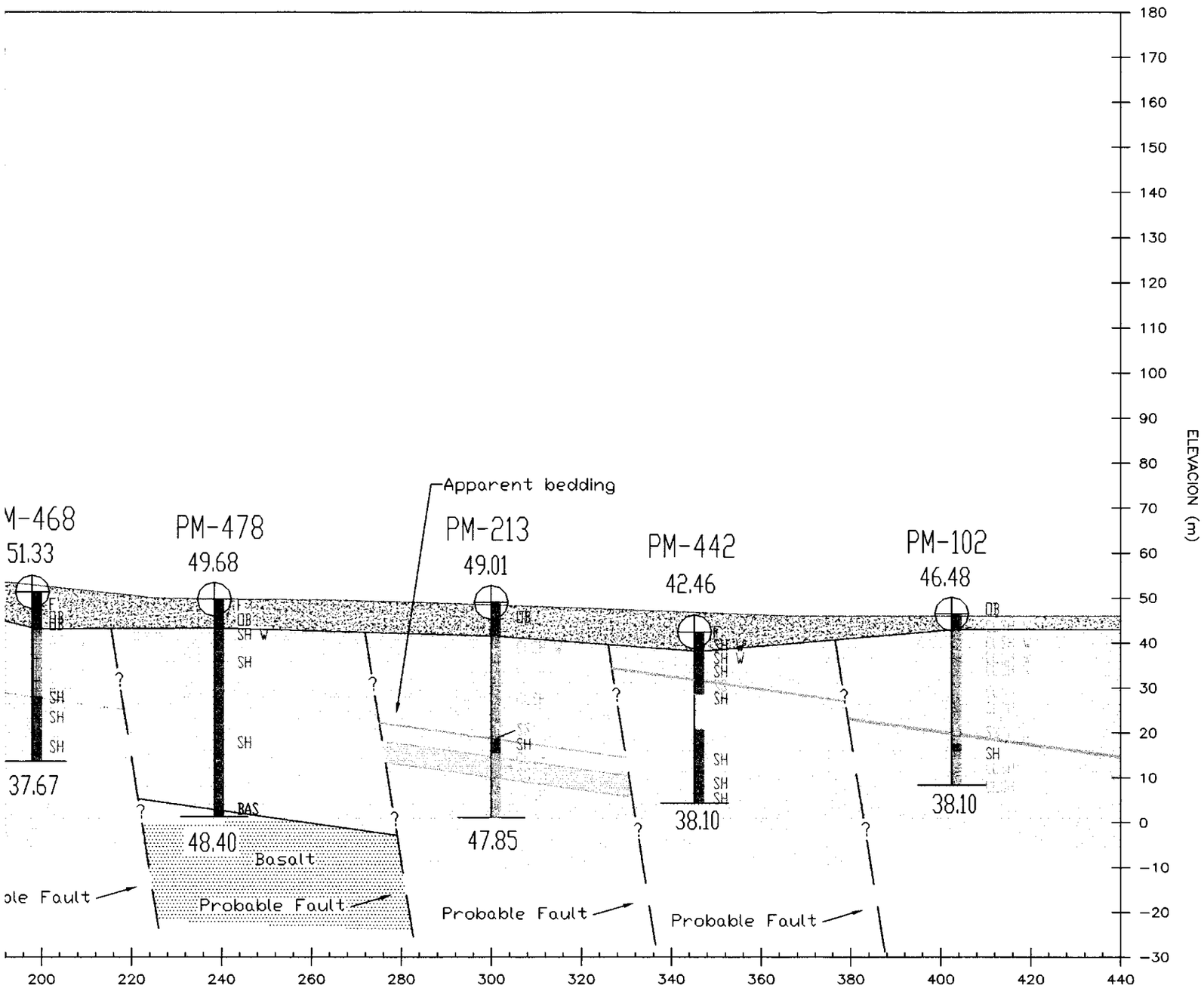
Description: Channel Deepening
Comments: West Bank 62K+000 - Channel Bottom = 22 ft + design + blasted 16 ft (case 8)
File Name: 62K000_8.slz
Last Saved Date: 4/7/02
Last Saved Time: 4:48:57 PM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: Tension Crack Line
Seismic Coefficient: (none)



Summary, 62k + 000 (2034 + 12)

General Description	Range of stations:	61k + 900 to 62k + 200			
	Sector:	Marieta			
	Maximum height (m):	70			
	Cotangent of slope angle (cot. β):	1.19			
History	Last slide event:	No known slide			
Geology	Formation:	Pedro Miguel / La Boca / Cucaracha			
	Lithology:	Agglomerate / Clayshale / Sandstone / Siltstone / Conglomerate			
	Critical stratum at toe:	Siltstone			
	Apparent dip of bedding:	Toward the slope			
Stability Analysis	Critical failure mechanism:	Rotational, Tension crack			
	Shear strength model:	Fully softened, La Boca / First Time, Pedro Miguel			
		Operative average pore pressure ratio (aproximate), Ru:	Factor of Safety	Relative Factor of Safety	Percentage of Change (%)
	Case 1: Channel bottom = 32 ft	0.280	1.072	1.000	0.00
	Case 2: Channel bottom = 27 ft, Blasted material only		1.055	0.984	-1.59
	Case 3: Channel bottom = 27 ft, Blasted & removed		1.042	0.972	-2.80
	Case 4.1: Channel bottom = 27 ft, Design (underwater slope)		1.030	0.961	-3.92
	Case 4.2: Channel bottom = 27 ft, Design (& dry excavation)	0.272	1.092	1.019	1.87
	Case 5: Channel bottom = 22 ft, Blasted material only		1.028	0.959	-4.10
	Case 6: Channel bottom = 22 ft, Blasted & removed		1.001	0.934	-6.62
	Case 7.1: Channel bottom = 22 ft, Design (underwater slope)		1.001	0.934	-6.62
	Case 7.2: Channel bottom = 22 ft, Design (& dry excavation)	0.303	1.090	1.017	1.68
	Case 8: Channel bottom = 16 ft, Blasted		0.935	0.872	-12.78
Conclusions:	Stabilization is required for Case 4 and Case 7				


ELEVACION (m)
LINEA CENTRAL DEL CANAL
LINEA DE PRISMA OESTE EXISTENTE
LINEA DE PRISMA OESTE NUEVO
CWCR-13
79.39
PA-17
33.50
F
ST
CONG
ST
CONG
33.53
83.80
Apparent bedding
Fault
N10W/60°SW
Pedro Miguel Fm.
Cucaracha Fm.
La Boca Fm.
Fault
N-S/78°E
Contact: Pedro Miguel
Probably with La Boca Fm.
62K+000 (2034+12)



AUTORIDAD DEL CANAL DE PANAMA

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DIVISION DE INGENIERIA
ALTOS DE BALBOA, REPUBLICA DE PANAMA

SECCION GEOLOGICA

CORTE GAILLARD

ESTACION 62K+000 (2034+12) OESTE

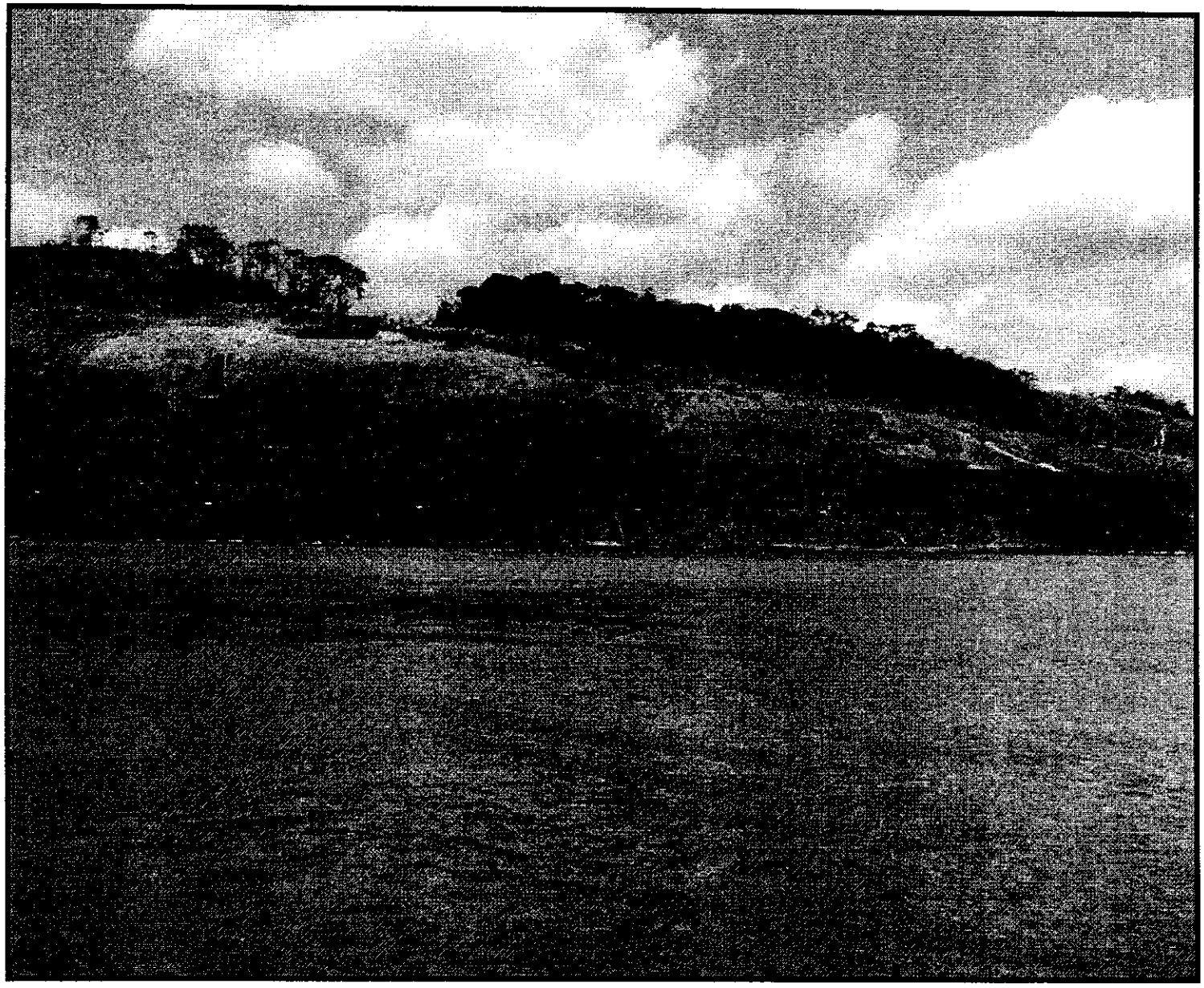
ESCALA: 1:1000	FECHA: ABRIL 2002
GEOLOGIA POR: P. FRANCESCHI	DIBUJADO POR: J. RAMESCH

station 63k + 050 (2068 + 56)

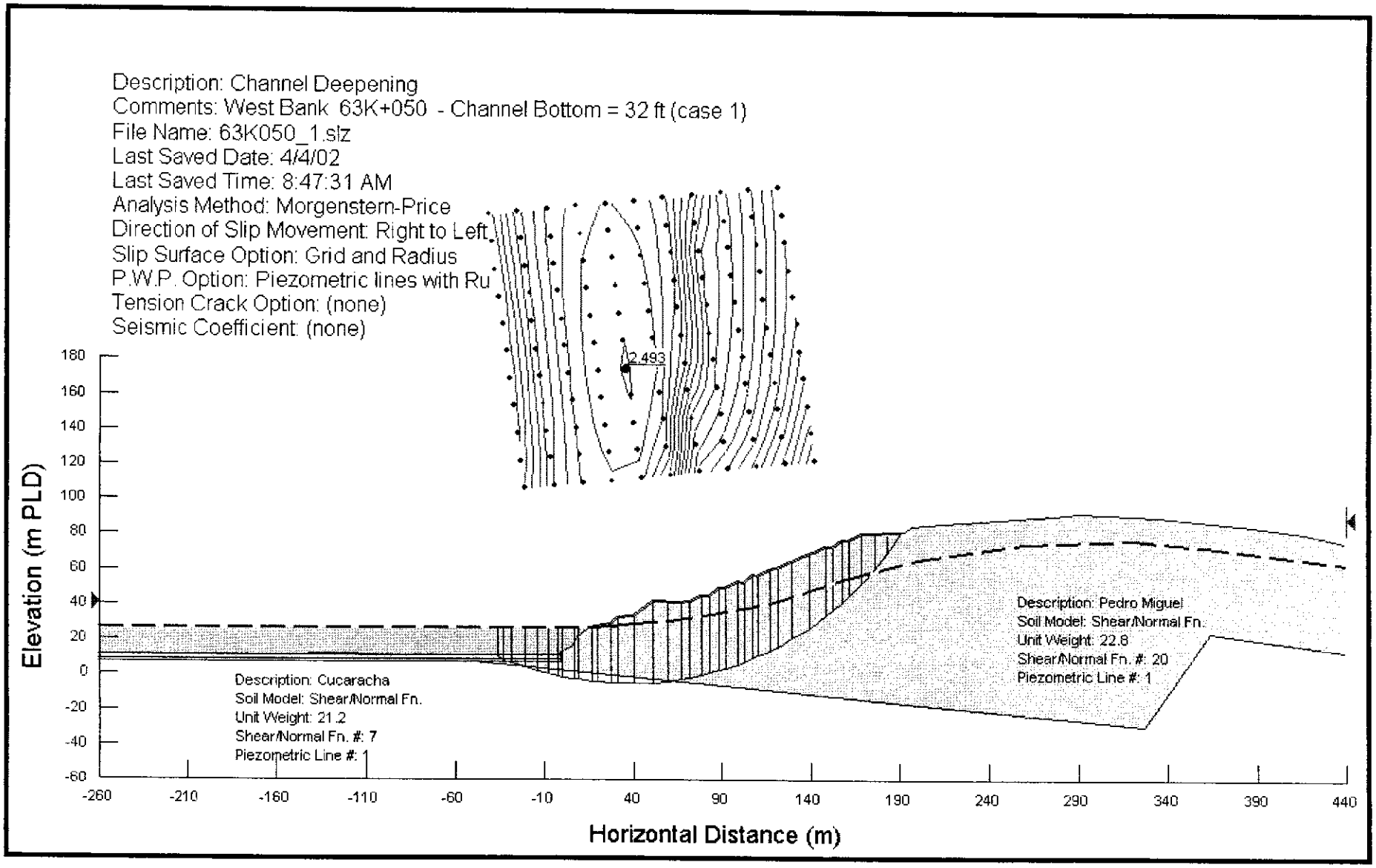
West

Station: 63k + 050 (Cartagena)

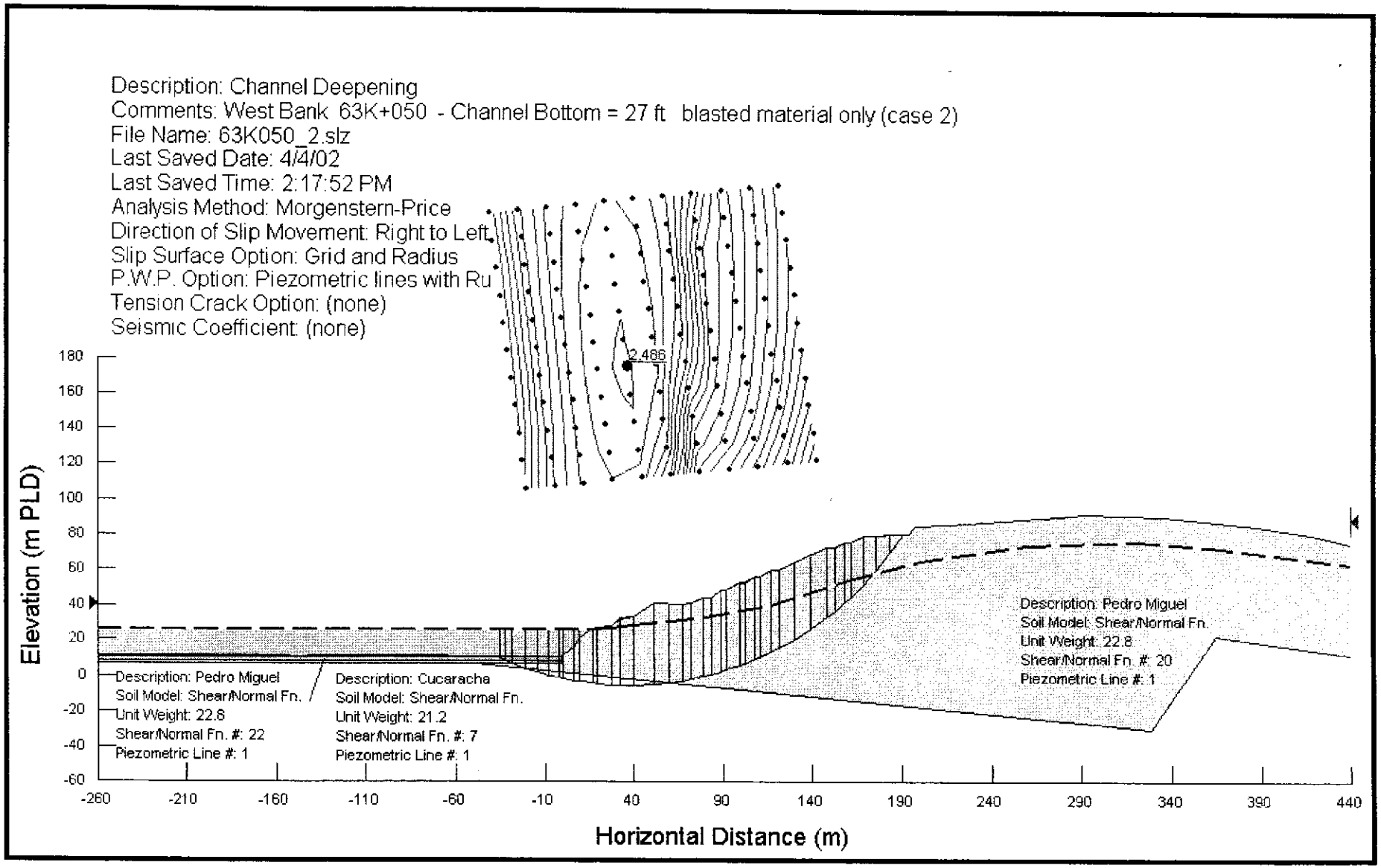
April 16, 2002



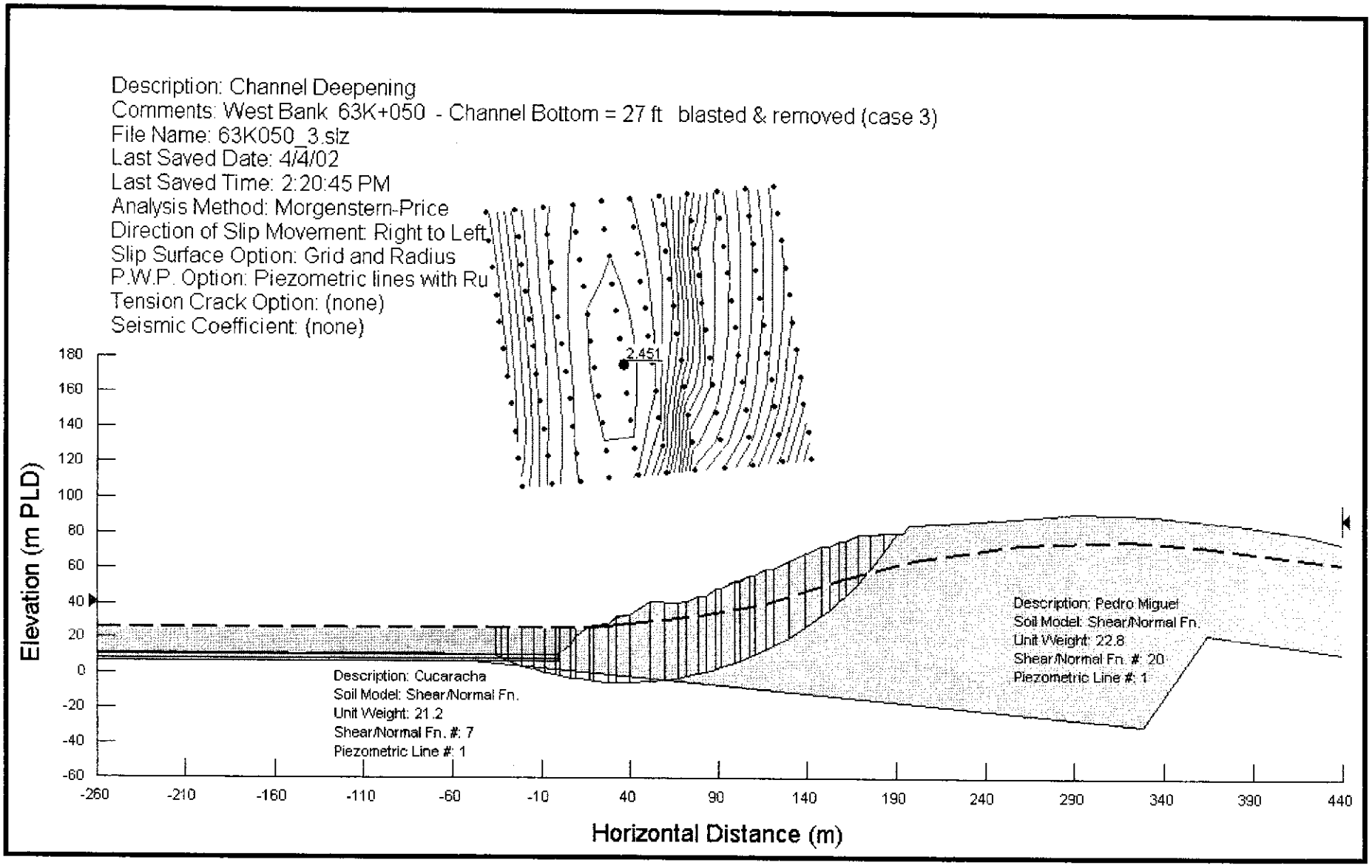
Case 1, Channel bottom = 32 ft



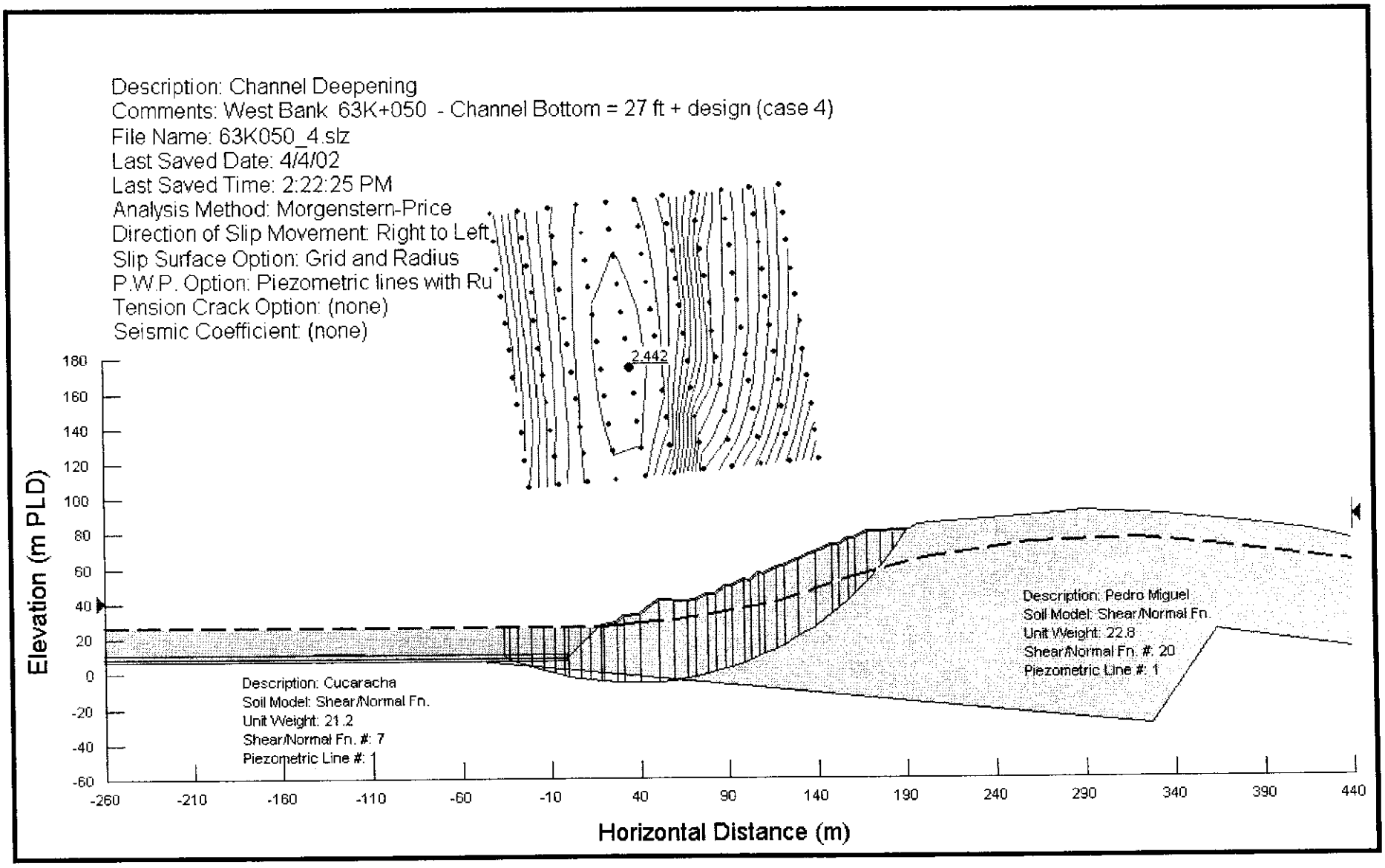
Case 2, Channel bottom = 27 ft, Blasted material only



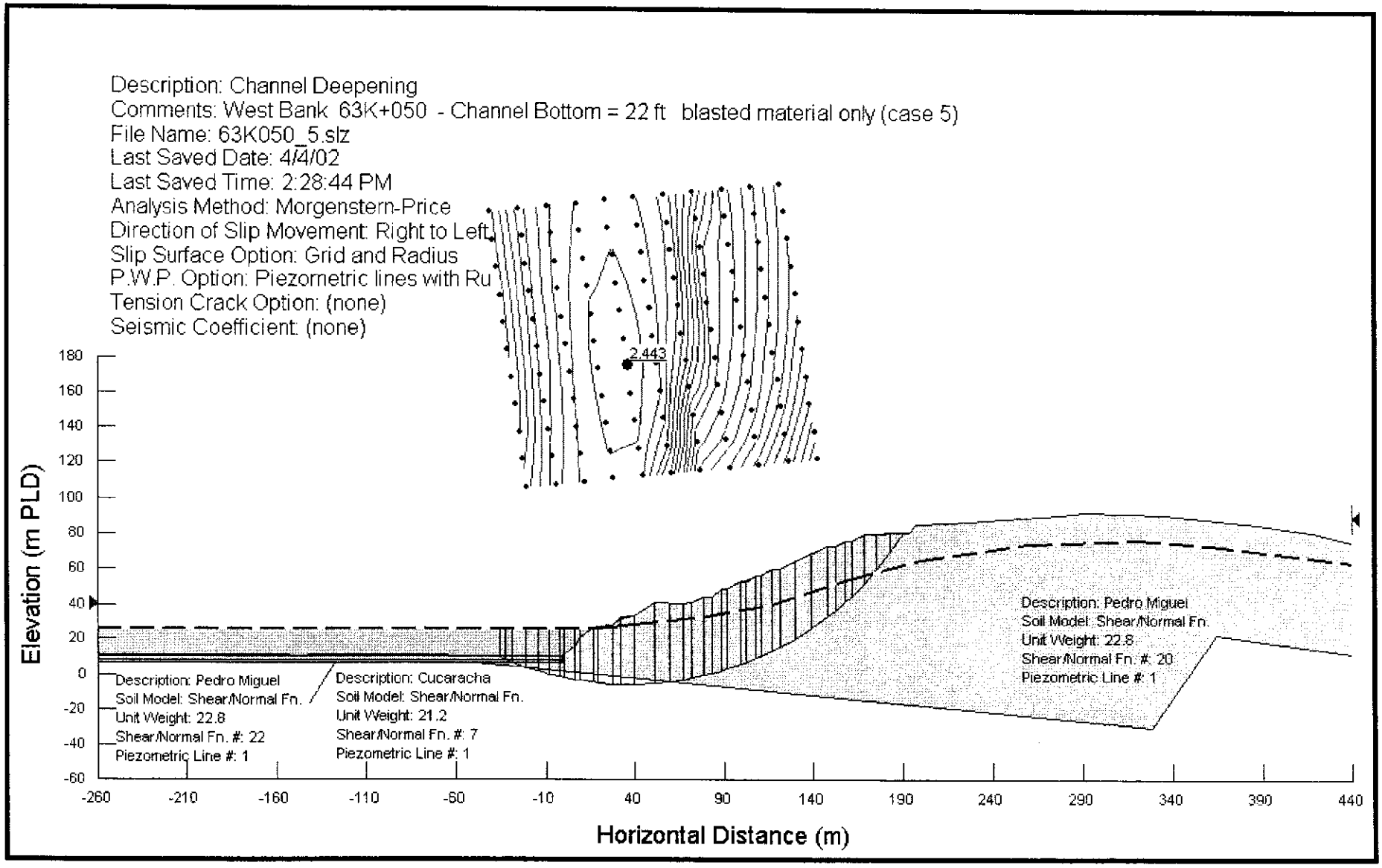
Case 3, Channel bottom = 27 ft, Blasted & removed



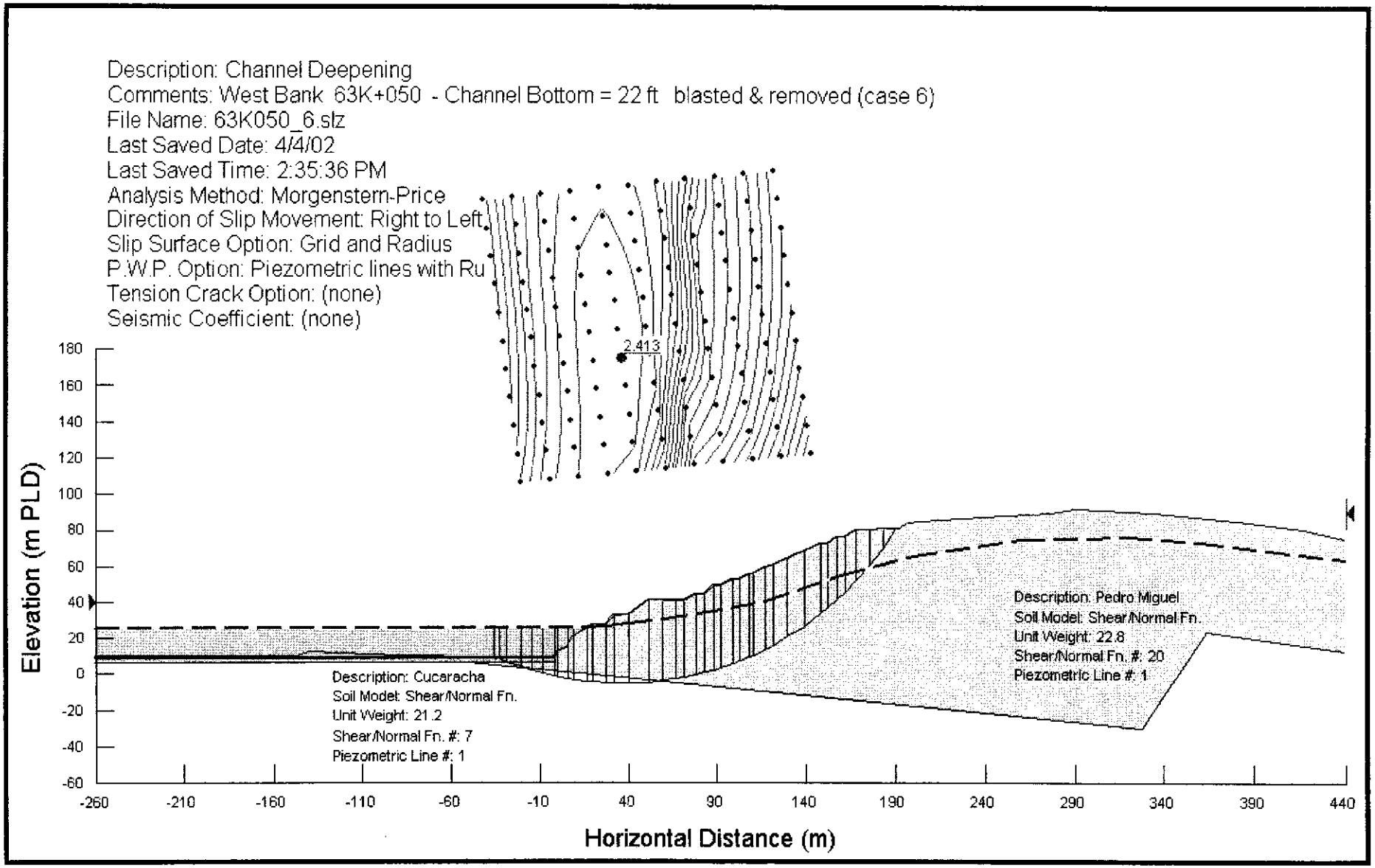
Case 4, Channel bottom = 27 ft, Design (underwater slope)



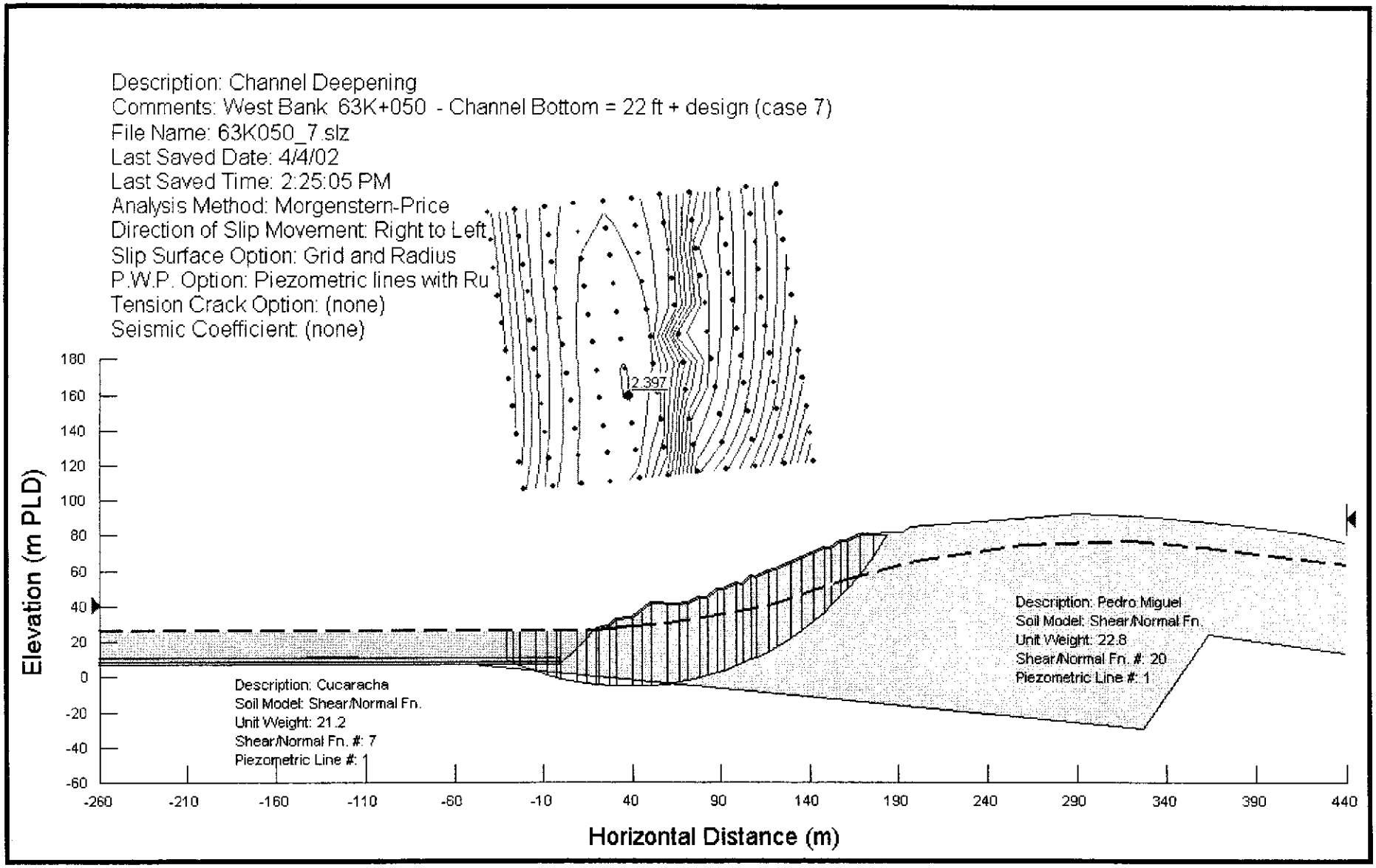
Case 5, Channel bottom = 22 ft, Blasted material only



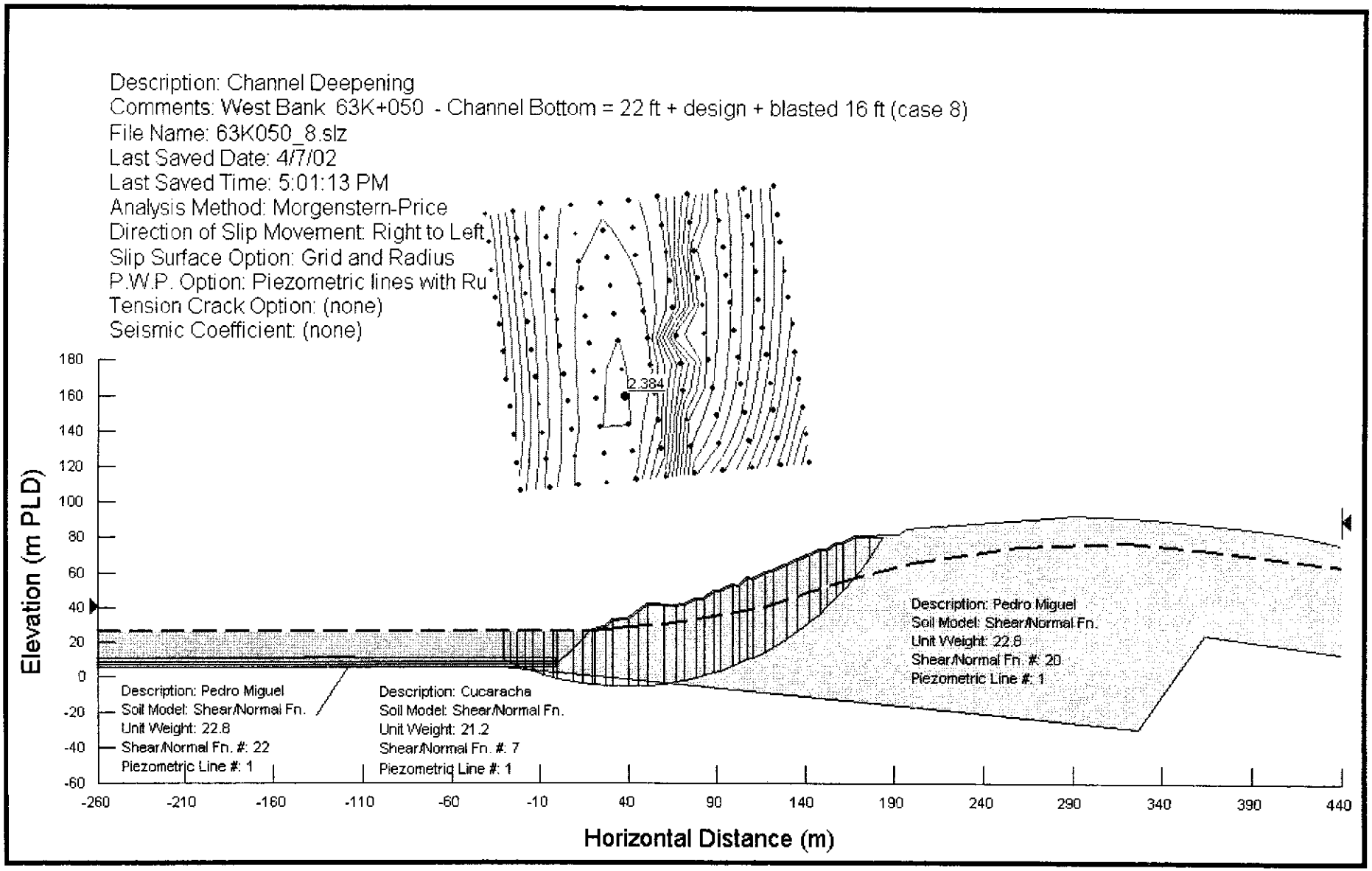
Case 6, Channel bottom = 22 ft, Blasted & removed



Case 7, Channel bottom = 27 ft, Design (underwater slope)

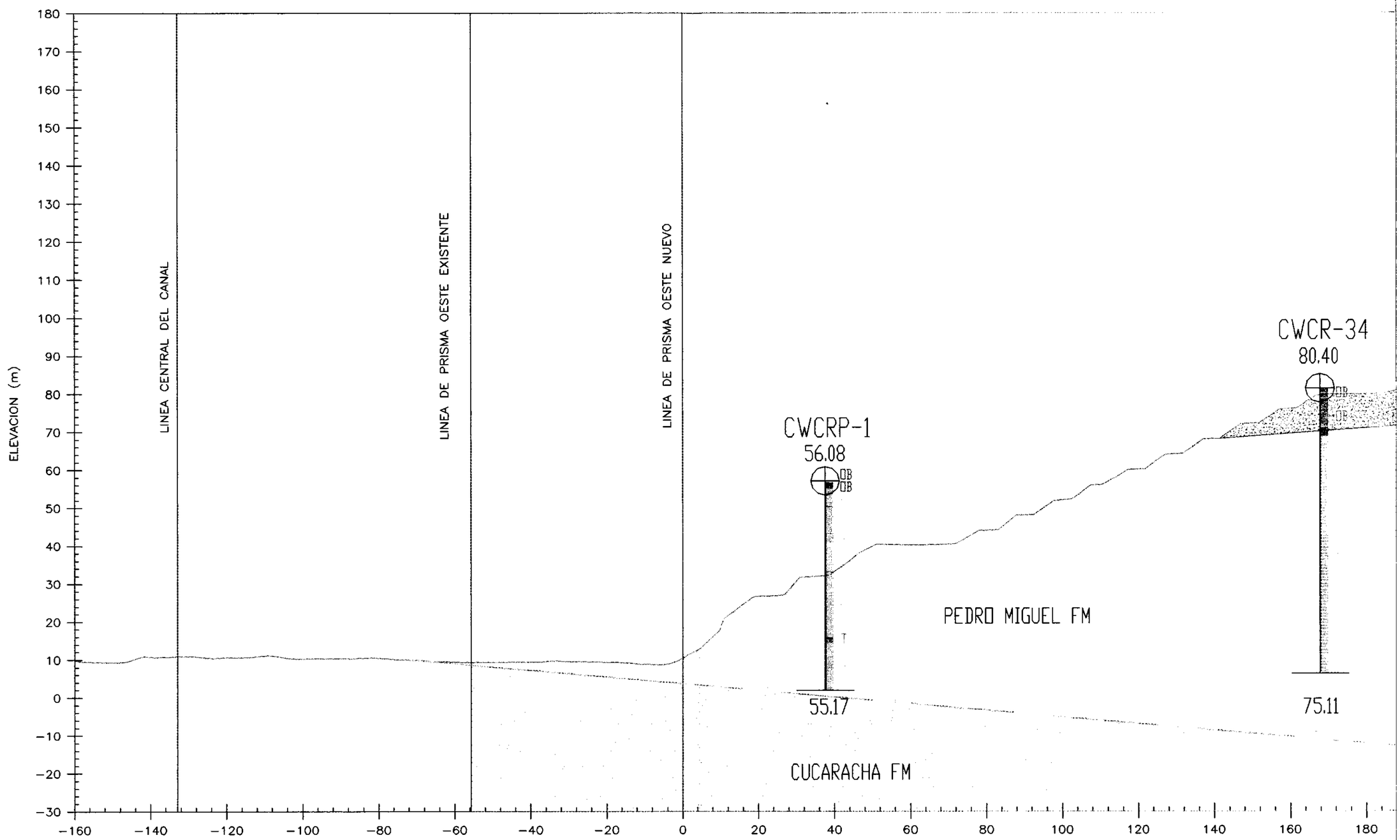


Case 8, Channel bottom = 16 ft, Blasted

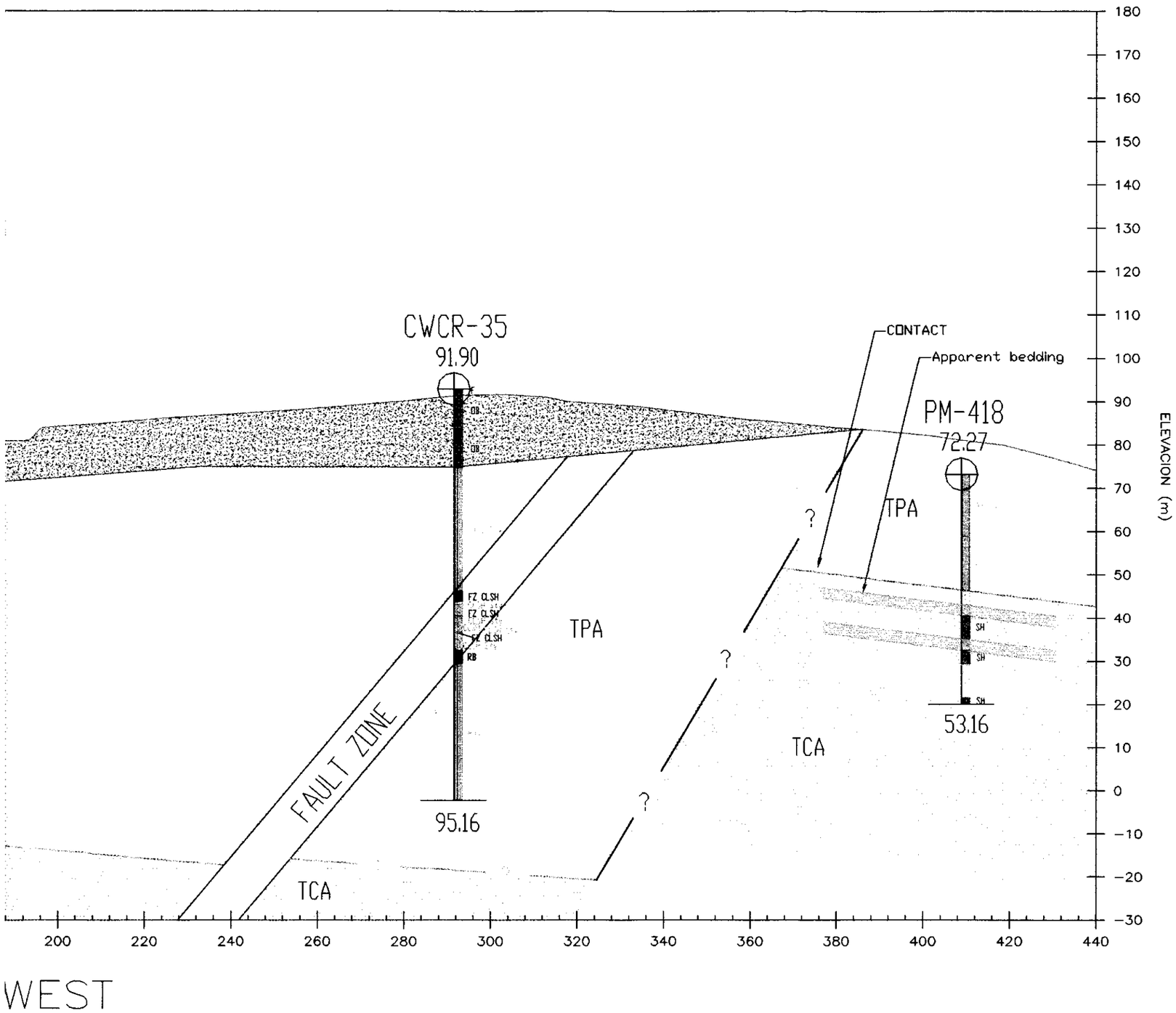


Summary, 63k + 050 (2068 + 56)

General Description	Range of stations:	62k + 910 to 63k + 150			
	Sector:	Cartagena			
	Maximum height (m):	75			
	Cotangent of slope angle (cot. β):	2.9			
History	Last slide event:	October 7, 1936 (Cartagena slide)			
Geology	Formation:	Pedro Miguel / Cucaracha			
	Lithology:	Agglomerate / Basalt / Clayshale			
	Critical stratum at toe:	Shale / Agglomerate			
	Apparent dip of bedding:	Toward slope in Cucaracha / Pedro Miguel no defined			
Stability Analysis	Critical failure mechanism:	Rotational			
	Shear strength model:	Fully softened, Cucaracha / First time, Cucaracha			
		Operative average pore pressure ratio (aproximate), Ru:	Factor of Safety	Relative Factor of Safety	Percentage of Change (%)
	Case 1: Channel bottom = 32 ft	0.308	2.493	1.000	0.00
	Case 2: Channel bottom = 27 ft, Blasted material only		2.486	0.997	-0.28
	Case 3: Channel bottom = 27 ft, Blasted & removed		2.451	0.983	-1.68
	Case 4.1: Channel bottom = 27 ft, Design (underwater slope)		2.442	0.980	-2.05
	Case 4.2: Channel bottom = 27 ft, Design (& dry excavation)	0.306	2.442	0.980	-2.05
	Case 5: Channel bottom = 22 ft, Blasted material only		2.443	0.980	-2.01
	Case 6: Channel bottom = 22 ft, Blasted & removed		2.413	0.968	-3.21
	Case 7.1: Channel bottom = 22 ft, Design (underwater slope)		2.397	0.961	-3.85
	Case 7.2: Channel bottom = 22 ft, Design (& dry excavation)	0.306	2.397	0.961	-3.85
	Case 8: Channel bottom = 16 ft, Blasted		2.384	0.956	-4.37
Conclusions:	No stabilization is required				



63K+050 (2068+56)



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SECCION GEOLOGICA

CORTE GAILLARD

ESTACION 63K+050 (2068+56) OESTE

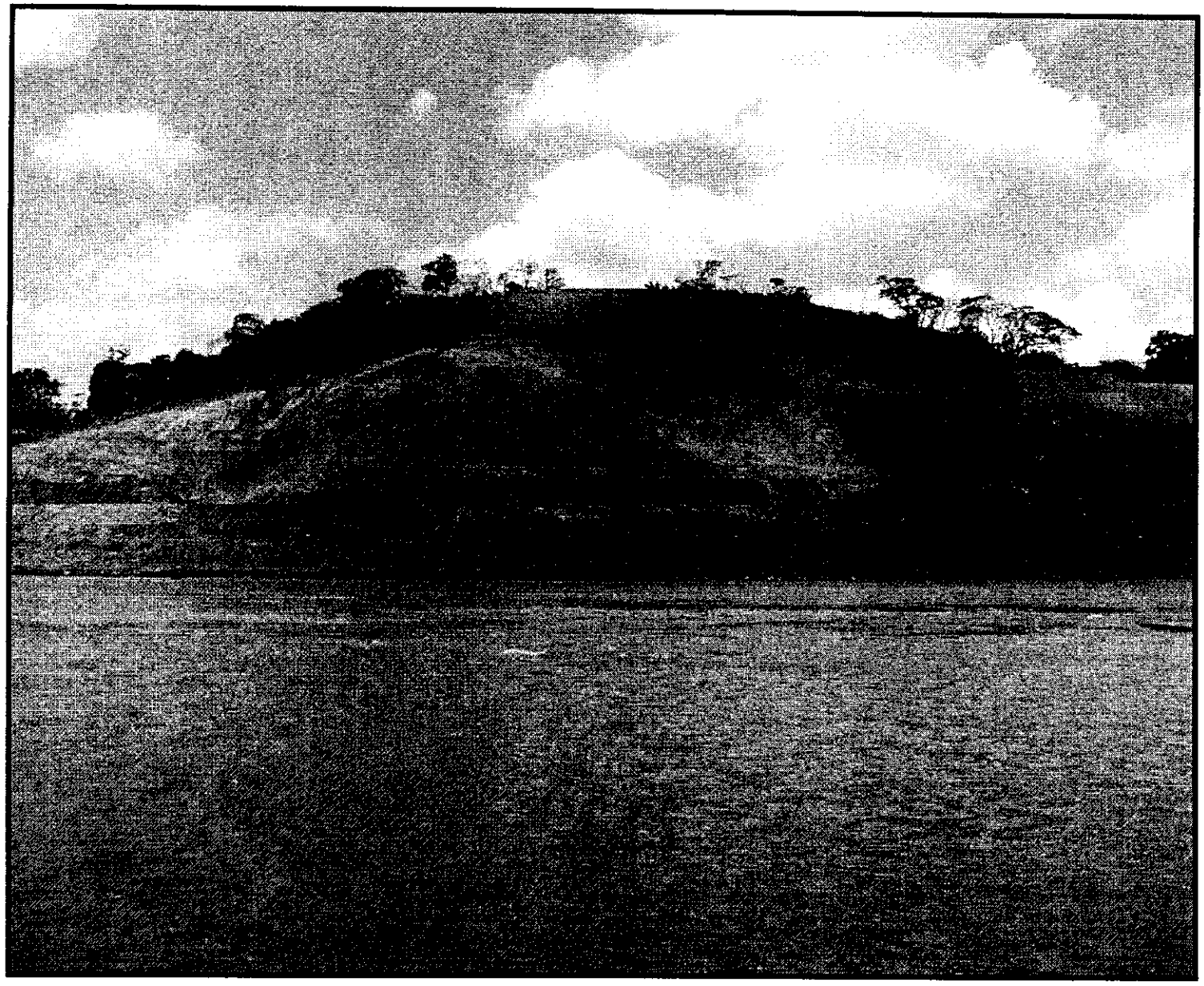
ESCALA: 1:1000	FECHA: ABRIL 2002
GEOLOGIA POR: P. FRANCESCHI	DIBUJADO POR: J. RAMESCH

station 63k + 327 (2077 + 65)

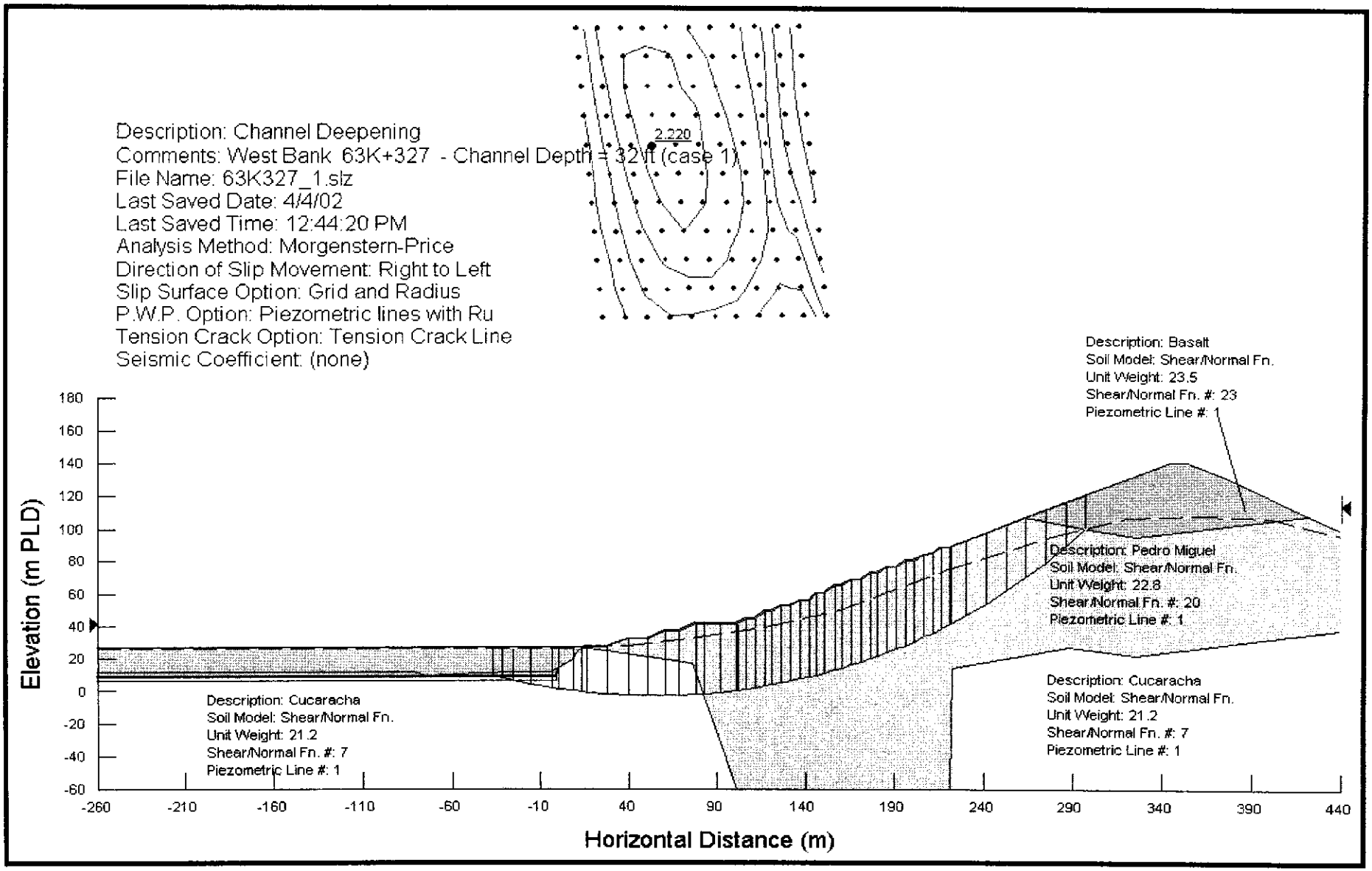
West

Station: 63k + 327 (Cartagena)

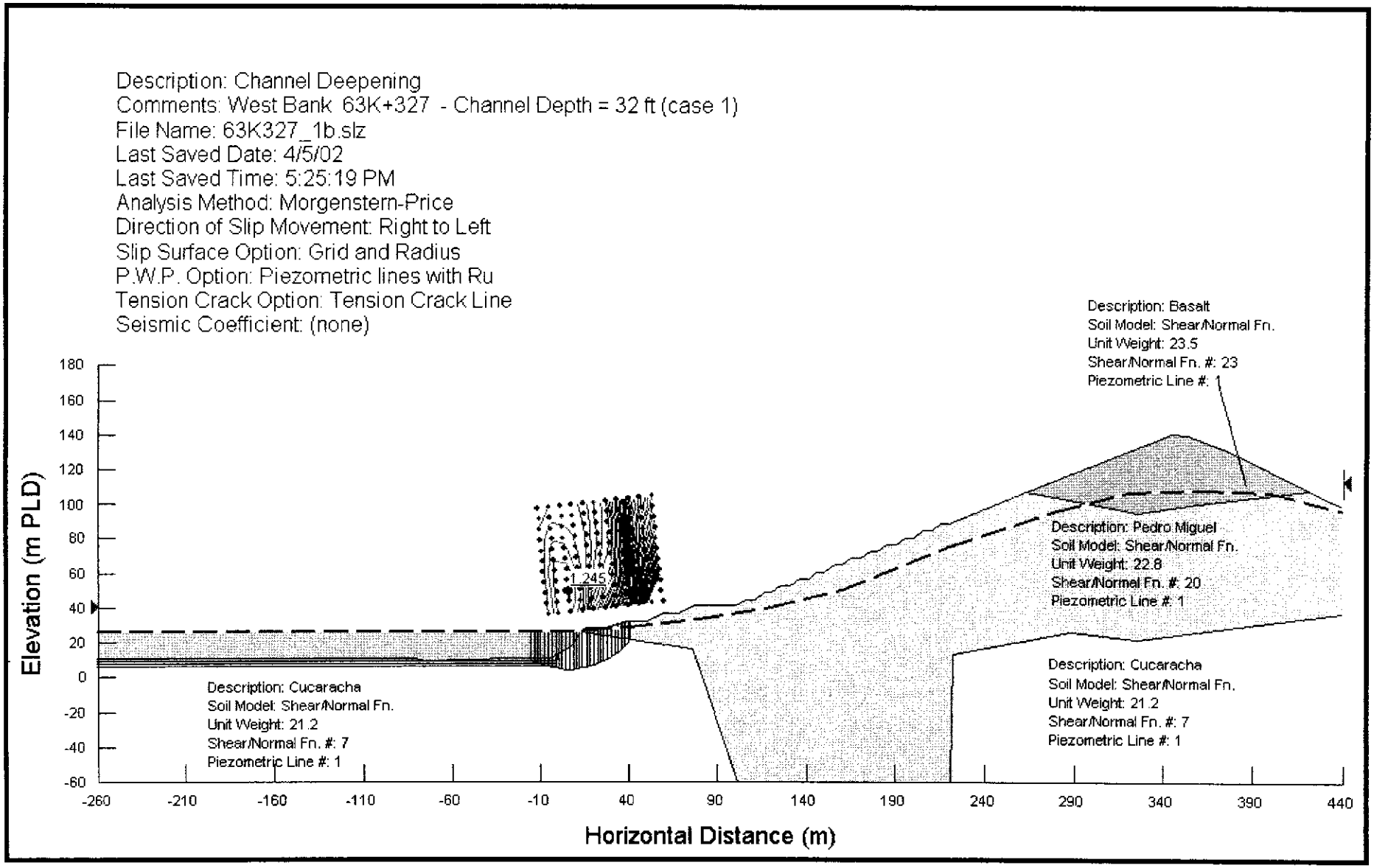
April 16, 2002



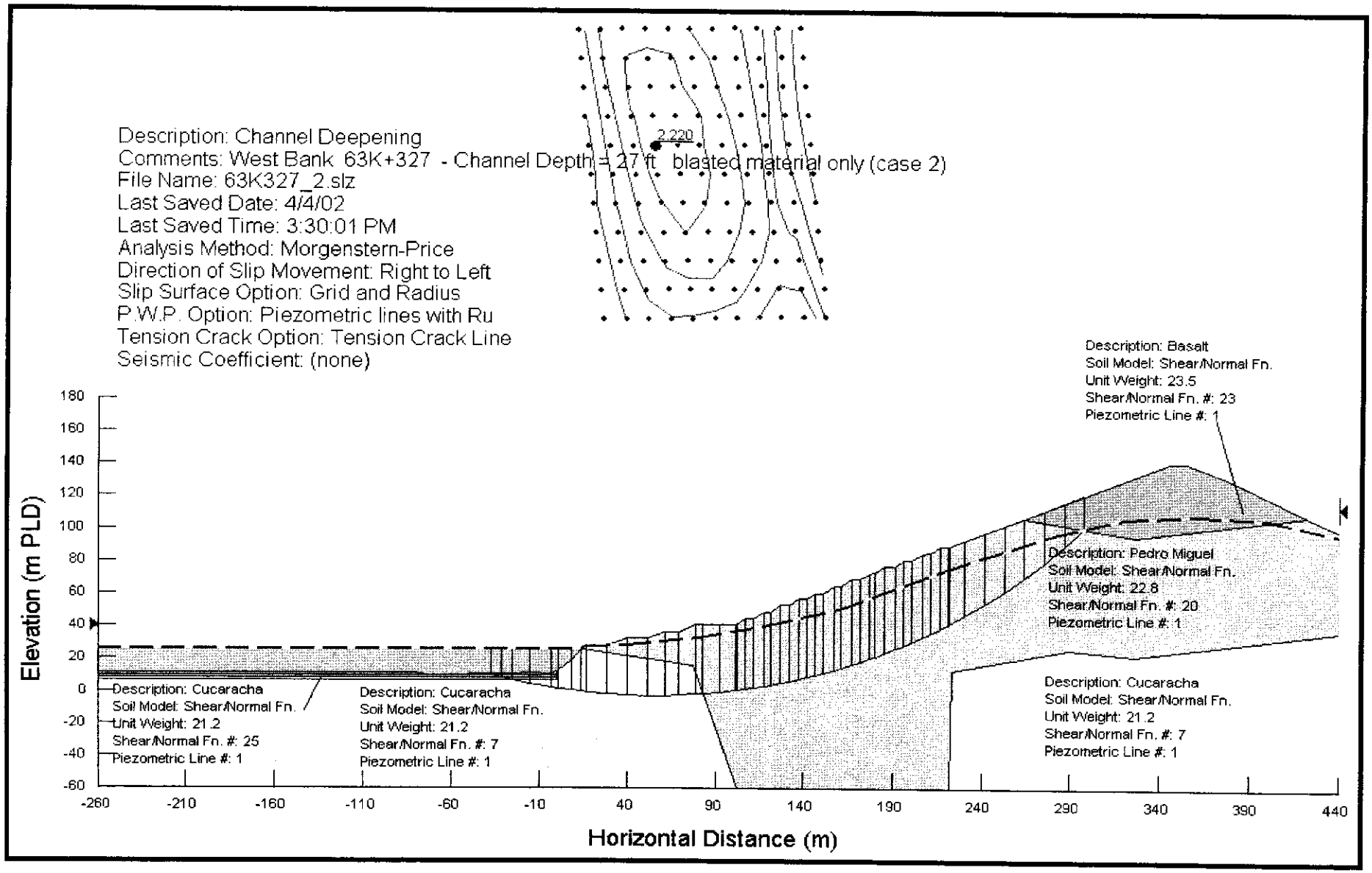
Case 1, Channel bottom = 32 ft



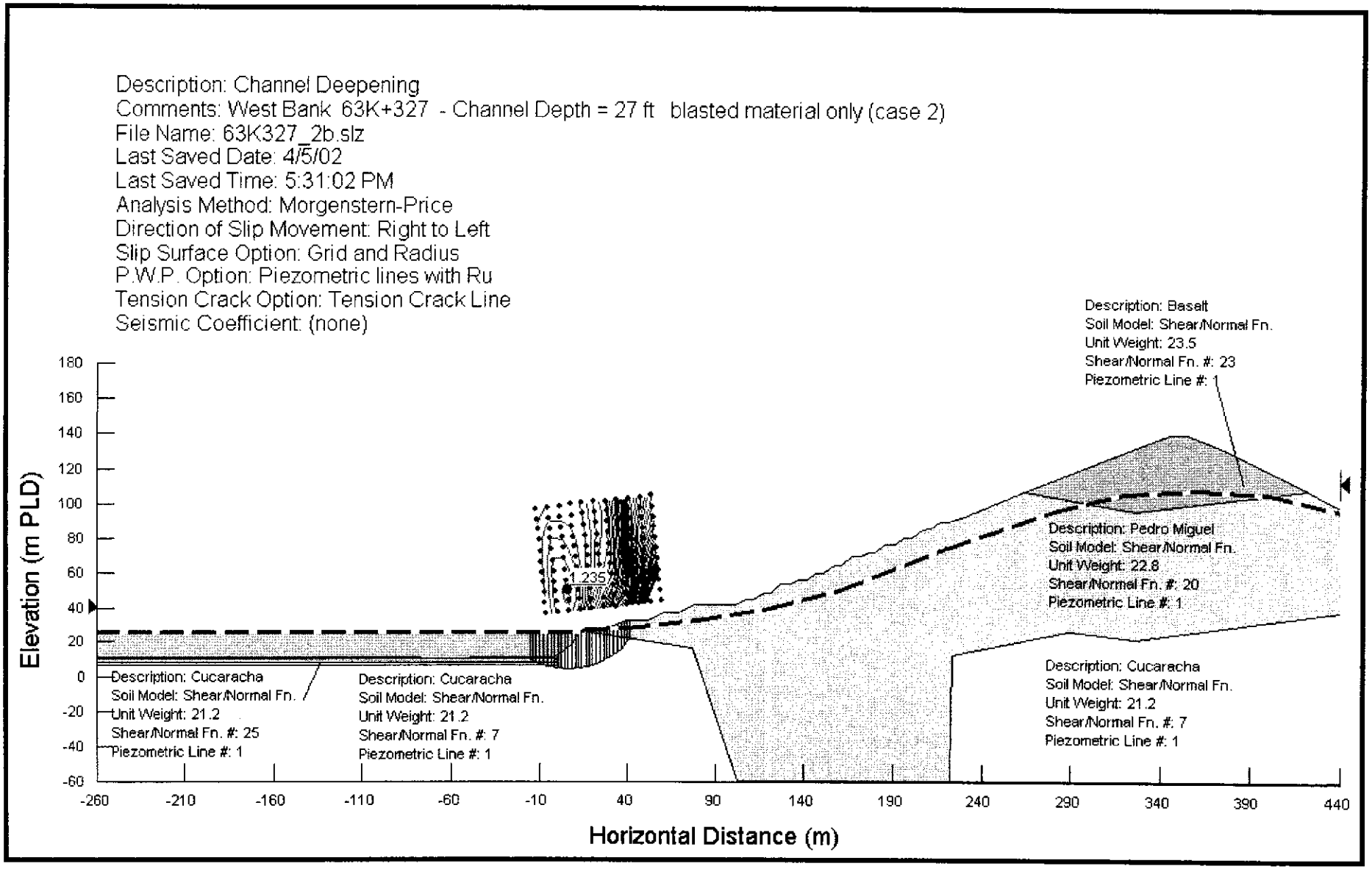
Case 1b, Channel bottom = 32 ft



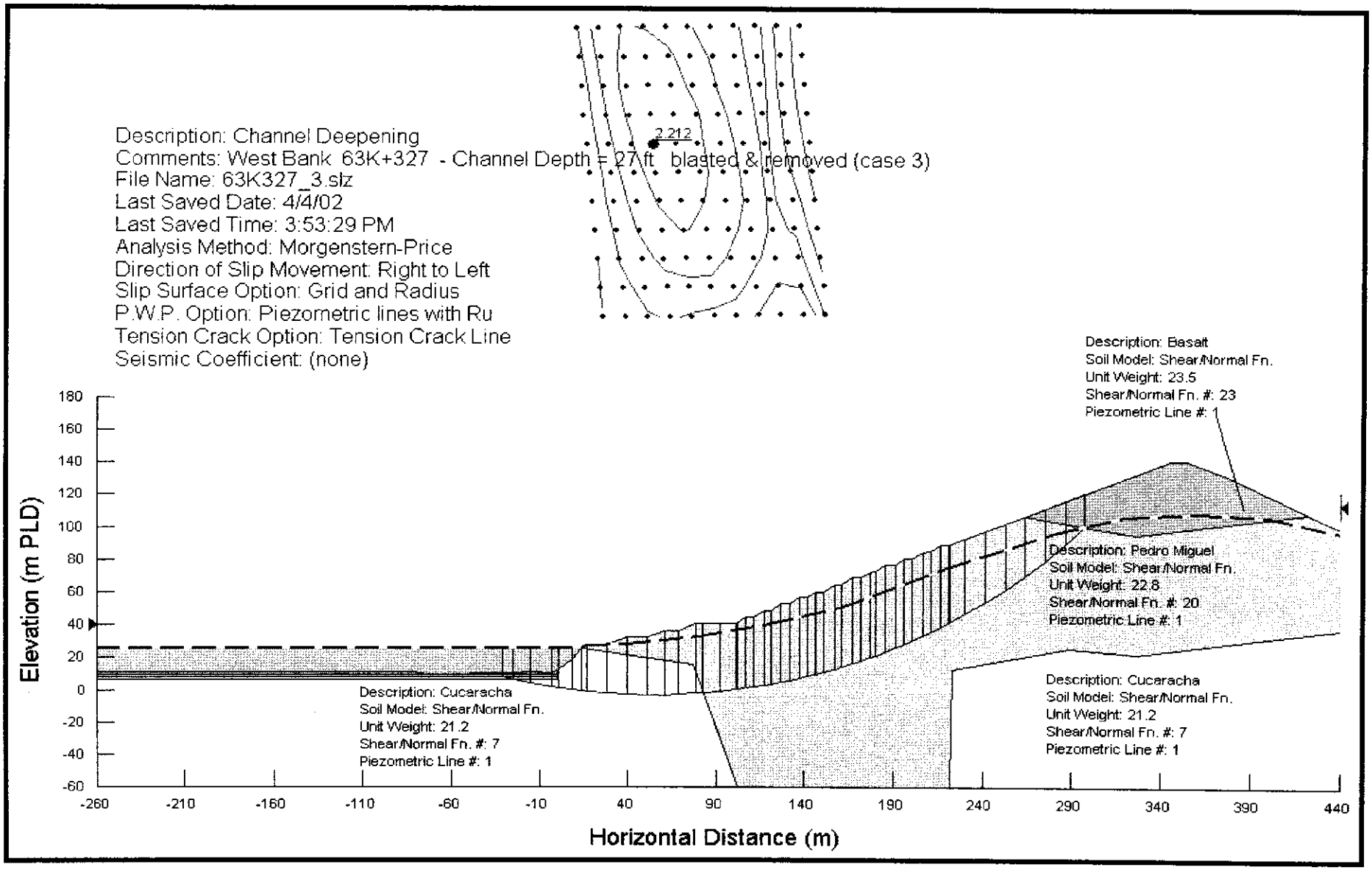
Case 2, Channel bottom = 27 ft, Blasted material only



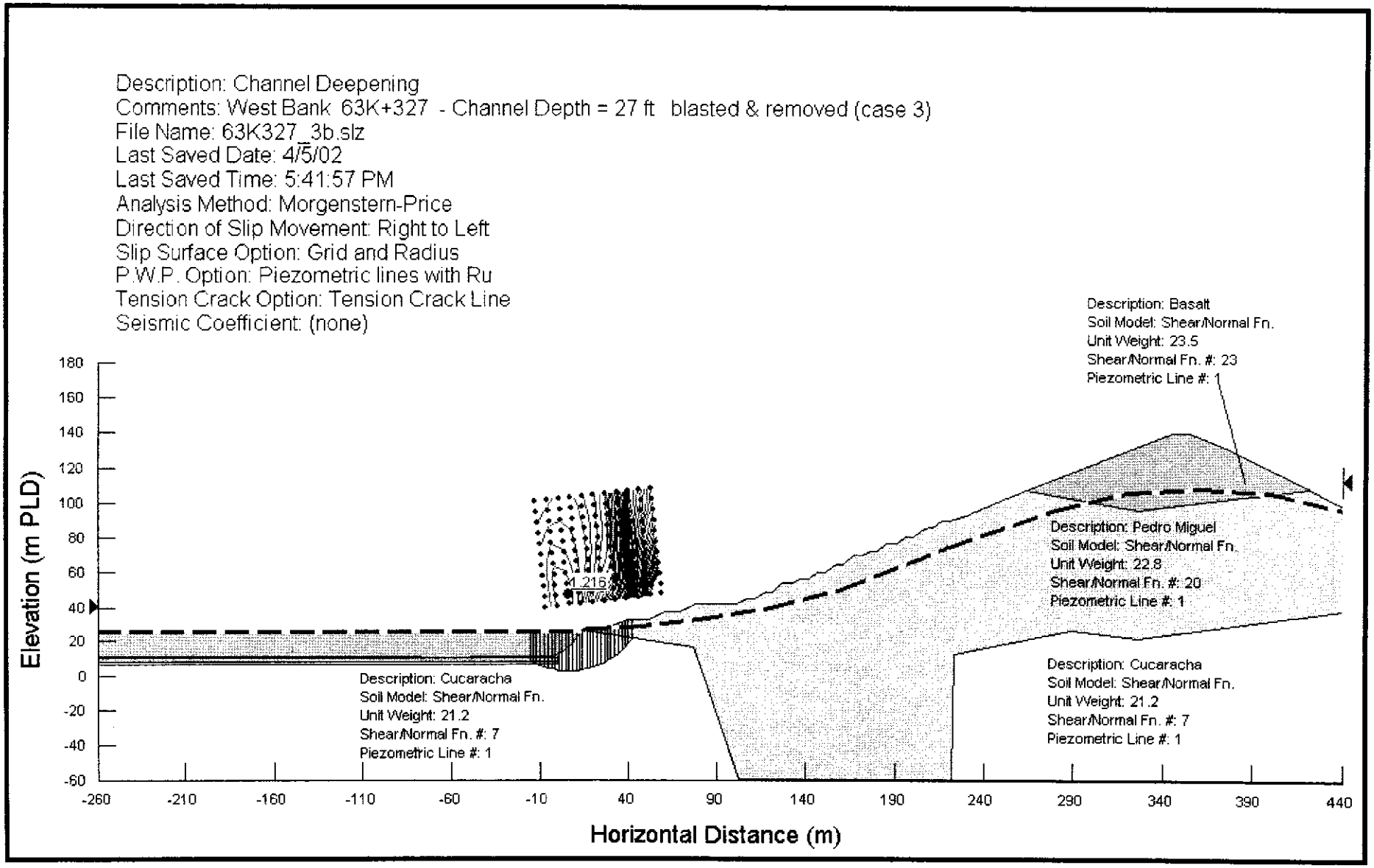
Case 2b, Channel bottom = 27 ft, Blasted material only



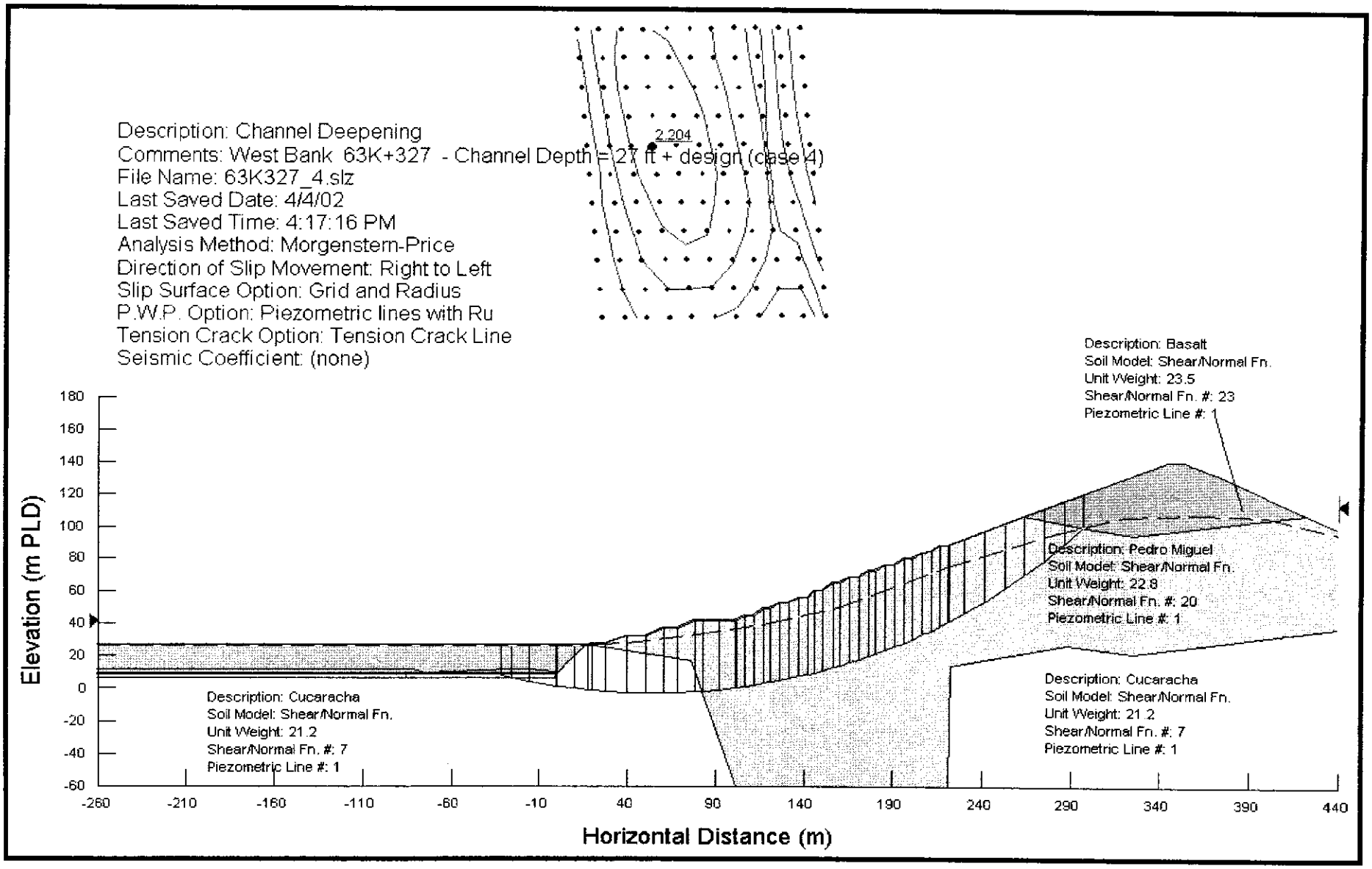
Case 3, Channel bottom = 27 ft, Blasted & removed



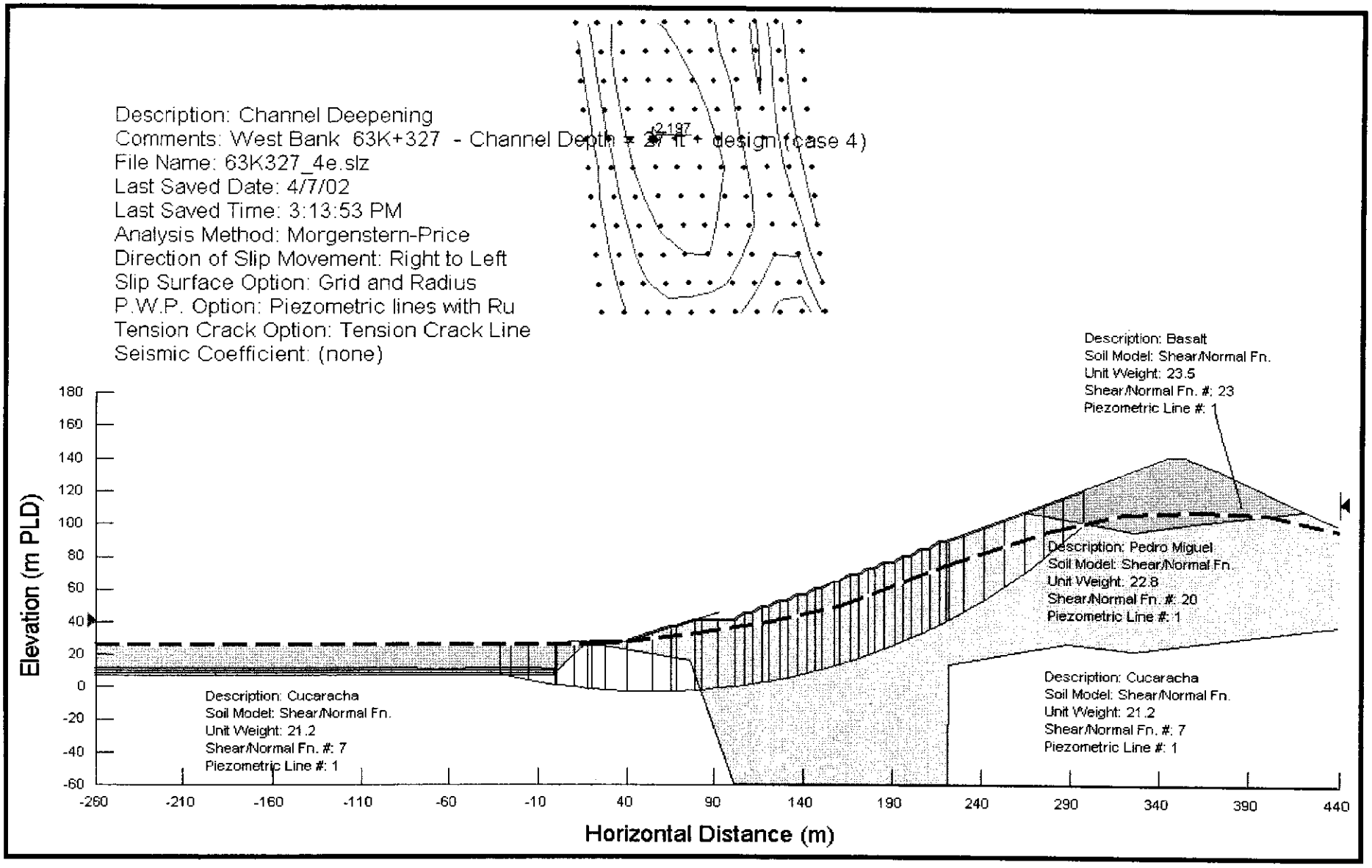
Case 3b, Channel bottom = 27 ft, Blasted & removed



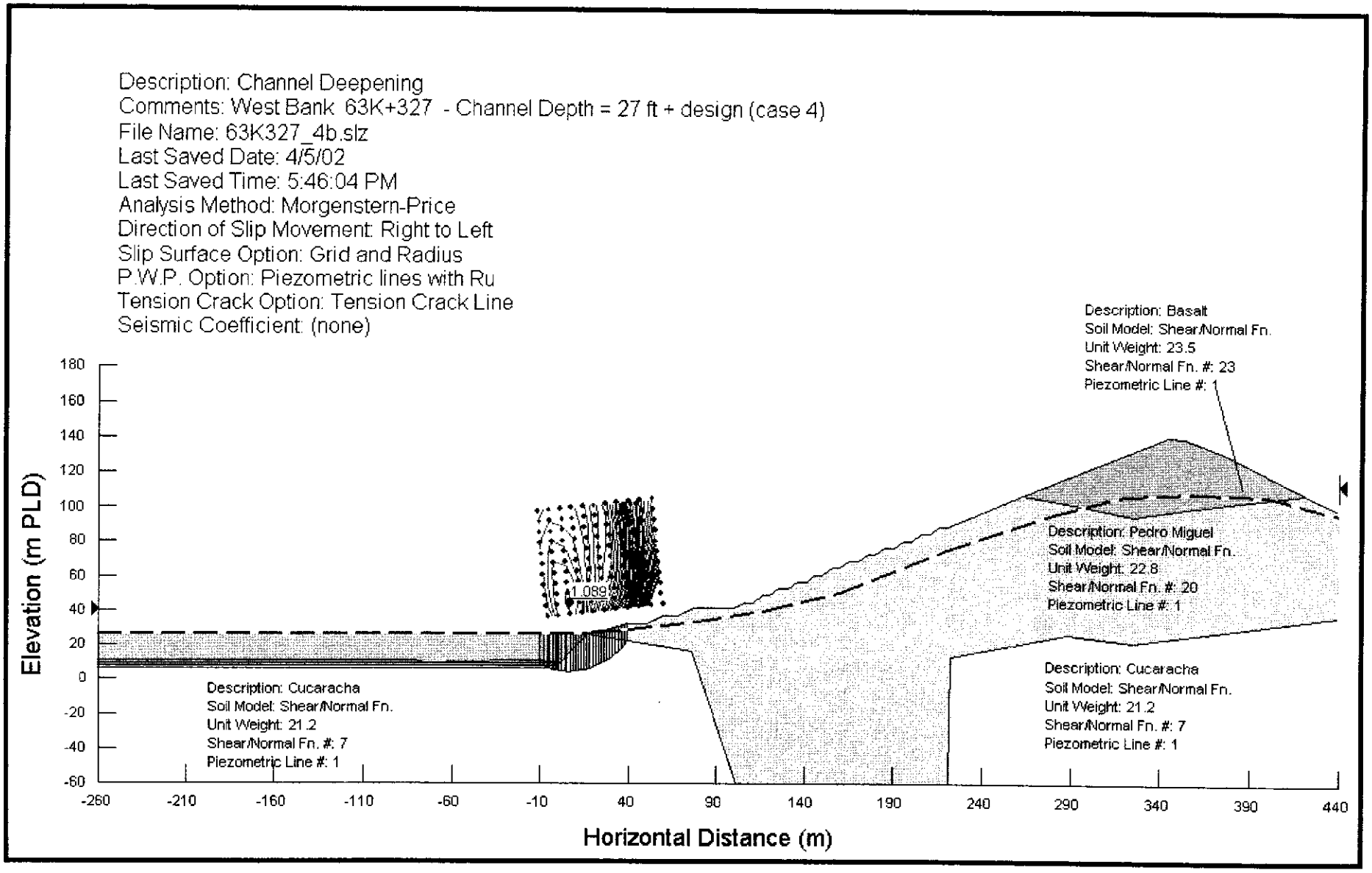
Case 4.1.a, Channel bottom = 27 ft, Design (underwater slope)



Case 4.2.a, Channel bottom = 27 ft, Design (& dry excavation)

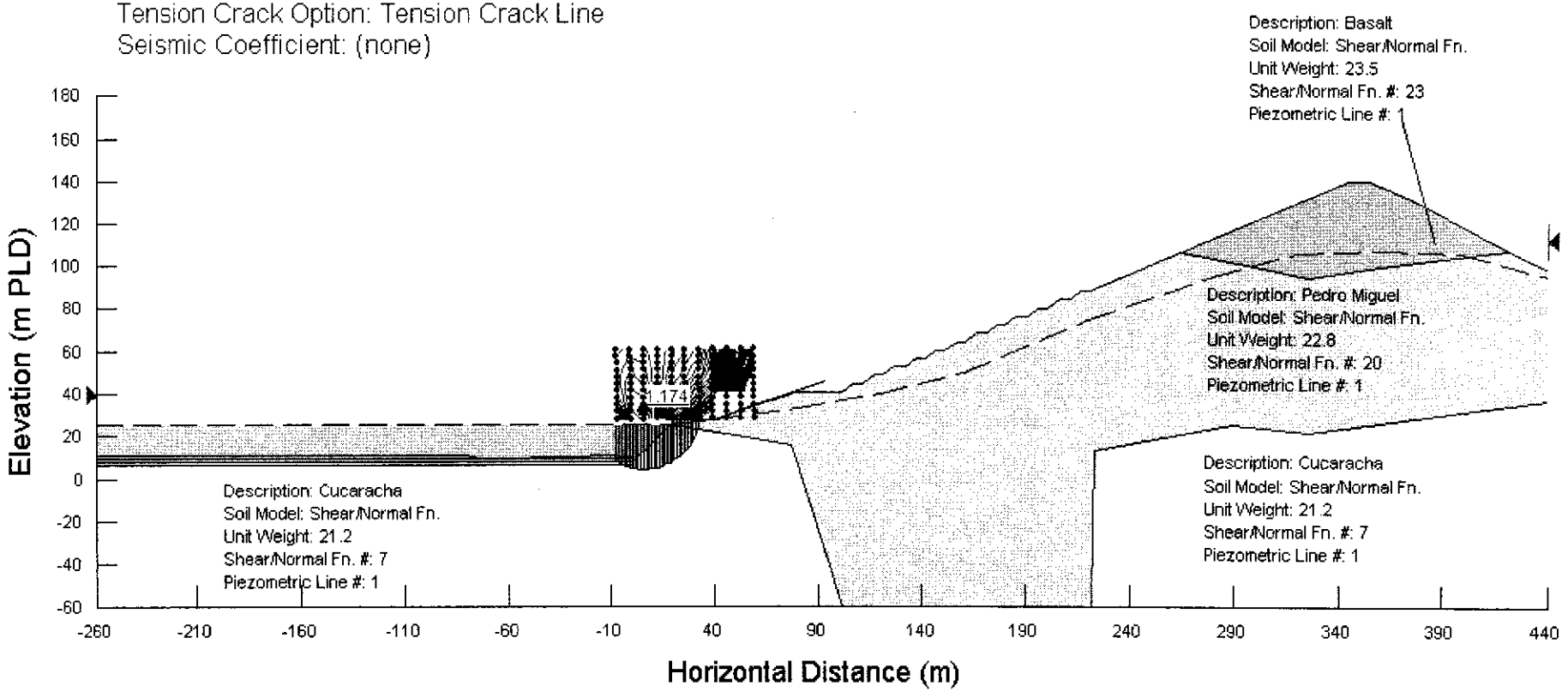


Case 4.1.b, Channel bottom = 27 ft, Design (underwater slope)

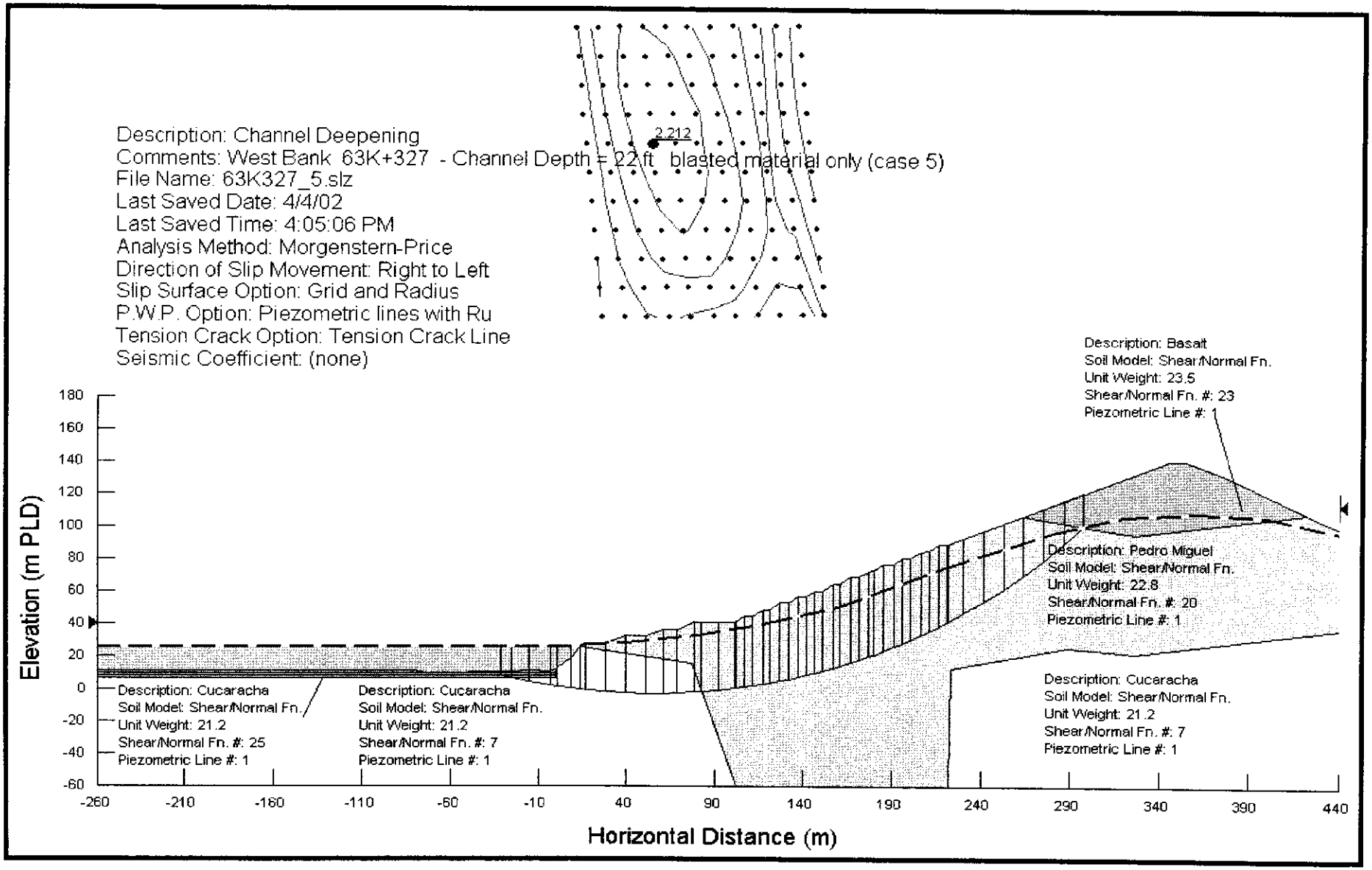


Case 4.2.b, Channel bottom = 27 ft, Design (& dry excavation)

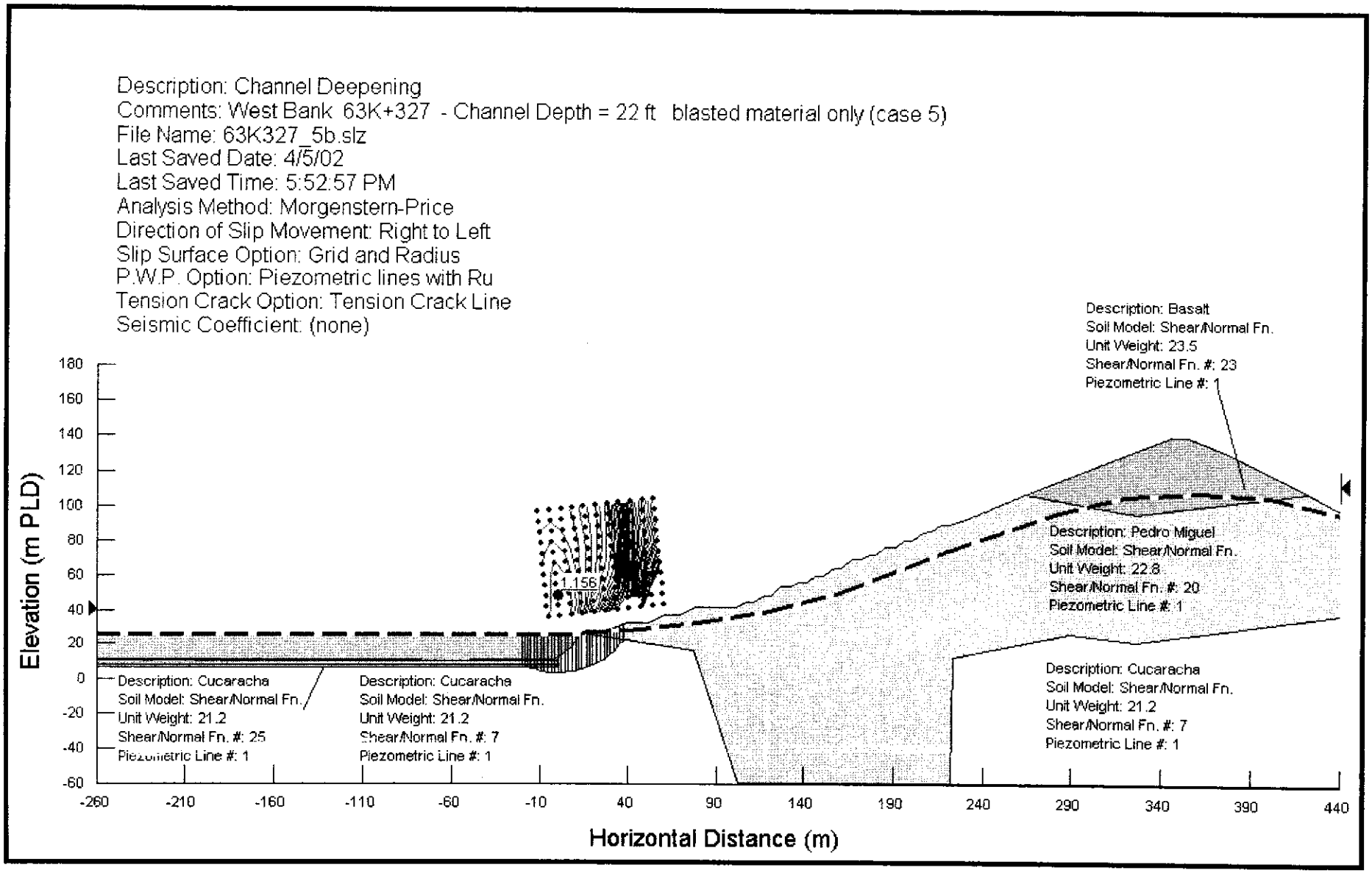
Description: Channel Deepening
Comments: West Bank 63K+327 - Channel Depth = 27 ft + design (case 4)
File Name: 63K327_4be.slz
Last Saved Date: 4/7/02
Last Saved Time: 3:14:59 PM
Analysis Method: Morgenstern-Price
Direction of Slip Movement: Right to Left
Slip Surface Option: Grid and Radius
P.W.P. Option: Piezometric lines with Ru
Tension Crack Option: Tension Crack Line
Seismic Coefficient: (none)



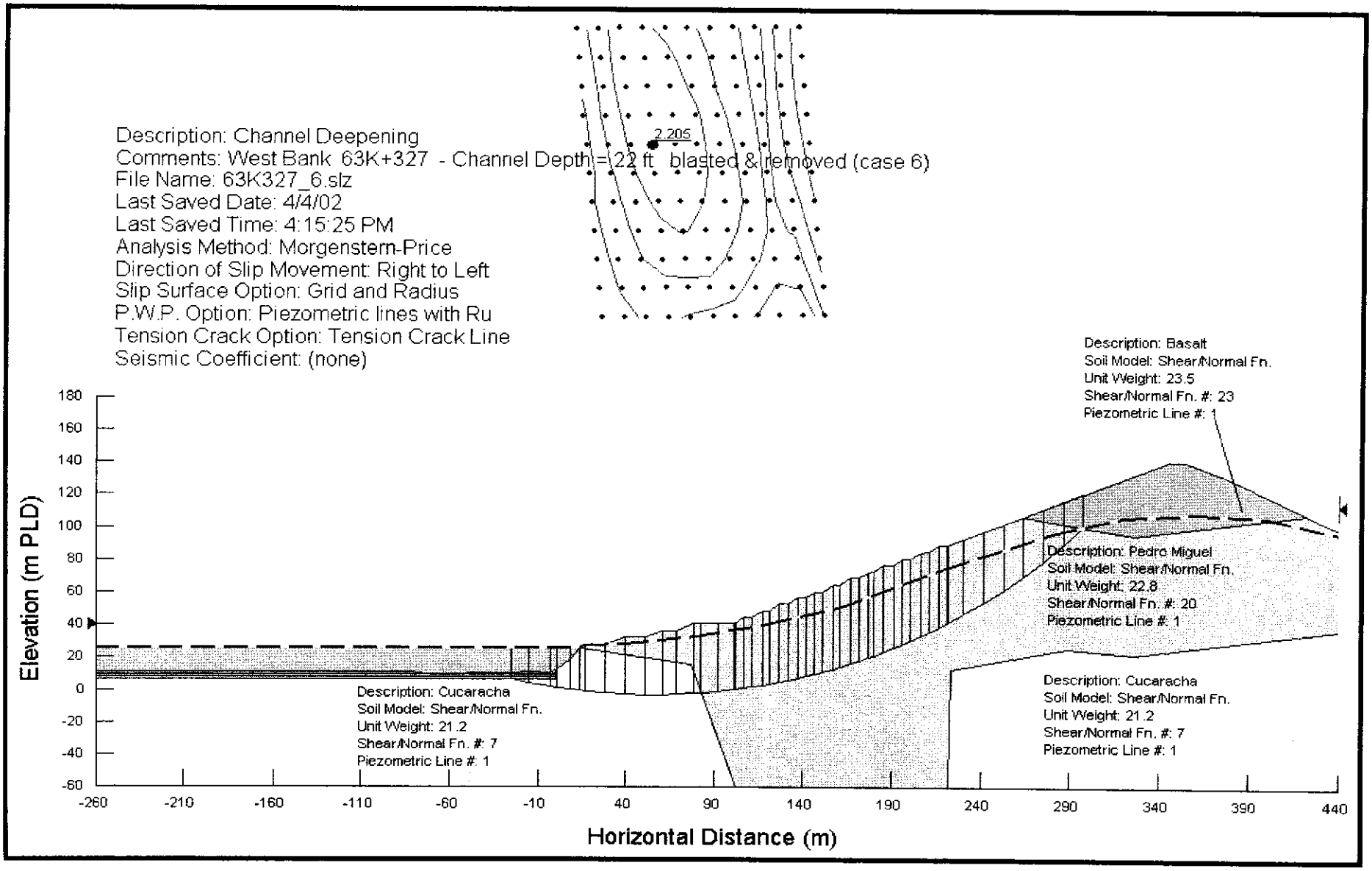
Case 5, Channel bottom = 22 ft, Blasted material only



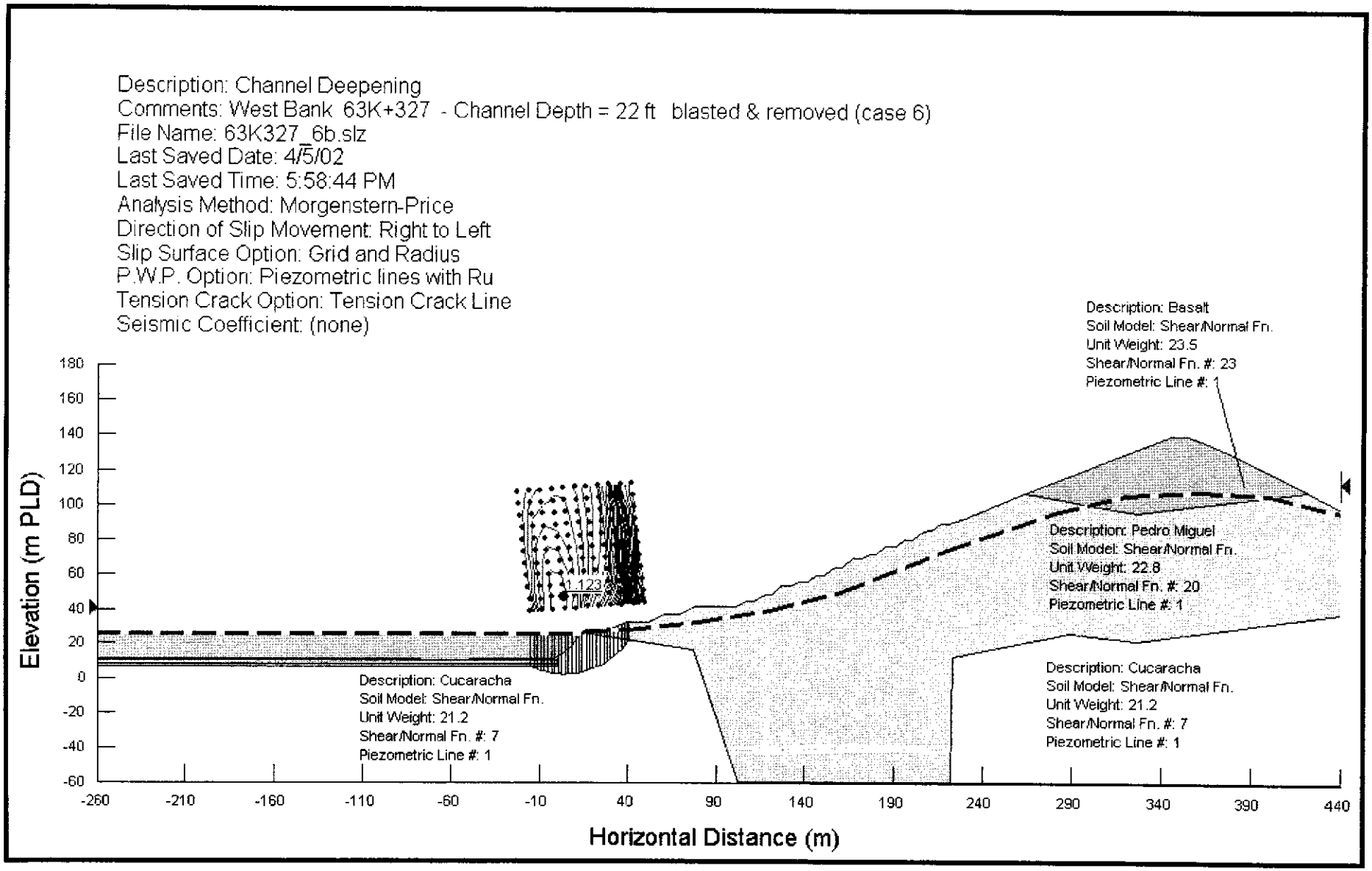
Case 5b, Channel bottom = 22 ft, Blasted material only



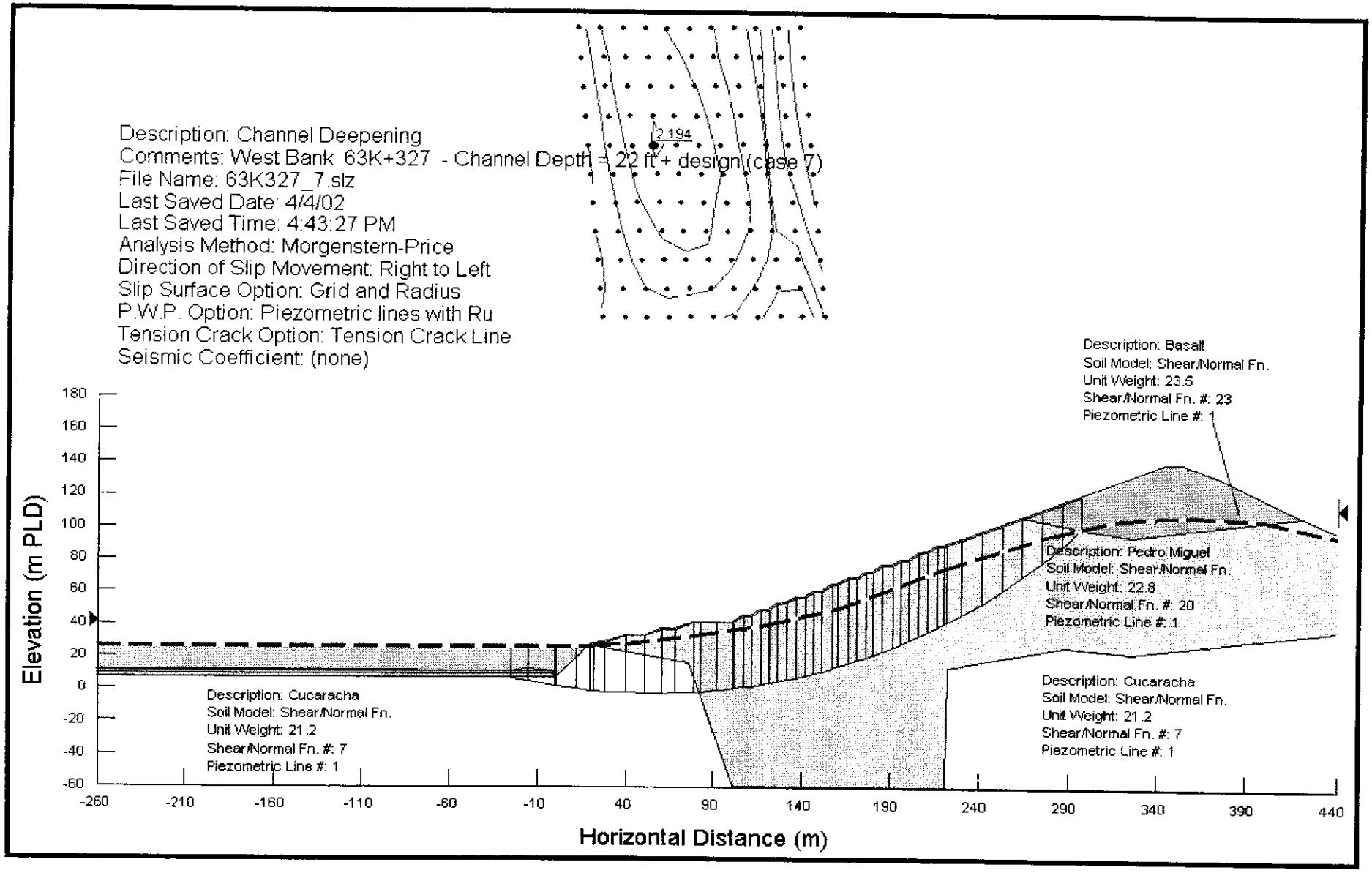
Case 6, Channel bottom = 22 ft, Blasted & removed



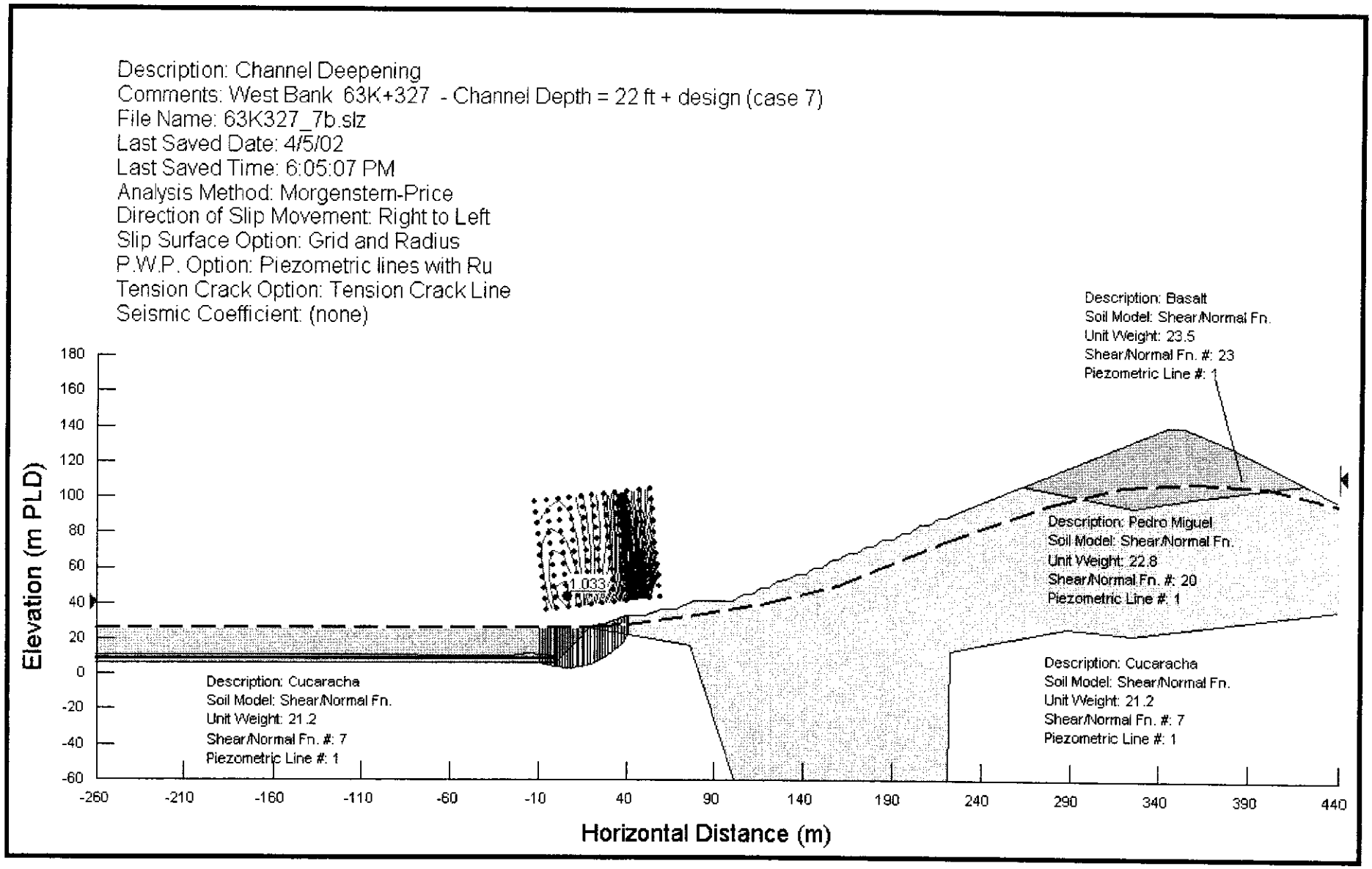
Case 6b, Channel bottom = 22 ft, Blasted & removed



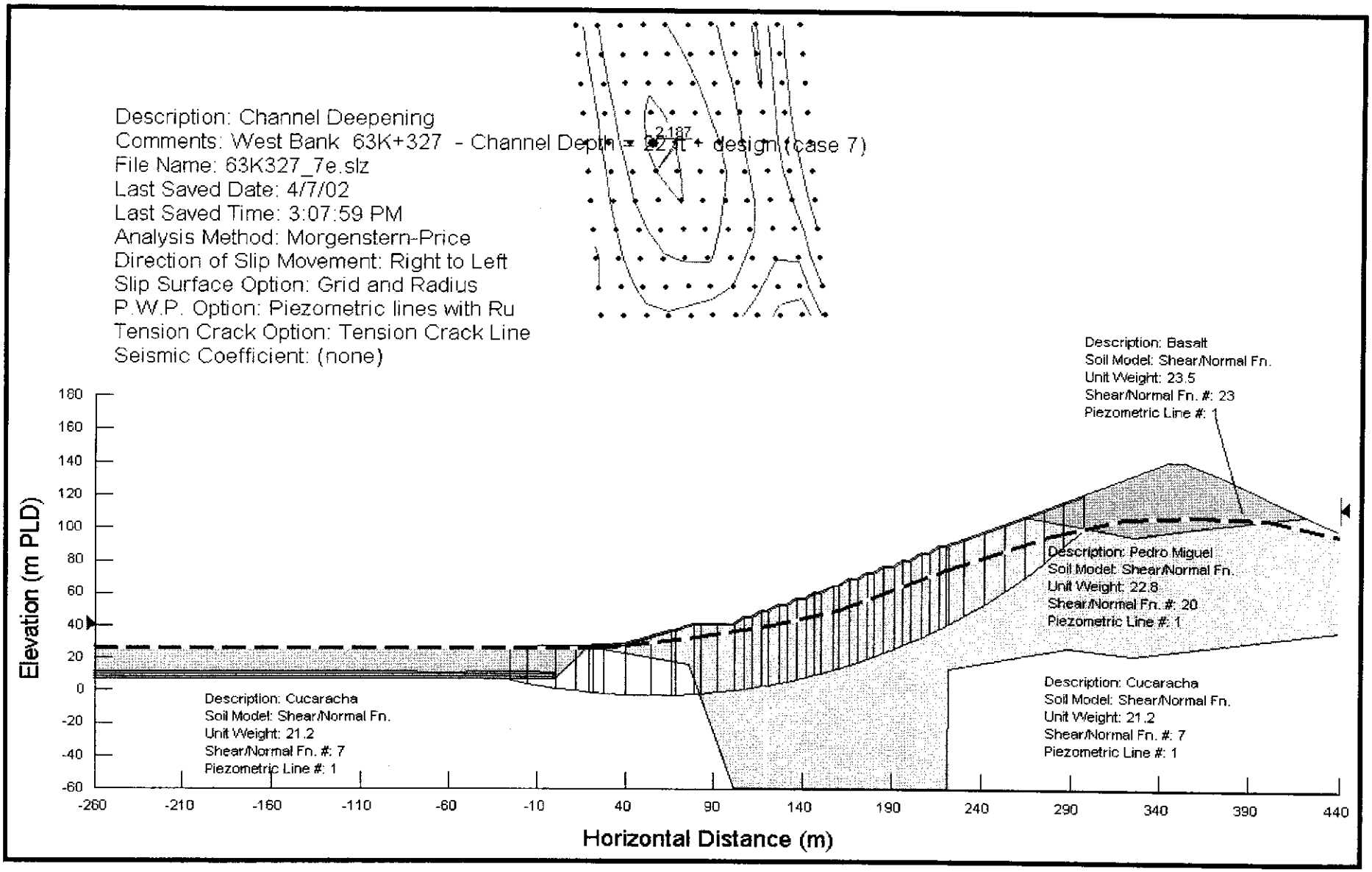
Case 7.1.a, Channel bottom = 27 ft, Design (underwater slope)



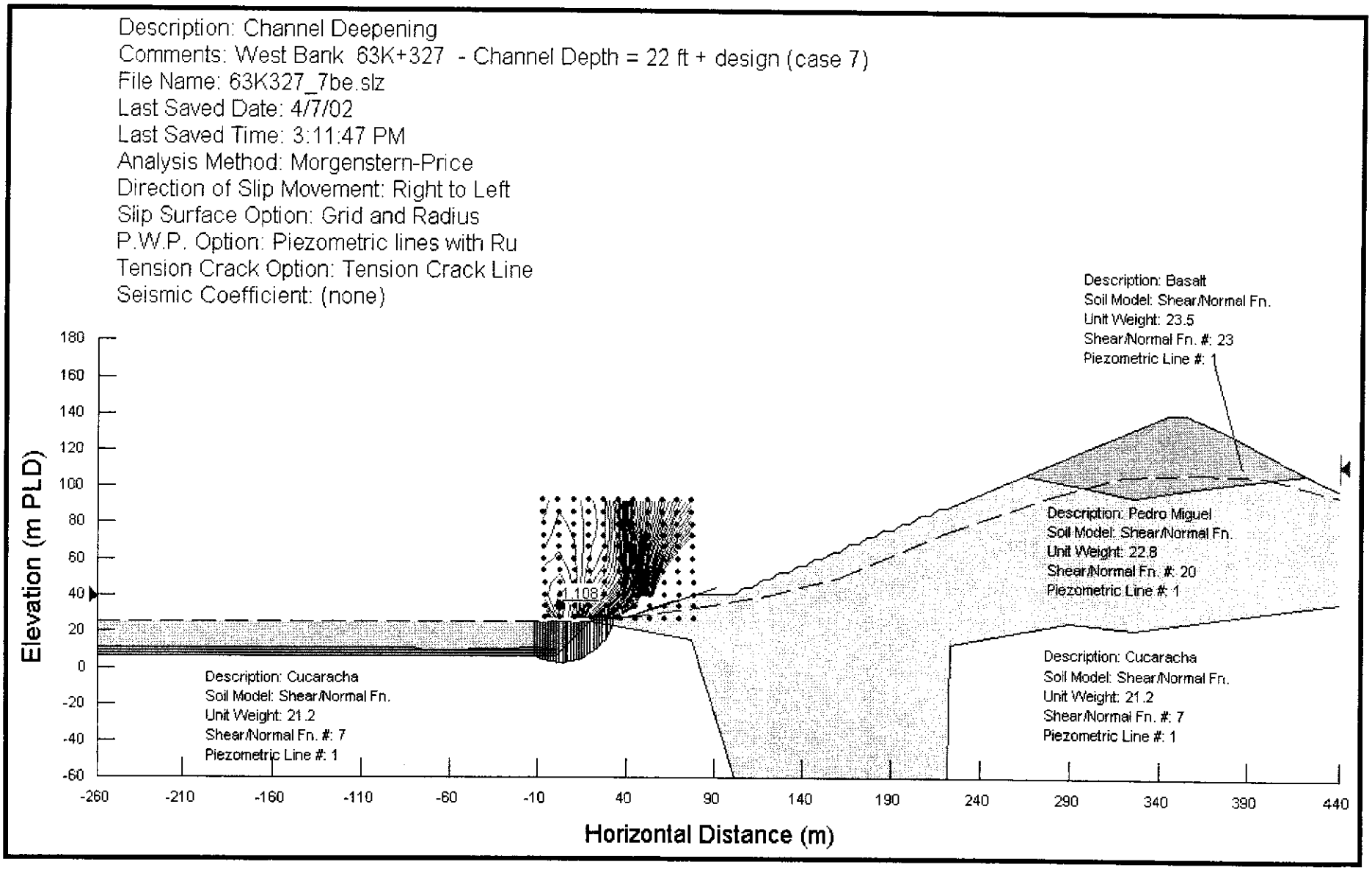
Case 7.1.b, Channel bottom = 27 ft, Design (underwater slope)



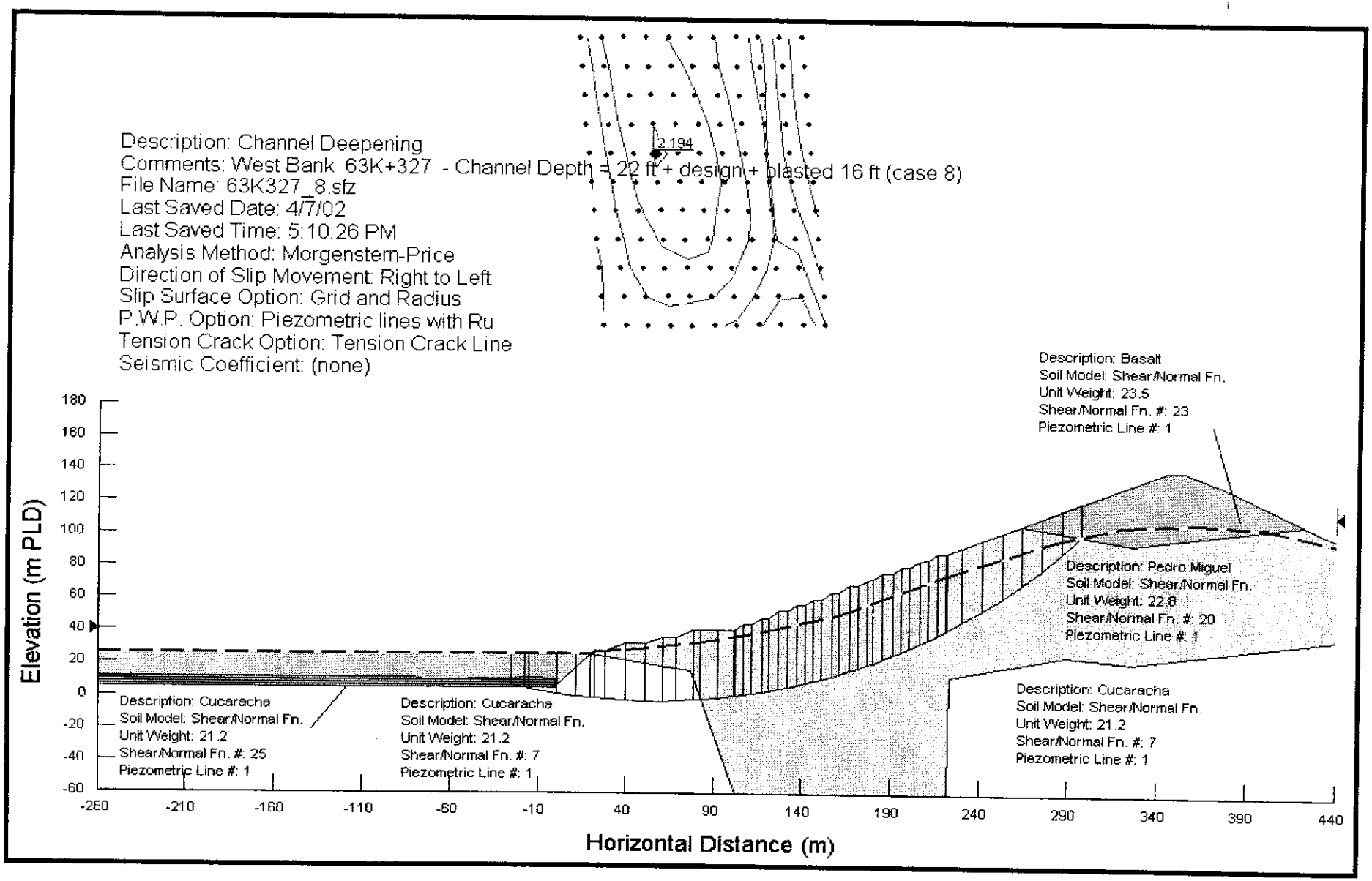
Case 7.2.a, Channel bottom = 27 ft, Design (& dry excavation)



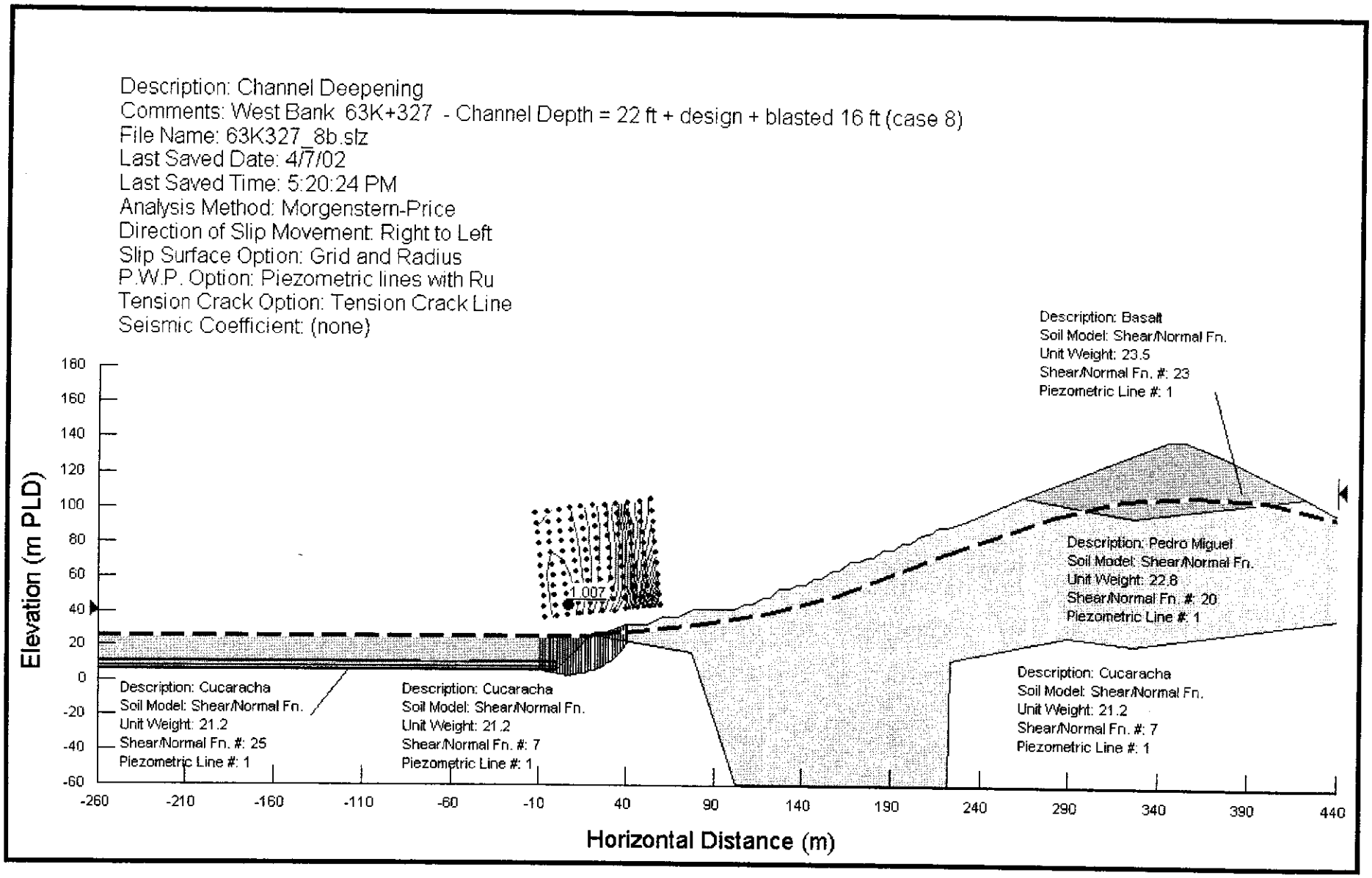
Case 7.2.b, Channel bottom = 27 ft, Design (& dry excavation)



Case 8, Channel bottom = 16 ft, Blasted



Case 8b, Channel bottom = 16 ft, Blasted

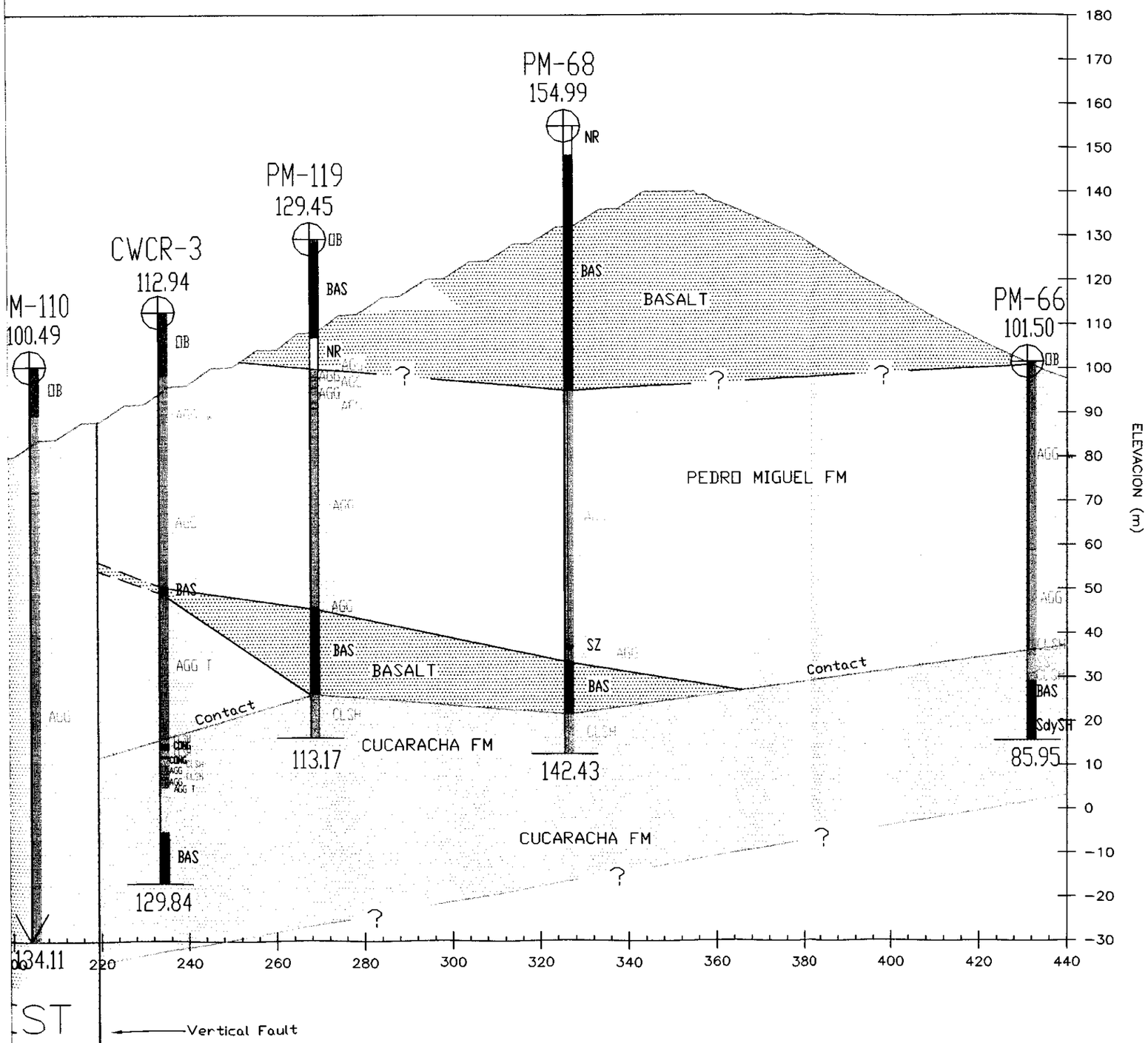


Summary, 63k + 327 (2077 + 65)

General Description	Range of stations:	63k + 150 to 63k + 725
	Sector:	Cartagena
	Maximum height (m):	130
	Cotangent of slope angle (cot. β):	2.7
History	Last slide event:	September 9, 1923 (Cartagena Slide) / A slide ocurred during widening
Geology	Formation:	Pedro Miguel / La Boca / Cucaracha
	Lithology:	Agglomerate / Basalt / Sandstone / Clayshale
	Critical stratum at toe:	Sandy siltstone
	Apparent dip of bedding:	Toward the slope
Stability Analysis	Critical failure mechanism:	Rotational - Tension cracks
	Shear strength model:	Fully Softened, Cucaracha / First Time, Pedro Miguel

	Operative average pore pressure ratio (aproximate), Ru:	Factor of Safety		Relative Factor of Safety		Percentage of Change (%)	
		(a)	(b)	(a)	(b)	(a)	(b)
Case 1: Channel bottom = 32 ft	0.342	2.220	1.245	1.000	1.000	0.00	0.00
Case 2: Channel bottom = 27 ft, Blasted material only		2.220	1.235	1.000	0.992	0.00	-0.80
Case 3: Channel bottom = 27 ft, Blasted & removed		2.212	1.216	0.996	0.977	-0.36	-2.33
Case 4.1: Channel bottom = 27 ft, Design (underwater slope)		2.204	1.089	0.993	0.875	-0.72	-12.53
Case 4.2: Channel bottom = 27 ft, Design (& dry excavation)	0.342	2.197	1.174	0.990	0.943	-1.04	-5.70
Case 5: Channel bottom = 22 ft, Blasted material only		2.212	1.156	0.996	0.929	-0.36	-7.15
Case 6: Channel bottom = 22 ft, Blasted & removed		2.205	1.123	0.993	0.902	-0.68	-9.80
Case 7.1: Channel bottom = 22 ft, Design (underwater slope)		2.194	1.033	0.988	0.830	-1.17	-17.03
Case 7.2: Channel bottom = 22 ft, Design (& dry excavation)	0.341	2.187	1.108	0.985	0.890	-1.49	-11.00
Case 8: Channel bottom = 16 ft, Blasted		2.194	1.007	0.988	0.809	-1.17	-19.12

Conclusions: Stabilization is required for Case 4 and Case 7



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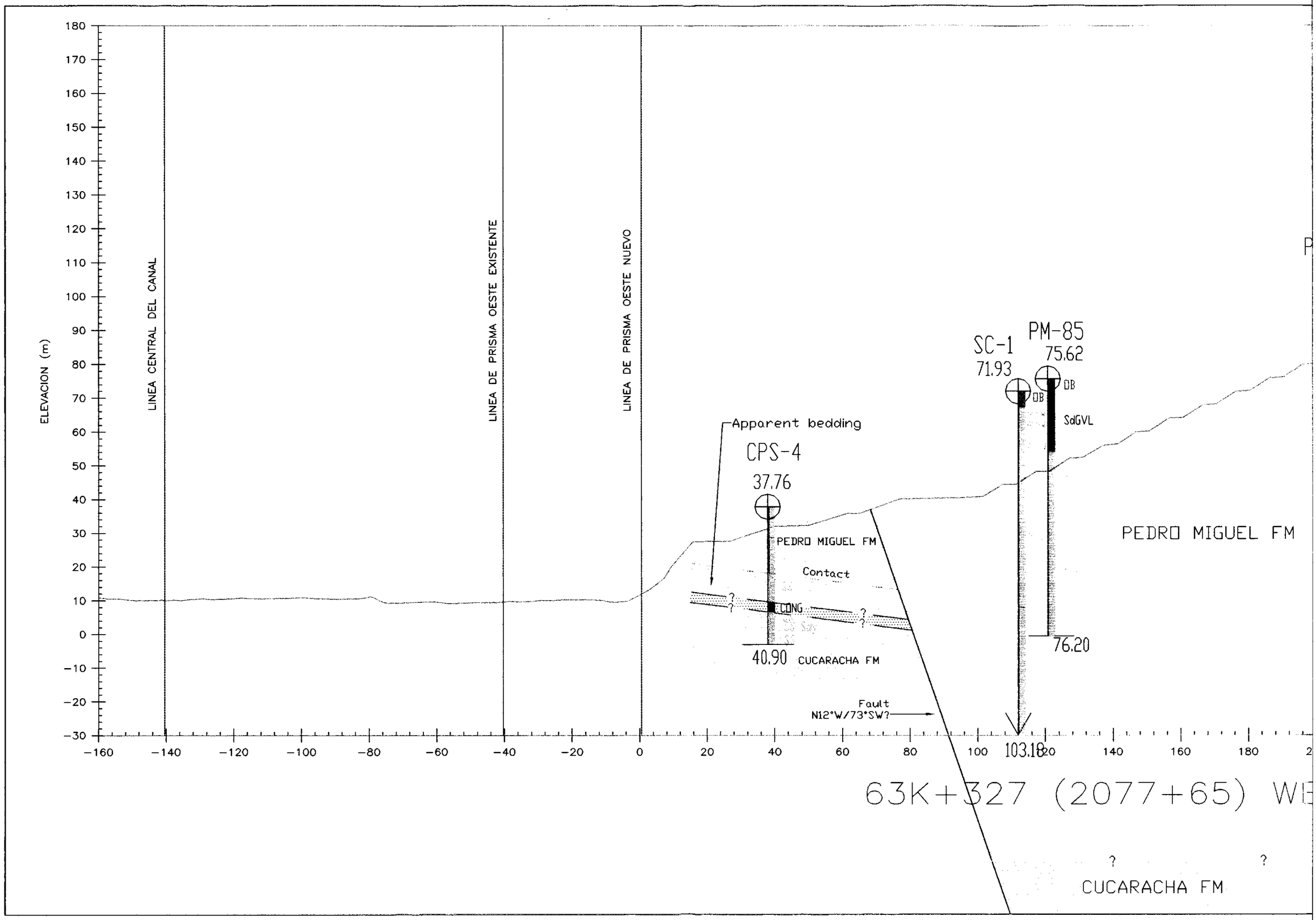
ESTACION 63K+327 (2077+65) OESTE

ESCALA: 1:1000	FECHA: ABRIL 2002
GEOLOGIA POR: P. FRANCESCHI	DIBUJADO POR: J. RAMESCH


ELEVACION (m)
LINEA CENTRAL DEL CANAL
LINEA DE PRISMA OESTE EXISTENTE
LINEA DE PRISMA OESTE NUEVO
Apparent bedding
CPS-4
37.76
PEDRO MIGUEL FM
Contact
CONG
40.90
CUCARACHA FM
Fault
N12°W/73°SW?
SC-1
71.93
PM-85
75.62
DB
DB
SdGVL
76.20
PEDRO MIGUEL FM
103.18
63K+327 (2077+65) WE
CUCARACHA FM