water affairs

Department:
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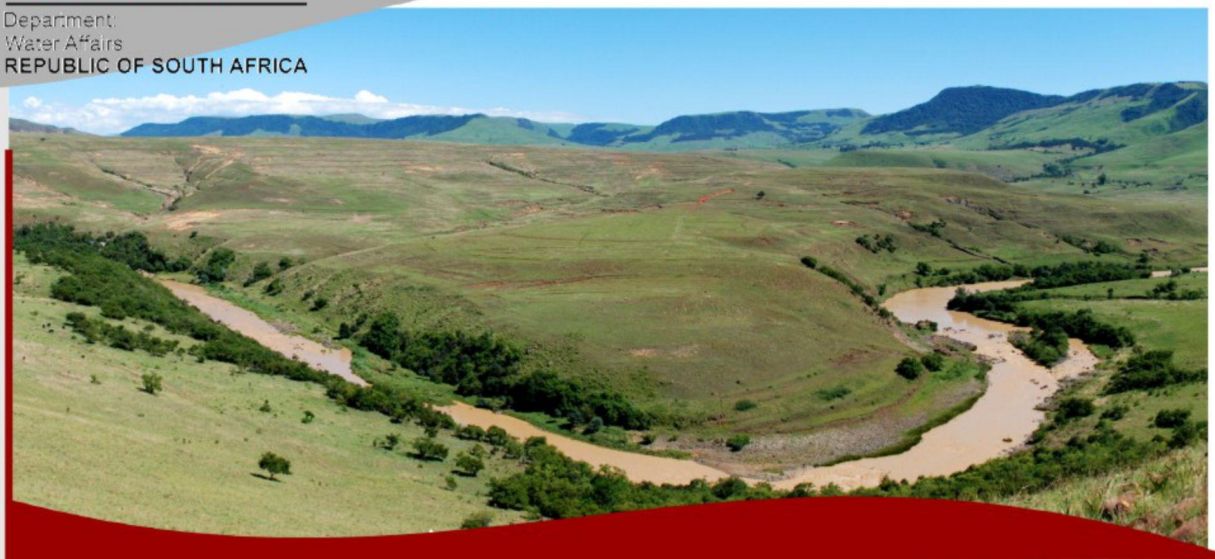

REPORT NO: P WMA 11/U10/00/3312/3/1

The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study: Raw Water

ENGINEERING FEASIBILITY DESIGN REPORT

VOLUME 2 - ANNEXURES

FINAL

MAY 2015

W100_2013/J01763

Project name:	***The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study Raw Water***
Report Title:	***Feasibility Design Report***
Sub-report title:	***Volume 2 – Annexures***
Authors:	***DB Badenhorst, K Delport, J Enslin, C Fynn, J Lombaard, G Robertson, M Trümpelmann, D van der Merwe, Prof A van Schalkwyk***
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CONSULTANTS: AECOM (BKS*) in association with AGES, MM&A and Urban-Econ.

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PREAMBLE

In June 2014, two years after the commencement of the uMkhomazi Water Project Phase 1 Feasibility Study, a new Department of Water and Sanitation was formed by Cabinet, including the formerly known Department of Water Affairs.

In order to maintain consistent reporting, all reports emanating from Module 1 of the study will be published under the Department of Water Affairs name.

CONTENTS OF REPORT

The uMkhomazi Water Project Feasibility Design Report is divided into two volumes.

The first volume (**Volume 1**) contains the main text, dealing with the technical aspects as well as the financial aspects of the project.

The second volume (**Volume 2: Annexures**) contains the annexures to the *Feasibility Design Report (P WMA 11/U10/00/3312/3/1)* which are referred to in the text and is numbered according to the chapters in **Volume 1**. The annexures contain figures, tables and information which, for ease of reading, have been removed from **Volume 1**.

Volume 2 is divided into the following annexures:

- Annexure 3 – Smithfield Dam
- Annexure 4 – uMkhomazi – uMlaza Tunnel
- Annexure 5: Langa Dam
- Annexure 6: Raw Water Pipeline
- Annexure 7: Hydropower Plant
- Annexure 8: Flow Gauging Weirs
- Annexure 9: Roads
- Annexure 10: Waste Disposal Sites
- Annexure 11: Land Acquisition
- Annexure 12: Accommodation and Related Structures

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Annexure 3 A – Smithfield Dam: Artistic Impression

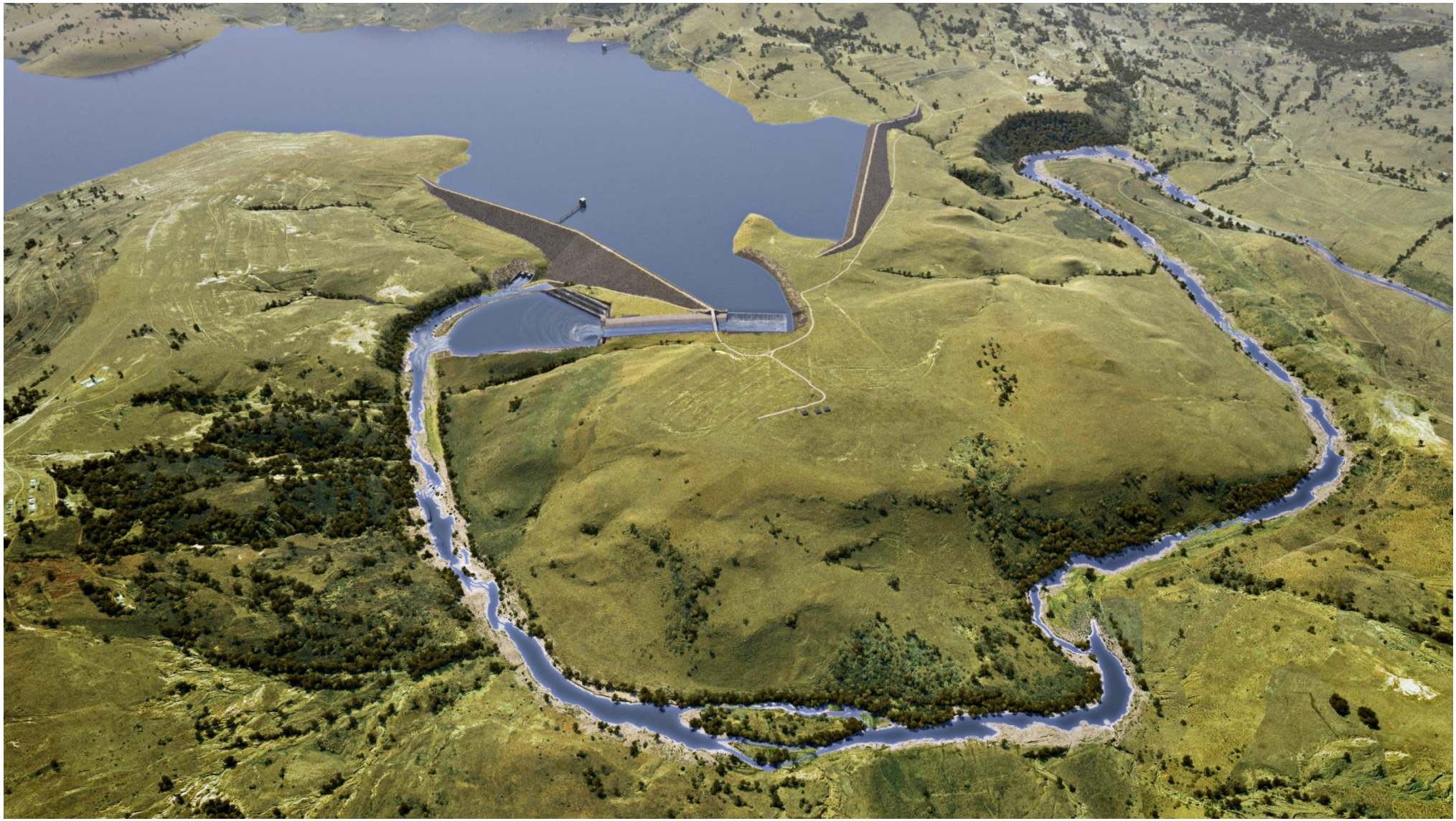


Figure 3.A.1: Three-dimensional layout of Smithfield Dam (view 1)

Figure 3.A.2: Three-dimensional layout of Smithfield Dam (view 2)

Figure 3.A.3: Three-dimensional layout of Smithfield Dam (view 3)

Annexure 3 B – Smithfield Dam: Flood hydrology data

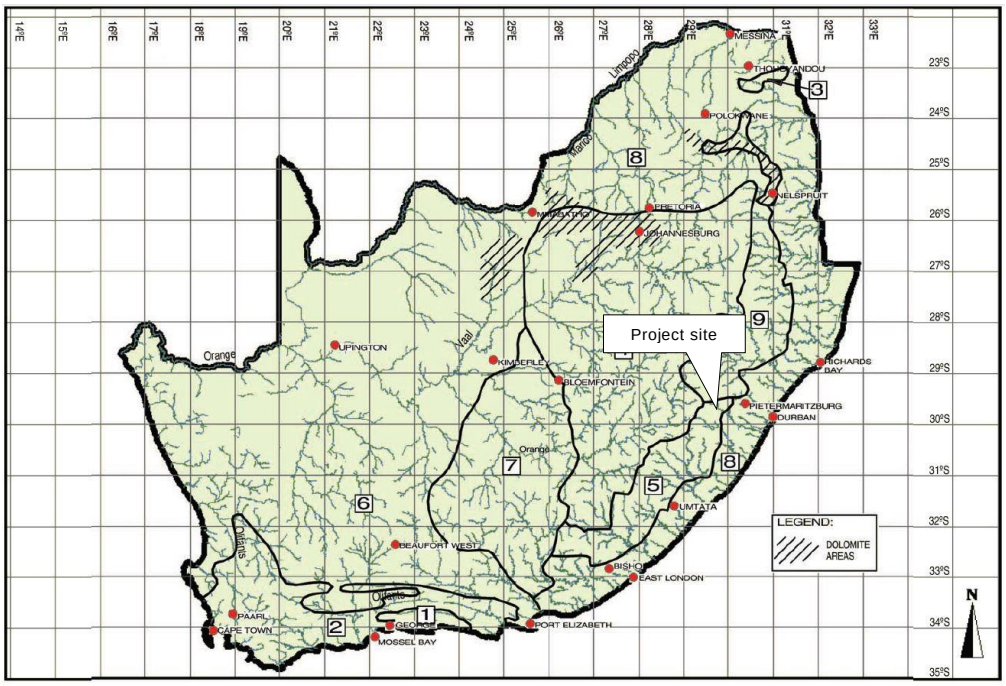


Figure 3.B.1: Veld zone determination

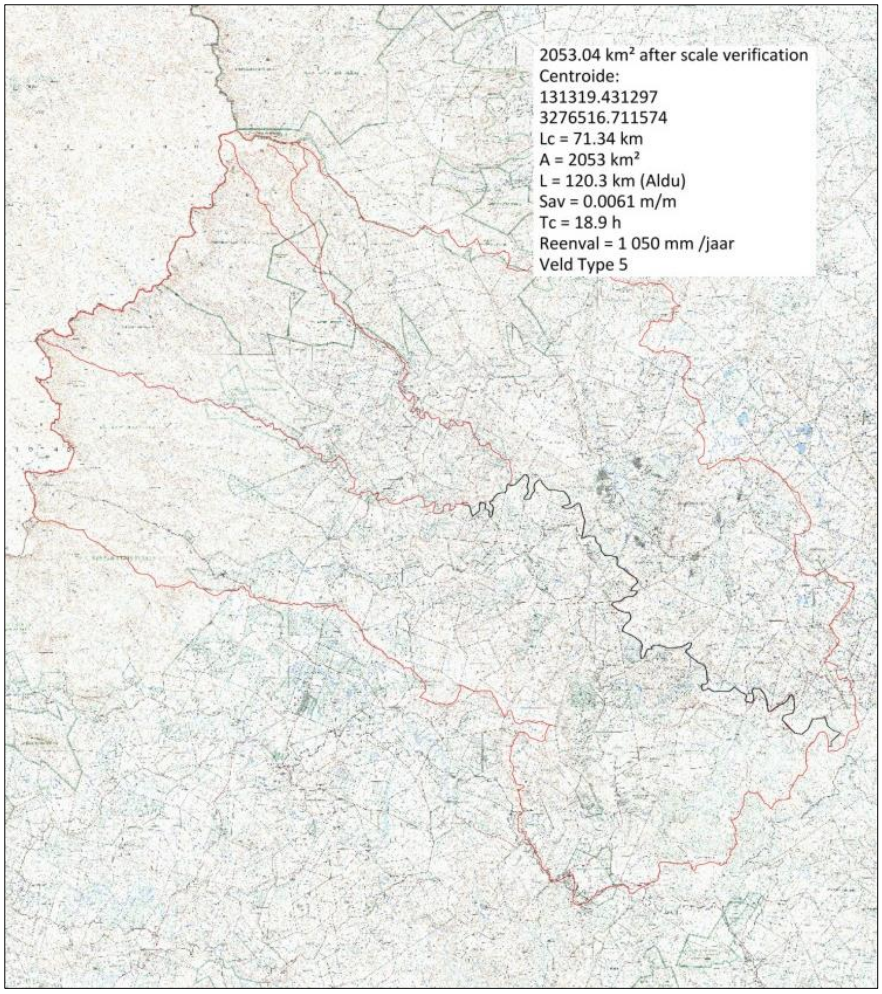


Figure 3.B.2: Unit hydrograph information

Table 3.B.1: 2014 determined hydrographs

Hydrograph 1:200		
Hydrgraph Q	2115.7	m³/s
Determined (	2620	m³/s
Ratio =	1.24	

Hydrograph RMF		
Hydrgraph Q (	2115.7	m³/s
Determined C	4540	m³/s
Ratio =	2.15	

Hydrograph RMF $_{+\Delta}$ (SEF)		
Hydrgraph Q (	2116	m³/s
Determined C	5650	m³/s
Ratio =	2.67	

Hrs	QpS/D	Qe	Qmax	Hrs	QpS/D	Qe	Qmax	Hrs	QpS/D	Qe	Qmax
2	0.47	22.11	27.38	2.00	0.47	22.11	47.45	2.00	0.47	22.11	59.05
2.5	0.75	35.01	43.36	2.50	0.75	35.01	75.13	2.50	0.75	35.01	93.50
3	1.12	52.36	64.84	3.00	1.12	52.36	112.36	3.00	1.12	52.36	139.84
3.5	1.61	75.40	93.37	3.50	1.61	75.40	161.79	3.50	1.61	75.40	201.35
4	2.29	107.18	132.73	4.00	2.29	107.18	230.00	4.00	2.29	107.18	286.23
4.5	3.19	149.26	184.83	4.50	3.19	149.26	320.28	4.50	3.19	149.26	398.59
5	4.42	206.54	255.76	5.00	4.42	206.54	443.19	5.00	4.42	206.54	551.55
5.5	6.11	285.77	353.88	5.50	6.11	285.77	613.22	5.50	6.11	285.77	763.15
6	8.22	384.36	475.97	6.00	8.22	384.36	824.77	6.00	8.22	384.36	1026.42
6.5	10.67	498.76	617.63	6.50	10.67	498.76	1070.25	6.50	10.67	498.76	1331.92
7	13.42	627.28	776.80	7.00	13.42	627.28	1346.05	7.00	13.42	627.28	1675.15
7.5	16.47	769.94	953.45	7.50	16.47	769.94	1652.17	7.50	16.47	769.94	2056.11
8	19.66	918.74	1137.72	8.00	19.66	918.74	1971.46	8.00	19.66	918.74	2453.47
8.5	22.91	1070.91	1326.16	8.50	22.91	1070.91	2298.01	8.50	22.91	1070.91	2859.86
9	26.19	1224.01	1515.75	9.00	26.19	1224.01	2626.53	9.00	26.19	1224.01	3268.70
9.5	29.41	1374.65	1702.30	9.50	29.41	1374.65	2949.78	9.50	29.41	1374.65	3670.98
10	32.58	1522.83	1885.80	10.00	32.58	1522.83	3267.76	10.00	32.58	1522.83	4066.70
10.5	35.04	1637.54	2027.85	10.50	35.04	1637.54	3513.90	10.50	35.04	1637.54	4373.03
11	37.15	1736.43	2150.31	11.00	37.15	1736.43	3726.11	11.00	37.15	1736.43	4637.12
11.5	39.01	1823.04	2257.56	11.50	39.01	1823.04	3911.95	11.50	39.01	1823.04	4868.40
12	40.63	1898.90	2351.50	12.00	40.63	1898.90	4074.73	12.00	40.63	1898.90	5070.98
12.5	42.04	1964.62	2432.88	12.50	42.04	1964.62	4215.76	12.50	42.04	1964.62	5246.49
13	43.22	2020.21	2501.72	13.00	43.22	2020.21	4335.04	13.00	43.22	2020.21	5394.93
13.5	44.19	2065.35	2557.63	13.50	44.19	2065.35	4431.92	13.50	44.19	2065.35	5515.50
14	44.88	2097.60	2597.56	14.00	44.88	2097.60	4501.12	14.00	44.88	2097.60	5601.61
14.5	45.27	2115.72	2620.00	14.50	45.27	2115.72	4540.00	14.50	45.27	2115.72	5650.00
15	45.26	2115.11	2619.24	15.00	45.26	2115.11	4538.68	15.00	45.26	2115.11	5648.36
15.5	44.71	2089.62	2587.67	15.50	44.71	2089.62	4483.98	15.50	44.71	2089.62	5580.29
16	43.69	2041.86	2528.53	16.00	43.69	2041.86	4381.51	16.00	43.69	2041.86	5452.75
16.5	42.27	1975.68	2446.58	16.50	42.27	1975.68	4239.49	16.50	42.27	1975.68	5276.01
17	40.50	1893.06	2344.27	17.00	40.50	1893.06	4062.21	17.00	40.50	1893.06	5055.39
17.5	38.39	1794.17	2221.81	17.50	38.39	1794.17	3850.00	17.50	38.39	1794.17	4791.30
18	36.10	1687.14	2089.27	18.00	36.10	1687.14	3620.34	18.00	36.10	1687.14	4505.48

Table 3.B.1 (continued)

Hrs	QpS/D	Qe	Qmax	Hrs	QpS/D	Qe	Qmax	Hrs	QpS/D	Qe	Qmax
18.5	33.70	1574.89	1950.26	18.50	33.70	1574.89	3379.46	18.50	33.70	1574.89	4205.72
19	31.23	1459.72	1807.64	19.00	31.23	1459.72	3132.33	19.00	31.23	1459.72	3898.16
19.5	28.78	1345.32	1665.98	19.50	28.78	1345.32	2886.84	19.50	28.78	1345.32	3592.66
20	26.35	1231.69	1525.26	20.00	26.35	1231.69	2643.01	20.00	26.35	1231.69	3289.20
20.5	24.56	1148.00	1421.62	20.50	24.56	1148.00	2463.42	20.50	24.56	1148.00	3065.71
21	23.03	1076.44	1333.01	21.00	23.03	1076.44	2309.87	21.00	23.03	1076.44	2874.62
21.5	21.68	1013.18	1254.66	21.50	21.68	1013.18	2174.11	21.50	21.68	1013.18	2705.67
22	20.47	956.51	1184.50	22.00	20.47	956.51	2052.52	22.00	20.47	956.51	2554.35
22.5	19.36	904.92	1120.60	22.50	19.36	904.92	1941.81	22.50	19.36	904.92	2416.57
23	18.35	857.77	1062.22	23.00	18.35	857.77	1840.65	23.00	18.35	857.77	2290.67
23.5	17.42	814.16	1008.22	23.50	17.42	814.16	1747.07	23.50	17.42	814.16	2174.21
24	16.55	773.47	957.83	24.00	16.55	773.47	1659.75	24.00	16.55	773.47	2065.54
24.5	15.74	735.54	910.86	24.50	15.74	735.54	1578.36	24.50	15.74	735.54	1964.25
25	14.98	700.22	867.12	25.00	14.98	700.22	1502.57	25.00	14.98	700.22	1869.94
25.5	14.27	666.75	825.67	25.50	14.27	666.75	1430.74	25.50	14.27	666.75	1780.54
26	13.60	635.42	786.87	26.00	13.60	635.42	1363.52	26.00	13.60	635.42	1696.89
26.5	12.96	605.94	750.36	26.50	12.96	605.94	1300.25	26.50	12.96	605.94	1618.15
27	12.37	577.99	715.76	27.00	12.37	577.99	1240.28	27.00	12.37	577.99	1543.52
27.5	11.80	551.27	682.67	27.50	11.80	551.27	1182.94	27.50	11.80	551.27	1472.17
28	11.25	525.94	651.29	28.00	11.25	525.94	1128.57	28.00	11.25	525.94	1404.50
28.5	10.74	501.83	621.44	28.50	10.74	501.83	1076.84	28.50	10.74	501.83	1340.12
29	10.25	478.95	593.10	29.00	10.25	478.95	1027.74	29.00	10.25	478.95	1279.02
29.5	9.78	457.14	566.10	29.50	9.78	457.14	980.95	29.50	9.78	457.14	1220.79
30	9.33	436.26	540.24	30.00	9.33	436.26	936.14	30.00	9.33	436.26	1165.02
30.5	8.91	416.45	515.71	30.50	8.91	416.45	893.63	30.50	8.91	416.45	1112.12
31	8.51	397.72	492.51	31.00	8.51	397.72	853.43	31.00	8.51	397.72	1062.09
31.5	8.13	379.90	470.45	31.50	8.13	379.90	815.21	31.50	8.13	379.90	1014.52
32	7.77	363.01	449.53	32.00	7.77	363.01	778.96	32.00	7.77	363.01	969.42
32.5	7.43	347.04	429.76	32.50	7.43	347.04	744.69	32.50	7.43	347.04	926.77
33	7.10	331.84	410.93	33.00	7.10	331.84	712.07	33.00	7.10	331.84	886.17
33.5	6.79	317.40	393.06	33.50	6.79	317.40	681.10	33.50	6.79	317.40	847.62
34	6.50	303.89	376.32	34.00	6.50	303.89	652.10	34.00	6.50	303.89	811.54
34.5	6.23	290.99	360.35	34.50	6.23	290.99	624.42	34.50	6.23	290.99	777.09
35	5.96	278.55	344.95	35.00	5.96	278.55	597.73	35.00	5.96	278.55	743.87
35.5	5.71	266.88	330.49	35.50	5.71	266.88	572.69	35.50	5.71	266.88	712.71
36	5.47	255.52	316.42	36.00	5.47	255.52	548.31	36.00	5.47	255.52	682.36
36.5	5.23	244.46	302.73	36.50	5.23	244.46	524.58	36.50	5.23	244.46	652.84
37	5.00	233.87	289.61	37.00	5.00	233.87	501.84	37.00	5.00	233.87	624.54
37.5	4.79	223.89	277.25	37.50	4.79	223.89	480.43	37.50	4.79	223.89	597.89
38	4.58	214.21	265.27	38.00	4.58	214.21	459.67	38.00	4.58	214.21	572.05
38.5	4.38	204.69	253.48	38.50	4.38	204.69	439.24	38.50	4.38	204.69	546.63
39	4.19	195.63	242.26	39.00	4.19	195.63	419.80	39.00	4.19	195.63	522.43
39.5	4.00	186.88	231.42	39.50	4.00	186.88	401.01	39.50	4.00	186.88	499.06
40	3.82	178.59	221.15	40.00	3.82	178.59	383.22	40.00	3.82	178.59	476.92

Table 3.B.1 (continued)

Hrs	QpS/D	Qe	Qmax	Hrs	QpS/D	Qe	Qmax	Hrs	QpS/D	Qe	Qmax
40.5	3.65	170.45	211.08	40.50	3.65	170.45	365.76	40.50	3.65	170.45	455.18
41	3.48	162.46	201.19	41.00	3.48	162.46	348.62	41.00	3.48	162.46	433.86
41.5	3.31	154.63	191.49	41.50	3.31	154.63	331.82	41.50	3.31	154.63	412.94
42	3.14	146.95	181.98	42.00	3.14	146.95	315.34	42.00	3.14	146.95	392.44
42.5	2.99	139.74	173.04	42.50	2.99	139.74	299.85	42.50	2.99	139.74	373.17
43	2.84	132.67	164.30	43.00	2.84	132.67	284.70	43.00	2.84	132.67	354.30
43.5	2.69	125.76	155.74	43.50	2.69	125.76	269.87	43.50	2.69	125.76	335.85
44	2.55	119.01	147.37	44.00	2.55	119.01	255.37	44.00	2.55	119.01	317.81
44.5	2.41	112.40	139.20	44.50	2.41	112.40	241.20	44.50	2.41	112.40	300.17
45	2.27	106.11	131.40	45.00	2.27	106.11	227.69	45.00	2.27	106.11	283.36
45.5	2.14	99.81	123.60	45.50	2.14	99.81	214.18	45.50	2.14	99.81	266.55
46	2.00	93.67	116.00	46.00	2.00	93.67	201.00	46.00	2.00	93.67	250.15
46.5	1.88	87.68	108.58	46.50	1.88	87.68	188.15	46.50	1.88	87.68	234.15
47	1.75	81.85	101.35	47.00	1.75	81.85	175.63	47.00	1.75	81.85	218.57
47.5	1.63	76.16	94.32	47.50	1.63	76.16	163.44	47.50	1.63	76.16	203.40
48	1.51	70.64	87.47	48.00	1.51	70.64	151.57	48.00	1.51	70.64	188.63
48.5	1.40	65.26	80.82	48.50	1.40	65.26	140.04	48.50	1.40	65.26	174.28
49	1.28	60.04	74.35	49.00	1.28	60.04	128.84	49.00	1.28	60.04	160.34
49.5	1.18	54.97	68.08	49.50	1.18	54.97	117.96	49.50	1.18	54.97	146.81
50	1.07	49.91	61.80	50.00	1.07	49.91	107.09	50.00	1.07	49.91	133.27
50.5	0.96	44.99	55.72	50.50	0.96	44.99	96.55	50.50	0.96	44.99	120.15
51	0.86	40.39	50.01	51.00	0.86	40.39	86.66	51.00	0.86	40.39	107.85
51.5	0.77	36.09	44.69	51.50	0.77	36.09	77.44	51.50	0.77	36.09	96.37
52	0.69	32.09	39.74	52.00	0.69	32.09	68.87	52.00	0.69	32.09	85.71
52.5	0.60	28.25	34.99	52.50	0.60	28.25	60.63	52.50	0.60	28.25	75.45
53	0.53	24.72	30.62	53.00	0.53	24.72	53.05	53.00	0.53	24.72	66.02
53.5	0.46	21.50	26.62	53.50	0.46	21.50	46.13	53.50	0.46	21.50	57.41
54	0.39	18.43	22.82	54.00	0.39	18.43	39.54	54.00	0.39	18.43	49.21
54.5	0.34	15.66	19.40	54.50	0.34	15.66	33.61	54.50	0.34	15.66	41.83
55	0.28	13.05	16.16	55.00	0.28	13.05	28.01	55.00	0.28	13.05	34.86
55.5	0.23	10.75	13.31	55.50	0.23	10.75	23.07	55.50	0.23	10.75	28.71

Table 3.B.1 (continued)

Hydrograph PMF			
Hydrgraph Q max =		2115.72	m³/s
Determined Q max=		6185	m³/s
Ratio =		2.92	
Hrs	QpS/D	Qe	Qmax
2	0.47	22.11	64.64
2.5	0.75	35.01	102.35
3	1.12	52.36	153.08
3.5	1.61	75.40	220.41
4	2.29	107.18	313.34
4.5	3.19	149.26	436.33
5	4.42	206.54	603.78
5.5	6.11	285.77	835.41
6	8.22	384.36	1123.61
6.5	10.67	498.76	1458.04
7	13.42	627.28	1833.77
7.5	16.47	769.94	2250.80
8	19.66	918.74	2685.79
8.5	22.91	1070.91	3130.66
9	26.19	1224.01	3578.21
9.5	29.41	1374.65	4018.59
10	32.58	1522.83	4451.78
10.5	35.04	1637.54	4787.11
11	37.15	1736.43	5076.21
11.5	39.01	1823.04	5329.39
12	40.63	1898.90	5551.15
12.5	42.04	1964.62	5743.28
13	43.22	2020.21	5905.78
13.5	44.19	2065.35	6037.76
14	44.88	2097.60	6132.03
14.5	45.27	2115.72	6185.00
15	45.26	2115.11	6183.20
15.5	44.71	2089.62	6108.69
16	43.69	2041.86	5969.08
16.5	42.27	1975.68	5775.60
17	40.50	1893.06	5534.09
17.5	38.39	1794.17	5244.99
18	36.10	1687.14	4932.11
18.5	33.70	1574.89	4603.96
19	31.23	1459.72	4267.28
19.5	28.78	1345.32	3932.85

Hrs	QpS/D	Qe	Qmax
20	26.35	1231.69	3600.66
20.5	24.56	1148.00	3356.01
21	23.03	1076.44	3146.82
21.5	21.68	1013.18	2961.87
22	20.47	956.51	2796.22
22.5	19.36	904.92	2645.39
23	18.35	857.77	2507.58
23.5	17.42	814.16	2380.09
24	16.55	773.47	2261.13
24.5	15.74	735.54	2150.25
25	14.98	700.22	2047.00
25.5	14.27	666.75	1949.14
26	13.60	635.42	1857.56
26.5	12.96	605.94	1771.38
27	12.37	577.99	1689.67
27.5	11.80	551.27	1611.57
28	11.25	525.94	1537.50
28.5	10.74	501.83	1467.02
29	10.25	478.95	1400.13
29.5	9.78	457.14	1336.39
30	9.33	436.26	1275.34
30.5	8.91	416.45	1217.43
31	8.51	397.72	1162.66
31.5	8.13	379.90	1110.59
32	7.77	363.01	1061.21
32.5	7.43	347.04	1014.52
33	7.10	331.84	970.08
33.5	6.79	317.40	927.88
34	6.50	303.89	888.38
34.5	6.23	290.99	850.67
35	5.96	278.55	814.31
35.5	5.71	266.88	780.20
36	5.47	255.52	746.98
36.5	5.23	244.46	714.66
37	5.00	233.87	683.68
37.5	4.79	223.89	654.50
38	4.58	214.21	626.22
38.5	4.38	204.69	598.39
39	4.19	195.63	571.90
39.5	4.00	186.88	546.32

Table 3.B.1 (continued)

Hrs	QpS/D	Qe	Qmax
40	3.82	178.59	522.08
40.5	3.65	170.45	498.28
41	3.48	162.46	474.94
41.5	3.31	154.63	452.05
42	3.14	146.95	429.60
42.5	2.99	139.74	408.50
43	2.84	132.67	387.85
43.5	2.69	125.76	367.65
44	2.55	119.01	347.90
44.5	2.41	112.40	328.60
45	2.27	106.11	310.19
45.5	2.14	99.81	291.79
46	2.00	93.67	273.83
46.5	1.88	87.68	256.32
47	1.75	81.85	239.27
47.5	1.63	76.16	222.66
48	1.51	70.64	206.50
48.5	1.40	65.26	190.78
49	1.28	60.04	175.52
49.5	1.18	54.97	160.71
50	1.07	49.91	145.89
50.5	0.96	44.99	131.53
51	0.86	40.39	118.06
51.5	0.77	36.09	105.49
52	0.69	32.09	93.82
52.5	0.60	28.25	82.60
53	0.53	24.72	72.27
53.5	0.46	21.50	62.85
54	0.39	18.43	53.87
54.5	0.34	15.66	45.79
55	0.28	13.05	38.16
55.5	0.23	10.75	31.42

Table 3.B.2: DWA hydrographs

DWA 1:200 hydrograph	
Hrs	QpS/D
0	0
0.9	63.9
1.8	133.4
2.7	143.4
3.6	175.4
4.5	272.1
5.4	447.6
6.3	695.6
7.2	997.2
8.1	1326
9	1654
9.9	1954.3
10.8	2204.8
11.7	2389.9
12.6	2501.5
13.5	2540
14.4	2513.4
15.3	2437
16.2	2331.7
17.1	2222.1
18	2134.2
18.9	2014.1
19.8	1853.1
20.7	1704.9
21.6	1568.6
22.5	1443.2
23.4	1327.8
24.3	1221.6
25.2	1124
26.1	1034.1
27	951.4
27.9	875.3
28.8	805.3
29.7	741
30.6	681.7

Triangular hydrograph RMF	
RMF	4540

Hrs	QpS/D
0	0
0.9	216
1.8	432
2.7	649
3.6	865
4.5	1081
5.4	1297
6.3	1513
7.2	1730
8.1	1946
9	2162
9.9	2378
10.8	2594
11.7	2810
12.6	3027
13.5	3243
14.4	3459
15.3	3675
16.2	3891
17.1	4108
18	4324
18.9	4540
19.8	4432
20.7	4324
21.6	4216
22.5	4108
23.4	4000
24.3	3891
25.2	3783
26.1	3675
27	3567
27.9	3459
28.8	3351
29.7	3243
30.6	3135

Table 3.B.2 (continued)

Hrs	QpS/D			
31.5	627.2		31.5	3027
32.4	577.1		32.4	2919
33.3	530.9		33.3	2810
34.2	488.5		34.2	2702
35.1	449.4		35.1	2594
36	413.5		36	2486
36.9	380.4		36.9	2378
37.8	350		37.8	2270
38.7	322		38.7	2162
39.6	296.3		39.6	2054
40.5	272.6		40.5	1946
41.4	250.8		41.4	1838
42.3	230.7		42.3	1730
43.2	212.3		43.2	1621
44.1	195.3		44.1	1513
45	179.7		45	1405
45.9	165.3		45.9	1297
46.8	152.1		46.8	1189
47.7	139.9		47.7	1081
48.6	128.8		48.6	973
49.5	118.5		49.5	865
50.4	109		50.4	757
51.3	100.3		51.3	649
52.2	92.3		52.2	540
53.1	84.9		53.1	432
54	78.1		54	324
54.9	71.9		54.9	216
55.8	66.1		55.8	108
56.7	60.8		56.7	0
57.6	56			
58.5	51.5			
59.4	47.4			
60.3	43.6			
61.2	40.1			
62.1	36.9			
63	33.9			
63.9	31.2			
64.8	28.7			
65.7	26.4			
66.6	24.3			
67.5	22.4			
68.4	20.6			
69.3	18.9			
70.2	17.4			

Table 3.B.2 (continued)

Hrs	QpS/D
71.1	16
72	14.8
72.9	13.6
73.8	12.5
74.7	11.5
75.6	10.6
76.5	9.7
77.4	8.9
78.3	8.2
79.2	7.6
80.1	7
81	6.4
81.9	5.9
82.8	5.4
83.7	5
84.6	4.6
85.5	4.2
86.4	3.9
87.3	3.6
88.2	3.3
89.1	3
90	2.8
90.9	2.6
91.8	2.4
92.7	2.2
93.6	2
94.5	1.8
95.4	1.7
96.3	1.6
97.2	1.4
98.1	1.3
99	1.2
99.9	1.1
100.8	1
101.7	0.9
102.6	0.9
103.5	0.8
104.4	0.7
105.3	0.7
106.2	0.6
107.1	0.6
108	0.5
108.9	0.5

Hrs	QpS/D
109.8	0.4
110.7	0.4
111.6	0.4
112.5	0.3
113.4	0.3
114.3	0.3
115.2	0.3
116.1	0.2
117	0.2
117.9	0.2
118.8	0.2
119.7	0.2

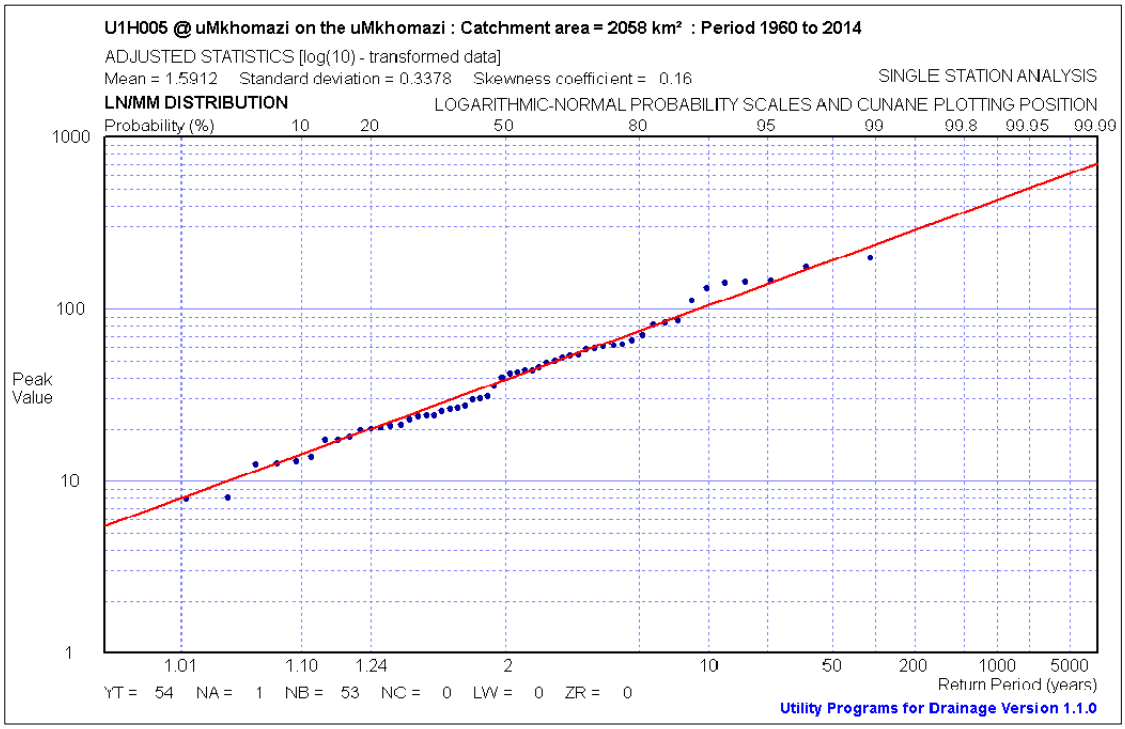


Figure 3.B.3: Log-Normal Distribution

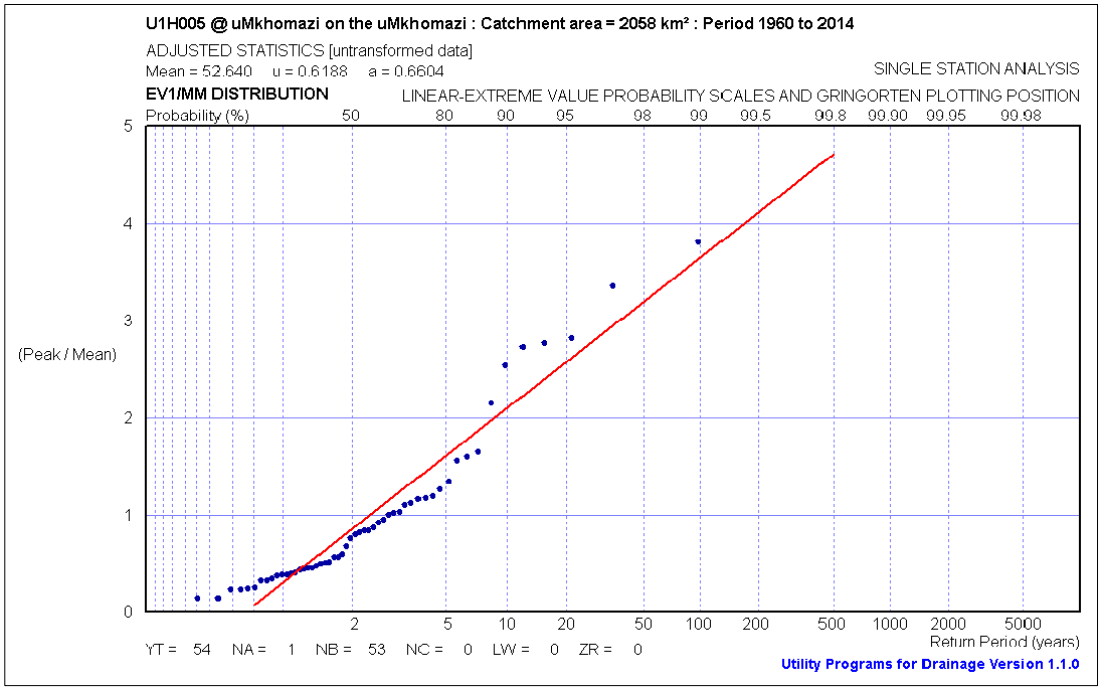


Figure 3.B.4: Extreme Value, Type 1 Distribution

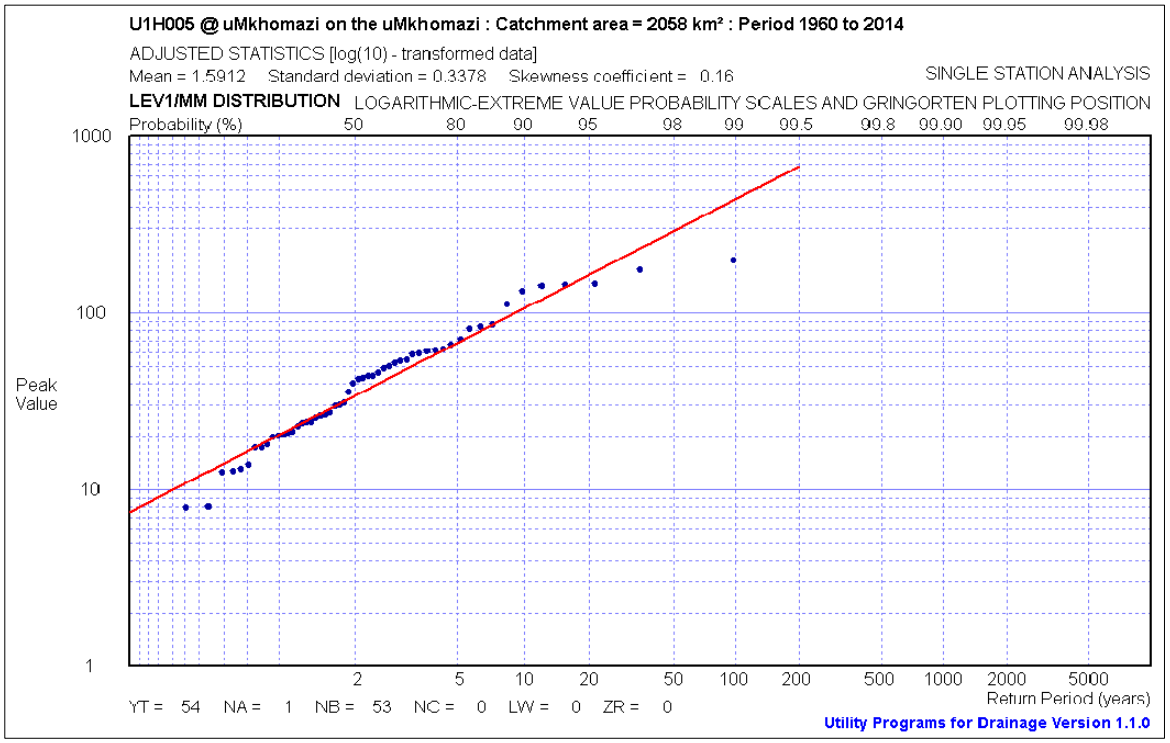


Figure 3.B.5: Log-Extreme value Type 1 Distribution

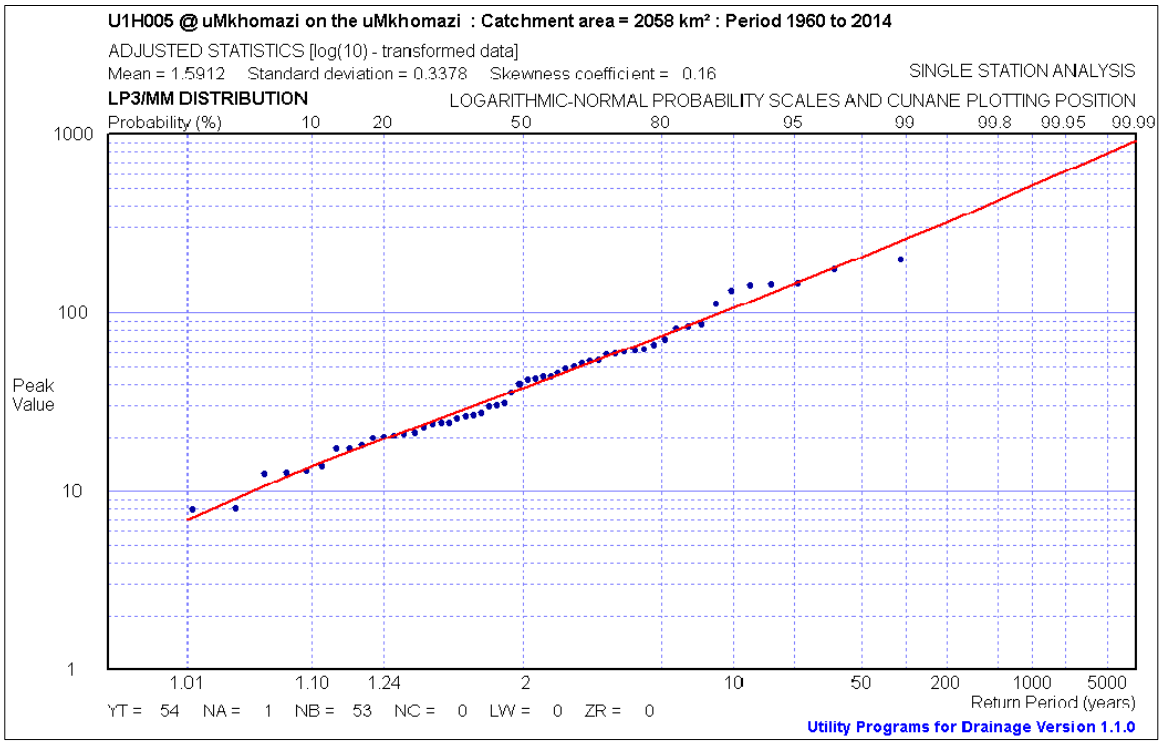
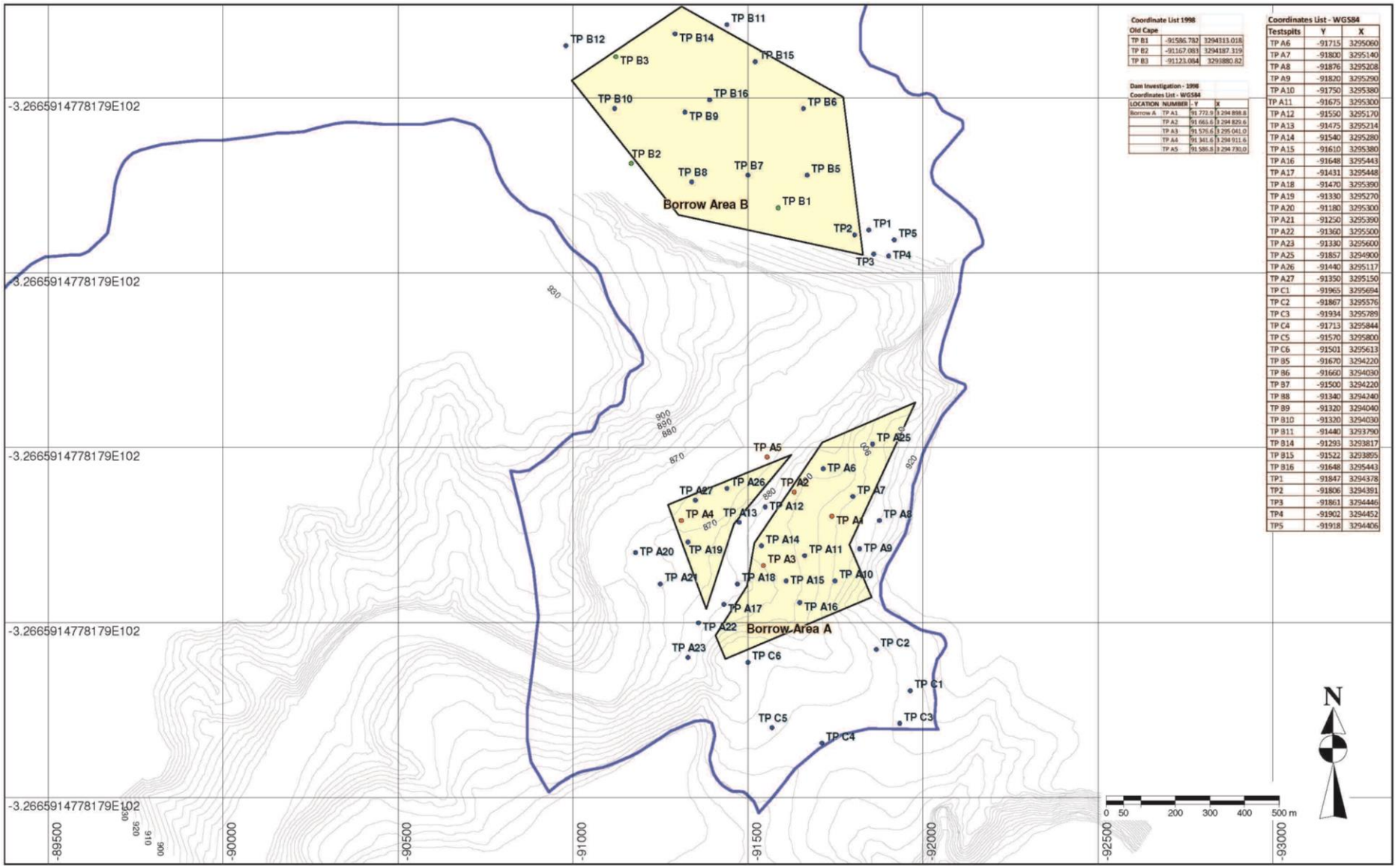


Figure 3.B.6: Log-Pearson Type III, Distribution

Annexure 3 C - Smithfield Dam: Geotechnical information



Coordinate List 1998
Old Cape

TP B1	-91586.782	3294313.018	
TP B2	-91167.083	3294187.319	
TP B3	-91123.084	3293880.82	

Dam Investigation - 1998
Coordinates List - WGS84

LOCATION	NUMBER	Y	X
Borrow A	TP A1	91 772.9	3 294 898.8
	TP A2	91 661.6	3 294 829.6
	TP A3	91 576.6	3 295 041.0
	TP A4	91 341.6	3 294 911.6
	TP A5	91 586.8	3 294 780.0

Coordinates List - WGS84

Testspits	Y	X
TP A6	-91715	3295060
TP A7	-91800	3295140
TP A8	-91876	3295208
TP A9	-91820	3295290
TP A10	-91750	3295380
TP A11	-91675	3295300
TP A12	-91550	3295170
TP A13	-91475	3295214
TP A14	-91540	3295280
TP A15	-91610	3295380
TP A16	-91648	3295443
TP A17	-91431	3295448
TP A18	-91470	3295390
TP A19	-91330	3295270
TP A20	-91180	3295300
TP A21	-91250	3295390
TP A22	-91360	3295500
TP A23	-91330	3295600
TP A25	-91857	3294900
TP A26	-91440	3295117
TP A27	-91350	3295150
TP C1	-91965	3295694
TP C2	-91867	3295576
TP C3	-91934	3295789
TP C4	-91713	3295844
TP C5	-91570	3295800
TP C6	-91501	3295613
TP B5	-91670	3294220
TP B6	-91660	3294030
TP B7	-91500	3294220
TP B8	-91340	3294240
TP B9	-91320	3294040
TP B10	-91320	3294030
TP B11	-91440	3293790
TP B14	-91293	3293817
TP B15	-91522	3293895
TP B16	-91648	3295443
TP1	-91847	3294378
TP2	-91806	3294391
TP3	-91861	3294446
TP4	-91902	3294452
TP5	-91918	3294406

Figure 3.C.1: Borrow areas and test pit location

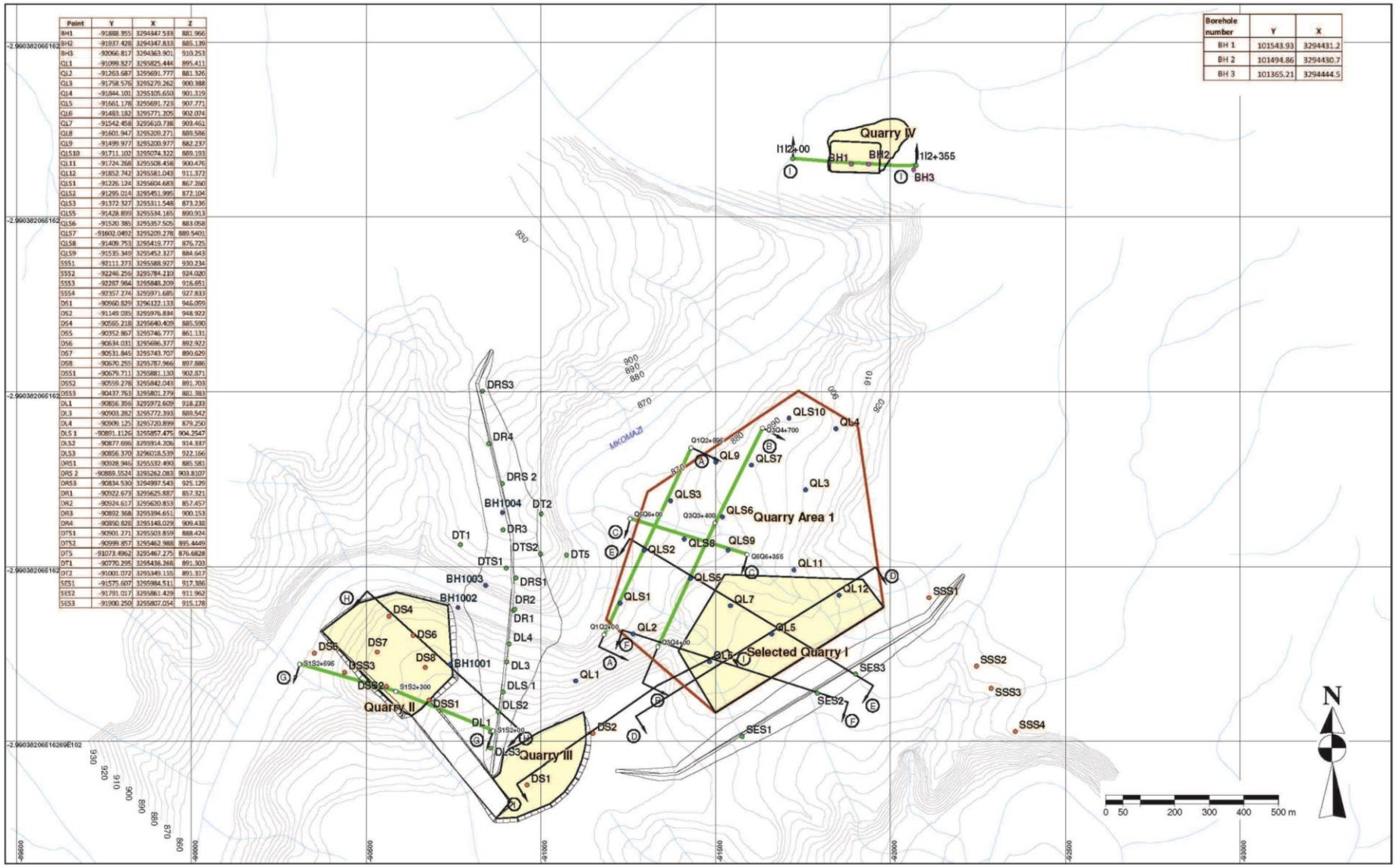


Figure 3.C.2: Borehole position, seismic lines

Annexure 3 D – Smithfield Dam: River diversion

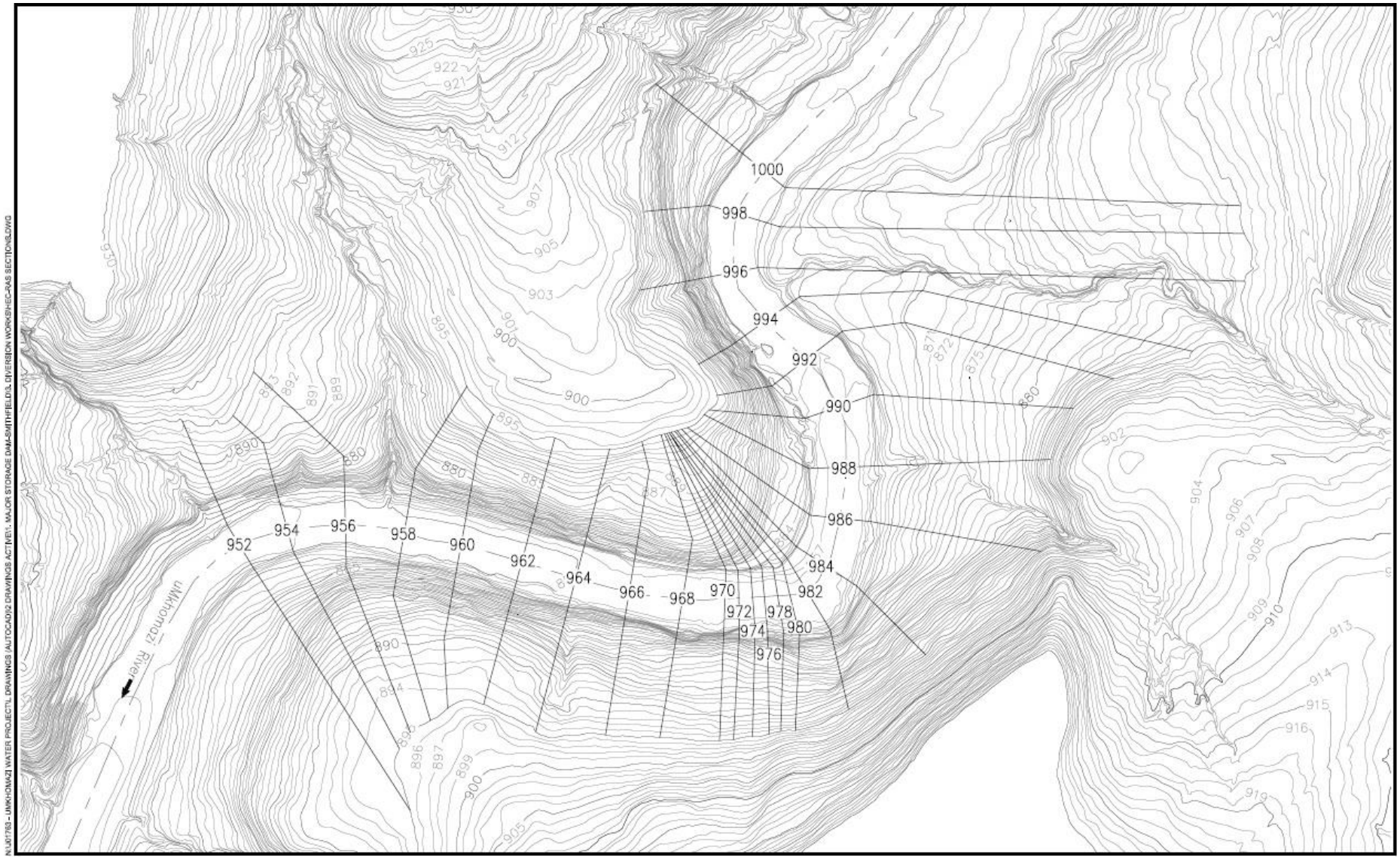


Figure 3.D.1: Cross section layout at Smithfield Dam

HECRAS - MODELLING

1. Introduction

Six coffer dams were proposed in conjunction with other river diversion infrastructure to enable construction of the Smithfield Dam Main Embankment. The location and numbering of the coffer dams are shown in **Table 3.D.1**.

The crest level of coffer dams 1 to 6 was determined with the aid of the computer program HEC-RAS (Hydrologic Engineering Centres River Analysis System) developed by the Hydrologic Engineering Centre of the U.S Army Corps of Engineers and tunnel discharge curves.

Table 3.D.1 provides the river diversion phase when each coffer dam is implemented, the flood frequency that coffer dams must accommodate without overtopping and the flood peak of the associated flood frequency.

Table 3.D.1: Coffer dam properties and associated risks

Coffer Dam	River diversion phase	Flood	Flood peak
Earthfill coffer dam	1 – Water flows in river	1:10	937
Earthfill coffer dam	1 – Water flows in river	1:10	937
Earthfill coffer dam	2 – Water diverted through	1:10 winter flood	74.5
Rockfill coffer dam 4	2 – Water diverted through	1:50	1708
RCC coffer dam 5	2 – Water diverted through	1:20 winter flood	145.1
Rockfill coffer dam 6	4 – Water diverted through	1:50	1708

The crest levels for Coffer Dams 1 and 2 were determined using HEC-RAS results. The crest levels for Coffer Dams 3, 5 and 6 was determined using both HEC-RAS results and the tunnel discharge curves. The crest level of Coffer Dam 4 was determined with the HEC-RAS tailwater level.

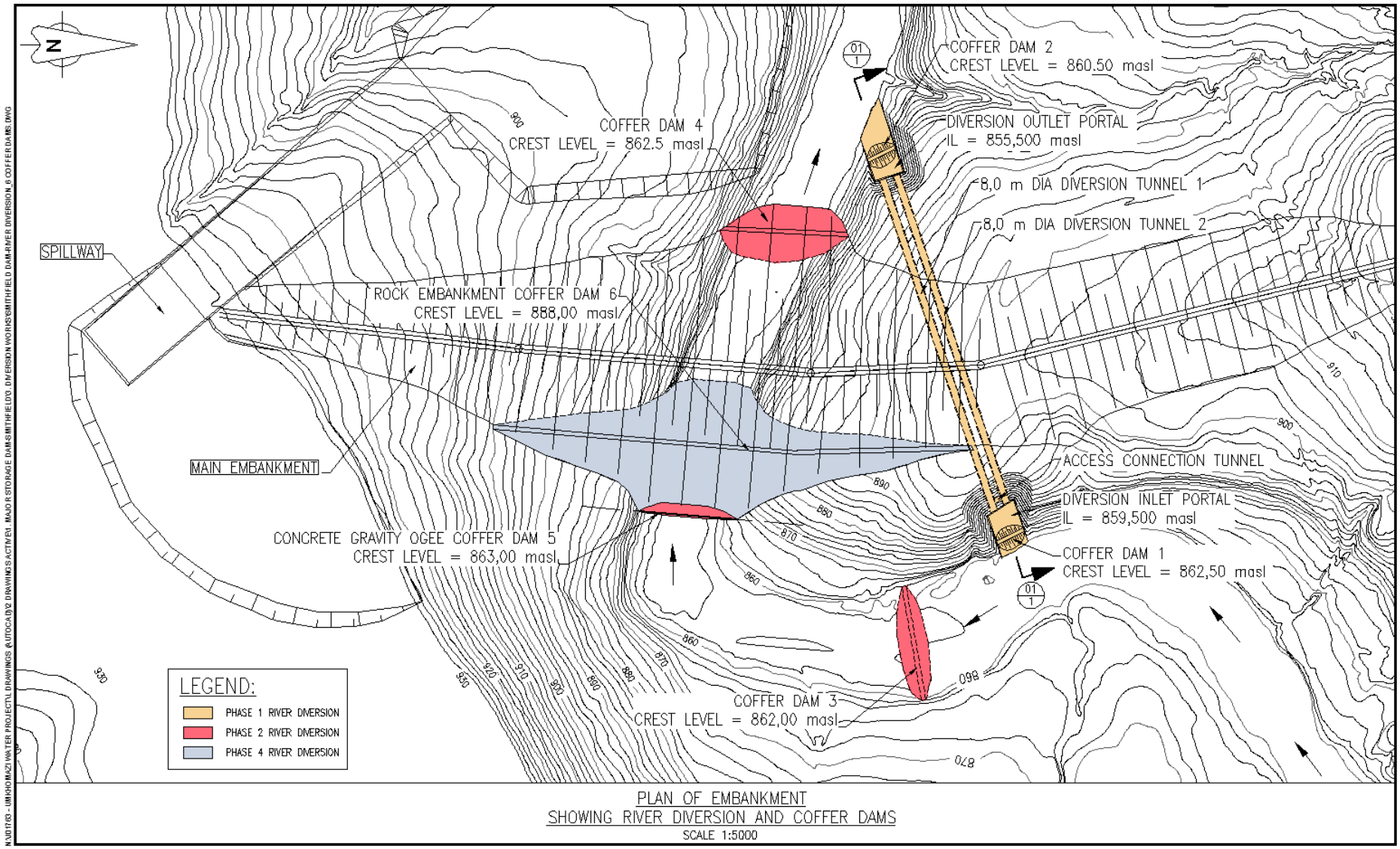


Figure 3.D.2: Coffer dam location and numbering

2. HEC-RAS modelling

2.1 Geometric data input

Cross-sections were taken approximately every 60m. In the vicinity of Coffer Dams 5 and 6 the cross-sections were taken every 15m to allow for a more detailed analysis of the water surface level. The layout of the cross-sections is shown in **Figure 3.D.3**.

Three river geometries were modelled for in HEC-RAS:

- The relevant uMkhomazi River section as is, with no river diversion infrastructure, to ensure that the modelled section is realistic.
- The relevant uMkhomazi River section with Coffer Dam 1 and 2 constructed at the tunnels' inlet and outlet portals. Coffer dam 1 and 2 are located at cross-sections 994 and 959 respectively. For both the coffer dams, the upstream slope was taken as 1V:1.3H with the modelled crest level at 866.2 masl for Coffer Dam 1 and 862.6 masl for Coffer Dam 2.
- The relevant uMkhomazi River section with a culvert system from cross-section 978 to cross-section 959 to mimic the flow through the tunnels as HEC-RAS does not have the capability to model simultaneous flow through the river and the tunnels. The layout of the culvert system is shown in **Figure 3.D.4**. The length of the culvert system is similar to the actual tunnel lengths of 390m. An arch shaped culvert was modelled to correspond with the tunnel shape used in the discharge curve calculations. Assuming that the inlet of the tunnels will be bellmouthed, the entrance loss coefficient at the inlets was taken as 0.1. The exit loss coefficient was taken as 1. The upstream and downstream view of the culvert is shown in **Figure 3.D.5**.

The Manning's n-value for the main channel as well as for the floodplains was taken as 0.03, assuming that the main channel is clean and straight with no rifts or deep pools and that the floods plains are grassed.

The Manning's n-value for the culverts was taken as 0.015 (concrete lining), however, it must be noted that Tunnel 1 will not be lined.

It was assumed that the water surface level at Coffer Dam 3's position would be equal to the water surface level at the modelled culvert inlet, due to the water being somewhat stagnant in the vicinity of Coffer dam 3 when water is diverted through the tunnels.

For the crest level determination of Coffer Dams 3, 5 and 6, it was assumed that the water surface level at the specific coffer dam will be equal to the headwater level at the culvert system inlets when water is diverted through the tunnels.

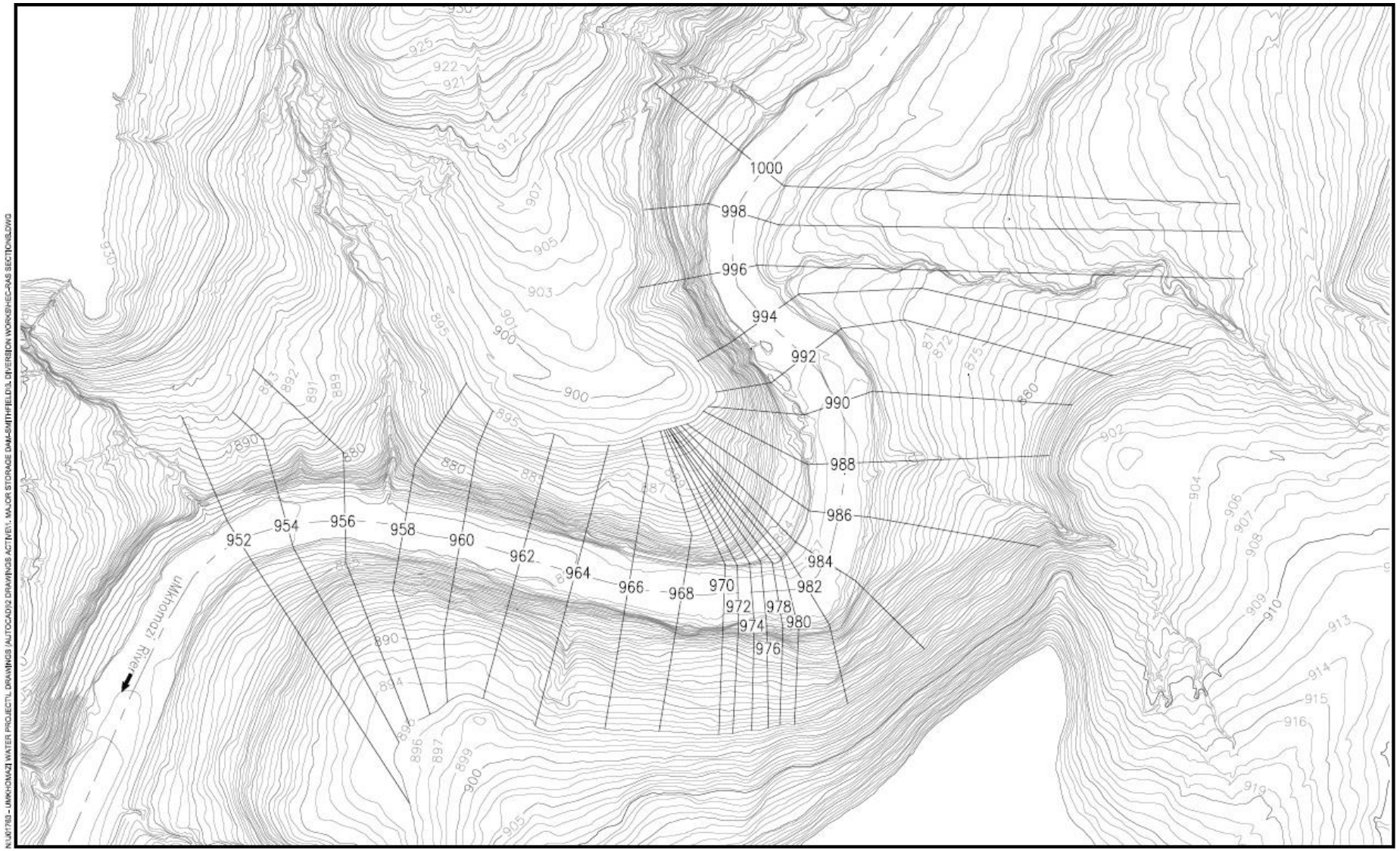


Figure 3.D.3: Cross-section layout

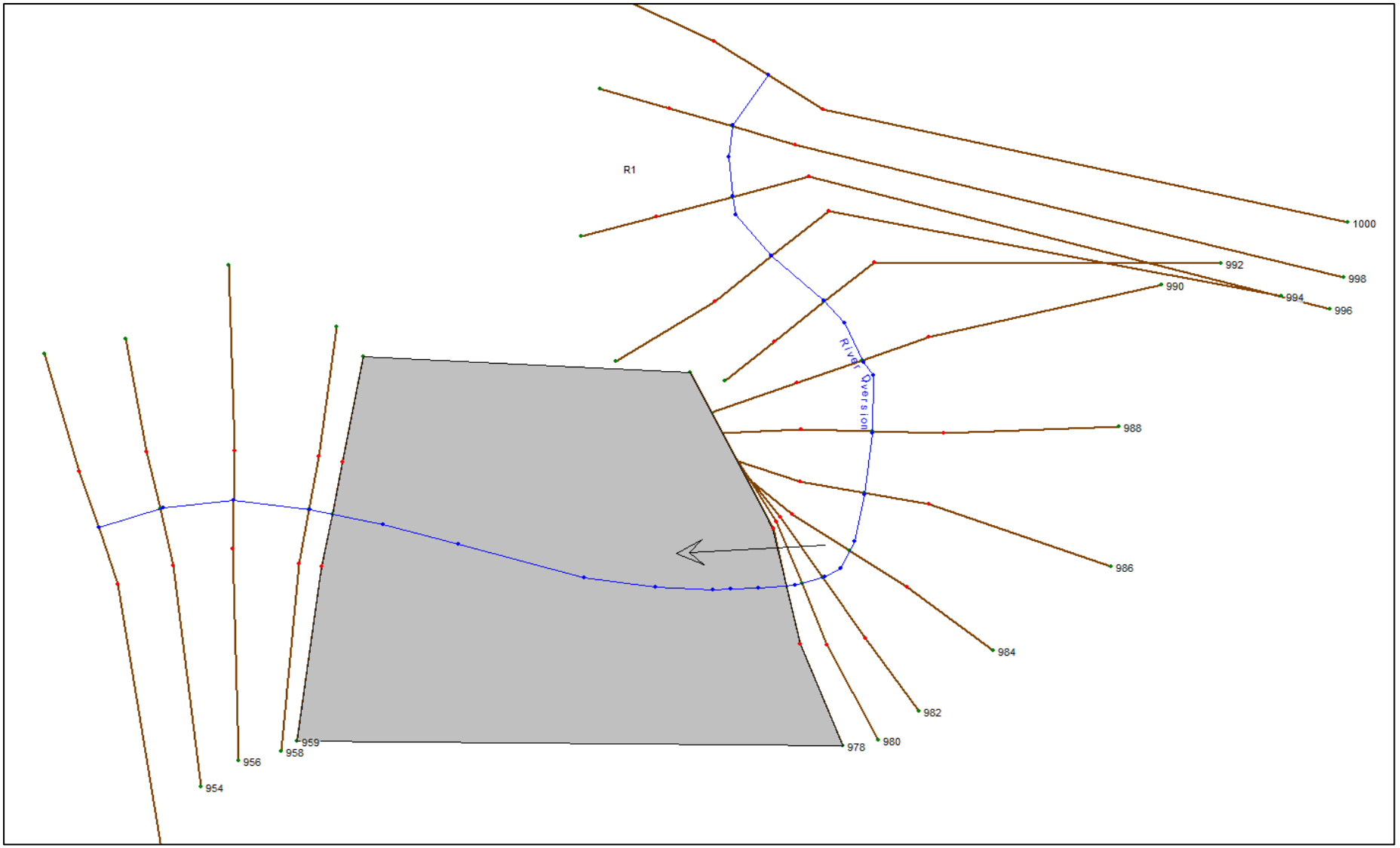


Figure 3.D.4: Layout of HEC-RAS culvert system

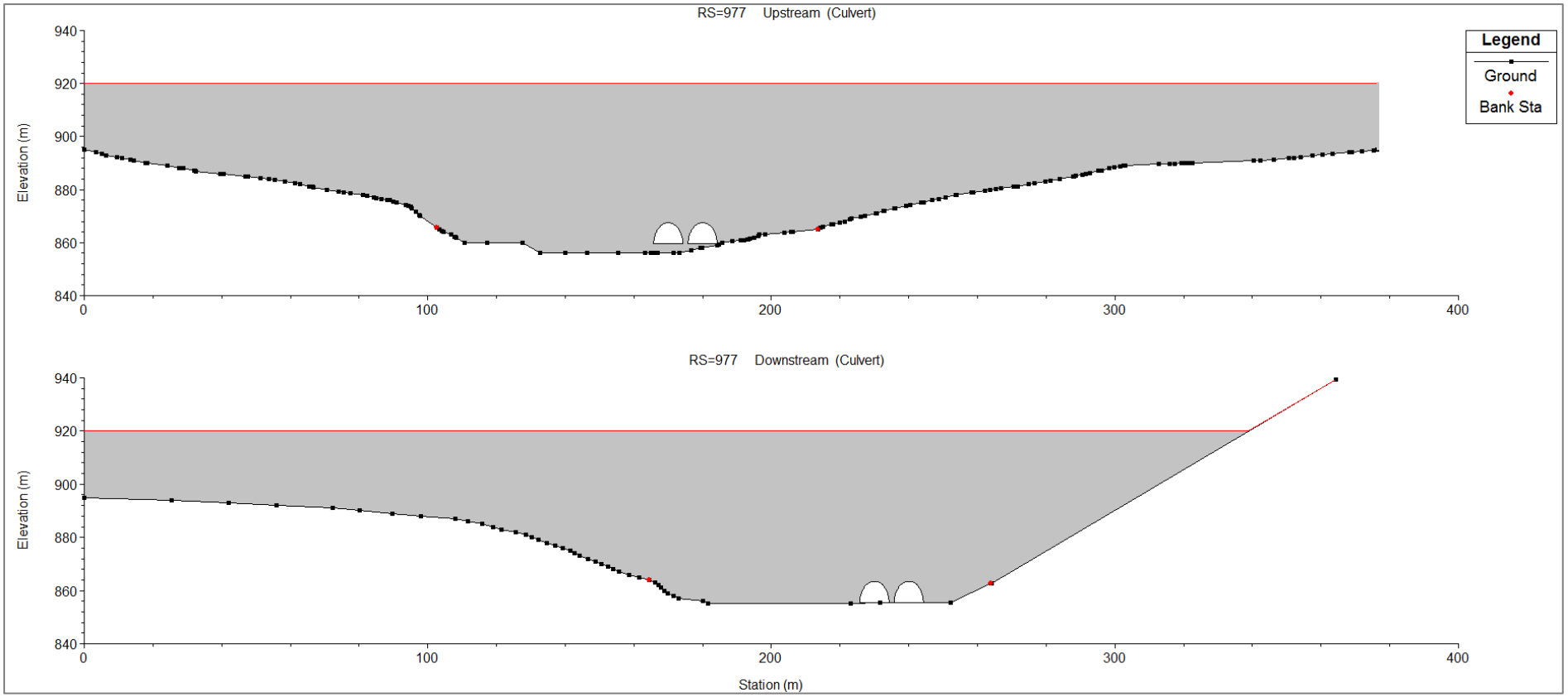


Figure 3.D.5: Upstream and downstream layout of culvert system

2.2 Flow Data Input

Steady flow simulations were run in the HEC-RAS model. The external reach boundary conditions were selected to be normal depth with the upstream slope being 0.00256 m/m and the downstream slope being 0.00154 m/m. The flow regime was assumed to be mixed between subcritical and supercritical.

The steady flow data was set up for the recurrence interval floods as given in **Table 3.D.2**.

Table 3.D.2: Flood peaks

Recurrence period	Flood peak – 12 months	Flood peak – winter
1:2	336	38
1:10	937	74.5
1:20	1 244	145.1
1:50	1 708	206.2
1:100	2 389	325.4

2.3 HEC-RAS results

A description of each coffer dam is given first and followed by figures of the visual results thereafter.

2.3.1 Coffer Dams 1 and 2

The HEC-RAS results and the recommended crest level for Coffer Dams 1 and 2 are given in **Table 3.D.3** and depicted in **Figure 3.D.6** and **Figure 3.D.7**, respectively.

Table 3.D.3: Coffer dams 1 and 2 results

	Cross-	NGL	Water	Recommended	Recommended
Coffer Dam 1	994	859.5	861.89	862.5	3
Coffer Dam 2	959	855.5	859.63	860.5	5

2.3.2 Coffer Dam 3

For the 1:10 year winter flood the headwater level at the inlet of the culvert system is 861.44 masl. The water surface profile for the 1:10 year winter flood is shown in **Figure 3.D.8**.

2.3.3 Coffer Dam 4

The main purpose of Coffer dam 4 is to prevent back flow to enter the Main Dam Embankment construction area. The height of Coffer dam 6 was determined in correlation with the tailwater level at the outlet of the tunnels i.e. at the outlet of the HEC-RAS modelled culvert system. For the 1:50 year flood event the tailwater level at the outlet of the tunnels is at 861.78 masl (See **Figure 3.D.9**).

The crest level of Coffer dam 4 is recommended to be at 862.5 masl.

2.3.4 Coffer Dam 5

As shown in **Figure 3.D.10**, the water surface level for the 1:20 year winter flood at the inlet of the culvert system is 862.55 masl.

2.3.5 Coffer Dam 6

The headwater level at the tunnel inlets, and hence at Coffer Dam 6, generated by HEC-RAS is 887.87 masl. The tunnel will be full flowing, equivalent to an outlet controlled culvert. The water surface profile is depicted in **Figure 3.D.11**.

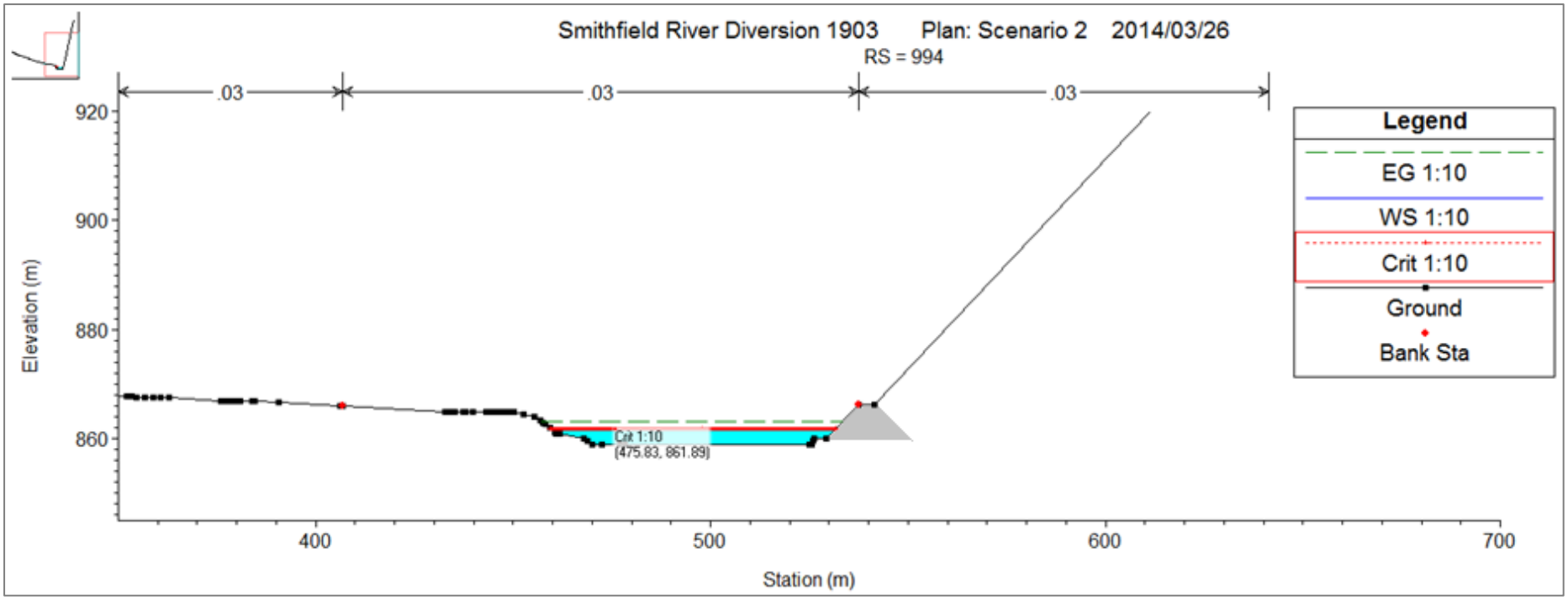


Figure 3.D.6: Coffer dam 1 (cross-section 994) with 1:10 year flood event

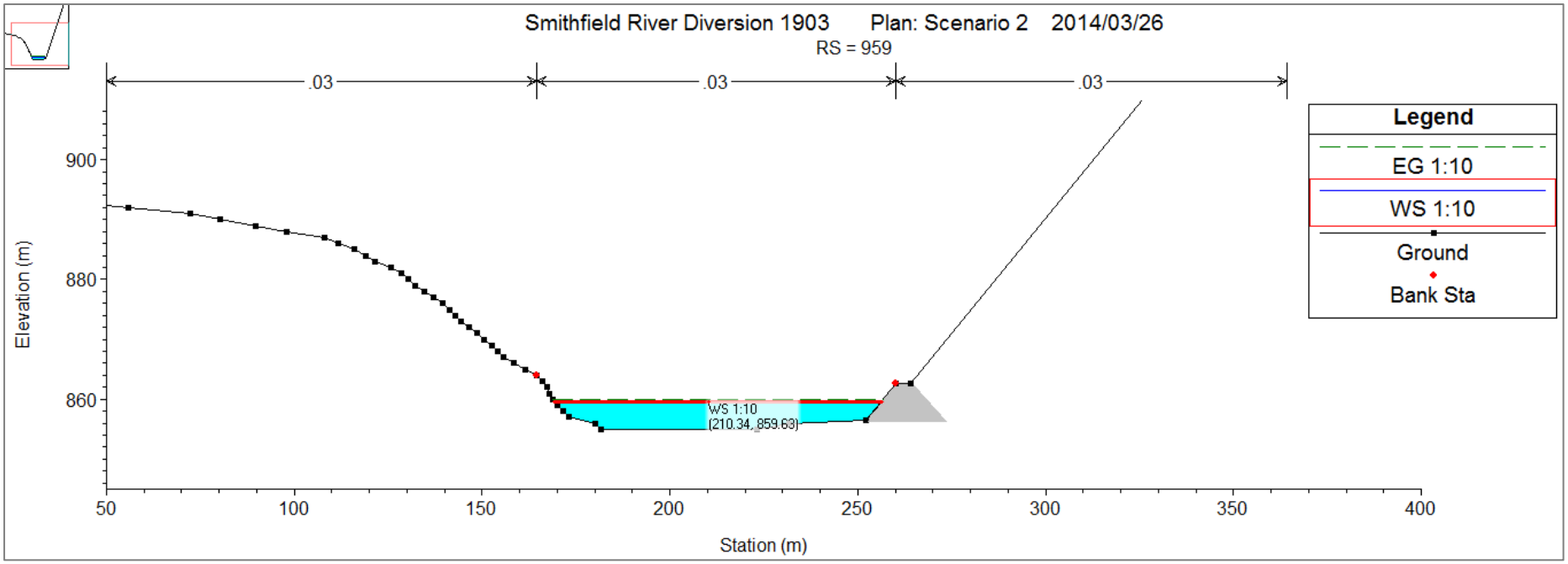


Figure 3.D.7: Coffer dam 2 (cross-section 959) with 1:10 year flood event

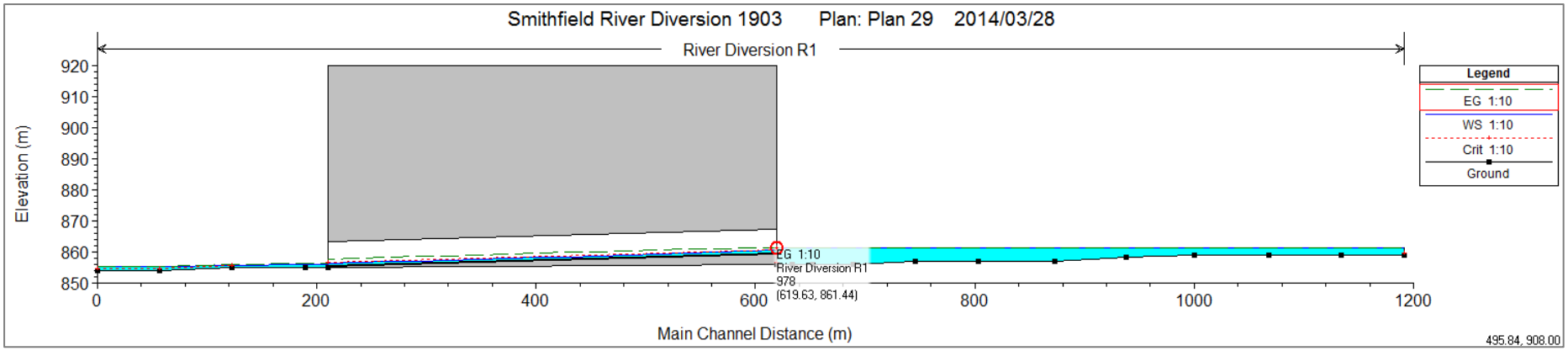


Figure 3.D.8: Water surface profile for the 1:10 year winter flood event (Coffer Dam 3)

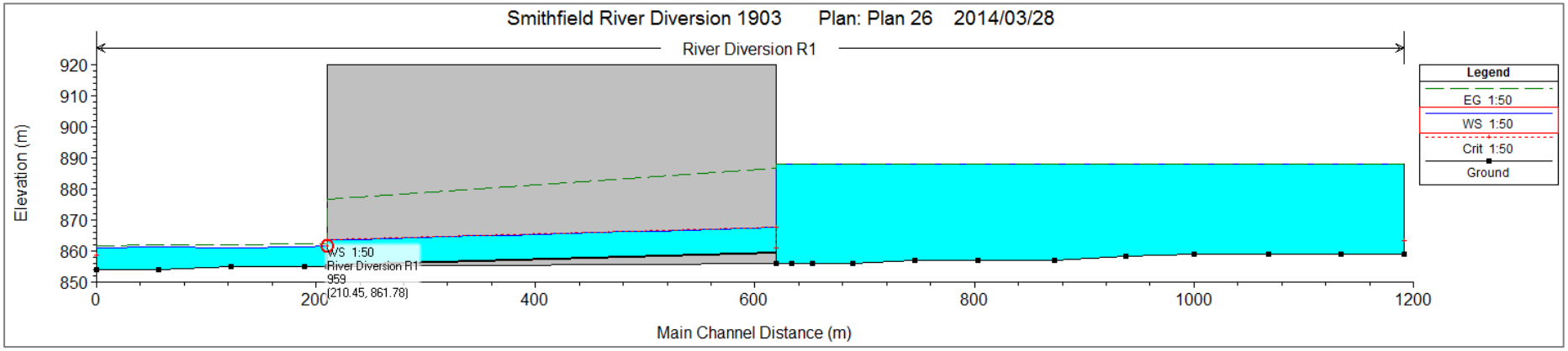


Figure 3.D.9: Water surface profile for 1:50 year flood (Coffer dam 4)

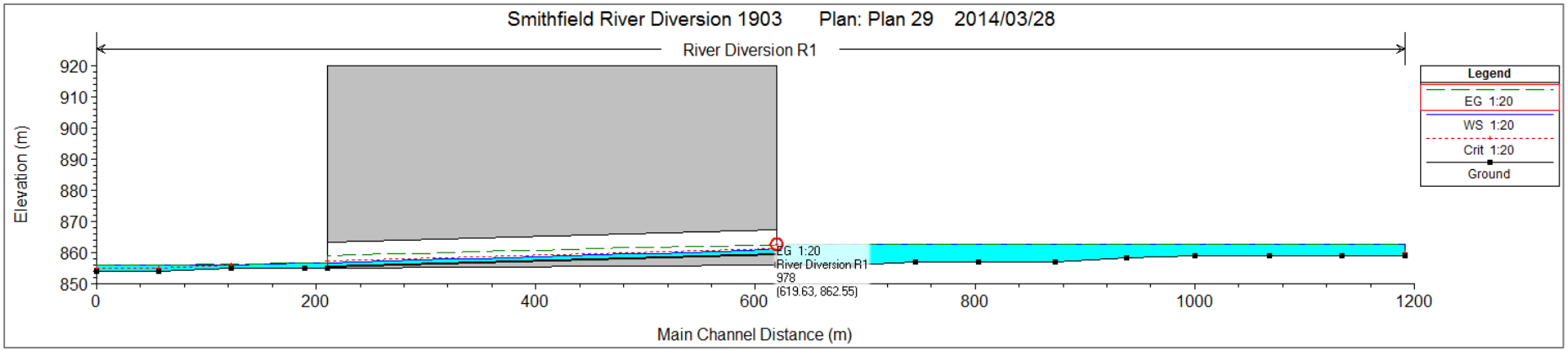


Figure 3.D.10: Water surface profile for 1:20 year flood event (Coffer Dam 5)

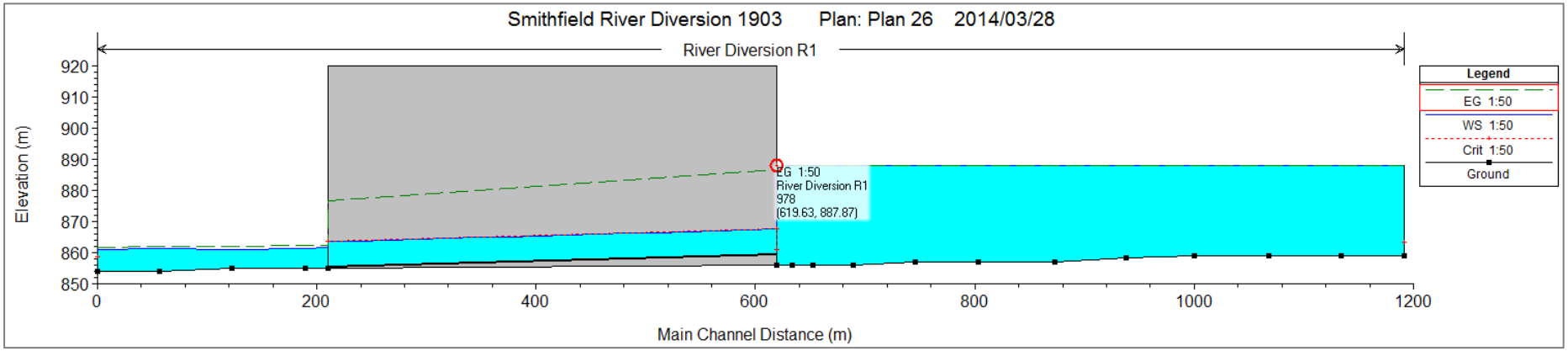


Figure 3.D.11: Water surface profile for 1:50 year flood (Coffer Dam 6)

3 Empirical headwater determinationDischarge curve

The flow through the tunnels at certain head water levels (discharge curves), determined with empirical equations, to determine the required coffer dam crest levels for Coffer Dams 3, 5 and 6 are shown in **Figure 3.D.12**.

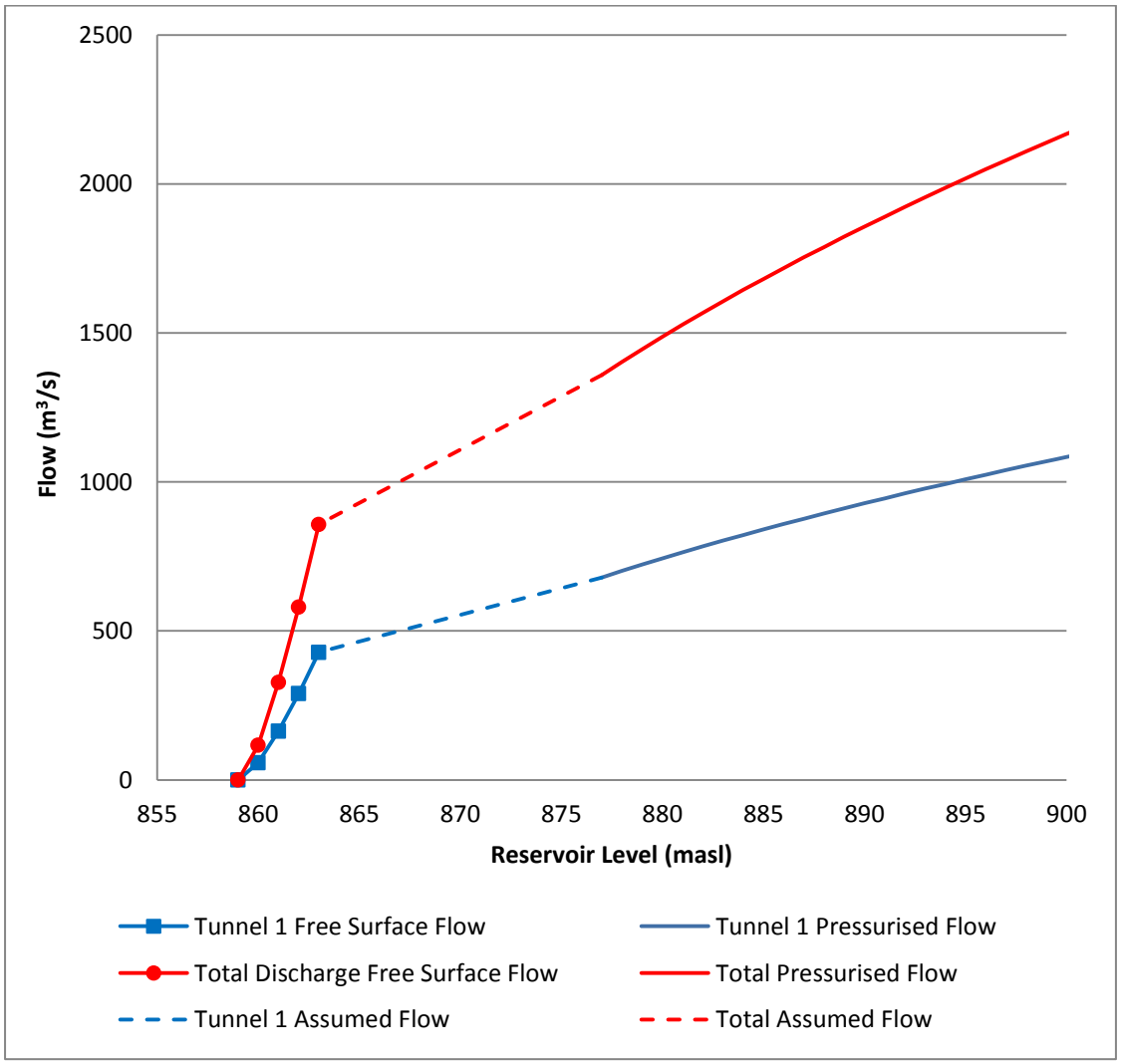


Figure 3.D.12: Discharge curves

3.2 Discharge curve results

The discharge curve results for Coffer Dams 3, 5 and 6 are given in **Table 3.D.4** below.

Table 3.D.4: Discharge curve results

Coffer Dam	NGL (masl)	Q (m^3/s)	Headwater elevation
Coffer Dam 3	858	74.5	860.15
Coffer Dam 5	856	145.1	860.82
Coffer Dam 6	856	1 708	885.26

4 Comparison of HEC-RAS and discharge curve results

The comparison of the HEC-RAS and discharge curve results are summarised in **Table 3.D.5**. Also included in **Table 3.D.5** are the recommended crest levels for each coffer dam and comments.

Table 3.D.5: Summary of HEC-RAS and discharge curve results

Coffer dam	NGL	Accommodated flood event	WS elevation		Crest elevation		Height from NGL		Comments and recommendations
			Discharge	HEC-	Discharge	HEC-	Discharge	HEC-	
1	859.5	1:10	-	861.89	-	862.4	-	2.9	Recommended crest level: **862.5 masl**
2	855.5	1:10	-	859.63	-	860.2	-	4.7	Recommended crest level: **860.5 masl**
3	858	1:10 winter	860.15	861.44	860.7	862	2.2	4	Recommended crest level: **862 masl**
4	856	1:50	-	861.78	-	862.3	-	6.3	Recommended crest level: **862.5 masl**
5	856	1:20 winter	860.82	862.55	860.3	863	4.7	7	Recommended crest level: **863 masl**
6	856	1:50	885.26	887.87	886.8	888.4	30.3	32.4	Recommended crest level: **888 masl**

Annexure 3 E – Smithfield Dam: Spillway sizing and design

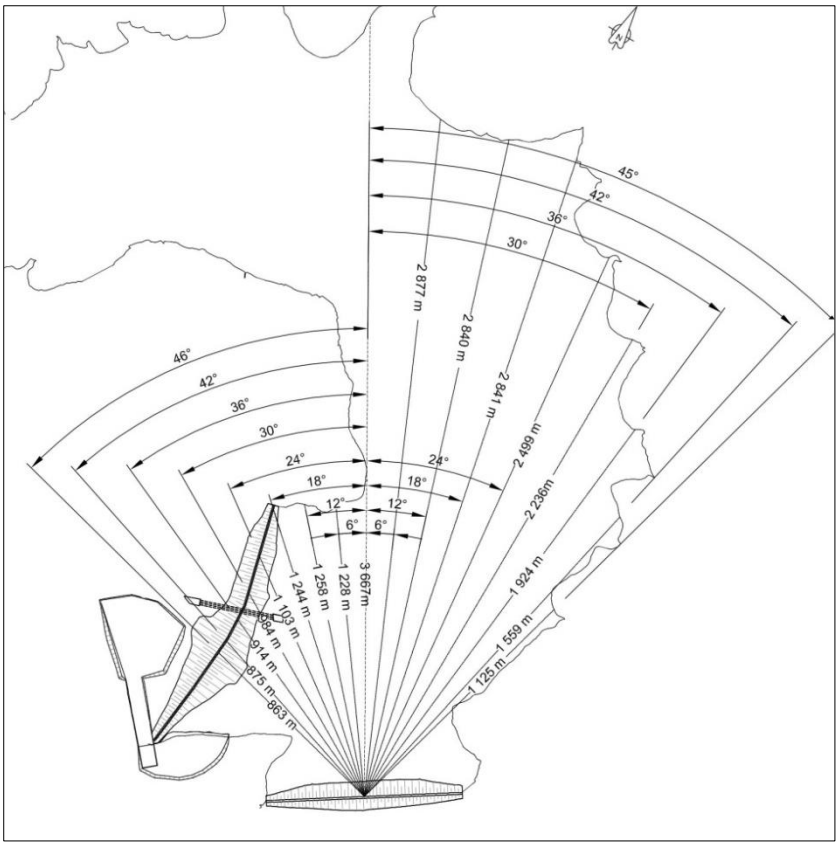


Figure 3.E.1: Wind setup determination of the saddle wall

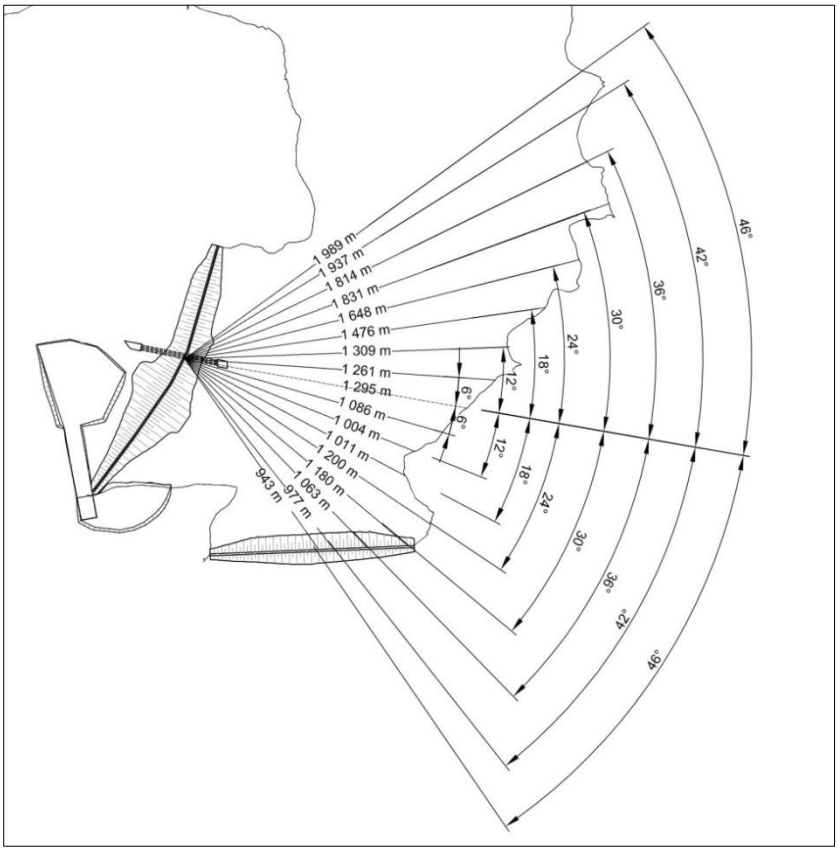


Figure 3.E.2: Wind setup determination for main wall

Table 3.E.1: Routed SEF for spillway lengths of 120, 160 and 200 m

Spillway length = 120 m			
Time (hr)	**Inflow (m^3/s)**	**Outflow (m^3/s)**	**Level (masl)**
0	0	0	930
1.05	30.85	0.84	930.01
2.15	70.76	3.51	930.02
3.25	175.7	10	930.07
4.35	377.77	24.42	930.16
5.45	762.86	54	930.36
6.55	1379.98	143.25	930.73
7.65	2177.17	351.86	931.32
8.74	3060.82	743.26	932.13
9.84	3943.01	1345.64	933.09
10.94	4608.07	2115.78	934.09
12.04	5086.77	2924.67	935
13.14	5429.9	3608.32	935.68
14.24	5625.32	4205.19	936.24
15.34	5601.39	4662.73	936.64
16.44	5295.45	4924.5	936.87
17.54	**4765.58**	**4958.55**	**936.90**
18.64	4116.53	4782.9	936.75
19.74	3443.97	4450.16	936.46
20.84	2933.86	4040.23	936.09
21.94	2571.97	3644.87	935.71
23.04	2280.54	3283.13	935.36
24.14	2037.18	2959.19	935.03
25.24	1826.13	2645.83	934.7
26.34	1643.97	2381.59	934.4
27.44	1481.66	2145.41	934.13
28.54	1336.12	1941.47	933.88
29.64	1205.49	1762.83	933.65
30.74	1088.34	1602.36	933.45
31.84	983.78	1463.14	933.25
32.94	890.75	1333.96	933.08
34.04	808.49	1221.09	932.91
35.14	734.84	1120.56	932.76
36.24	667.9	1026.79	932.61
37.34	606.15	941.28	932.48
38.44	549.43	868.61	932.35
39.54	498.3	799.61	932.23
40.64	449.58	734.54	932.12
41.74	404.22	672.97	932.01
42.84	360.47	621.93	931.91
43.94	320.78	573.05	931.81
45.04	281.9	525.86	931.71
46.14	246.27	480.42	931.62
47.24	211.44	436.69	931.53
48.34	179.41	399.74	931.44
49.44	148.66	365.77	931.36
50.54	119.79	332.47	931.27
51.64	94.36	299.95	931.19
52.74	71.35	268.72	931.11
53.84	52.85	238.94	931.04

Table 3.E.1 (continued)

Spillway length = 160 m			
Time (hr)	**Inflow (m^3/s)**	**Outflow (m^3/s)**	**Level (masl)**
0	0	0	930
1.05	30.85	1.13	930.01
2.15	70.76	4.68	930.02
3.25	175.7	13.25	930.07
4.35	377.77	32.29	930.16
5.45	762.86	71.22	930.35
6.55	1379.98	186.42	930.71
7.65	2177.17	453.1	931.28
8.74	3060.82	933.28	932.03
9.84	3943.01	1653.34	932.89
10.94	4608.07	2518.73	933.75
12.04	5086.77	3374.04	934.49
13.14	5429.9	4113.06	935.07
14.24	5625.32	4651.8	935.46
15.34	5601.39	5035.55	935.73
16.44	**5295.45**	**5199.39**	**935.84**
17.54	4765.58	5131.09	935.79
18.64	4116.53	4854.04	935.6
19.74	3443.97	4431.85	935.3
20.84	2933.86	3951.46	934.94
21.94	2571.97	3475.94	934.57
23.04	2280.54	3082.63	934.24
24.14	2037.18	2741.12	933.95
25.24	1826.13	2454.69	933.69
26.34	1643.97	2208.85	933.46
27.44	1481.66	1999.86	933.25
28.54	1336.12	1808.68	933.06
29.64	1205.49	1645.12	932.88
30.74	1088.34	1498	932.72
31.84	983.78	1361.69	932.57
32.94	890.75	1243.81	932.43
34.04	808.49	1139.69	932.29
35.14	734.84	1042.51	932.17
36.24	667.9	952.43	932.05
37.34	606.15	874.59	931.95
38.44	549.43	806.32	931.85
39.54	498.3	741.26	931.75
40.64	449.58	679.82	931.66
41.74	404.22	621.58	931.57
42.84	360.47	568.01	931.49
43.94	320.78	524.52	931.41
45.04	281.9	481.89	931.33
46.14	246.27	440.29	931.25
47.24	211.44	399.86	931.18
48.34	179.41	360.82	931.11
49.44	148.66	323.18	931.04
50.54	119.79	290.9	930.97
51.64	94.36	264.33	930.91
52.74	71.35	238.19	930.84
53.84	52.85	212.77	930.78

Table 3.E.1 (continued)

Spillway length = 200m			
Time (hr)	**Inflow (m^3/s)**	**Outflow (m^3/s)**	**Level (masl)**
0	0	0	930
1.05	30.85	1.42	930.01
2.15	70.76	5.82	930.02
3.25	175.7	16.44	930.06
4.35	377.77	39.94	930.16
5.45	762.86	87.9	930.34
6.55	1379.98	226.87	930.69
7.65	2177.17	545.42	931.24
8.74	3060.82	1103.31	931.94
9.84	3943.01	1908.88	932.72
10.94	4608.07	2826.8	933.47
12.04	5086.77	3696.3	934.08
13.14	5429.9	4409.75	934.55
14.24	5625.32	4949.76	934.88
15.34	5601.39	5245.96	935.07
16.44	**5295.45**	**5324.97**	**935.13**
17.54	4765.58	5212.72	935.04
18.64	4116.53	4845.57	934.82
19.74	3443.97	4329.2	934.5
20.84	2933.86	3798.91	934.15
21.94	2571.97	3339.44	933.84
23.04	2280.54	2949.97	933.56
24.14	2037.18	2625.26	933.32
25.24	1826.13	2354.87	933.1
26.34	1643.97	2121.89	932.91
27.44	1481.66	1918.94	932.73
28.54	1336.12	1733.78	932.57
29.64	1205.49	1575.85	932.42
30.74	1088.34	1435.94	932.28
31.84	983.78	1305.64	932.15
32.94	890.75	1185.73	932.03
34.04	808.49	1086.85	931.92
35.14	734.84	997.23	931.81
36.24	667.9	913.12	931.72
37.34	606.15	834.55	931.62
38.44	549.43	761.59	931.54
39.54	498.3	700.06	931.46
40.64	449.58	646.52	931.38
41.74	404.22	594.41	931.31
42.84	360.47	544.2	931.23
43.94	320.78	495.96	931.16
45.04	281.9	449.88	931.1
46.14	246.27	405.91	931.03
47.24	211.44	368.61	930.97
48.34	179.41	337.57	930.91
49.44	148.66	306.41	930.85
50.54	119.79	275.56	930.79
51.64	94.36	245.26	930.73
52.74	71.35	216.18	930.67
53.84	52.85	188.51	930.62

Table 3.E.2: Preliminary cost estimation for 120 m, 160 m and 200 m spillway lengths

AECOM	MAIN DAM BILL OF QUANTITIES		One main side channel spillway Spillway length L =120m			
Left flank:		ECRD				
River section:		ECRD				
Right flank:		ECRD				
				Quantity	Rate	Cost
	SABS 1200 DE					
1	8.3.1	**Site clearance**				
					0	
1.1	8.3.1.1	Clear and strip site	Ha	18	23250	410 645.63
1.2	8.3.1.1	Remove and grub large trees(Complet with stumps) or stumps only, as scheduled, of girth				
		(a) over 1m and up to and including 2m	No	0	0	0.00
		(b) over 2m and up to and including 3m	No	0	0	0.00
		(c) over 3m, in increments of 1m	No	0	0	0.00
1.3	8.3.1.3	Extra-over 8.3.1.1 for removal of rocks, etc., as specified in SABS 1200 DE Para. 5.2.1.1 (c)	m^3	0	0	0.00
1.4	8.3.1.4	Extra-over 8.3.1.1 for removal and recovering of fencing	m^3	0	0	0.00
1.5	8.3.1.5	Extra-over 8.3.1.1 for recovering other scheduled material	m^3	0	0	0.00
1.6	8.3.1.6	Clearing of the basin	Ha	0	23250	0.00
2	8.3.2	Remove topsoil to nominal depth 150mm, stockpile and maintain	m^2	176 622	20	3 532 435.51
3	8.3.3	**Excavation**				
3.1		a) Material unsuitable for embankment	m^3	1 226 928	31.6	38 770 931.66
3.2		b) Material suitable for embankment from essential excavations for:				
		1) Core trench	m^3	0	0	0.00
		2) Spillway	m^3	0	0	0.00
		3) Pipe trenches	m^3	0	0	0.00
		4) Outlet works	m^3	0	0	0.00
		Extra over (b) (1) - (4) for excavation in:				
		1) Intermediate material	m^3	0	0	0.00
		2) Hard rock material	m^3	0	36.5	0.00
3.4	8.3.4	Preparation of exposed surfaces				
		a) Core trench				
		b) Area to be covered by dam wall	m^2	177 071	92.55	16 387 907.21
3.5	8.3.5	**Forming Embankment**				
		a) Selected impervious material (Clay material)	m^3	892 721	48.37	43 180 937.19
		b) Transition	m^3	0	97.94	0.00
		c) Unselected pervious material				
		i) Earthfill	m^3	0	48.37	0.00
		ii) Rockfill - Type 1 (Outer zone)	m^3	3 649 060	91	332 064 428.47
		iii) Rockfill - Type 2 (Inner zone)	m^3	0	91	0.00
		d) Rip-rap	m^3	0	438.52	0.00
		e) Topsoil from stockpile to downstream slope	m^3	0	0	0.00
		f) Coarse filter material	m^3	68 453	789.45	54 040 359.97
		g) Fine filter material	m^3	68 453	789.45	54 040 359.97
		h) Gravel capping	m^3	0	91	0.00
3.6		**Concrete Works**				
3.6.1		(a) Formwork				
		(i) Gang formed	m	0	475	0.00
		(ii) Intricate	m	0	480	0.00
3.6.2		(b) Concrete				
		(i) Rollcrete	m^3	0	1156.76	0.00
		(ii) IVRCC	m^2	0	45.4	0.00
		(iii) CVC	m^3	0	1981.85	0.00
		(iv) Mass	m^3	0	1981.85	0.00
3.6.3		(c) Reinforcing	t	0	12854.15	0.00
3.6.4		(d) Waterstop	m	0	944.69	0.00
3.7		**Drilling & Grouting**				
3.7.1		(a) Curtain grouting	m	15 819	1054.15	16 675 281.31
3.7.2		(b) Consolidation grouting	m	5 750	1054.15	6 061 362.50
Total						565 164 649

Table 3.E.2 (continued)

AECOM SADDLE DAM BILL OF QUANTITIES

Left flank:		Earthfill				
River section:		Earthfill				
Right flank:		Earthfill				
				Quantity	Rate	Cost
	SABS 1200 DE					
1	8.3.1	**Site clearance**				
					0	
1.1	8.3.1.1	Clear and strip site	Ha	11	23250	250 525.03
1.2	8.3.1.1	Remove and grub large trees(Complet with stumps) or stumps only, as scheduled, of girth				
		(a) over 1m and up to and including 2m	No	0	0	0.00
		(b) over 2m and up to and including 3m	No	0	0	0.00
		(c) over 3m, in increments of 1m	No	0	0	0.00
1.3	8.3.1.3	Extra-over 8.3.1.1 for removal of rocks, etc., as specified in SABS 1200 DE Para. 5.2.1.1 (c)	m^3	0	0	0.00
1.4	8.3.1.4	Extra-over 8.3.1.1 for removal and recovering of fencing	m^3	0	0	0.00
1.5	8.3.1.5	Extra-over 8.3.1.1 for recovering other scheduled material	m^3	0	0	0.00
1.6	8.3.1.6	Clearing of the basin	Ha	0	23250	0.00
2	8.3.2	Remove topsoil to nominal depth 150mm, stockpile and maintain	m^2	107 753	20	2 155 054.00
3	8.3.3	**Excavation**				
3.1		a) Material unsuitable for embankment	m^3	245 850	31.6	7 768 855.26
3.2		b) Material suitable for embankment from essential excavations for:				
		1) Core trench	m^3	0	0	0.00
		2) Spillway	m^3	0	0	0.00
		3) Pipe trenches	m^3	0	0	0.00
		4) Outlet works	m^3	0	0	0.00
		Extra over (b) (1) - (4) for excavation in:				
		1) Intermediate material	m^3	0	0	0.00
		2) Hard rock material	m^3	0	36.5	0.00
3.4	8.3.4	Preparation of exposed surfaces				
		a) Core trench				
		b) Area to be covered by dam wall	m^2	139 211	92.55	12 883 951.94
3.5	8.3.5	**Forming Embankment**				
		a) Selected impervious material (Clay material)	m^3	345 797	48.37	16 726 202.69
		b) Transition	m^3	20 191	97.94	1 977 545.72
		c) Unselected pervious material				
		i) Earthfill	m^3	914 697	48.37	44 243 912.41
		ii) Rockfill - Type 1 (Outer zone)	m^3	0	91	0.00
		iii) Rockfill - Type 2 (Inner zone)	m^3	0	91	0.00
		d) Rip-rap	m^3	20 191	438.52	8 854 332.73
		e) Topsoil from stockpile to downstream slope	m^2	0	0	0.00
		f) Coarse filter material	m^3	32 585	789.45	25 724 188.78
		g) Fine filter material	m^3	32 585	789.45	25 724 188.78
		h) Gravel capping	m^2	8 077	91	734 966.96
3.6		**Concrete Works**				
3.6.1		(a) Formwork				
		(i) Gang formed	m	0	475	0.00
		(ii) Intricate	m	0	480	0.00
3.6.2		(b) Concrete				
		(i) Rollcrete	m^3	0	1156.76	0.00
		(ii) IVRCC	m^2	0	45.4	0.00
		(iii) CVC	m^3	0	1981.85	0.00
		(iv) Mass	m^3	0	1981.85	0.00
3.6.3		(c) Reinforcing	t	0	12854.15	0.00
3.6.4		(d) Waterstop	m	0	944.69	0.00
3.7		**Drilling & Grouting**				
3.7.1		(a) Curtain grouting	m	6 736	1054.15	7 100 799.20
3.7.2		(b) Consolidation grouting	m	5 750	1054.15	6 061 362.50
Total						160 205 886

Table 3.E.2 (continued)

AECOM DIVERSION WORKS

ITEM NO	PAYMENT		UNIT	Quantity	Rate (R)	AMOUNT (R)
		STAGE 1: PORTALS AND TUNNELS				
1	**1.0**	**SITE CLEARANCE**				
	1.1	**Clear and grub**				
		(a) Portal footprints	ha	0.12	R 23 250.00	R 2 794.38
	1.2	**Remove and grub large trees and tree stumps of girth**				
		(a) Over 1 m and up to and including 2m	No	0.00	R 0.00	R 0.00
	1.3	**Remove topsoil to nominal depth of 150 mm and stockpile**	m³	1 201.89	R 10.28	R 12 355.39
2	**2.0**	**EXCAVATION AND BACKFILL FOR DAMS AND WATERWAYS**				
		Bulk Excavation				
	2.1	**Inlet portal**				
		(a) Excavate in all materials				
		(i) Excavation (stockpile)	m³	3 025.00	R 91.00	R 275 275.00
		(b) Extra over for:				
		(i) Intermediate	m³	302.50	R 0.00	
		(ii) Hard Rock	m³	302.50	R 31.60	R 9 559.00
		(iii) Boulder, Class A	m³	0.00	R 0.00	R 0.00
		(iv) Boulder, Class B	m³	0.00	R 0.00	R 0.00
	2.2	**Outlet Portal**				
		(a) Excavate in all materials				
		(i) Excavation (stockpile)	m³	3 025.00	R 91.00	R 275 275.00
		(b) Extra over for:				
		(i) Intermediate	m³	302.50	R 0.00	
		(ii) Hard Rock	m³	302.50	R 31.60	R 9 559.00
		(iii) Boulder, Class A	m³	0.00	R 0.00	R 0.00
		(iv) Boulder, Class B	m³	0.00	R 0.00	R 0.00
	2.3	**Dewatering**	Sum	0.00	R 0.00	R 0.00
		SUB TOTAL: STAGE 1				R 584 817.77
		STAGE 2 Cofferdam				
3		**SITE CLEARANCE**				
	3.1	**Clear and grub**				
		(a) Embankment footprint	ha	0.52	R 26 546.00	R 13 910
	3.2	Remove and grub large trees and tree stumps of girth				
		(a) over 1 m and up to and including 2 m	No	0.00	R 0.00	R 0
	3.3	Remove topsoil to nominal depth of 150 mm and stockpile	m³	5 240.00	R 10.28	R 53 867
4	**4.1**	**EXCAVATIONS AND BACKFILL FOR DAMS AND WATERWAYS**				
		(a) Excavate all materials				
		(i) Topsoil at Upstream & Downstream cofferdam	m³	5 240.00	R 51.42	R 269 441
5	**5.1**	**EMBANKMENT CONSTRUCTION**				
		Earthfill Upstream & Downstream Cofferdam Construction.				
		(a) Forming Embankment				
		Using material from designated borrow areas or commercial sources				
		(i) Soil cement at 3% cement	m³	2 860.00	R 300.00	R 858 000
		(ii) Rockfill	m³	22 140.00	R 91.00	R 2 014 740
		SUB TOTAL: COFFERDAM				R 3 209 958
6		**TUNNEL CONSTRUCTION**				
	6.1	TUNNEL EXCAVATION				
		(a) Tunnel	m³	14 872.30	R 2 700.00	R 40 155 209
	6.2	ROCK SUPPORT				
		(a) Rockbolts	m	4 208.00	R 50.00	R 210 400
		(b) Shotcrete	m³	3 304.96	R 3 350.00	R 11 071 601
		(c) Reinforcing mesh	m²	3 304.96	R 35.00	R 115 673
	6.3	DEWATERING	Sum	1.00	R 100 000.00	R 100 000
		SUB TOTAL: TUNNEL				R 51 652 883
		SUB TOTAL: STAGE 1 + STAGE 2				R 55 447 659
		STAGE 3				
7		**MEDIUM PRESSURE PIPELINES**				
		Supply, lay, and bed pipes complete with couplings				
		(a) 500 mm diameter concrete pipe (class 75D) in concrete	m	0.00	R 0.00	R 0
		(b) Water control in tunnel	Prov Sum	0.00	R 0.00	R 0
8		**PLUG OF TUNNEL**				
	8.1	Scheduled Formwork items- Class 1				
		(a) Vertical formwork	m²	0.00	R 591.29	R 0
	8.2	Scheduled Concrete items				
		Strength and Mass concrete				
		(a) Sealing of bulkheads shaft with mass concrete 25 Mpa/19 mm	m³	0.00	R 0.00	R 0
		(b) Plug 25 MPa/19 mm	m³	0.00		R 0
	8.3	Joints				
		(a) Swellable water stops	m	0.00	R 951.32	R 0
	8.4	Miscellaneous and Sundry items				
		(a) Bulkheads incl reinforcement at 120 kg/m³	No	0.00	R 0.00	R 0
		Sub total: STAGE 3				R 0
TOTAL CARRIED FORWARD TO SUMMARY						**R 55 447 659**

Table 3.E.2 (continued)

AECOM	MAIN DAM BILL OF QUANTITIES		One main side channel spillway L = 160m			
Left flank:		ECRD				
River section:		ECRD				
Right flank:		ECRD				
				Quantity	Rate	Cost
	SABS 1200 DE					
1	8.3.1	**Site clearance**				
					0	
1.1	8.3.1.1	Clear and strip site	Ha	17	23250	400 679.22
1.2	8.3.1.1	Remove and grub large trees(Complet with stumps) or stumps only, as scheduled, of girth				
		(a) over 1m and up to and including 2m	No	0	0	0.00
		(b) over 2m and up to and including 3m	No	0	0	0.00
		(c) over 3m, in increments of 1m	No	0	0	0.00
1.3	8.3.1.3	Extra-over 8.3.1.1 for removal of rocks, etc., as specified in SABS 1200 DE Para. 5.2.1.1 (c)	m^3	0	0	0.00
1.4	8.3.1.4	Extra-over 8.3.1.1 for removal and recovering of fencing	m^3	0	0	0.00
1.5	8.3.1.5	Extra-over 8.3.1.1 for recovering other scheduled material	m^3	0	0	0.00
1.6	8.3.1.6	Clearing of the basin	Ha	0	23250	0.00
2	8.3.2	Remove topsoil to nominal depth 150mm, stockpile and maintain	m^2	172 335	20	3 446 703.01
3	8.3.3	**Excavation**				
3.1		a) Material unsuitable for embankment	m^3	1 196 545	31.6	37 810 828.82
3.2		b) Material suitable for embankment from essential excavations for:				
		1) Core trench	m^3	0	0	0.00
		2) Spillway	m^3	0	0	0.00
		3) Pipe trenches	m^3	0	0	0.00
		4) Outlet works	m^3	0	0	0.00
		Extra over (b) (1) - (4) for excavation in:				
		1) Intermediate material	m^3	0	0	0.00
		2) Hard rock material	m^3	0	36.5	0.00
3.4	8.3.4	Preparation of exposed surfaces				
		a) Core trench				
		b) Area to be covered by dam wall	m^2	172 784	92.55	15 991 180.06
3.5	8.3.5	**Forming Embankment**				
		a) Selected impervious material (Clay material)	m^3	859 762	48.37	41 586 677.72
		b) Transition	m^3	0	97.94	0.00
		c) Unselected pervious material				
		i) Earthfill	m^3	0	48.37	0.00
		ii) Rockfill - Type 1 (Outer zone)	m^3	3 499 092	91	318 417 417.31
		iii) Rockfill - Type 2 (Inner zone)	m^3	0	91	0.00
		d) Rip-rap	m^3	0	438.52	0.00
		e) Topsoil from stockpile to downstream slope	m^3	0	0	0.00
		f) Coarse filter material	m^3	66 642	789.45	52 610 468.66
		g) Fine filter material	m^3	66 642	789.45	52 610 468.66
		h) Gravel capping	m^3	0	91	0.00
3.6		**Concrete Works**				
3.6.1		(a) Formwork				
		(i) Gang formed	m	0	475	0.00
		(ii) Intricate	m	0	480	0.00
3.6.2		(b) Concrete				
		(i) Rollcrete	m^3	0	1156.76	0.00
		(ii) IVRCC	m^2	0	45.4	0.00
		(iii) CVC	m^3	0	1981.85	0.00
		(iv) Mass	m^3	0	1981.85	0.00
3.6.3		(c) Reinforcing	t	0	12854.15	0.00
3.6.4		(d) Waterstop	m	0	944.69	0.00
3.7		**Drilling & Grouting**				
3.7.1		(a) Curtain grouting	m	15 420	1054.15	16 255 228.89
3.7.2		(b) Consolidation grouting	m	5 750	1054.15	6 061 362.50
Total						545 191 015

Table 3.E.2 (continued)

AECOM SADDLE DAM BILL OF QUANTITIES

Left flank:		Earthfill				
River section:		Earthfill				
Right flank:		Earthfill				
				Quantity	Rate	Cost
	SABS 1200 DE					
1	8.3.1	**Site clearance**				
					0	
1.1	8.3.1.1	Clear and strip site	Ha	10	23250	235 755.47
1.2	8.3.1.1	Remove and grub large trees(Complet with stumps) or stumps only, as scheduled, of girth				
		(a) over 1m and up to and including 2m	No	0	0	0.00
		(b) over 2m and up to and including 3m	No	0	0	0.00
		(c) over 3m, in increments of 1m	No	0	0	0.00
1.3	8.3.1.3	Extra-over 8.3.1.1 for removal of rocks, etc., as specified in SABS 1200 DE Para. 5.2.1.1 (c)	m^3	0	0	0.00
1.4	8.3.1.4	Extra-over 8.3.1.1 for removal and recovering of fencing	m^3	0	0	0.00
1.5	8.3.1.5	Extra-over 8.3.1.1 for recovering other scheduled material	m^3	0	0	0.00
1.6	8.3.1.6	Clearing of the basin	Ha	0	23250	0.00
2	8.3.2	Remove topsoil to nominal depth 150mm, stockpile and maintain	m^2	101 400	20	2 028 004.00
3	8.3.3	**Excavation**				
3.1		a) Material unsuitable for embankment	m^3	232 416	31.6	7 344 359.82
3.2		b) Material suitable for embankment from essential excavations for:				
		1) Core trench	m^3	0	0	0.00
		2) Spillway	m^3	0	0	0.00
		3) Pipe trenches	m^3	0	0	0.00
		4) Outlet works	m^3	0	0	0.00
		Extra over (b) (1) - (4) for excavation in:				
		1) Intermediate material	m^3	0	0	0.00
		2) Hard rock material	m^3	0	36.5	0.00
3.4	8.3.4	Preparation of exposed surfaces				
		a) Core trench				
		b) Area to be covered by dam wall	m^2	130 798	92.55	12 105 354.12
3.5	8.3.5	**Forming Embankment**				
		a) Selected impervious material (Clay material)	m^3	317 544	48.37	15 359 605.33
		b) Transition	m^3	19 036	97.94	1 864 425.02
		c) Unselected pervious material				
		i) Earthfill	m^3	826 526	48.37	39 979 072.55
		ii) Rockfill - Type 1 (Outer zone)	m^3	0	91	0.00
		iii) Rockfill - Type 2 (Inner zone)	m^3	0	91	0.00
		d) Rip-rap	m^3	19 036	438.52	8 347 842.13
		e) Topsoil from stockpile to downstream slope	m^2	0	0	0.00
		f) Coarse filter material	m^3	30 564	789.45	24 128 512.97
		g) Fine filter material	m^3	30 564	789.45	24 128 512.97
		h) Gravel capping	m^3	7 615	91	692 924.96
3.6		**Concrete Works**				
3.6.1		(a) Formwork				
		(i) Gang formed	m	0	475	0.00
		(ii) Intricate	m	0	480	0.00
3.6.2		(b) Concrete				
		(i) Rollcrete	m^3	0	1156.76	0.00
		(ii) IVRCC	m^3	0	45.4	0.00
		(iii) CVC	m^3	0	1981.85	0.00
		(iv) Mass	m^3	0	1981.85	0.00
3.6.3		(c) Reinforcing	t	0	12854.15	0.00
3.6.4		(d) Waterstop	m	0	944.69	0.00
3.7		**Drilling & Grouting**				
3.7.1		(a) Curtain grouting	m	6 338	1054.15	6 680 746.78
3.7.2		(b) Consolidation grouting	m	5 750	1054.15	6 061 362.50
Total						148 956 479

Table 3.E.2 (continued)

AECOM SPILLWAY AND CHUTE

ITEM NO	PAYMENT	DESCRIPTION	UNIT	Quantity	Rate	AMOUNT (R)
		SABS 1200 DE				
	8.3.3	Excavation				
		a) Material unsuitable for embankment	m^3	280341	R 51	R 14 414 192
		b) Material suitable for embankment from essential excavations for:				
		2) Spillway	m^3	0	R 0	R 0
		3) Pipe trenches	m^3	0	R 0	R 0
		4) Outlet works	m^3	0	R 0	R 0
		SABS 1200 - GA				
		CONVENTIONAL CONCRETE FOR DAMS				
8	8.1.1	Scheduled Formwork items				
	8.1.1.1	Class F4				
		(a) Verical				
		(i) Chute	m^2	16490	R 334	R 5 510 949
		(b) Sloped				
		(i) Ogee of spillway	m^2	1370	R 411	R 563 577
		(ii) Round	m^2	0	R 411	R 0
		(c) Sloping				
		(i) Stilling basin blocks	m^2	0	R 0	R 0
		(ii) Horizontal	m^2	0	R 0	R 0
	8.1.2	Scheduled Reinforcement items	t	2314	R 12 854	R 29 743 434
	8.1.2.1	Anchors				
		(a) Anchor bars	m	2572	R 0	R 0
	8.1.3	Scheduled Concrete items				
	8.1.3.1	Strength & Mass Concrete				
		(a) Grade 25 MPa/19 mm	m^3	34656	R 1 414	R 49 002 268
		(i) Spillway, bridges and retaining wall	m^3	0	R 1 414	R 0
	8.1.3.2	Secondary Concrete				
		(a) Grade 25 MPa/19 mm	m^3	0	R 1 414	R 0
	8.1.3.3	Keyways on contraction joints				
		(a) Bridges dimensions to be given in detail design	m		R 0	R 0
	8.1.3.4	Unformed Surface Finishes				
		Class U2 (Wood-floated) finish				
		(a) Chute and Stilling basin floor	m^2	51584	R 14	R 729 375
		(b) Top of bridges	m^2	0	R 14	R 0
16		**WATERSTOPS, JOINTING AND BEARINGS**				
	16.1	Scheduled items				
		Waterstops				
						R 0
		(a) 250 mm Centre bulb PVC waterstop	m	1802	R 685	R 1 234 368
	16.2	Joint sealants				
		(a) Chute wall - 12mm expanding cork	m	0	R 0	R 0
		(b) Chute wall - 12m Impregnated Bitumen Fibre board	m	0	R 0	R 0
		(c) Chute wall - 12 x 12 mm Polysulphide sealant	m	0	R 0	R 0
17		**SUB-SOIL DRAINAGE**				
	17.1	Scheduled items				
		Excavating soft material situated within the following depth ranges below the surface level:				
		(a) 0 m to 1,5 m	m^3	782	R 0	R 0
		(b) Extra over sub-item (a), irrespective of depth, for:				
		(i) Excavation in hard material	m^3	0	R 0	R 0
	17.2	Natural permeable material in sub-soil drainage systems				
		(a) Sand as specified on detail drawings	m^3	738	R 0	R 0
	17.3	Pipes in sub-soil drainage system				
		(a) 110 NB, Class 6, HDPE pressure pipe, non perforated, complying with SANS 533, Part II	m	0	R 0	R 0
		(b) 75 NB, flexible slotted drainage pipes with smooth bore, "Drainex" or equivalent by Kaytech	m	2171	R 0	R 0
	17.4	Caps to higher ends of sub-surface drain pipes				
		(a) High end of pipes of Drainex pipes	No	0	R 0	R 0
	17.5	Concrete outlet structures for sub-soil drainage systems complete as per drawings				
		(a) Concrete 1500 mm dia	No	0	R 0	R 0
	17.6	Overhaul for material hauled in excess of 1.0 km freehaul				
		(a) Sand for filter material (10 km)	$m^3.km$	0	R 0	R 0
						R 0
TOTAL CARRIED FORWARD TO SUMMARY						R 101 198 163

Table 3.E.2 (continued)

AECOM	MAIN DAM BILL OF QUANTITIES		One main side channel spillway L = 200m			
Left flank:		ECRD				
River section:		ECRD				
Right flank:		ECRD				
				Quantity	Rate	Cost
	SABS 1200 DE					
1	8.3.1	**Site clearance**				
					0	
1.1	8.3.1.1	Clear and strip site	Ha	17	23250	394 034.96
1.2	8.3.1.1	Remove and grub large trees(Complet with stumps) or stumps only, as scheduled, of girth				
		(a) over 1m and up to and including 2m	No	0	0	0.00
		(b) over 2m and up to and including 3m	No	0	0	0.00
		(c) over 3m, in increments of 1m	No	0	0	0.00
1.3	8.3.1.3	Extra-over 8.3.1.1 for removal of rocks, etc., as specified in SABS 1200 DE Para. 5.2.1.1 (c)	m^3	0	0	0.00
1.4	8.3.1.4	Extra-over 8.3.1.1 for removal and recovering of fencing	m^3	0	0	0.00
1.5	8.3.1.5	Extra-over 8.3.1.1 for recovering other scheduled material	m^3	0	0	0.00
1.6	8.3.1.6	Clearing of the basin	Ha	0	23250	0.00
2	8.3.2	Remove topsoil to nominal depth 150mm, stockpile and maintain	m^2	169 477	20	3 389 548.01
3	8.3.3	**Excavation**				
3.1		a) Material unsuitable for embankment	m^3	1 176 319	31.6	37 171 679.92
3.2		b) Material suitable for embankment from essential excavations for:				
		1) Core trench	m^3	0	0	0.00
		2) Spillway	m^3	0	0	0.00
		3) Pipe trenches	m^3	0	0	0.00
		4) Outlet works	m^3	0	0	0.00
		Extra over (b) (1) - (4) for excavation in:				
		1) Intermediate material	m^3	0	0	0.00
		2) Hard rock material	m^3	0	36.5	0.00
3.4	8.3.4	Preparation of exposed surfaces				
		a) Core trench				
		b) Area to be covered by dam wall	m^2	169 926	92.55	15 726 695.30
3.5	8.3.5	**Forming Embankment**				
		a) Selected impervious material (Clay material)	m^3	838 170	48.37	40 542 281.09
		b) Transition	m^3	0	97.94	0.00
		c) Unselected pervious material				
		i) Earthfill	m^3	0	48.37	0.00
		ii) Rockfill - Type 1 (Outer zone)	m^3	3 401 263	91	309 514 909.15
		iii) Rockfill - Type 2 (Inner zone)	m^3	0	91	0.00
		d) Rip-rap	m^3	0	438.52	0.00
		e) Topsoil from stockpile to downstream slope	m^3	0	0	0.00
		f) Coarse filter material	m^3	65 434	789.45	51 657 207.79
		g) Fine filter material	m^3	65 434	789.45	51 657 207.79
		h) Gravel capping	m^3	0	91	0.00
3.6		**Concrete Works**				
3.6.1		(a) Formwork				
		(i) Gang formed	m	0	475	0.00
		(ii) Intricate	m	0	480	0.00
3.6.2		(b) Concrete				
		(i) Rollcrete	m^3	0	1156.76	0.00
		(ii) IVRCC	m^2	0	45.4	0.00
		(iii) CVC	m^3	0	1981.85	0.00
		(iv) Mass	m^3	0	1981.85	0.00
3.6.3		(c) Reinforcing	t	0	12854.15	0.00
3.6.4		(d) Waterstop	m	0	944.69	0.00
3.7		**Drilling & Grouting**				
3.7.1		(a) Curtain grouting	m	15 155	1054.15	15 975 193.94
3.7.2		(b) Consolidation grouting	m	5 750	1054.15	6 061 362.50
SUB-TOTAL CARRIED FORWARD TO SUMMARY						532 090 120

Table 3.E.2 (continued)

AECOM

INLET AND OUTLET WORKS

ITEM NO	PAYMENT		UNIT	Quantity	Rate (R)	AMOUNT (R)
1	1.1	Earthworks				
		(a) Clearing and grubbing	ha	0.08	R 23 250.00	R 1 907
		(b) Excavation - soft	m^3	1 070.00	R 180.00	R 192 600
		(c) Excavation - rock	m^3	1 070.00	R 300.00	R 321 000
		(d) Rockfill to abutments	m^3	0.00	R 50.39	R 0
2	2.1	Rock supports				
		(a) Rockbolts - 3m long	no	0.00	R 437.04	R 0
		(c) Rock anchors - 20m long, 25mm	no	0.00	R 218.52	R 0
		(d) Shotcrete and mesh - 75 mm long	m^2	0.00	R 299.50	R 0
					R 0.00	
3		ACCESS BRIDGE				
	3.1	Formwork				
		(a) Smooth vertical	m^2	969.80	R 488.46	R 473 706
		(b) Smooth horizontal	m^2	641.20	R 488.46	R 313 199
		(c) Smooth balustrade	m^2	0.00	R 730.12	R 0
	3.2	Unformed surface finish	m^2	641.20	R 14.14	R 9 066
	3.3	Reinforcing				R 0
		(a) Mild steel	t	0.00	R 12 854.15	R 0
		(b) High yield steel	t	85.12	R 13 419.74	R 1 142 288
		(c) Mesh	t	0.00	R 59.13	R 0
	3.4	Concrete				
		(a) Mass	m^3	0.00	R 1 156.87	R 0
		(b) Structural	m^3	841.50	R 1 413.96	R 1 189 845
	3.5	Miscellaneous				
		(a) Bridge bearings	No	4.00	R 16 196.23	R 64 785
		(b) Joints	m	4.00	R 170.96	R 684
		(c) Other e.g.. Rainwater goods, ducting, etc	Sum	0.00	R 102 833.23	R 0
4		INTAKE TOWER AND OUTLET WORKS				
	4.1	Drilling and grouting				
		(a) Consolidation grouting	m drill	0.00	R 287.93	R 0
	4.2	Formwork				
		(a) Smooth vertical - curved and plain	m^2	9 678.00	R 591.29	R 5 722 515
		(b) Smooth horizontal	m^2	610.00	R 591.29	R 360 688
		(c) Intricate	m^2	0.00	R 1 619.62	R 0
		(d) Form openings	m^2	0.00	R 796.96	R 0
	4.3	Uniform surface finish	m^2	760.00	R 14.65	R 11 137
	4.4	Reinforcing				
		(a) Mild steel	t	0.00	R 14 139.57	R 0
		(b) High yield steel	t	639.00	R 13 419.74	R 8 575 211
		(c) Mesh	t	0.00	R 64.27	R 0
		(d) Mechanical rebar couples	No	0.00	R 442.18	R 0
	4.5	Concrete				
		(a) Mass	m^3	0.00	R 1 156.87	R 0
		(b) Structural	m^3	6 588.00	R 1 700.00	R 11 199 600
	4.6	Structural Steelwork				
		(a) Steel sections	Sum	1.00	R 2 000 000.00	R 2 000 000
		(b) Sheeting	m^2	0.00	R 0.00	R 0
					R 0.00	
	4.7	Miscellaneous			R 0.00	
		(a) Waterstops	m	0.00	R 951.32	R 0
		(b) Other e.g.. Conduits, outlets, water proofing, etc.	Sum	0.00	R 0.00	R 0
5	5.1	Site works				
		(a) Site access roads	km	1.00	R 0.00	R 0
		(b) Site services	Sum	0.00	R 0.00	R 0
6	6.1	Contractors accommodation				R 0
7	7.1	Mechanical Items				
		(a) Gates and screens	Sum	1.00	R 20 000 000.00	R 20 000 000
		(b) Lifting equipment	Sum	1.00	R 10 000 000.00	R 10 000 000
		(c) Pipework and valves	Sum	1.00	R 15 000 000.00	R 15 000 000
8	8.1	Electrical Installation	Sum	0.00	R 0.00	R 0
SUB-TOTAL CARRIED FORWARD TO SUMMARY						R 76 578 230

Table 3.E.2 (continued)

AECOM SPILLWAY AND CHUTE

ITEM NO	PAYMENT	DESCRIPTION	UNIT	Quantity	Rate	AMOUNT (R)
		SABS 1200 DE				
	8.3.3	Excavation				
		a) Material unsuitable for embankment	m^3	294051	R 51	R 15 119 106
		b) Material suitable for embankment from essential excavations for:				
		2) Spillway	m^3	0	R 0	R 0
		3) Pipe trenches	m^3	0	R 0	R 0
		4) Outlet works	m^3	0	R 0	R 0
		SABS 1200 - GA				
		CONVENTIONAL CONCRETE FOR DAMS				
8	8.1.1	Scheduled Formwork items				
	8.1.1.1	Class F4				
		(a) Verical				
		(i) Chute	m^2	17404	R 334	R 5 816 660
		(b) Sloped				
		(i) Ogee of spillway	m^2	1785	R 411	R 734 290
		(ii) Round	m^2	0	R 411	R 0
		(c) Sloping				
		(i) Stilling basin blocks	m^2	0	R 0	R 0
		(ii) Horizontal	m^2	0	R 0	R 0
	8.1.2	Scheduled Reinforcement Items	t	2448	R 12 854	R 31 472 395
	8.1.2.1	Anchors				
		(a) Anchor bars	m	2572	R 0	R 0
	8.1.3	Scheduled Concrete Items				
	8.1.3.1	Strength & Mass Concrete				
		(a) Grade 25 MPa/19 mm	m^3	37847	R 1 414	R 53 513 638
		(i) Spillway, bridges and retaining wall	m^3	0	R 1 414	R 0
	8.1.3.2	Secondary Concrete				
		(a) Grade 25 MPa/19 mm	m^3	0	R 1 414	R 0
	8.1.3.3	Keyways on contraction joints				
		(a) Bridges dimensions to be given in detail design	m		R 0	R 0
	8.1.3.4	Unformed Surface Finishes				
		Class U2 (Wood-floated) finish				
		(a) Chute and Stilling basin floor	m^2	54137	R 14	R 765 468
		(b) Top of bridges	m^2	0	R 14	R 0
16		**WATERSTOPS, JOINTING AND BEARINGS**				
	16.1	Scheduled items				
		Waterstops				R 0
		(a) 250 mm Centre bulb PVC waterstop	m	1807	R 685	R 1 237 934
	16.2	Joint sealants				
		(a) Chute wall - 12mm expanding cork	m	0	R 0	R 0
		(b) Chute wall - 12m Impregnated Bitumen Fibre board	m	0	R 0	R 0
		(c) Chute wall - 12 x 12 mm Polysulphide sealant	m	0	R 0	R 0
17		**SUB-SOIL DRAINAGE**				
	17.1	Scheduled items				
		Excavating soft material situated within the following depth ranges below the surface level :				
		(a) 0 m to 1,5 m	m^3	782	R 0	R 0
		(b) Extra over sub-item (a), irrespective of depth, for:				
		(i) Excavation in hard material	m^3	0	R 0	R 0
	17.2	Natural permeable material in sub-soil drainage systems				
		(a) Sand as specified on detail drawings	m^3	738	R 0	R 0
	17.3	Pipes in sub-soil drainage system				
		(a) 110 NB, Class 6, HDPE pressure pipe, non perforated, complying with SANS 533, Part II	m	0	R 0	R 0
		(b) 75 NB, flexible slotted drainage pipes with smooth bore, "Drainex" or equivalent by Kaytech	m	2171	R 0	R 0
	17.4	Caps to higher ends of sub-surface drain pipes				
		(a) High end of pipes of Drainex pipes	No	0	R 0	R 0
	17.5	Concrete outlet structures for sub-soil drainage systems complete as per drawings				
		(a) Concrete 1500 mm dia	No	0	R 0	R 0
	17.6	Overhaul for material hauled in excess of 1.0 km freehaul				
		(a) Sand for filter material (10 km)	$m^3.km$	0	R 0	R 0
						R 0
TOTAL CARRIED FORWARD TO SUMMARY						R 108 659 490

Table 3.E.2 (continued)

AECOM SADDLE DAM BILL OF QUANTITIES

Left flank:		Earthfill				
River section:		Earthfill				
Right flank:		Earthfill				
				Quantity	Rate	Cost
	SABS 1200 DE					
1	8.3.1	**Site clearance**				
					0	
1.1	8.3.1.1	Clear and strip site	Ha	10	23250	224 611.77
1.2	8.3.1.1	Remove and grub large trees(Complet with stumps) or stumps only, as scheduled, of girth				
		(a) over 1m and up to and including 2m	No	0	0	0.00
		(b) over 2m and up to and including 3m	No	0	0	0.00
		(c) over 3m, in increments of 1m	No	0	0	0.00
1.3	8.3.1.3	Extra-over 8.3.1.1 for removal of rocks, etc., as specified in SABS 1200 DE Para. 5.2.1.1 (c)	m^3	0	0	0.00
1.4	8.3.1.4	Extra-over 8.3.1.1 for removal and recovering of fencing	m^3	0	0	0.00
1.5	8.3.1.5	Extra-over 8.3.1.1 for recovering other scheduled material	m^3	0	0	0.00
1.6	8.3.1.6	Clearing of the basin	Ha	0	23250	0.00
2	8.3.2	Remove topsoil to nominal depth 150mm, stockpile and maintain	m^2	96 607	20	1 932 144.25
3	8.3.3	**Excavation**				
3.1		a) Material unsuitable for embankment	m^3	221 318	31.6	6 993 638.53
3.2		b) Material suitable for embankment from essential excavations for:				
		1) Core trench	m^3	0	0	0.00
		2) Spillway	m^3	0	0	0.00
		3) Pipe trenches	m^3	0	0	0.00
		4) Outlet works	m^3	0	0	0.00
		Extra over (b) (1) - (4) for excavation in:				
		1) Intermediate material	m^3	0	0	0.00
		2) Hard rock material	m^3	0	36.5	0.00
3.4	8.3.4	Preparation of exposed surfaces				
		a) Core trench				
		b) Area to be covered by dam wall	m^2	124 197	92.55	11 494 476.76
3.5	8.3.5	**Forming Embankment**				
		a) Selected impervious material (Clay material)	m^3	299 113	48.37	14 468 107.04
		b) Transition	m^3	18 138	97.94	1 776 403.89
		c) Unselected pervious material				
		i) Earthfill	m^3	772 753	48.37	37 378 075.29
		ii) Rockfill - Type 1 (Outer zone)	m^3	0	91	0.00
		iii) Rockfill - Type 2 (Inner zone)	m^3	0	91	0.00
		d) Rip-rap	m^3	18 138	438.52	7 953 733.24
		e) Topsoil from stockpile to downstream slope	m^3	0	0	0.00
		f) Coarse filter material	m^3	29 116	789.45	22 985 571.93
		g) Fine filter material	m^3	29 116	789.45	22 985 571.93
		h) Gravel capping	m^3	7 255	91	660 211.37
3.6		**Concrete Works**				
3.6.1		(a) Formwork				
		(i) Gang formed	m	0	475	0.00
		(ii) Intricate	m	0	480	0.00
3.6.2		(b) Concrete				
		(i) Rollcrete	m^3	0	1156.76	0.00
		(ii) IVRCC	m^2	0	45.4	0.00
		(iii) CVC	m^3	0	1981.85	0.00
		(iv) Mass	m^3	0	1981.85	0.00
3.6.3		(c) Reinforcing	t	0	12854.15	0.00
3.6.4		(d) Waterstop	m	0	944.69	0.00
3.7		**Drilling & Grouting**				
3.7.1		(a) Curtain grouting	m	6 067	1054.15	6 395 198.10
3.7.2		(b) Consolidation grouting	m	5 500	1054.15	5 797 825.00
Total						141 045 569

Table 3.E.3: Preliminary cost estimation for 150 m main and 100 m fuse plug

AECOM	MAIN DAM BILL OF QUANTITIES			Main side channel spillway L = 150m		
Left flank:		ECRD				
River section:		ECRD				
Right flank:		ECRD				
				Quantity	Rate	Cost
	SABS 1200 DE					
1	8.3.1	**Site clearance**				
					0	
1.1	8.3.1.1	Clear and strip site	Ha	17	23250	392 611.18
1.2	8.3.1.1	Remove and grub large trees(Complet with stumps) or stumps only, as scheduled, of girth				
		(a) over 1m and up to and including 2m	No	0	0	0.00
		(b) over 2m and up to and including 3m	No	0	0	0.00
		(c) over 3m, in increments of 1m	No	0	0	0.00
1.3	8.3.1.3	Extra-over 8.3.1.1 for removal of rocks, etc., as specified in SABS 1200 DE Para. 5.2.1.1 (c)	m^3	0	0	0.00
1.4	8.3.1.4	Extra-over 8.3.1.1 for removal and recovering of fencing	m^3	0	0	0.00
1.5	8.3.1.5	Extra-over 8.3.1.1 for recovering other scheduled material	m^3	0	0	0.00
1.6	8.3.1.6	Clearing of the basin	Ha	0	23250	0.00
2	8.3.2	Remove topsoil to nominal depth 150mm, stockpile and maintain	m^2	168 865	20	3 377 300.51
3	8.3.3	**Excavation**				
3.1		a) Material unsuitable for embankment	m^3	1 171 985	31.6	37 034 719.44
3.2		b) Material suitable for embankment from essential excavations for:				
		1) Core trench	m^3	0	0	0.00
		2) Spillway	m^3	0	0	0.00
		3) Pipe trenches	m^3	0	0	0.00
		4) Outlet works	m^3	0	0	0.00
		Extra over (b) (1) - (4) for excavation in:				
		1) Intermediate material	m^3	0	0	0.00
		2) Hard rock material	m^3	0	36.5	0.00
3.4	8.3.4	Preparation of exposed surfaces				
		a) Core trench				
		b) Area to be covered by dam wall	m^2	169 314	92.55	15 670 019.99
3.5	8.3.5	**Forming Embankment**				
		a) Selected impervious material (Clay material)	m^3	833 580	48.37	40 320 254.87
		b) Transition	m^3	0	97.94	0.00
		c) Unselected pervious material				
		i) Earthfill	m^3	0	48.37	0.00
		ii) Rockfill - Type 1 (Outer zone)	m^3	3 380 523	91	307 627 576.72
		iii) Rockfill - Type 2 (Inner zone)	m^3	0	91	0.00
		d) Rip-rap	m^3	0	438.52	0.00
		e) Topsoil from stockpile to downstream slope	m^3	0	0	0.00
		f) Coarse filter material	m^3	65 176	789.45	51 452 937.60
		g) Fine filter material	m^3	65 176	789.45	51 452 937.60
		h) Gravel capping	m^3	0	91	0.00
3.6		**Concrete Works**				
3.6.1		(a) Formwork				
		(i) Gang formed	m	0	475	0.00
		(ii) Intricate	m	0	480	0.00
3.6.2		(b) Concrete				
		(i) Rollcrete	m^3	0	1156.76	0.00
		(ii) IVRCC	m^2	0	45.4	0.00
		(iii) CVC	m^3	0	1981.85	0.00
		(iv) Mass	m^3	0	1981.85	0.00
3.6.3		(c) Reinforcing	t	0	12854.15	0.00
3.6.4		(d) Waterstop	m	0	944.69	0.00
3.7		**Drilling & Grouting**				
3.7.1		(a) Curtain grouting	m	15 098	1054.15	15 915 186.45
3.7.2		(b) Consolidation grouting	m	5 750	1054.15	6 061 362.50
Total						529 304 907

Table 3.E.3 (continued)

AECOM SADDLE DAM BILL OF QUANTITIES

Left flank:		Earthfill				
River section:		Earthfill				
Right flank:		Earthfill				
				Quantity	Rate	Cost
	SABS 1200 DE					
1	8.3.1	**Site clearance**				
					0	
1.1	8.3.1.1	Clear and strip site	Ha	10	23250	221 926.39
1.2	8.3.1.1	Remove and grub large trees(Complet with stumps) or stumps only, as scheduled, of girth				
		(a) over 1m and up to and including 2m	No	0	0	0.00
		(b) over 2m and up to and including 3m	No	0	0	0.00
		(c) over 3m, in increments of 1m	No	0	0	0.00
1.3	8.3.1.3	Extra-over 8.3.1.1 for removal of rocks, etc., as specified in SABS 1200 DE Para. 5.2.1.1 (c)	m^3	0	0	0.00
1.4	8.3.1.4	Extra-over 8.3.1.1 for removal and recovering of fencing	m^3	0	0	0.00
1.5	8.3.1.5	Extra-over 8.3.1.1 for recovering other scheduled material	m^3	0	0	0.00
1.6	8.3.1.6	Clearing of the basin	Ha	0	23250	0.00
2	8.3.2	Remove topsoil to nominal depth 150mm, stockpile and maintain	m^2	95 452	20	1 909 044.25
3	8.3.3	**Excavation**				
3.1		a) Material unsuitable for embankment	m^3	218 868	31.6	6 916 218.53
3.2		b) Material suitable for embankment from essential excavations for:				
		1) Core trench	m^3	0	0	0.00
		2) Spillway	m^3	0	0	0.00
		3) Pipe trenches	m^3	0	0	0.00
		4) Outlet works	m^3	0	0	0.00
		Extra over (b) (1) - (4) for excavation in:				
		1) Intermediate material	m^3	0	0	0.00
		2) Hard rock material	m^3	0	36.5	0.00
3.4	8.3.4	Preparation of exposed surfaces				
		a) Core trench				
		b) Area to be covered by dam wall	m^2	122 647	92.55	11 350 933.58
3.5	8.3.5	**Forming Embankment**				
		a) Selected impervious material (Clay material)	m^3	294 107	48.37	14 225 940.94
		b) Transition	m^3	17 928	97.94	1 755 836.49
		c) Unselected pervious material				
		i) Earthfill	m^3	757 343	48.37	36 632 673.88
		ii) Rockfill - Type 1 (Outer zone)	m^3	0	91	0.00
		iii) Rockfill - Type 2 (Inner zone)	m^3	0	91	0.00
		d) Rip-rap	m^3	17 928	438.52	7 861 644.04
		e) Topsoil from stockpile to downstream slope	m^3	0	0	0.00
		f) Coarse filter material	m^3	28 748	789.45	22 695 449.05
		g) Fine filter material	m^3	28 748	789.45	22 695 449.05
		h) Gravel capping	m^3	7 171	91	652 567.37
3.6		**Concrete Works**				
3.6.1		(a) Formwork				
		(i) Gang formed	m	0	475	0.00
		(ii) Intricate	m	0	480	0.00
3.6.2		(b) Concrete				
		(i) Rollcrete	m^3	0	1156.76	0.00
		(ii) IVRCC	m^3	0	45.4	0.00
		(iii) CVC	m^3	0	1981.85	0.00
		(iv) Mass	m^3	0	1981.85	0.00
3.6.3		(c) Reinforcing	t	0	12854.15	0.00
3.6.4		(d) Waterstop	m	0	944.69	0.00
3.7		**Drilling & Grouting**				
3.7.1		(a) Curtain grouting	m	5 994	1054.15	6 318 666.81
3.7.2		(b) Consolidation grouting	m	5 500	1054.15	5 797 825.00
Total						139 034 175

Table 3.E.3 (continued)

AECOM DIVERSION WORKS

ITEM NO	PAYMENT		UNIT	Quantity	Rate (R)	AMOUNT (R)
		STAGE 1: PORTALS AND TUNNELS				
1	**1.0**	**SITE CLEARANCE**				
	1.1	**Clear and grub**				
		(a) Portal footprints	ha	0.12	R 23 250.00	R 2 794.38
	1.2	**Remove and grub large trees and tree stumps of girth**				
		(a) Over 1 m and up to and including 2m	No	0.00	R 0.00	R 0.00
	1.3	**Remove topsoil to nominal depth of 150 mm and stockpile**	m³	1 201.89	R 10.28	R 12 355.39
2	**2.0**	**EXCAVATION AND BACKFILL FOR DAMS AND WATERWAYS**				
		Bulk Excavation				
	2.1	**Inlet portal**				
		(a) Excavate in all materials				
		(i) Excavation (stockpile)	m³	3 025.00	R 91.00	R 275 275.00
		(b) Extra over for:				
		(i) Intermediate	m³	302.50	R 0.00	
		(ii) Hard Rock	m³	302.50	R 31.60	R 9 559.00
		(iii) Boulder, Class A	m³	0.00	R 0.00	R 0.00
		(iv) Boulder, Class B	m³	0.00	R 0.00	R 0.00
	2.2	**Outlet Portal**				
		(a) Excavate in all materials				
		(i) Excavation (stockpile)	m³	3 025.00	R 91.00	R 275 275.00
		(b) Extra over for:				
		(i) Intermediate	m³	302.50	R 0.00	
		(ii) Hard Rock	m³	302.50	R 31.60	R 9 559.00
		(iii) Boulder, Class A	m³	0.00	R 0.00	R 0.00
		(iv) Boulder, Class B	m³	0.00	R 0.00	R 0.00
	2.3	**Dewatering**	Sum	0.00	R 0.00	R 0.00
		SUB TOTAL: STAGE 1				R 584 817.77
		STAGE 2 Cofferdam				
3		**SITE CLEARANCE**				
	3.1	**Clear and grub**				
		(a) Embankment footprint	ha	0.52	R 26 546.00	R 13 910
	3.2	Remove and grub large trees and tree stumps of girth				
		(a) over 1 m and up to and including 2 m	No	0.00	R 0.00	R 0
	3.3	Remove topsoil to nominal depth of 150 mm and stockpile	m³	5 240.00	R 10.28	R 53 867
4	**4.1**	**EXCAVATIONS AND BACKFILL FOR DAMS AND WATERWAYS**				
		(a) Excavate all materials				
		(i) Topsoil at Upstream & Downstream cofferdam	m³	5 240.00	R 51.42	R 269 441
5	**5.1**	**EMBANKMENT CONSTRUCTION**				
		Earthfill Upstream & Downstream Cofferdam Construction.				
		(a) Forming Embankment				
		Using material from designated borrow areas or commercial sources				
		(i) Soil cement at 3% cement	m³	2 860.00	R 300.00	R 858 000
		(ii) Rockfill	m³	22 140.00	R 91.00	R 2 014 740
		SUB TOTAL: COFFERDAM				R 3 209 958
6		**TUNNEL CONSTRUCTION**				
	6.1	TUNNEL EXCAVATION				
		(a) Tunnel	m³	14 872.30	R 2 700.00	R 40 155 209
	6.2	ROCK SUPPORT				
		(a) Rockbolts	m	4 208.00	R 50.00	R 210 400
		(b) Shotcrete	m³	3 304.96	R 3 350.00	R 11 071 601
		(c) Reinforcing mesh	m²	3 304.96	R 35.00	R 115 673
	6.3	DEWATERING	Sum	1.00	R 100 000.00	R 100 000
		SUB TOTAL: TUNNEL				R 51 652 883
		SUB TOTAL: STAGE 1 + STAGE 2				R 55 447 659
		STAGE 3				
7		**MEDIUM PRESSURE PIPELINES**				
		Supply, lay, and bed pipes complete with couplings				
		(a) 500 mm diameter concrete pipe (class 75D) in concrete	m	0.00	R 0.00	R 0
		(b) Water control in tunnel	Prov Sum	0.00	R 0.00	R 0
8		**PLUG OF TUNNEL**				
	8.1	Scheduled Formwork items- Class 1				
		(a) Vertical formwork	m²	0.00	R 591.29	R 0
	8.2	Scheduled Concrete items				
		Strength and Mass concrete				
		(a) Sealing of bulkheads shaft with mass concrete 25 Mpa/19 mm	m³	0.00	R 0.00	R 0
		(b) Plug 25 MPa/19 mm	m³	0.00		R 0
	8.3	Joints				
		(a) Swellable water stops	m	0.00	R 951.32	R 0
	8.4	Miscellaneous and Sundry items				
		(a) Bulkheads incl reinforcement at 120 kg/m³	No	0.00	R 0.00	R 0
		Sub total: STAGE 3				R 0
TOTAL CARRIED FORWARD TO SUMMARY						**R 55 447 659**

Table 3.E.3 (continued)

AECOM INLET AND OUTLET WORKS

ITEM NO	PAYMENT		UNIT	Quantity	Rate (R)	AMOUNT (R)
1	1.1	Earthworks				
		(a) Clearing and grubbing	ha	0.08	R 23 250.00	R 1 907
		(b) Excavation - soft	m^3	1 070.00	R 180.00	R 192 600
		(c) Excavation - rock	m^3	1 070.00	R 300.00	R 321 000
		(d) Rockfill to abutments	m^3	0.00	R 50.39	R 0
2	2.1	Rock supports				
		(a) Rockbolts - 3m long	no	0.00	R 437.04	R 0
		(c) Rock anchors - 20m long, 25mm	no	0.00	R 218.52	R 0
		(d) Shotcrete and mesh - 75 mm long	m^2	0.00	R 299.50	R 0
					R 0.00	
3		ACCESS BRIDGE				
	3.1	Formwork				
		(a) Smooth vertical	m^2	968.00	R 488.46	R 472 827
		(b) Smooth horizontal	m^2	640.00	R 488.46	R 312 613
		(c) Smooth balustrade	m^2	0.00	R 730.12	R 0
	3.2	Unformed surface finish	m^2	640.00	R 14.14	R 9 049
	3.3	Reinforcing				R 0
		(a) Mild steel	t	0.00	R 12 854.15	R 0
		(b) High yield steel	t	84.00	R 13 419.74	R 1 127 256
		(c) Mesh	t	0.00	R 59.13	R 0
	3.4	Concrete				
		(a) Mass	m^3	0.00	R 1 156.87	R 0
		(b) Structural	m^3	840.00	R 1 413.96	R 1 187 724
	3.5	Miscellaneous				
		(a) Bridge bearings	No	4.00	R 16 196.23	R 64 785
		(b) Joints	m	4.00	R 170.96	R 684
		(c) Other e.g.. Rainwater goods, ducting, etc	Sum	0.00	R 102 833.23	R 0
4		INTAKE TOWER AND OUTLET WORKS				
	4.1	Drilling and grouting				
		(a) Consolidation grouting	m drill	0.00	R 287.93	R 0
	4.2	Formwork				
		(a) Smooth vertical - curved and plain	m^2	9 658.00	R 591.29	R 5 710 689
		(b) Smooth horizontal	m^2	609.00	R 591.29	R 360 096
		(c) Intricate	m^2	0.00	R 1 619.62	R 0
		(d) Form openings	m^2	0.00	R 796.96	R 0
	4.3	Uniform surface finish	m^2	759.00	R 14.65	R 11 122
	4.4	Reinforcing				
		(a) Mild steel	t	0.00	R 14 139.57	R 0
		(b) High yield steel	t	639.00	R 13 419.74	R 8 575 211
		(c) Mesh	t	0.00	R 64.27	R 0
		(d) Mechanical rebar couples	No	0.00	R 442.18	R 0
	4.5	Concrete				
		(a) Mass	m^3	0.00	R 1 156.87	R 0
		(b) Structural	m^3	6 588.00	R 1 700.00	R 11 199 600
	4.6	Structural Steelwork				
		(a) Steel sections	Sum	1.00	R 2 000 000.00	R 2 000 000
		(b) Sheeting	m^2	0.00	R 0.00	R 0
					R 0.00	
	4.7	Miscellaneous			R 0.00	
		(a) Waterstops	m	0.00	R 951.32	R 0
		(b) Other e.g.. Conduits, outlets, water proofing, etc.	Sum	0.00	R 0.00	R 0
5	5.1	Site works				
		(a) Site access roads	km	1.00	R 0.00	R 0
		(b) Site services	Sum	0.00	R 0.00	R 0
6	6.1	Contractors accommodation				R 0
7	7.1	Mechanical Items				
		(a) Gates and screens	Sum	1.00	R 20 000 000.00	R 20 000 000
		(b) Lifting equipment	Sum	1.00	R 10 000 000.00	R 10 000 000
		(c) Pipework and valves	Sum	1.00	R 15 000 000.00	R 15 000 000
8	8.1	Electrical Installation	Sum	0.00	R 0.00	R 0
TOTAL CARRIED FORWARD TO SUMMARY						R 76 547 165

Table 3.E.3 (continued)

AECOM SPILLWAY AND CHUTE

ITEM NO	PAYMENT	DESCRIPTION	UNIT	Quantity	Rate	AMOUNT (R)
		SABS 1200 DE				
	8.3.3	Excavation				
		a) Material unsuitable for embankment	m^3	203001	R 51	R 10 437 645
		b) Material suitable for embankment from essential excavations for:				
		2) Spillway	m^3	0	R 0	R 0
		3) Pipe trenches	m^3	0	R 0	R 0
		4) Outlet works	m^3	0	R 0	R 0
		SABS 1200 - GA				
		CONVENTIONAL CONCRETE FOR DAMS				
8	8.1.1	Scheduled Formwork items				
	8.1.1.1	Class F4				
		(a) Verical				
		(i) Chute	m^2	17176	R 334	R 5 740 280
		(b) Sloped				
		(i) Ogee of spillway	m^2	1457	R 411	R 599 226
		(ii) Round	m^2	0	R 411	R 0
		(c) Sloping				
		(i) Stilling basin blocks	m^2	0	R 0	R 0
		(ii) Horizontal	m^2	0	R 0	R 0
	8.1.2	Scheduled Reinforcement items	t	1565	R 12 854	R 20 111 846
	8.1.2.1	Anchors				
		(a) Anchor bars	m	1669	R 0	R 0
	8.1.3	Scheduled Concrete items				
	8.1.3.1	Strength & Mass Concrete				
		(a) Grade 25 MPa/19 mm	m^3	27091	R 1 414	R 38 306 006
		(i) Spillway, bridges and retaining wall	m^3	0	R 1 414	R 0
	8.1.3.2	Secondary Concrete				
		(a) Grade 25 MPa/19 mm	m^3	0	R 1 414	R 0
	8.1.3.3	Keyways on contraction joints				
		(a) Bridges dimensions to be given in detail design	m		R 0	R 0
	8.1.3.4	Unformed Surface Finishes				
		Class U2 (Wood-floated) finish				
		(a) Chute and Stilling basin floor	m^2	36854	R 14	R 521 100
		(b) Top of bridges	m^2	0	R 14	R 0
16		**WATERSTOPS, JOINTING AND BEARINGS**				
	16.1	Scheduled Items				
		Waterstops				R 0
		(a) 250 mm Centre bulb PVC waterstop	m	1242	R 685	R 850 713
	16.2	Joint sealants				
		(a) Chute wall - 12mm expanding cork	m	0	R 0	R 0
		(b) Chute wall - 12m Impregnated Bitumen Fibre board	m	0	R 0	R 0
		(c) Chute wall - 12 x 12 mm Polysulphide sealant	m	0	R 0	R 0
17		**SUB-SOIL DRAINAGE**				
	17.1	Scheduled Items				
		Excavating soft material situated within the following depth ranges below the surface level:				
		(a) 0 m to 1,5 m	m^3	579	R 0	R 0
		(b) Extra over sub-item (a), irrespective of depth, for:				
		(i) Excavation in hard material	m^3	0	R 0	R 0
	17.2	Natural permeable material in sub-soil drainage systems				
		(a) Sand as specified on detail drawings	m^3	546	R 0	R 0
	17.3	Pipes in sub-soil drainage system				
		(a) 110 NB, Class 6, HDPE pressure pipe, non perforated, complying with SANS 533, Part II	m	0	R 0	R 0
		(b) 75 NB, flexible slotted drainage pipes with smooth bore, "Drainex" or equivalent by Kaytech	m	1607	R 0	R 0
	17.4	Caps to higher ends of sub-surface drain pipes				
		(a) High end of pipes of Drainex pipes	No	0	R 0	R 0
	17.5	Concrete outlet structures for sub-soil drainage systems complete as per drawings				
		(a) Concrete 1500 mm dia	No	0	R 0	R 0
	17.6	Overhaul for material hauled in excess of 1.0 km freehaul				
		(a) Sand for filter material (10 km)	$m^3.km$	0	R 0	R 0
						R 0
TOTAL CARRIED FORWARD TO SUMMARY						R 76 566 817

Table 3.E.3 (continued)

AECOM FUSE PLUG SPILLWAY BILL OF QUANTITIES Main spillway L = 150m

				Quantity	Rate	Cost
	SABS 1200 DE					
1	8.3.1	**Site clearance**			**Measured in Saddle Dam BoQ**	
					0	
3	8.3.3	**Excavation**			**Measured in Saddle Dam BoQ**	
3.5	8.3.5	**Forming Embankment**				
		a) Selected impervious material (Clay material)	m^3	4 390	48.37	212 344.30
		b) Transition	m^3	0	97.94	0.00
		c) Unselected pervious material				
		i) Earthfill	m^3	0	48.37	0.00
		ii) Rockfill - Type 1 (Outer zone)	m^3	2 580	91	234 780.00
		iii) Rockfill - Type 2 (Inner zone)	m^3	0	91	0.00
		d) Rip-rap	m^3	2 120	438.52	929 662.40
		e) Topsoil from stockpile to downstream slope	m^3	0	0	0.00
		f) Coarse filter material	m^3	2 430	789.45	1 918 363.50
		g) Fine filter material	m^3	3 920	789.45	3 094 644.00
		h) Gravel capping	m^3	2 120	91	192 920.00
3.6		**Concrete Works**				
3.6.1		(a) Formwork				
		(i) Gang formed*	m	2 180	475	1 035 500.00
		(ii) Intricate*	m	2 704	480	1 297 920.00
3.6.2		(b) Concrete				
		(i) Rollcrete	m^3	0	1156.76	0.00
		(ii) IVRCC	m^2	0	45.4	0.00
		(iii) CVC*	m^3	3 432	1981.85	6 801 709.20
		(iv) Mass	m^3	1 440	1981.85	2 853 864.00
3.6.3		(c) Reinforcing	t	412	12854.15	5 293 853.14
3.6.4		(d) Waterstop	m	0	944.69	0.00
3.7		**Drilling & Grouting**			**Measured in Saddle Dam BoQ**	
Total						**23 865 561**

**including parapet wall for main and saddle embankments*

Table 3.E.4: Routed SEF for main spillway with fuse plug

Main spillway length= 100m with 100m fuse plug			
Time (hr)	Inflow (m^3/s)	Outflow (m^3/s)	Level (masl)
0	0	0	930
1.05	30.85	0.69	930.01
2.15	70.76	2.87	930.02
3.25	175.7	8.19	930.07
4.35	377.77	20.05	930.16
5.45	762.86	44.38	930.36
6.55	1379.98	118.55	930.74
7.65	2177.17	292.77	931.35
8.74	3060.82	626.57	932.19
9.84	3943.01	1151.65	933.21
10.94	4608.07	3090.04	934.09
12.04	5086.77	3773.01	934.64
13.14	5429.9	4360.06	935.09
14.24	5625.32	4794.29	935.42
15.34	5601.39	5118.13	935.65
16.44	**5295.45**	**5249.17**	**935.74**
17.54	4765.58	5162.02	935.68
18.64	4116.53	4875.69	935.48
19.74	3443.97	4464.48	935.17
20.84	2933.86	3958.96	934.78
21.94	2571.97	3479.01	934.41
23.04	2280.54	3079.33	934.08
24.14	2037.18	2427.85	933.86
25.24	1826.13	2067.15	933.74
26.34	1643.97	1821.9	933.66
27.44	1481.66	1629.35	933.6
28.54	1336.12	1464.88	933.55
29.64	1205.49	1320.03	933.5
30.74	1088.34	1283.91	933.44
31.84	983.78	1233.5	933.35
32.94	890.75	1173.49	933.25
34.04	808.49	1108.01	933.14
35.14	734.84	1040.06	933.02
36.24	667.9	976.97	932.9
37.34	606.15	914.46	932.78
38.44	549.43	852.64	932.66
39.54	498.3	792.21	932.54
40.64	449.58	737.74	932.43
41.74	404.22	686.73	932.32
42.84	360.47	636.87	932.21
43.94	320.78	588.31	932.11
45.04	281.9	541.3	932
46.14	246.27	501.62	931.9
47.24	211.44	462.8	931.81
48.34	179.41	424.8	931.71
49.44	148.66	387.68	931.62
50.54	119.79	351.65	931.52
51.64	94.36	321.17	931.44
52.74	71.35	293.13	931.35
53.84	52.85	265.9	931.26

Table 3.E.4 (continued)

Main spillway length= 150m with 100m fuse plug			
Time (hr)	**Inflow (m^3/s)**	**Outflow (m^3/s)**	**Level (masl)**
0	0	0	930
1.05	30.85	1.06	930.01
2.15	70.76	4.39	930.02
3.25	175.7	12.45	930.07
4.35	377.77	30.34	930.16
5.45	762.86	66.96	930.35
6.55	1379.98	173.61	930.72
7.65	2177.17	421.34	931.29
8.74	3060.82	875.47	932.06
9.84	3943.01	1559.55	932.95
10.94	4608.07	3070.15	933.8
12.04	5086.77	4227.89	934.21
13.14	5429.9	4721.21	934.51
14.24	5625.32	5131.27	934.75
15.34	5601.39	5380.47	934.89
16.44	**5295.45**	**5415.56**	**934.91**
17.54	4765.58	5218.72	934.8
18.64	4116.53	4820.2	934.57
19.74	3443.97	4315.37	934.26
20.84	2933.86	3569.36	933.94
21.94	2571.97	2937.34	933.76
23.04	2280.54	2536.56	933.64
24.14	2037.18	2237.78	933.55
25.24	1826.13	2034.18	933.48
26.34	1643.97	1943.1	933.38
27.44	1481.66	1828.38	933.25
28.54	1336.12	1702.2	933.12
29.64	1205.49	1575.16	932.97
30.74	1088.34	1458.01	932.83
31.84	983.78	1342.74	932.69
32.94	890.75	1232.11	932.55
34.04	808.49	1134.72	932.42
35.14	734.84	1046.11	932.3
36.24	667.9	961.98	932.18
37.34	606.15	882.61	932.07
38.44	549.43	811.57	931.97
39.54	498.3	750.39	931.87
40.64	449.58	691.74	931.77
41.74	404.22	635.44	931.68
42.84	360.47	581.75	931.59
43.94	320.78	530.54	931.51
45.04	281.9	489.4	931.43
46.14	246.27	449.72	931.35
47.24	211.44	410.77	931.27
48.34	179.41	372.85	931.19
49.44	148.66	336.01	931.12
50.54	119.79	300.49	931.05
51.64	94.36	269.05	930.98
52.74	71.35	244.57	930.91
53.84	52.85	220.53	930.85

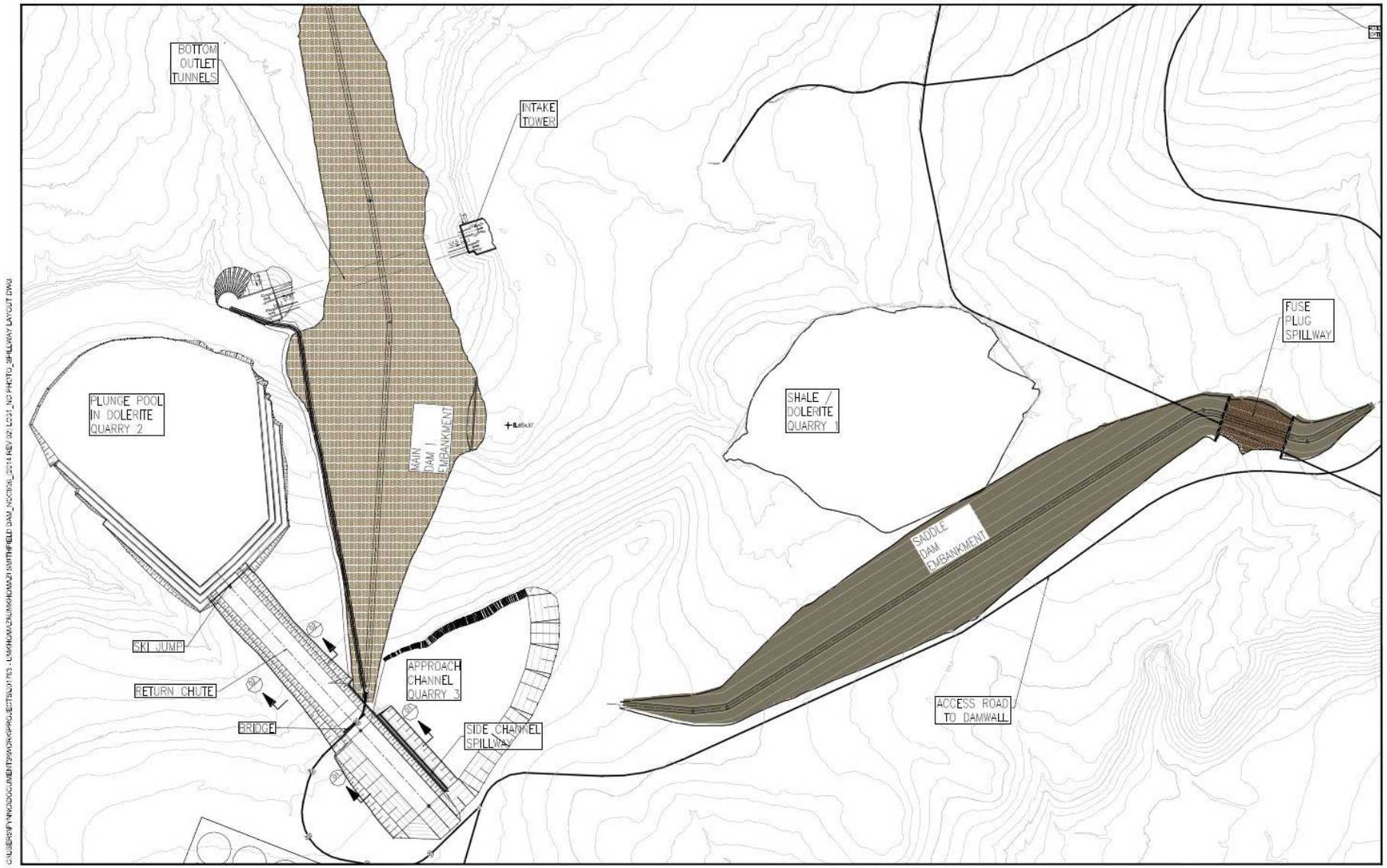


Figure 3.E.3: Smithfield Dam spillway layout

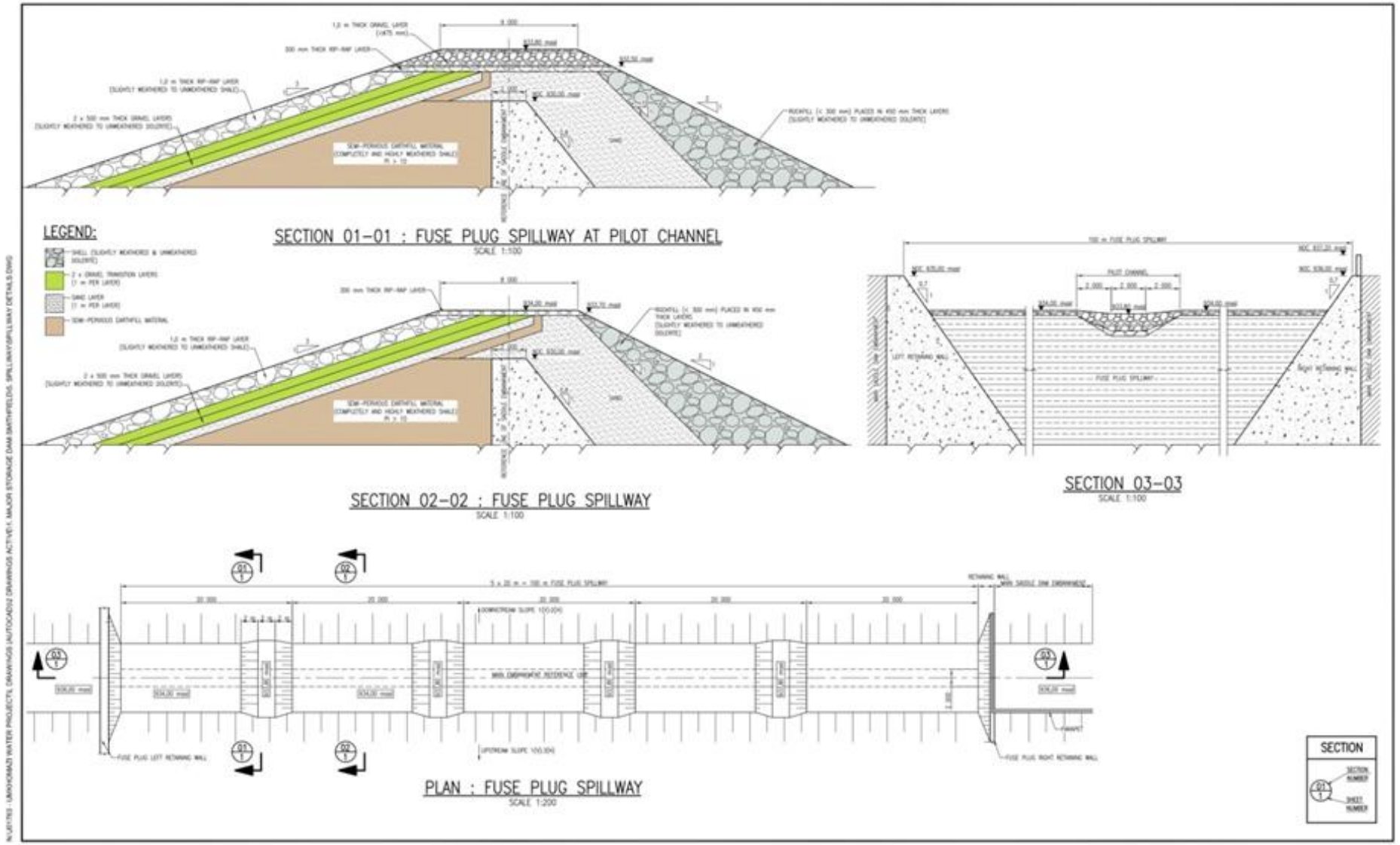


Figure 3.E.4: Fuse plug layout and design

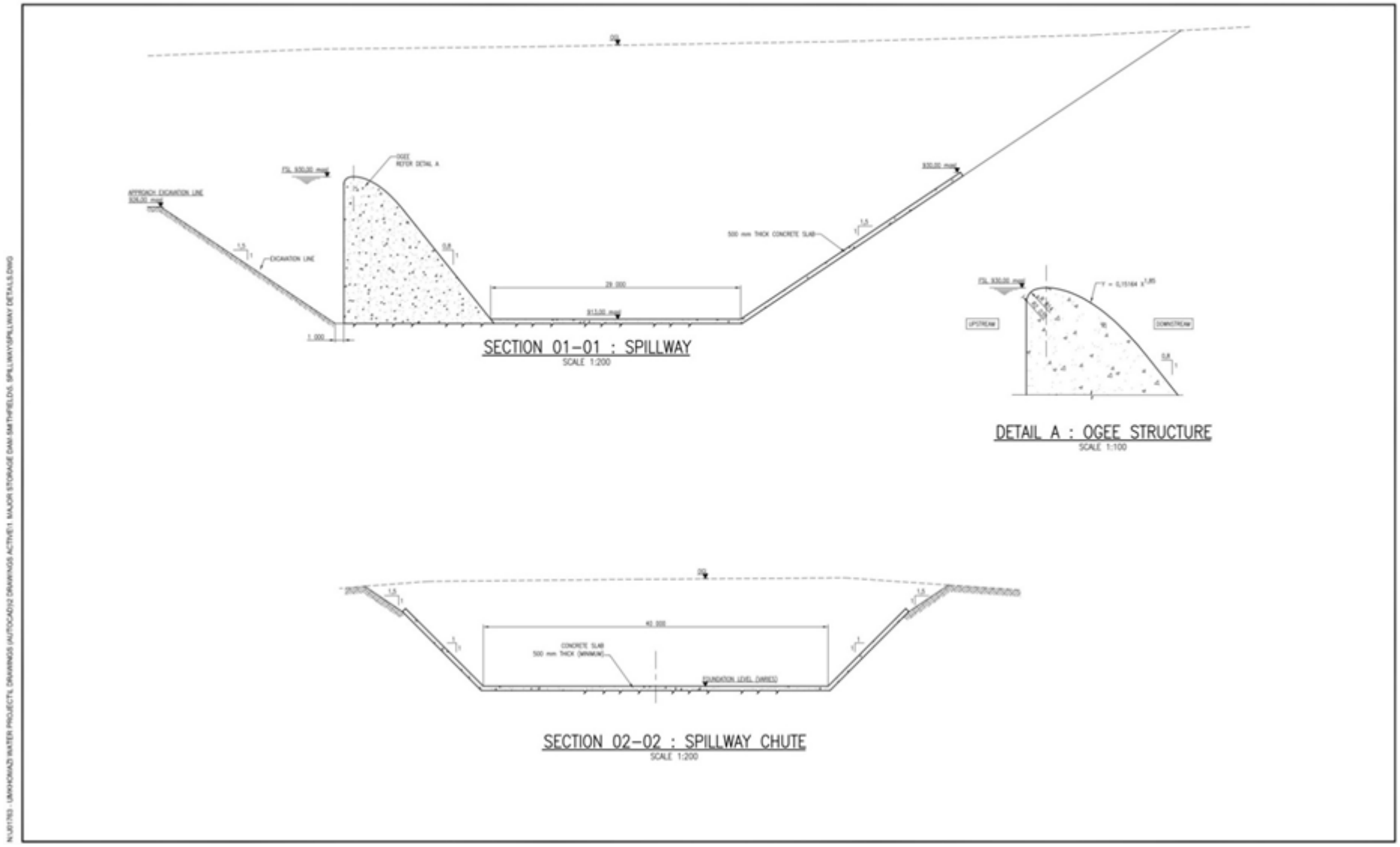


Figure 3.E.5: Chute design

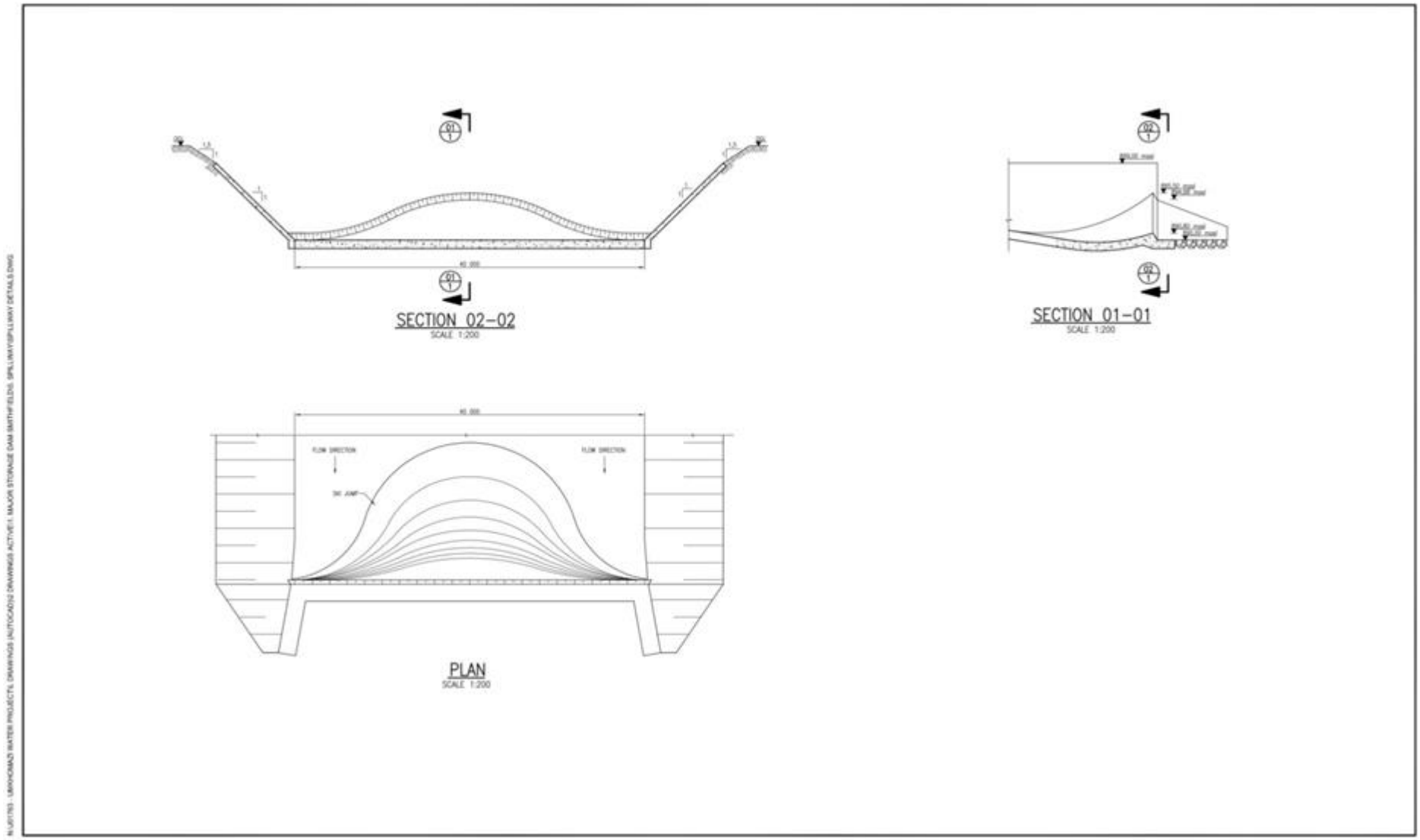


Figure 3.E.6: Ski jump layout

Annexure 3 F – Smithfield dam: Embankment layout and sections

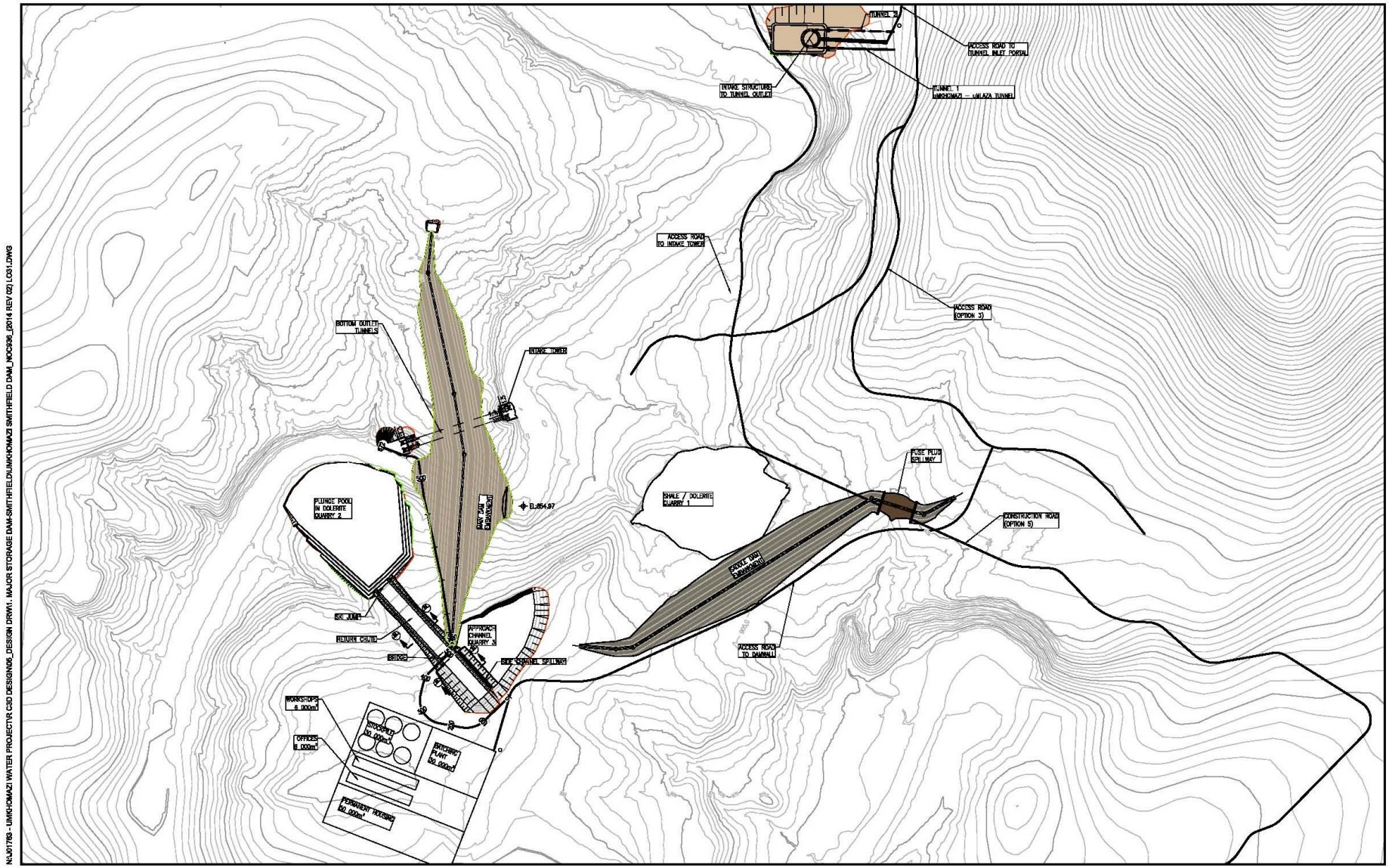


Figure 3.F.1: Smithfield Dam layout

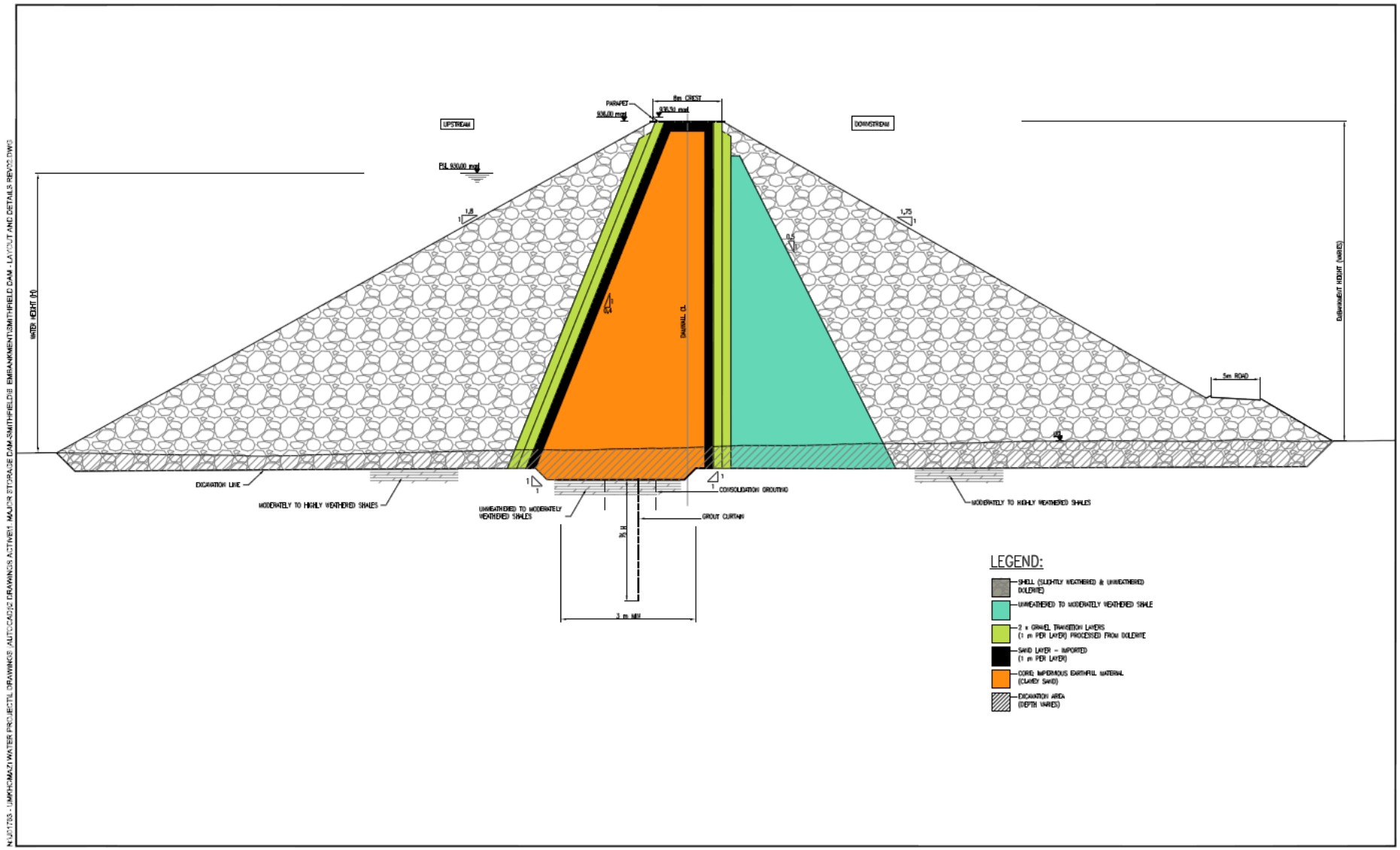


Figure 3.F.2: Cross-section of Smithfield Dam main embankment

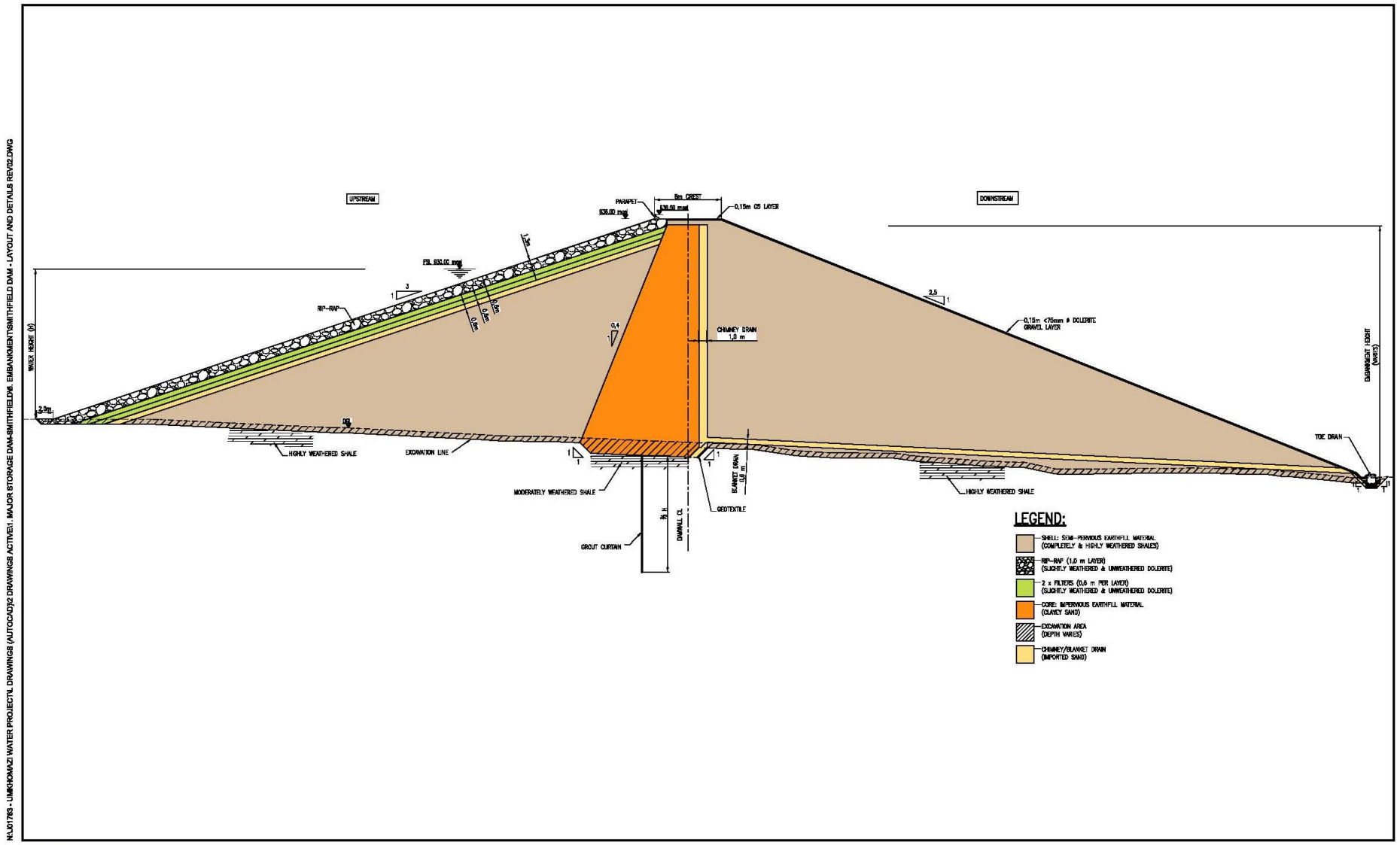


Figure 3.F.3: Cross-section of Smithfield Dam saddle embankment

Annexure 3 G – Smithfield dam: Available material

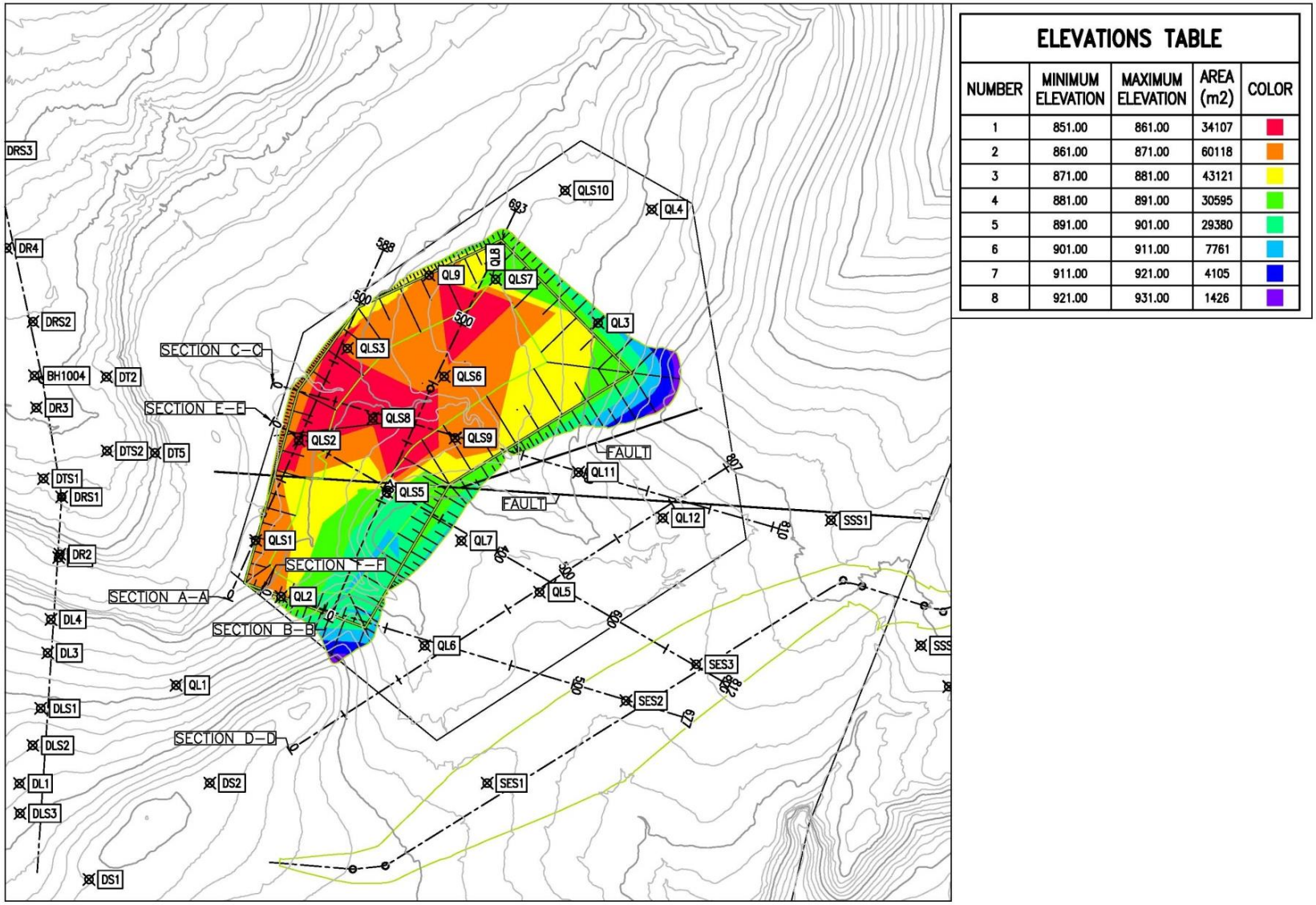
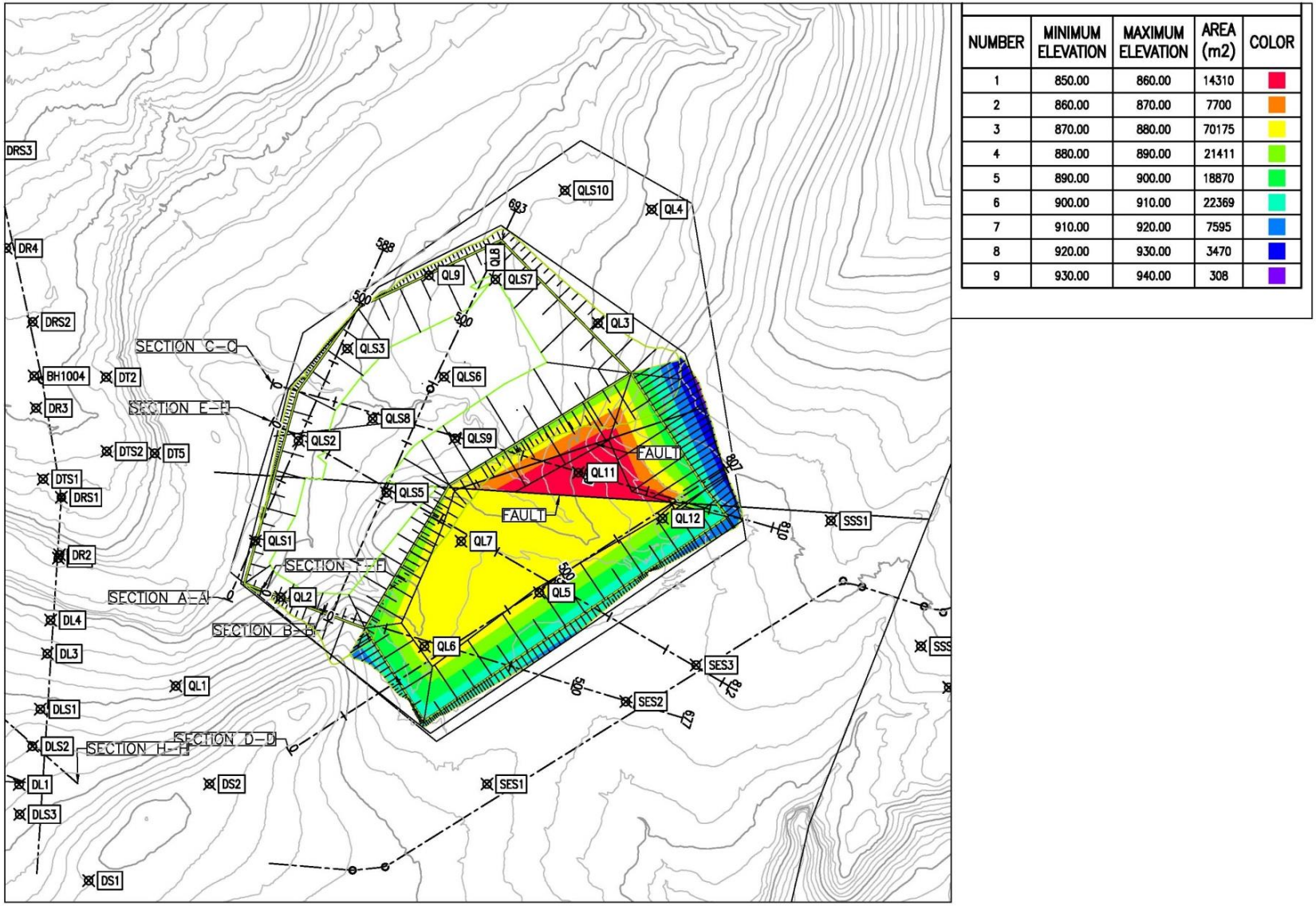


Figure 3.G.1: Plan layout of Quarry I with cross sections and proposed development (1)



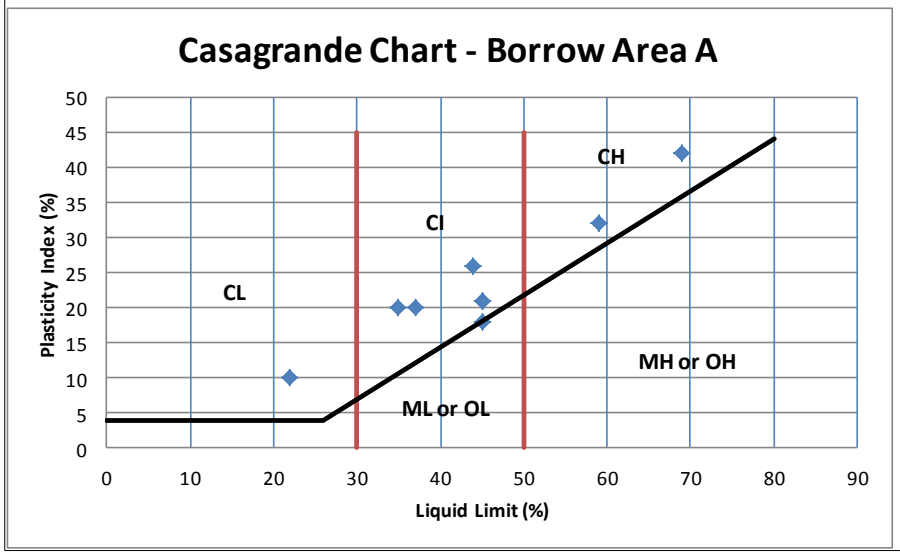
NUMBER	MINIMUM ELEVATION	MAXIMUM ELEVATION	AREA (m2)	COLOR
1	850.00	860.00	14310	
2	860.00	870.00	7700	
3	870.00	880.00	70175	
4	880.00	890.00	21411	
5	890.00	900.00	18870	
6	900.00	910.00	22369	
7	910.00	920.00	7595	
8	920.00	930.00	3470	
9	930.00	940.00	308	

Figure 3.G.2: Plan layout of Quarry I with cross sections and proposed development (2)

Smithfield Borrow Area A		
Test pit	LL	PI
TPA7	59	32
TPA9	69	42
TPA10	45	18
TPA11	44	26
TPA15	37	20
TPA17	45	21
TPA19	35	20
TPA22	45	21
TPA27	22	10

Smithfield Borrow Area B		
Test pit	LL	PI
TPB5	36	23
TPB7	42	14
TPB9	46	19
TPB11	36	21

Legend:	
CL	Clay, low plasticity
CI	Clay, intermediate plasticity
CH	Clay, high plasticity
ML/OL	Silt/Silty clays, slight or low plasticity
MH/OH	Silt/clay, high plasticity



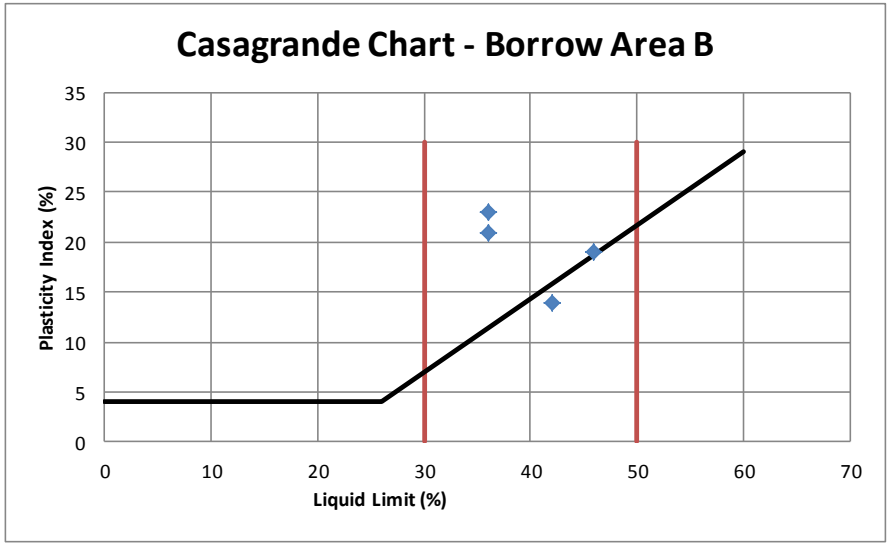


Figure 3.G.3: Casagrande plasticity charts for Borrow Areas A and B

Annexure 3 H – Smithfield Dam: Embankment stability

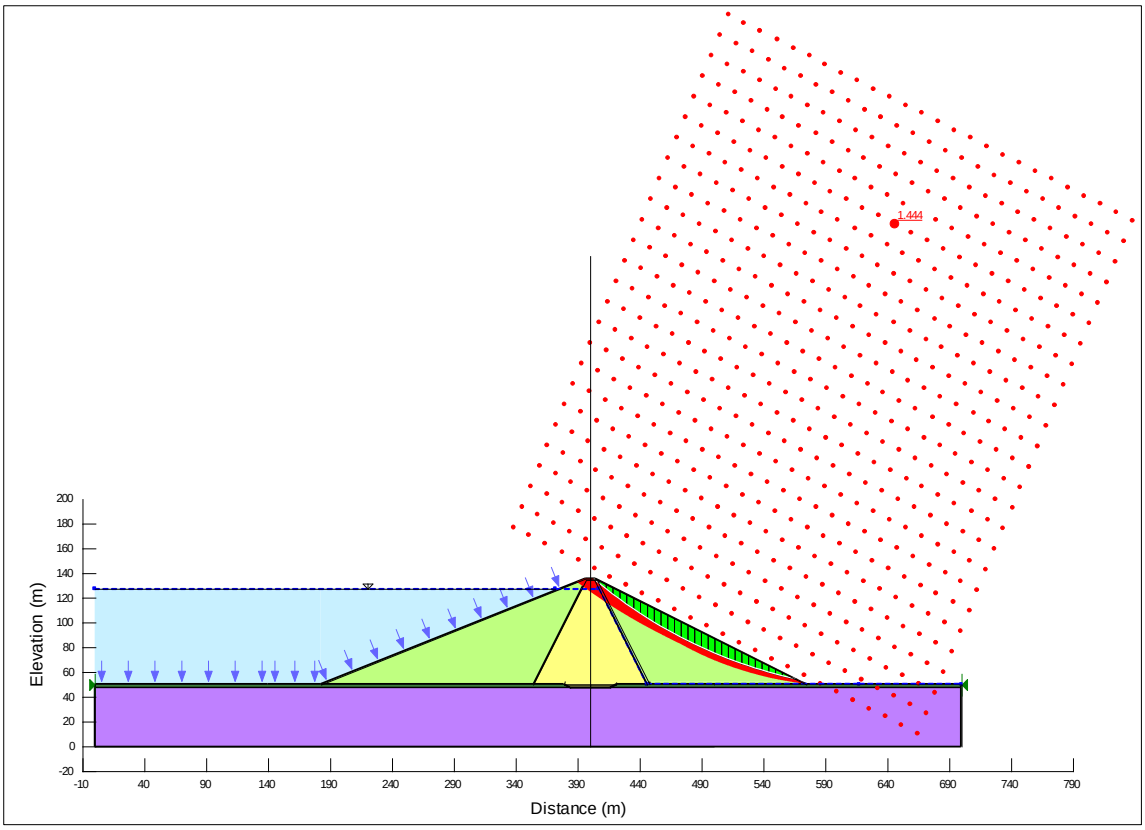


Figure 3.H.1: Earthfill dam: Upstream slope 1:2.5 (V:H), Downstream slope 1:2 (V:H), Analysis 1.1, Downstream, dam full with steady state flow

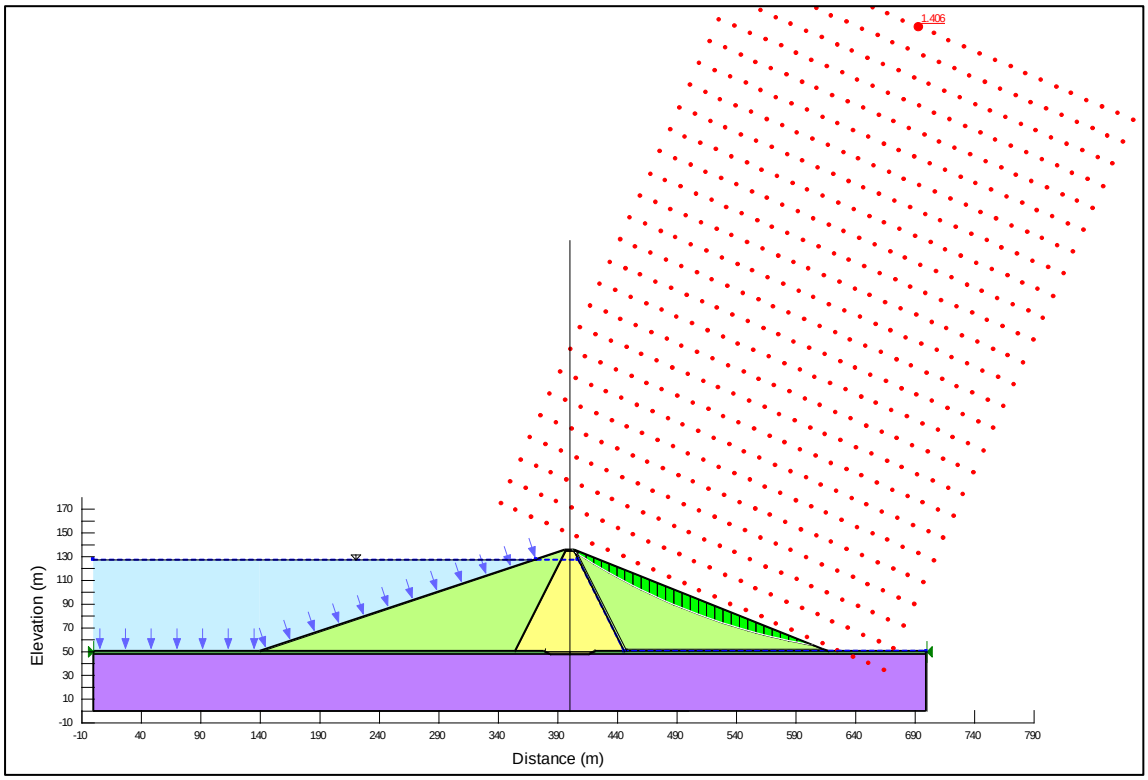


Figure 3.H.2: Earthfill dam: Upstream slope 1:3 (V:H), Downstream slope 1:25 (V:H), Analysis 2.2, Downstream, dam full with seismic action

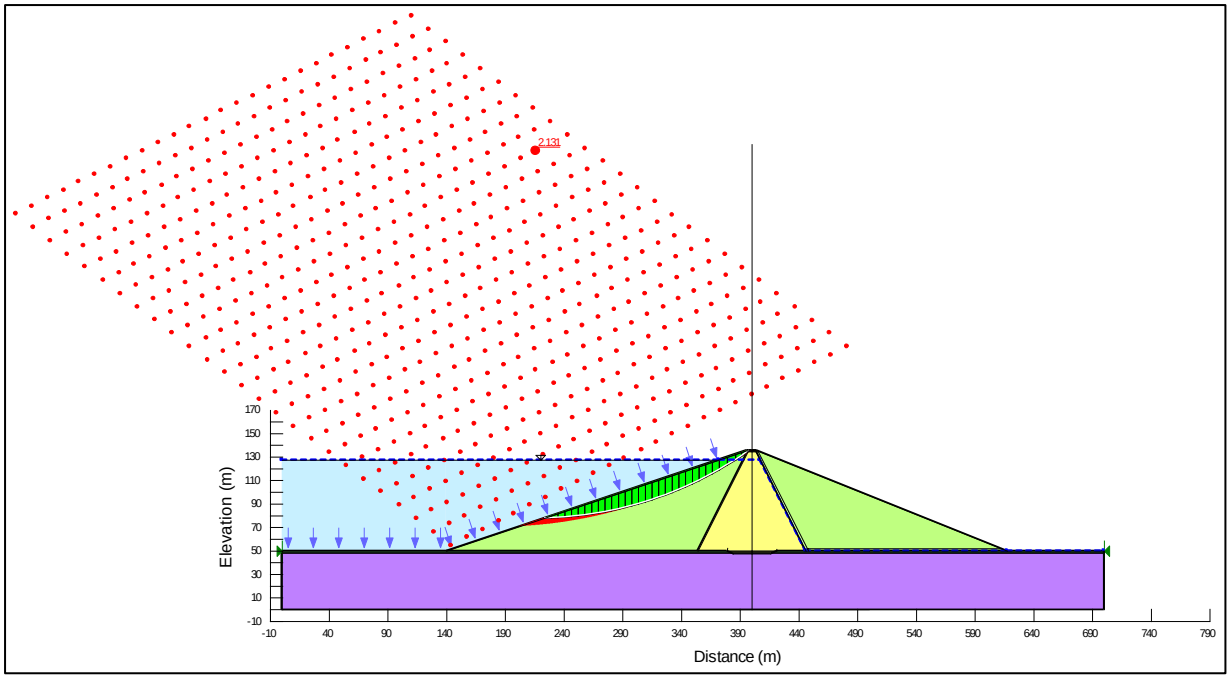


Figure 3.H.3: Earthfill dam: Upstream slope 1:3 (V:H), Downstream slope 1:2.5 (V:H), Analysis 2.3, Upstream, dam full with steady state

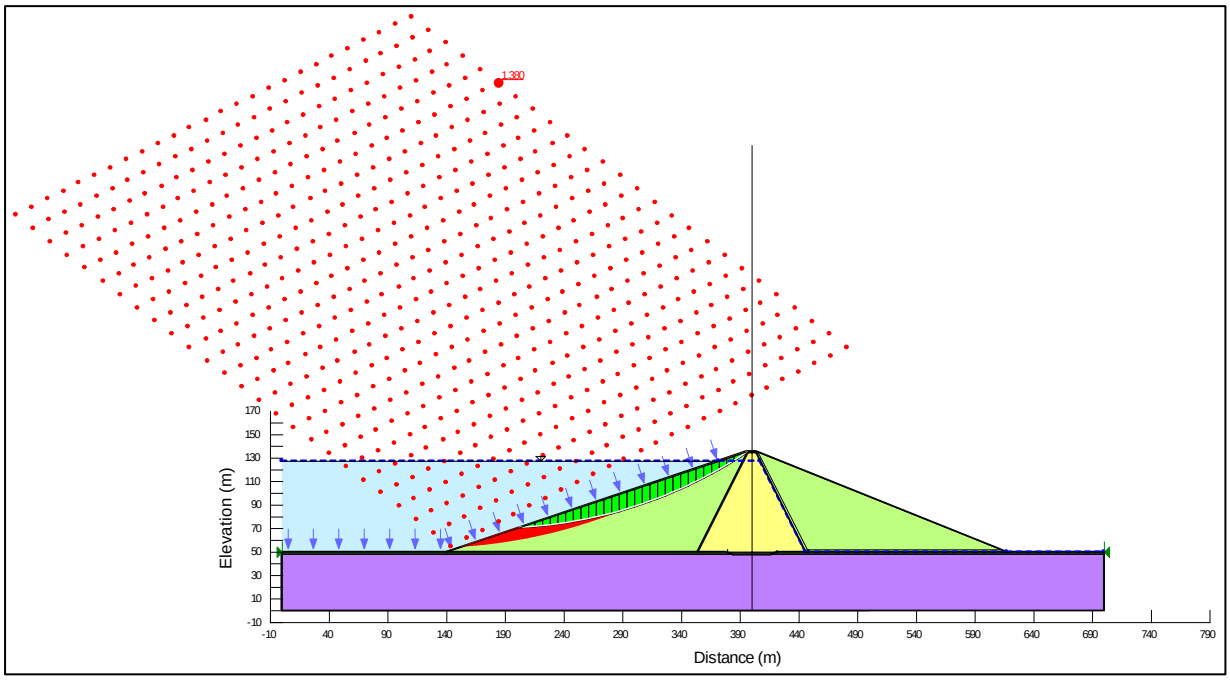


Figure 3.H.4: Earthfill dam: Upstream slope 1:3 (V:H), Downstream slope 1:2.5 (V:H), Analysis 2.4, Upstream, dam full with seismic action

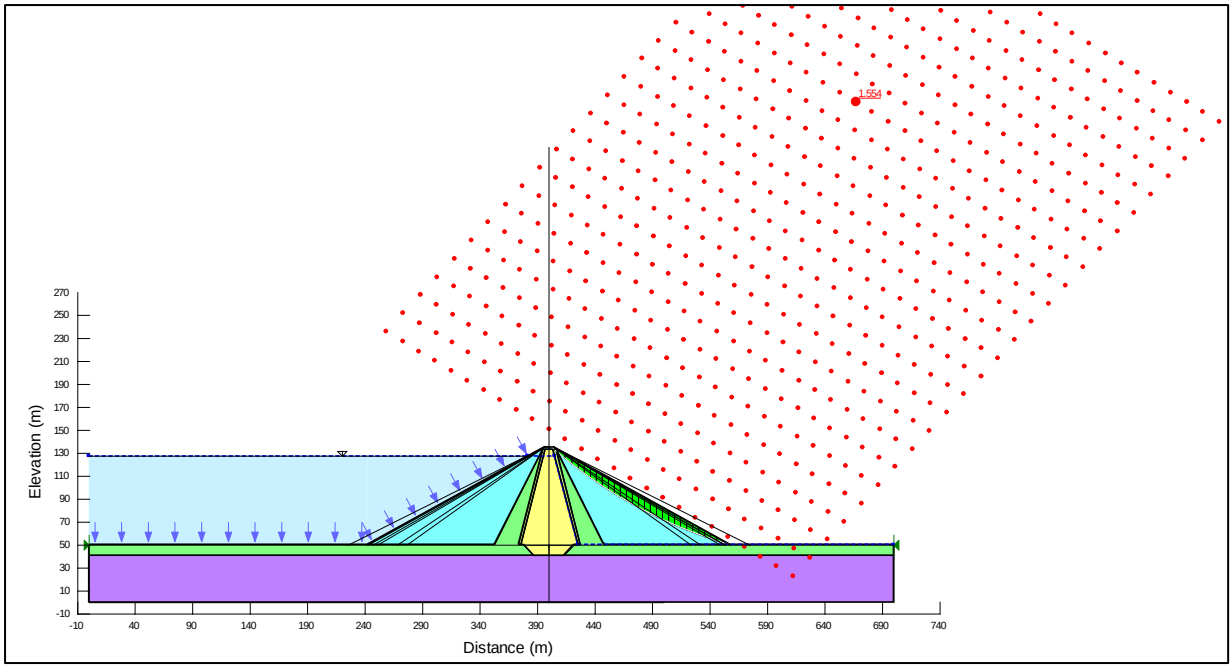


Figure 3.H.5: Zoned earth core rock fill dam: Upstream slopes 1:1.8 (V:H), downstream slope 1:1.8 (V:H), Analysis 5.1 Dam full and steady state flow

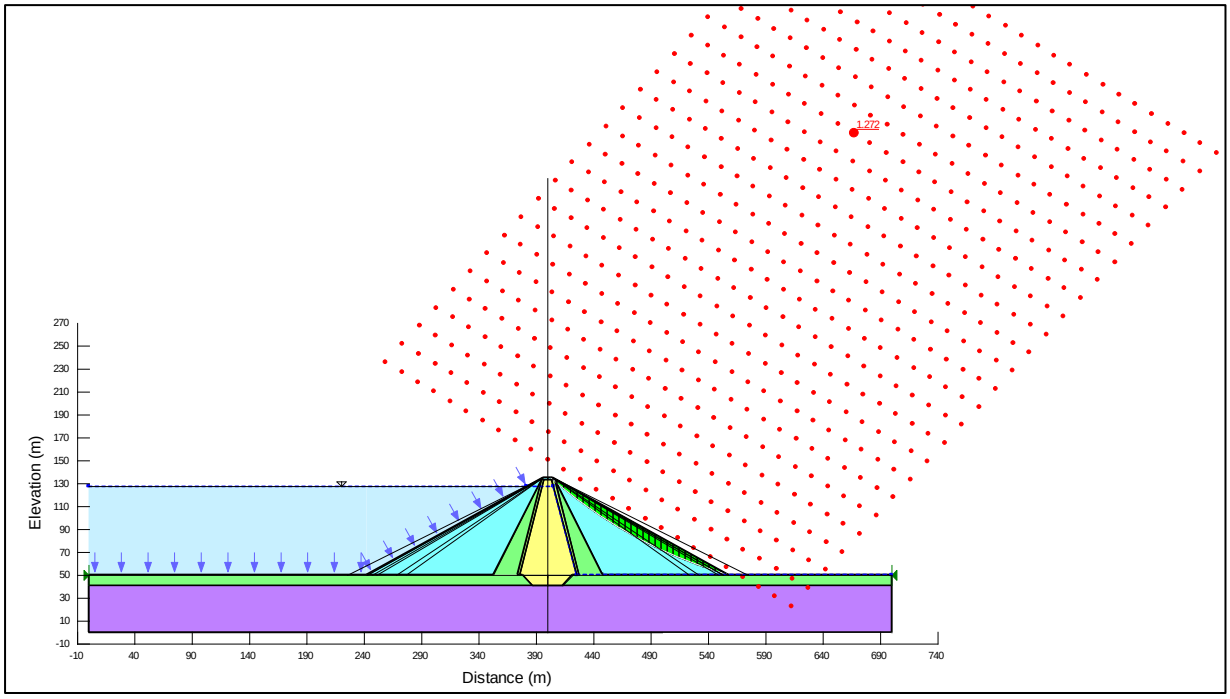


Figure 3.H.6: Zoned earth core rock fill dam: Upstream slopes 1:1.8 (V:H), downstream slope 1:1.8 (V:H), Analysis 5.4 Seismic load

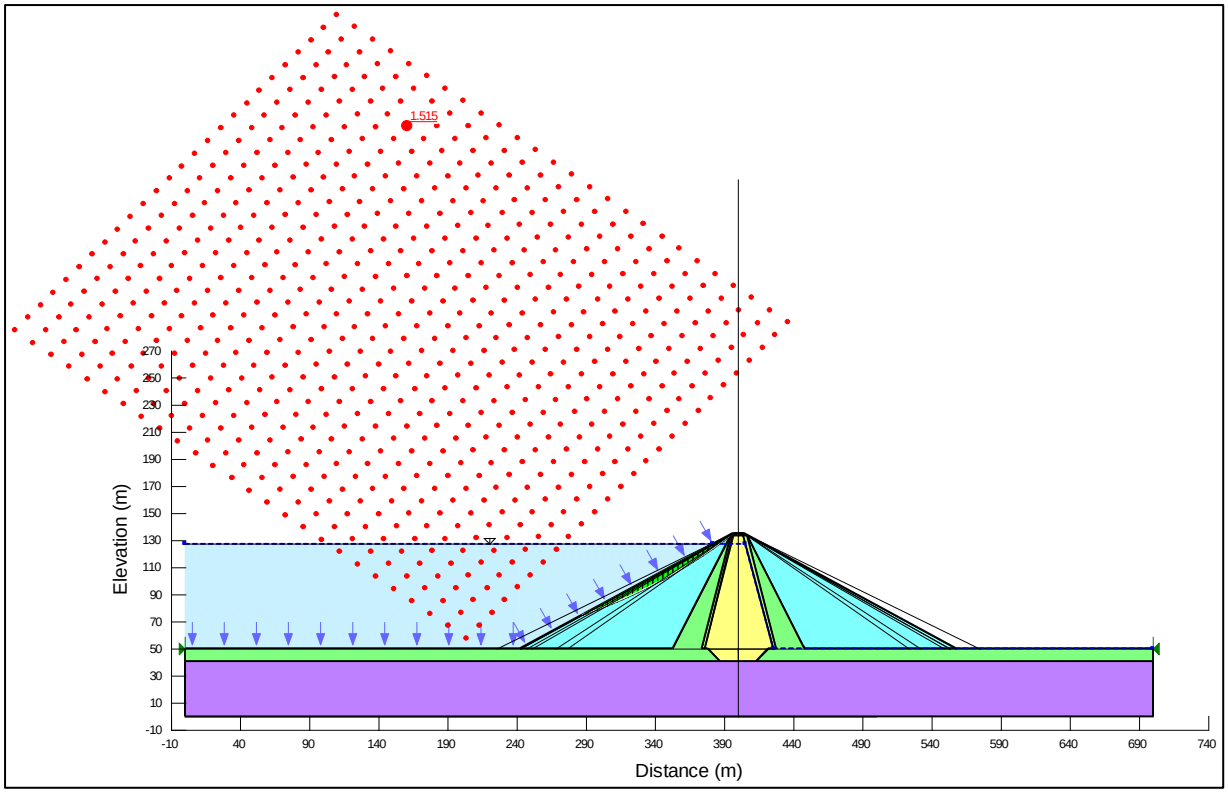


Figure 3.H.7: Zoned earth core rock fill dam: Upstream slopes 1:1.8 (V:H), downstream slope 1:1.8 (V:H), Analysis 5.3 Dam full and steady state flow

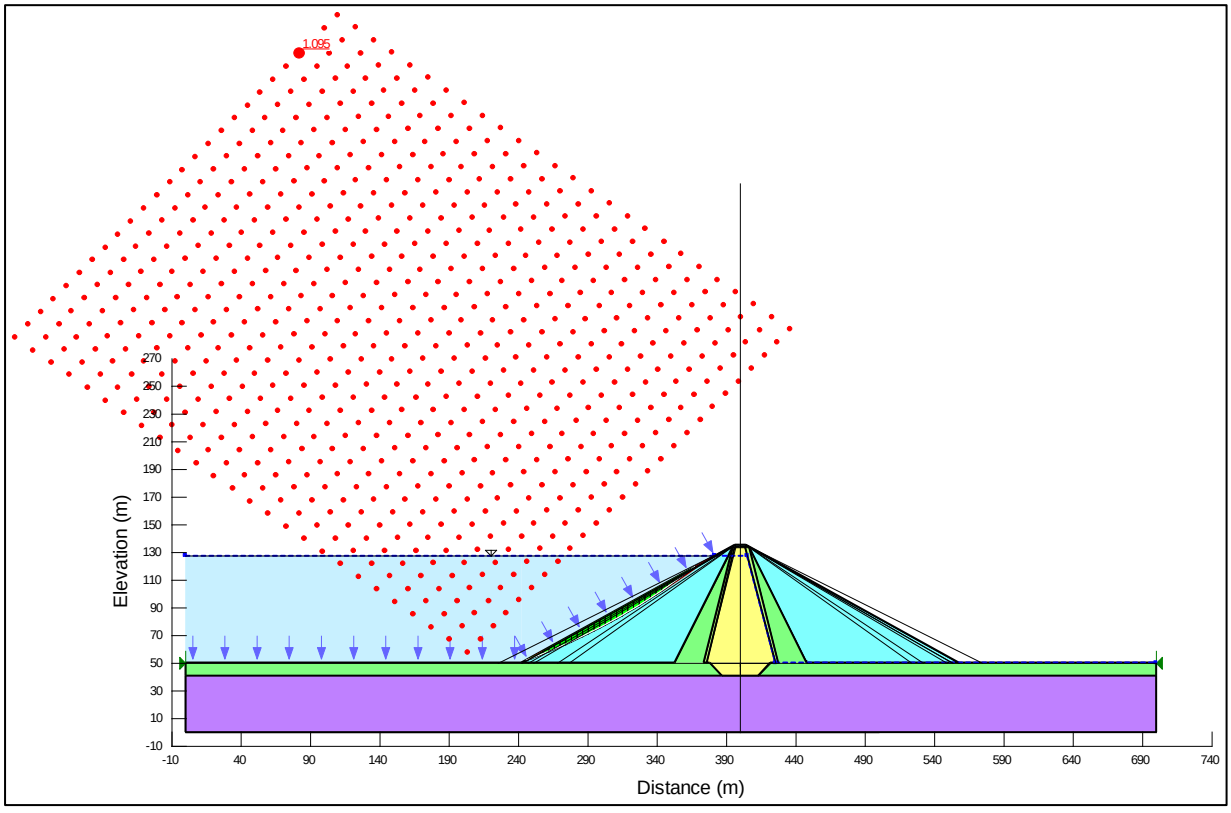


Figure 3.H.8: Zoned earth core rock fill dam: Upstream slopes 1:1.8 (V:H), downstream slope 1:1.8 (V:H), Analysis 5.4 Seismic load

Annexure 3 I – Smithfield Dam: Outlet works

Losses determination

$Z_{Considered}$	930	masl	Water surface level
Z_{Sleeve}	862	masl	Required water level sleeve valve outlet
H	68	m	Available head
Qmax per pipe	**20.7**	m^3/s	Transfer Capacity
D	**2**	m	Intake pipe
D_{sleeve}	**1**	m	Sleeve valve
kp	0.5	mm	Pipe hydraulic roughness
kt	1.5	mm	Tunnel hydraulic roughness
v	1.14E-06	m^2/s	Kinematic viscosity

Trash rack loss					
K	3.7		Area		
t	120	mm	16.25		See adjacent figure
b	120	mm			
k	3.7				
				0.00071	Q^2

Fine screen losses					
K	3.7		Area		
t	10	mm	16.25		
b	25	mm			
k	1.09				
				0.00021	Q^2

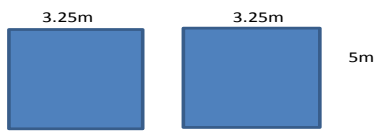
Inlet Tower minor losses					
Amount	**K**	**D_1 (m)**	**D_2 (m)**	**Q^2**	**Description**
1	0.5	**2**		0.0026	Entrance loss
1	0.1	**2**		0.0005	Bellmouth entrance
1	0.44	**2**		0.0023	Butterfly valve
1	0.75	**2**		0.0039	90-degree bend to connect to collector pipe (H->V)
1	0.75	**2**		0.0039	90 degree bend of collector pipe (V->H)
1	0.25	**2**	1	0.0194	Contraction to sleeve valve
1	0.35	**2**		0.0018	Inline flow of Y-piece to smaller sleeve valves
1	0.38	**1**		0.0314	Sleeve valve 100% open
1	1	**1**		0.0826	Exit loss
			Sub T	**0.14832**	Q^2

Total losses	**0.14924**	**Q^2**

Intake level dependant losses

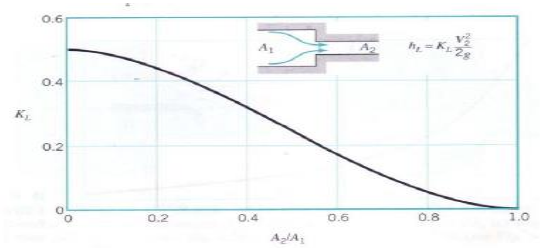
Inlet Tower minor losses					
Amount	**K**	**D_1 (m)**	**D_2 (m)**	**Q^2**	**Description**
1	0.35	**2**		0.0018	Tee pieces passed in vertical collector pipe (Kroon, J)
Friction losses through Intake tower pipes					
Up to tunnel collection pipe					
l (m)	**D (m)**	**V (m/s)**	**λ**		
1.00	2	4.705	0.01438	**0.00004**	L Q^2
			Sub T	**0.00004**	L Q^2

Trash rack and fine screens area



Total area = 32.50
Net area = 16.25

0.500



λ (Darcy-Weisbach)
0.014375183

Figure 3.I.1: Draw down calculations of Smithfield Dam

Table 3.I.1: Draw down calculations of Smithfield Dam

Water level (masl)	Volume (m^3)	H (m)	Intake 1 (masl)	Intake 2 (masl)	Losses Intake 1 (ito Q)	Losses Intake 2 (ito Q)	Q1 (m^3/s)	Q2 (m^3/s)	Q total (m^3/s)	Q total average (m^3/s)	V average (m/s)	Change in capacity (million m^3)	Change in time (days)	Tot time (days)
930.0	251.43	68.0	920	910	0.15858	0.15643	20.7	20.8	41.6					0
927.5	229.37	65.5	920	910	0.15858	0.15643	20.3	20.5	40.8	41.17	6.55	22.06	6.20	6.20
925.0	207.31	63.0	910	910	0.15643	0.15643	20.1	20.1	40.1	40.46	6.44	22.06	6.31	12.51
922.5	188.28	60.5	910	895	0.15643	0.15411	19.7	19.8	39.5	39.81	6.34	19.03	5.53	18.05
920.0	169.26	58.0	910	895	0.15643	0.15411	19.3	19.4	38.7	39.07	6.22	19.03	5.64	23.68
917.5	152.72	55.5	910	895	0.15643	0.15411	18.8	19.0	37.8	38.23	6.09	16.54	5.01	28.69
915.0	136.18	53.0	895	895	0.15411	0.15411	18.5	18.5	37.1	37.45	5.96	16.54	5.11	33.80
912.5	121.84	50.5	895	880	0.15411	0.15178	18.1	18.2	36.3	36.72	5.84	14.34	4.52	38.32
910.0	107.51	48.0	895	880	0.15411	0.15178	17.6	17.8	35.4	35.89	5.71	14.34	4.62	42.94
907.5	95.24	45.5	895	880	0.15411	0.15178	17.2	17.3	34.5	34.96	5.56	12.26	4.06	47.00
905.0	82.98	43.0	895	880	0.15411	0.15178	16.7	16.8	33.5	34.02	5.41	12.26	4.17	51.17
902.5	72.69	40.5	895	880	0.15411	0.15178	16.2	16.3	32.5	33.04	5.26	10.29	3.61	54.78
900.0	62.39	38.0	895	880	0.15411	0.15178	15.7	15.8	31.5	32.04	5.10	10.29	3.72	58.50
897.5	53.86	35.5	880	880	0.15178	0.15178	15.3	15.3	30.6	31.06	4.94	8.54	3.18	61.68
895.0	45.32	33.0	880	880	0.15178	0.15178	14.7	14.7	29.5	30.04	4.78	8.54	3.29	64.97
892.5	38.35	30.5	880	880	0.15178	0.15178	14.2	14.2	28.4	28.92	4.60	6.97	2.79	67.76
890.0	31.38	28.0	880	880	0.15178	0.15178	13.6	13.6	27.2	27.76	4.42	6.97	2.91	70.66
887.2	25.23	25.2	880	880	0.15178	0.15178	12.9	12.9	25.8	26.47	4.21	6.15	2.69	73.35
885.0	20.40	23.0	880	880	0.15178	0.15178	12.3	12.3	24.6	25.20	4.01	4.83	2.22	75.58
882.5	16.21	20.5	880	880	0.15178	0.15178	11.6	11.6	23.2	23.93	3.81	4.19	2.03	77.60
880.0	12.02	18.0	880	880	0.15178	0.15178	10.9	10.9	21.8	22.51	3.58	4.19	2.15	79.75

Annexure 3 J – Smithfield Dam: Tunnel

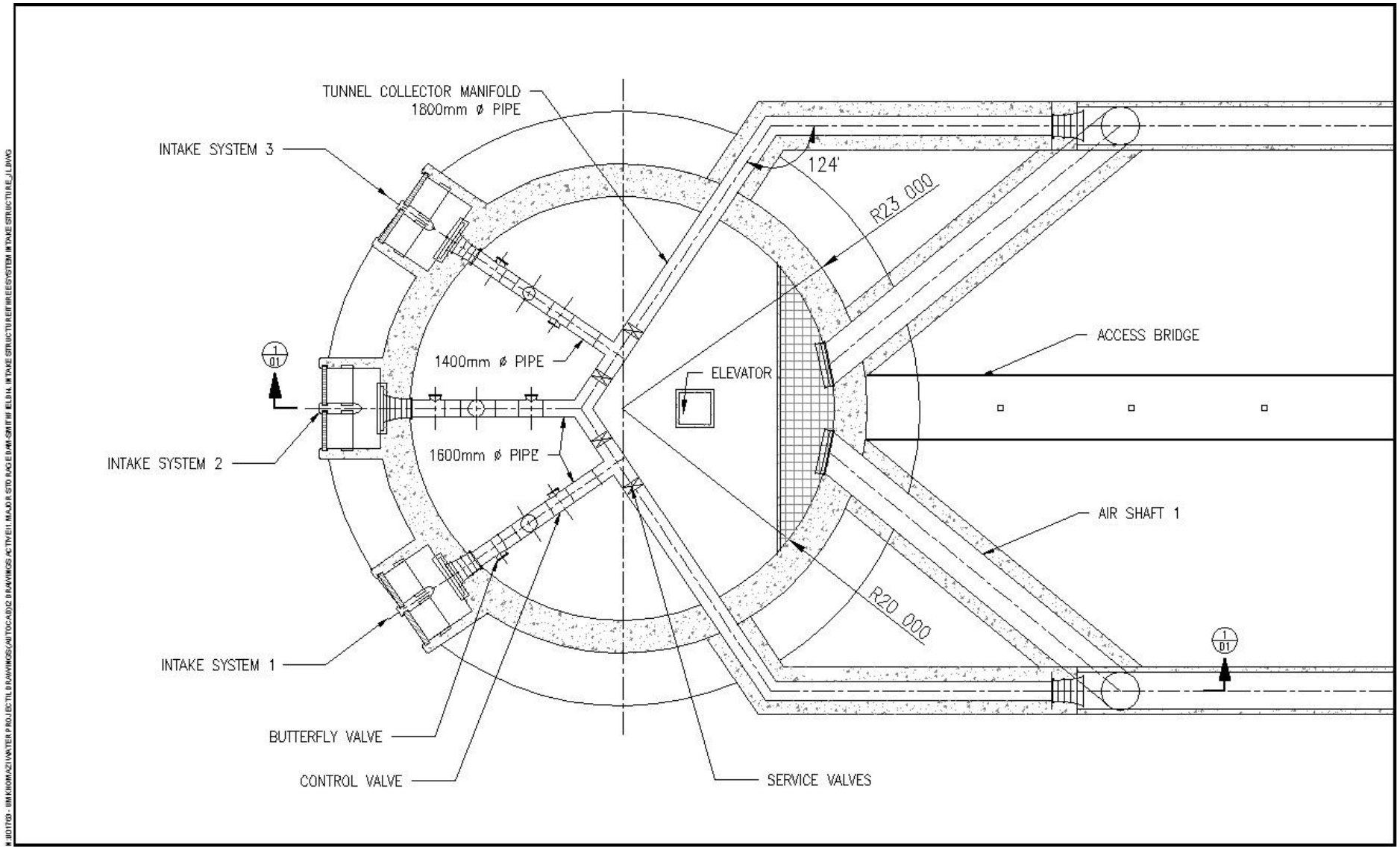


Figure 3.J.1: Layout of tunnel intake structure

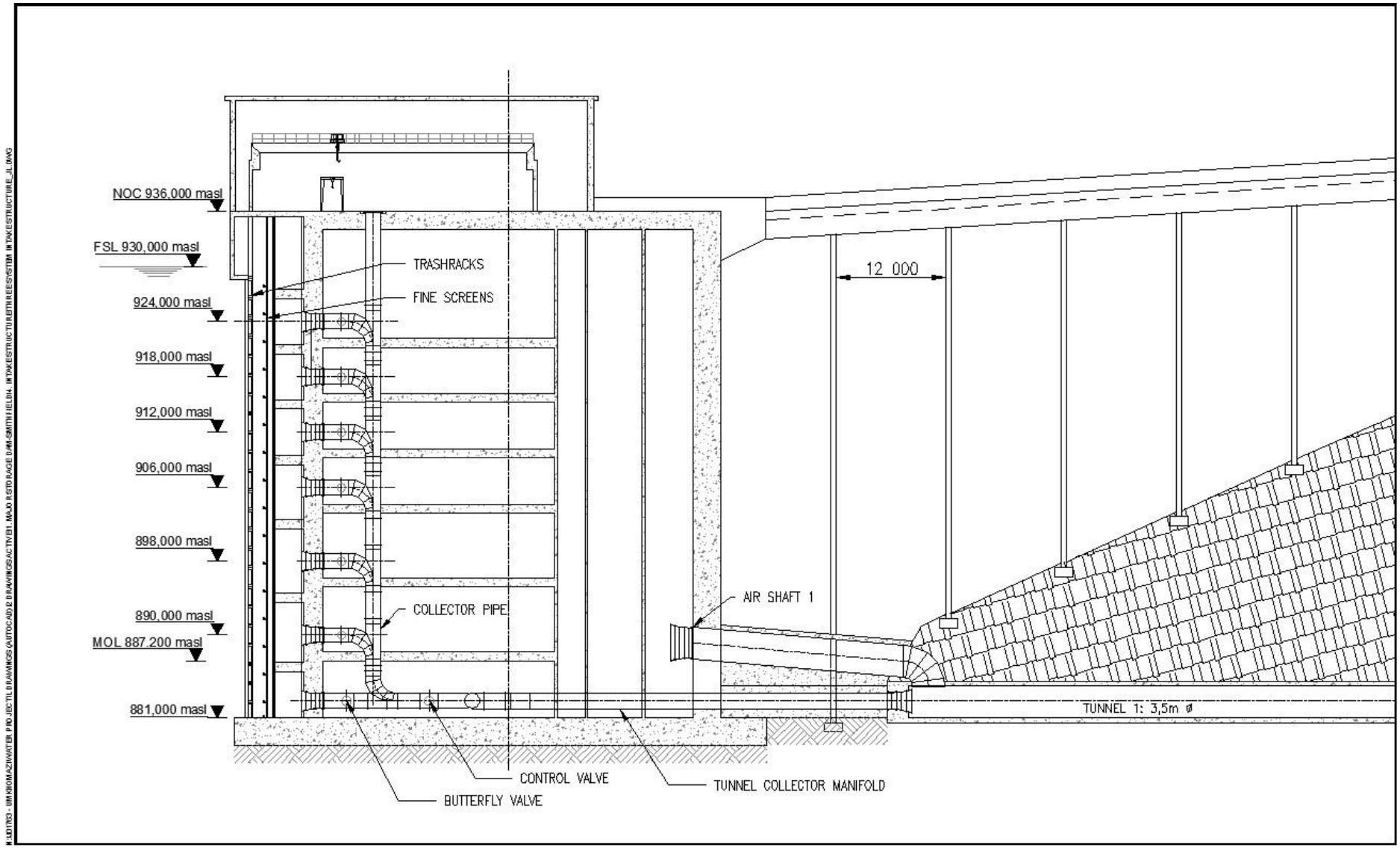


Figure 3.J.2: Layout of tunnel intake structure

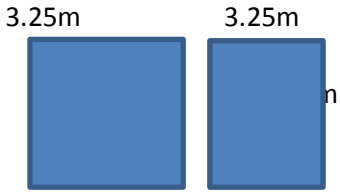
Table 3.J.1: Head loss calculations

Tunnel and pipe design for conveyance system from th eIntake Tower to the WtW			
Z_{MOL}	887.2	masl	Water surface level
Z_{WTW}	872	masl	Required water level at WT
H	15.2	m	Available head
Q	**8.65**	m/s	Transfer Capacity
D	**1.6**	m	Intake pipe
kp	0.5	mm	Pipe hydraulic roughness
kt	1.5	mm	Tunnel hydraulic roughnes
v	1.14E-06	m^2/s	Kinematic viscosity

Trashrack loss						
K	3.7		Area	V	**hl**	
t	120	mm	16.25	0.53	0.0534	See adjacent figure
b	120	mm				
k	3.7					
				Sub T	**0.05344**	

Fine screen losses						
K	3.7		Area	V	**hl**	
t	10	mm	16.25	0.53	0.01575	
b	25	mm				
k	1.090					
				Sub T	**0.01575**	

Trashrack and finescreens area



Total area =	32.5
Net area =	16.25

Table 3.J.1 (continued)

Inlet tower minor losses - WORST CASE: BOTTOM MIDDLE INLET						
Amount	**K**	**D_1 (m)**	**D_2 (m)**	**V (m/s)**	**hl (m)**	**Description**
1	0.5			-	-	Trash rack entrance loss
1	0.5			-	-	Trash rack exit loss
1	0.1	1.6		4.30	0.09	Bellmouth entrace
1	0.4	1.6		4.30	0.38	Butterfly valve
0	0.75	1.6		4.30	0.00	90-degree bend to connect to collector pipe (H->V)
1	0.35	1.6		4.30	0.33	Tee pieces passed in vertical collector pipe
0	0.75	1.6		4.30	0.00	90 degree bend to tunnel collector pipe (V->H)
1	0.3	1.6		4.30	0.28	Control valve before tunnel collector pipe
1	0.8	1.6		4.30	0.75	Y-Piece (Connection to tunnel collector pipe)
1	0.35	1.8		3.40	0.21	Tee pieces passed in tunnel collector pipe
2	0.3	1.8		3.40	0.35	Service valves passed in tunnel collector pipe
1	0.125	1.8		3.40	0.07	125-degree long bend to tunnel
1	1	1.8		3.40	0.59	Bellmouth exit
				Sub T	**3.06**	

Friction losses through intake tower pipes: WORST CASE: BOTTOM MIDDLE INLET										
Up to tunnel collection pipe										
l (m)	**D (m)**	**V (m/s)**	**λ**		**hf (m)**		Re	λ	Left	Right
18.20	1.6	4.302	0.015		0.16		7461661	0.015	8.117	8.119
Tunnel minor losses (verify whether required)										0.002
k	**D_1 (m)**	**D_2 (m)**	**V_1 (m/s)**	**V_2 (m/s)**	**hl (m)**					
0.5	1.6		4.302		0.009					
From tunnel collection pipe onwards										
l (m)	**D (m)**	**V (m/s)**	**λ**		**hf (m)**		Re	λ	Left	Right
61.50	1.8	3.399	0.015		0.30		6632588	0.015	8.214	8.214
Tunnel minor losses (verify whether required)										0.000
k	**D_1 (m)**	**D_2 (m)**	**V_1 (m/s)**	**V_2 (m/s)**	**hl (m)**					
0.5	1.8		3.399		0.0181					
				Sub T	**0.49**					

Table 3.J.1 (continued)

Friction losses through tunnel										
l (m)	**D (m)**	**V (m/s)**	**λ**		**hf (m)**	**Description**	Re	λ	Left	Right
32500	3.500	0.899	0.01631		6.240		3411045	0.016	7.830	7.830
Tunnel minor losses										0.000
k	**D_1 (m)**	**D_2 (m)**	**V_1 (m/s)**	**V_2 (m/s)**	**hl (m)**					
0.5	3.5		0.899		0.669	Coefficient of 1/km of tunnel				
				Sub T	**6.909**					
Energy gradeline at tunnel-wtw pipe connection					**876.672**	masl				
Friction losses through pipe to WTW										
l (m)	**D (m)**	**V (m/s)**	**λ**		**hf (m)**	**Description**	Re	λ	Left	Right
5143	2.600	1.629	0.014		3.708		4591792	0.014	8.495	8.494
				Sub T	**3.708**					-0.001
Pipe minor losses										
k	**D_1 (m)**	**D_2 (m)**	**V_1 (m/s)**	**V_2 (m/s)**	**hl (m)**	**Description**				
0.800	0.0	2.6	-	1.63	0.56	Coefficient of 1/km of pipe				
0.300	3.5	2.6	0.90	1.63	0.03	Contraction, 10° flare angle (Small dams, USBR)				
0.750	0.0	2.6	-	1.63	0.101	90° elbow (Manual of British Water Engineering Practice)				
0.750	0.0	2.6	-	1.63	0.101	90° elbow (Manual of British Water Engineering Practice)				
0.300	0.0	2.6	-	1.63	0.041	Butterfly valve (Manual of British Water Engineering Practice)				
1.500	0.0	0.0	-	-	-	Sleeve valve (Glenfield valves)				
1.000	0.0	2.6	-	1.63	0.135	Outlet loss				
				Sub T	**0.964**		Losses through tunnel and pipeline only			
							0.4571429			
			TOTAL LOSSES		15.2	m	11.581			
			AVAILABLE HEAD		15.2	m				
			Head left at WTW		**0.000**	**m**				

Annexure 3 K – Smithfield Dam: Cost estimate

Table 3.K.1: Cost estimate: Smithfield Dam: River diversion

SMITHFIELD DAM					
ITEM NO	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
1	**PART 1: RIVER DIVERSION**				
1.1	**SECTION: PHASE 1**				
	Excavation of inlet and outlet Portals				
	Bulk excavation				
	(a) Excavate all material and use for embankment or backfill or dispose	m³	120 830	100	12 083 000
	(b) Extra over for				
	(1) Intermediate excavation	-	-	-	Incl. in (a)
	(2) Hard rock excavation	m³	12 090	35	423 150
	Excavation of tunnels				
	Tunnel excavation				
	(b) Rock class II				
	(1) Tunnel 1 (access adit)	m³	19 260	1 290	24 845 400
	(2) Tunnel 2 (outlet tunnel)	m³	21 350	1 290	27 541 500
	Construction of cofferdams 1 (862.4 masl) & 2 (860.1 masl)				
	Preparation of exposed surfaces				
	(b) Area to be covered by dam wall	m²	910	105	95 550
	Forming of Embankment				
	(a) Selected impervious material	m³	3 052	55	167 860
	(b) Rip-Rap (300 mm layer)	m³	190	480	91 200
	Construction of tunnel 1				
	Rock support				
	(a) Rockbolts	m	6 400	285	1 824 000
	(b) Shotcrete	m³	200	5 885	1 177 000
	Concrete				
	(a) Tunnel floor	m³	870	2 775	2 414 250
	Formwork				
	(a) Smooth horizontal	m²	2 560	730	1 868 800
	Construction of tunnel 2				
	Rock support				
	(a) Rockbolts	m	6 400	285	1 824 000
	(b) Shotcrete	m³	200	5 885	1 177 000
	Concrete				
	(a) Linings and tunnel floor	m³	2 970	2 775	8 241 750
	(b) Overbreak concrete (DBT)	m²	1 480	2 245	3 322 600
	Formwork				
	(a) Smooth curved in tunnel	m²	9 860	730	7 197 800
	Grouting	m²	9 860	485	4 782 100
	Waterproof lining	m²	9 860	845	8 331 700
	IFR pipe (600 mm dia)	m	320	5 200	1 664 000

Table 3.K.1 (continued)

	Construction of intake and outlet of tunnels				
	Scheduled Formwork items				
	Smooth				
	(a) Vertical	m²	6 280	650	4 082 000
	(b) Horizontal	m²	700	730	511 000
	Scheduled concrete items				
	Strength concrete				
	(a) 30MPa structural concrete	m³	11 400	2 160	24 624 000
	Unformed surfaces				
	(a) Steel floated	m²	650	38	24 700
	Scheduled reinforcement items				
	Steel bars	t	1 150	14 000	16 100 000
1.2	**SECTION: PHASE 2**				
	Construction of cofferdams 3 (862 masl) & 4 (862 masl)				
	Forming of Embankment				
	(a) Selected impervious material				
	(1) Cofferdam 3	m³	5 460	55	300 300
	(d) Rip-Rap				
	(1) Cofferdam 3	m³	340	480	163 200
	Construction of cofferdams 5 (863 masl)				
	Preparation of exposed surfaces				
	(b) Area to be covered by dam wall	m²	470	105	49 350
	Scheduled Formwork items				
	Rough				
	(a) Vertical	m²	660	650	429 000
	(b) Sloped (ogee of spillway)	m²	1 060	650	689 000
	Scheduled concrete items				
	Blinding layers	m³	70	1 970	137 900
	Strength concrete				
	(a) 20 MPa mass concrete for wall	m³	2 970	2 160	6 415 200
	Waterstops, joints and sealing	m	390	800	312 000
	Scheduled reinforcement items				
	Steel bars	t	300	14 000	4 200 000
	Holding down bolts and anchors	m	2 380	90	214 200
1.3	**SECTION: PHASE 3**				
	Only Dam construction activities	-	-	-	-

Table 3.K.1 (continued)

1.4	**SECTION: PHASE 4**				
	Construction of cofferdams 6 (888 masl)				
	Scheduled concrete items				
	Strength concrete				
	(a) 30 MPa (for plinth)	m³	1 020	2 160	2 203 200
	(b) Shotcrete (HDPE protection)	m³	1 000	5 885	5 885 000
	HDPE liner installation				
	The rate will include all aspects as required by SANS 10409 (including all tests)	m²	20 020	35	700 700
	Holding down bolts and anchors (for plinth)	m	5 270	90	474 300
1.5	**SECTION: PHASE 5**				
	Only Dam construction activities continue	-	-	-	-
1.6	**SECTION: PHASE 6**				
	Plugging of Tunnel 2				
	Scheduled Formwork items				
	Rough				
	(a) Vertical	m²	150	500	75 000
	Scheduled concrete items				
	Strength concrete				
	(a) 20MPa mass concrete for wall	m³	260	2 160	561 600
	Grouting	m	100	1 150	115 000
	Holding down bolts and anchors	m	80	90	7 200
1.7	**SECTION: PHASE 7**				
	Plugging of Tunnel 1				
	Scheduled Formwork items				
	Rough				
	(a) Vertical	m²	150	500	75 000
	Scheduled concrete items				
	Strength concrete				
	(a) 20MPa mass concrete for wall	m³	380	2 160	820 800
	Grouting	m	90	1 150	103 500
	Holding down bolts and anchors	m	110	90	9 900
	Dewatering	Sum	1	110 000	110 000
TOTAL CARRIED FORWARD TO SUMMARY					**178 465 710**

Table 3.K.2: Cost estimate: Smithfield Dam: Development of quarries and borrow areas

SMITHFIELD DAM					
ITEM NO	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
2	PART 2: DEVELOPMENT OF QUARRIES AND BORROW AREAS				
2.1	SECTION: SITE CLEARANCE				
	Clear and grub				
	(a) Borrow area A	ha	21.8	10 430	227 380
	(b) Borrow area B	ha	34.7	10 430	361 930
	(d) Quarry I	ha	10.3	10 430	107 430
	(e) Quarry II	ha	10.5	10 430	109 520
	(f) Quarry III	ha	5.5	10 430	57 370
	(g) Quarry IV	ha	1.5	10 430	15 650
	Remove topsoil to nominal depth of 150 mm and stockpile				
	(a) Borrow area A	m³	120 000	27	3 240 000
	(b) Borrow area B	m³	100 000	27	2 700 000
	(d) Quarry I	m³	50 000	27	1 350 000
	(e) Quarry II	m³	40 000	27	1 080 000
	(f) Quarry III	m³	20 000	27	540 000
	(g) Quarry IV	m³	5 000	27	135 000
TOTAL CARRIED FORWARD TO SUMMARY					9 924 280

Table 3 K 3: Cost estimate: Smithfield Dam: Main dam embankment

SMITHFIELD DAM					
ITEM NO	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
3	**PART 3: SMITHFIELD MAIN DAM CONSTRUCTION**				
3.1	**SECTION: SITE CLEARANCE**				
	Site clearance				
	Clear and strip site	ha	21.4	41 900	896 660
	Remove topsoil to 150 mm, stockpile, and maintain	m³	32 100	27	866 700
3.2	**SECTION: EXCAVATION**				
	Excavation				
	(a) Material unsuitable for embankment	m³	0	35	0
	(b) Material suitable for embankment from essential excavations	m³	1 836 490	34	62 440 660
	(c) Extra-over item (b) for excavation in:				
	(1) Intermediate material	-	-	-	Incl. in (a)
	(2) Hard rock material	m³	612 170	40	24 486 800
	Preparation of exposed surfaces				
	(a) Core trench	m²	23 000	105	2 415 000
	(b) Area to be covered by dam wall	m²	190 970	105	20 051 850
3.3	**SECTION: EMBANKMENT CONSTRUCTION**				
	Forming embankment				
	(a) Core (impervious earthfill)	m³	609 040	55	33 497 200
	(b) Upstream and downstream shells (rockfill)				
	(1) Inner zone	m³	584 520	120	70 142 400
	(2) Outer zone	m³	3 775 850	120	453 102 000
	(c) Transition				
	(1) Gravel layer	m³	206 880	210	43 444 800
	(2) Sand layer	m³	74 850	860	64 371 000
3.4	**SECTION: DRILLING AND GROUTING**				
	Curtain grouting	m	16 440	1 150	18 906 000
	Consolidation grouting	m	10 000	1 150	11 500 000
3.5	**SECTION: PORTION OF ACCESS ROAD ON DAM WALL**				
	Forming embankment				
	(a) Upstream and downstream shells (rockfill)				
	(1) Outer zone	m³	24 710	100	2 471 000
	Placing of paving materials				
	(a) Geotextile	m²	3 600	35	126 000
	(b) Base	m³	490	50	24 500
	(c) Sub-base	m³	620	150	93 000
	(d) Curb	m³	110	2 600	286 000
	(e) Pavement blocks	m²	3 600	130	468 000

Table 3.K.3 (continued)

3.6	**SECTION: ACCESS BRIDGE OVER SPILLWAY**				
	Scheduled Formwork items				
	Smooth				
	(a) Vertical	m²	400	500	200 000
	(b) Horizontal	m²	300	650	195 000
	Scheduled concrete items				
	Strength concrete				
	(a) 30MPa structural concrete	m³	700	2 160	1 512 000
	Scheduled reinforcement items				
	Steel bars	t	140	14 000	1 960 000
	Paving materials				
	(a) Paving blocks	m²	260	130	33 800
TOTAL CARRIED FORWARD TO SUMMARY					**813 490 370**

Table 3.K.4: Cost estimate: Smithfield Dam: Saddle dam embankment

SMITHFIELD DAM					
ITEM NO	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
4	**PART 4: SMITHFIELD SADDLE DAM CONSTRUCTION**				
4.1	**SECTION: SITE CLEARANCE**				
	Site clearance				
	Clear and strip site	ha	11.3	41 900	473 470
	Remove topsoil to 150 mm, stockpile, and maintain	m³	16 950	27	457 650
4.2	**SECTION: EXCAVATION**				
	Excavation				
	(a) Material unsuitable for embankment	m³	0	35	0
	(b) Material suitable for embankment from essential excavations	m³	147 980	34	5 031 320
	(c) Extra-over item (b) for excavation in:				
	(1) Intermediate material	-	-	-	Incl. in (a)
	(2) Hard rock material	m³	44 400	40	1 776 000
	Preparation of exposed surfaces				
	(a) Core trench	m²	11 890	105	1 248 450
	(b) Area to be covered by dam wall	m²	100 660	105	10 569 300
4.3	**SECTION: EMBANKMENT CONSTRUCTION**				
	Forming embankment				
	(a) Core (impervious earthfill)	m³	152 900	55	8 409 500
	(b) Upstream and downstream shells (semi-pervious earthfill)	m³	827 510	55	45 513 050
	(c) Transition				
	(1) Gravel layer	m³	61 740	210	12 965 400
	(2) Sand layer	m³	28 830	860	24 793 800
	(c) Rip-rap	m³	72 420	480	34 761 600
	(f) Blanket and chimney drains	m³	47 000	860	40 420 000
	(h) Gravel capping				
	(1) Road on crest	m³	1 080	100	108 000
	(2) Downstream embankment	m³	7 530	100	753 000
4.4	**SECTION: DRILLING AND GROUTING**				
	Curtain grouting	m	41 000	1 300	53 300 000
	Consolidation grouting	m	10 000	1 150	11 500 000
TOTAL CARRIED FORWARD TO SUMMARY					**252 080 540**

Table 3.K.5: Cost estimate: Smithfield Dam: Main embankment side channel spillway

SMITHFIELD DAM					
ITEM NO	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
5	**PART 5: MAIN EMBANKMENT SIDE CHANNEL SPILLWAY**				
5.1	**SECTION: EXCAVATION**				
	Excavation				
	(a) Material unsuitable for embankment	m³	593 290	56	33 224 240
	(b) Material suitable for embankment from essential excavations	m³	0	54	0
	(c) Extra-over item (b) for excavation in				
	(1) Intermediate material	-	-	-	Incl. in (a)
	(2) Hard rock material	m³	177 980	65	11 568 700
5.2	**SECTION: CONSTRUCTION OF SPILLWAY**				
	Scheduled Formwork items				
	Smooth				
	(a) Vertical				
	(1) Side channel spillway	m²	2 760	650	1 794 000
	(2) Return chute	m²	440	650	286 000
	(3) Ski jump	m²	480	650	312 000
	(b) Sloped (ogee of spillway)				
	(1) Side channel spillway	m²	3 840	650	2 496 000
	(2) Ski jump	m²	400	650	260 000
	Scheduled reinforcement items				
	Steel bars				
	(1) Side channel spillway	t	2 680	14 000	37 520 000
	(2) Return chute	t	0	14 000	0
	(3) Ski jump	t	210	14 000	2 940 000
	High tensile welded mesh				
	(1) Side channel spillway	m²	10 800	50	540 000
	(2) Return chute	m²	16 240	50	812 000
	Scheduled concrete items				
	Strength concrete				
	(a) 25MPa mass concrete for wall				
	(1) Side channel spillway	m³	32 150	2 250	72 337 500
	(2) Return chute	m³	8 120	2 250	18 270 000
	(3) Ski jump	m³	2 040	2 250	4 590 000
	Unformed surface finishes				
	(1) Side channel spillway	m²	10 800	30	324 000
	(2) Return chute	m²	16 240	30	487 200
5.3	**SECTION: WATERSTOPS, JOINTING AND BEARINGS**				
	Waterstops, joints and sealing				
	(a) Ogee spillway	m	630	800	504 000
	(b) Chute	m	1 410	800	1 128 000

Table 3.K.5 (continued)

5.4	**SECTION: SUB-SOIL DRAINAGE**				
	Excavating soft material situated within the following depth ranges below the surface level: (a) 0 m to 1,5 m	m³	170	65	11 050
	Natural permeable material in sub-soil drainage systems	m³	170	800	136 000
	110 NB, flexible slotted drainage pipes with smooth bore, "Drainex" or equivalent by Kaytech	m	1 800	90	162 000
TOTAL CARRIED FORWARD TO SUMMARY					**189 702 690**

Table 3.K.6: Cost estimate: Smithfield Dam: Saddle embankment fuse plug spillway

SMITHFIELD DAM					
ITEM NO	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
6	**PART 6: SADDLE EMBANKMENT FUSE PLUG SPILLWAY**				
6.1	**SECTION: EMBANKMENT FORMING**				
	Forming embankment				
	(a) Semi-pervious earthfill material	m³	12 370	55	680 350
	(b) Sand	m³	7 590	860	6 527 400
	(c) Transition				
	(1) Gravel layer	m³	2 890	210	606 900
	(2) Sand layer	m³	1 410	860	1 212 600
	(d) Rip-rap	m³	3 090	480	1 483 200
	(e) Gravel capping	m³	350	100	35 000
	(f) Rockfill shell	m³	11 660	190	2 215 400
	Scheduled Formwork items				
	Smooth				
	(a) Vertical	m²	900	650	585 000
	(b) Sloped	m²	1 250	650	812 500
	Scheduled reinforcement items				
	Steel bars	ton	570	14 000	7 980 000
	Scheduled concrete items				
	Strength concrete				
	(a) 20MPa mass concrete for wall	m³	5 630	2 160	12 160 800
6.2	**SECTION: RETAINING WALLS**				
	Scheduled Formwork items				
	Rough				
	(a) Vertical	m²	1 660	650	1 079 000
	(b) Sloped	m²	2 020	730	1 474 600
	Scheduled reinforcement items				
	Steel bars	ton	820	14 000	11 480 000
	Scheduled concrete items				
	Strength concrete				
	(a) 20MPa mass concrete for wall	m³	8 200	2 160	17 712 000
TOTAL CARRIED FORWARD TO SUMMARY					**66 044 750**

Table 3.K.7: Cost estimate: Smithfield Dam: Outlet works, intake structure

SMITHFIELD DAM					
ITEM NO	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
7	**PART 7: OUTLET WORKS, INTAKE STRUCTURE**				
7.1	**SECTION: STRUCTURE**				
	Scheduled Formwork items				
	Smooth				
	(a) Vertical - curved and plain	m²	9 670	650	6 285 500
	(b) Horizontal	m²	1 860	730	1 357 800
	Scheduled concrete items				
	Strength concrete				
	(a) 30MPa structural concrete	m³	11 000	2 160	23 760 000
	Scheduled reinforcement items				
	Steel bars	t	2 200	14 000	30 800 000
7.2	**SECTION: HYDRO-MECHANICAL**				
	Pre-cast concrete				
	(a) Trashracks	No.	110	12 380	1 361 800
	Hydro-mechanical steelwork - storage, transport, procurement, fabrication, installation, testing and corrosion protection				
	(a) Fine screens	No.	80	307 000	24 560 000
	(b) Emergency gates	No.	2	2 735 000	5 470 000
	(c) Grappling beams	No.	2	154 000	308 000
	(d) Trash bin	No.	1	69 000	69 000
	(e) Other accessories	Sum	1	250 000	250 000
	Pipes				
	(a) 300 mm diameter	m	10	3 000	30 000
	(b) 2 000 mm diameter	m	300	20 000	6 000 000
	Valves				
	(a) Butterfly valves				
	(1) 2 000 mm diameter	No.	10	1 188 000	11 880 000
	(b) Sleeve valves				
	(1) 600 mm diameter	No.	2	770 000	1 540 000
	(2) 2 000 mm diameter	No.	2	2 750 000	5 500 000
	Elevator	Sum	1	2 000 000	2 000 000
	Cranes and hoists	Sum	1	10 000 000	10 000 000

Table 3.K.7 (continued)

7.3	**SECTION: ACCESS BRIDGE**				
	Scheduled Formwork items				
	Smooth				
	(a) Vertical	m²	1 560	500	780 000
	(b) Horizontal	m²	1 180	650	767 000
	Scheduled concrete items				
	Strength concrete				
	(a) 30MPa structural concrete	m³	2 730	2 160	5 896 800
	Scheduled reinforcement items				
	Steel bars	t	550	14 000	7 700 000
	Paving materials				
	(a) Paving blocks	m²	1 000	130	130 000
TOTAL CARRIED FORWARD TO SUMMARY					**146 445 900**

Table 3.K.8: Cost estimate: Smithfield Dam: Tunnel intake structure

SMITHFIELD DAM					
ITEM NO	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
8	**PART 8: TUNNEL INTAKE STRUCTURE**				
8.1	**SECTION: STRUCTURE**				
	Scheduled Formwork items				
	Smooth				
	(a) Vertical	m²	26 790	650	17 413 500
	(b) Horizontal	m²	8 090	730	5 905 700
	(c) Curved in tunnel	m²	2 180	730	1 591 400
	Scheduled concrete items				
	Strength concrete				
	(a) 30MPa structural concrete	m³	43 410	2 160	93 765 600
	Scheduled reinforcement items				
	Steel bars	t	6 520	14 000	91 280 000
	Unformed surfaces				
	(a) Steel floated	m²	2 620	38	99 560
8.2	**SECTION: HYDRO-MECHANICAL**				
	Pre-cast concrete				
	(a) Trashracks	No.	140	12 380	1 733 200
	Hydro-mechanical steelwork - storage, transport, procurement, fabrication, installation, testing and corrosion protection				
	(a) Fine screens	No.	52	307 000	15 964 000
	(b) Emergency gates	No.	2	2 735 000	5 470 000
	(c) Grappling beams	No.	2	154 000	308 000
	(d) Trash bin	No.	1	69 000	69 000
	(e) Other accessories	Sum	1	250 000	250 000
	Pipes				
	(a) 1 600 mm diameter	m	270	19 000	5 130 000
	(b) 1 800 mm diameter	m	64	21 000	1 344 000
	(c) 5 000 mm diameter	m	60	50 000	3 000 000
	Valves				
	(a) Butterfly valves				
	(1) 1 600 mm diameter	No.	21	605 000	12 705 000
	(2) 1 800 mm diameter	No.	4	825 000	3 300 000
	(b) Control valves				
	(1) 1 600 mm diameter	No.	3	605 000	1 815 000
	Cranes and hoists	Sum	1	12 000 000	12 000 000

Table 3.K.8 (continued)

8.3	**SECTION: ACCESS BRIDGE**				
	Scheduled Formwork items				
	Smooth				
	(a) Vertical	m²	1 560	500	780 000
	(b) Horizontal	m²	1 180	650	767 000
	Scheduled concrete items				
	Strength concrete				
	(a) 30MPa structural concrete	m³	2 730	2 160	5 896 800
	Scheduled reinforcement items				
	Steel bars	t	550	14 000	7 700 000
	Paving materials				
	(a) Paving blocks	m²	1 000	130	130 000
TOTAL CARRIED FORWARD TO SUMMARY					**288 417 760**

Table 3.K.9: Cost estimate: Smithfield Dam: Miscellaneous

SMITHFIELD DAM					
ITEM NO	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
9	**PART 9: MISCELLANEOUS**				
9.1	**SECTION: MISCELLANEOUS**				
	Electrical	Sum	1	4 934 000	4 934 000
	Telemetry	Sum	1	3 796 000	3 796 000
	Monitoring instrumentation	Sum	1	617 000	617 000
	Finishing and rehabilitation	Sum	1	3 854 000	3 854 000
	Miscellaneous steelworks	Sum	1	2 056 000	2 056 000
	Permanent infrastructure	Sum	1	34 600 000	34 600 000
	Permanent fence	Sum	1	3 532 000	3 532 000
	Floating boom	Sum	1	142 000	142 000
	Dayworks	Sum	1	19 650 000	19 650 000
TOTAL CARRIED FORWARD TO SUMMARY					**73 181 000**

Table 3.K.10: Cost estimate: Smithfield Dam: Summary

SUMMARY: SMITHFIELD DAM	
DESCRIPTION	**AMOUNT**
PART 1: RIVER DIVERSION	178 466 000
PART 2: DEVELOPMENT OF QUARRIES AND BORROW AREAS	9 925 000
PART 3: SMITHFIELD MAIN DAM CONSTRUCTION	813 491 000
PART 4: SMITHFIELD SADDLE DAM CONSTRUCTION	252 081 000
PART 5: MAIN EMBANKMENT SIDE CHANNEL SPILLWAY	189 703 000
PART 6: SADDLE EMBANKMENT FUSE PLUG SPILLWAY	66 045 000
PART 7: OUTLET WORKS, INTAKE STRUCTURE	146 446 000
PART 8: TUNNEL INTAKE STRUCTURE	288 418 000
PART 9: MISCELLANEOUS	73 181 000
TOTAL	**2 017 756 000**

Annexure 4 A – Techniques and Practices on Tunnelling

A – 1 Anticipated Excavation Method:

Tunnels may be excavated either by the use of tunnelling boring machines (TBM) which bore openings through the rock, or by the use of conventional drill and blast techniques. Both methods have their advantages and disadvantages, which have to be evaluated for each tunnel where the use of tunnelling machines is envisaged.

A – 2 Selection of the Excavation Method:

The selection of the excavation method for any rock tunnel project is a major decision which influences all aspects of the tunnelling operation. The excavation method directly influences:

- the possible shape of the tunnel;
- the rate of advance of the excavation and, therefore, the overall rate of advance of the tunnel and the duration of the project;
- the muck handling problem, in terms of the type of muck, sequence of mucking operation, type and capacity of the muck-handling system;
- the quality of the tunnel opening in terms of smoothness of the tunnel walls, or amount of overbreak, extent of loosening of the surrounding rock, and stability of the unsupported tunnel;
- the rock support and lining system; and
- the effect of the tunnelling operation on the local environment.

The choice of the excavation method may be influenced by specific conditions related to any of the above parameters. The proper selection of the excavation method is, therefore, of paramount importance in the design and construction of any tunnel.

A – 3 Drill and Blast Methods of Tunnelling:

The drill and blast method of excavating tunnels is more than 100 years old. Because of its continued use, the drill and blast method is now well-known and quite reliable. It has been tested and has proven successful in nearly all rock conditions.

The excavation of a tunnel by the drill and blast method is a cyclic operation. Each cycle referred to as a "round", consists of three successive operations, i.e. drilling, blasting and mucking. Because of the cyclic operation, the rate of advance of a drill and blast excavation is dependent on the efficiency of each individual operation, i.e. drilling, blasting, ventilation, mucking and installation of the support system.

A – 4 Advantages of the Drill and Blast Method:

Advantages of the drill and blast method may be summarised as follows:

a) The most obvious advantage of the drill and blast method is the experience gained by contractors and engineers from its very wide application in the past. Because of its continued use, well trained labour is easily available.

b) Another advantage of the method is the relatively low capital costs for the equipment. However, the drill and blast technique is more expensive in terms of consumables, and is less productive, so that it is advantageous only on short tunnel lengths (generally less than 2.5 km).

c) From a technical point of view, the drill and blast method is attractive because it can produce any shape of tunnel without special difficulties or costs.

d) Finally, the major advantage of the drill and blast method is its adaptability to practically all rock conditions. The drill and blast method is frequently used as the last remaining solution when other mining methods have failed.

A – 5 Disadvantages of the Drill and Blast Method:

Disadvantages of the drill and blast method may be summarised as follows:

a) A significant problem with the method is related to the cyclic operation. To achieve high advance rates, each sequence of the operation has to be carried out in the minimum amount of time. To do so, high capacity equipment is essential, which is particularly obvious for ventilation and muck-handling. Capital costs for such equipment are, therefore, greater than would be required for a continuous operation.

b) Further, the equipment used in each sequence is left unproductive for the duration of other sequences, so that it is in operation only 30 to 50 percent of

the time. The re-entry period, which repents about 10 percent of the time of the period of a round, is totally unproductive since neither man nor equipment can be utilised during this period.

c) Finally, unproductive time is spent in moving equipment and men in and out between the different sequences; this accounts for as much as 15 percent lost time.

d) Another problem associated with the drill and blast method is the lack of detailed control on the size and shape of the excavation. To eliminate so-called "tight spots" or underbreak, drill patterns are selected to produce overbreak. The amount of overbreak is governed by the blasting method and by the quality of the rock mass. It is a minimum for a tunnel excavated by the smooth wall technique in massive rock, where the increase in quantities over those assuming a "neat" tunnel opening are about 5 percent for muck and 20 percent for concrete. In blocky rock, increases can be as high as 20 percent for muck and 100 percent for concrete.

e) The drill and blast method also produces an unavoidable loosening of the rock surrounding the tunnel opening, hence additional rock support may be required to stabilize the opening (possibly as much as 20 percent).

f) The effects of blasting must also be considered. Blasting in rock generates vibrations which are transmitted through the surrounding ground to adjacent structure. Excessive vibration can result in damage to such structure.

A – 6 Full-Face Tunnel Boring Machines (TBMs):

The use of tunnel-boring machines dates back to the late 1800’s, but it is only since the 1950’s that the use of TBMs has become widespread. With this increasing use, major improvements have been achieved in the design of cutters and machines. As a result, TBMs can now be used in rocks with compressive strengths up to 275 MPa, and are extremely competitive when compared to other methods in softer rocks with compressive strengths less than 150 MPa.

When compared to the drill and blast method, TBMs are still in their early stages of development, yet it is possible to achieve advance rates in excess of 300 metres per week, or about 2 to 3 times that for drilled and blasted tunnels.

A – 7 Operation of TBMs:

A full-face tunnel boring machine (TBM) consists of a rotating head fitted with rock cutting tools or picks. The head is supported by a bearing on a structural support member that, in turn, is held in place by a hydraulically positioned wall-gripping mechanism. Both torque and thrust are applied to the cutting head, the machine thrust being provided by jacks reacting against the grippers, which are expanded laterally against the tunnel sidewalls. The rock cuttings fall to the invert at the tunnel face where they are removed by means of buckets or scoops that transfer the cuttings to a conveyor belt working immediately behind the cutting head. After advancing the cutting head through a pre-set boring stroke, the tunnelling machine is advanced by hydraulically pulling in the gripper mechanism from the tunnel walls, stroking forward, and edging the grippers to the new forward position on the wall; the machine is then set for the next advance stroke.

Although special machines have been designed to turn on a radius of 30 metres in both horizontal and vertical directions, the conveyors and back-up service equipment generally limit TBMs to turn with a radius of more than 100 metres.

The full-face rotary TBMs have provided the fastest and most reliable production of any excavation method or machine type. They can operate as "open" machines, or alternatively as "shielded" machines. The open machines have the advantage of allowing any type of ground support system to be installed as near to the tunnel face as possible. The shielded machines, on the other hand, are designed principally to allow the placing of pre-cast concrete segments. The shielded machines completely protect the equipment and personnel at the heading, but for reasons of economy are limited to permanent openings where full lining is required.

The following aspects need to be considered when choosing the type of TBM to be utilised on a project:

a) Cutting Tools

Tunnelling machines utilise several different types of rock cutting tools or picks. There are three common types, i.e. the drag bit, the disc cutter and button cutter, which are utilised for specific geological and operational conditions. As cutting tool replacement costs are high, it is important to

match tool type with machine type and operational and geological conditions.

b) Fracture Strength and Abrasion of Rock

The two mechanical characteristics of the rock which directly affect both pick replacement costs and excavation rates are, firstly, the ability of the rock to be fractured (which is generally measured in terms of the uni-axial compressive strength of the intact rock), and secondly the abrasiveness of the rock (for which no standard test exists, although the index of percentage silica is often used).

c) Personnel

A tunnelling machine is only as good as the personnel in charge of its operation. It is imperative therefore to have good organisation and supervision, and a thoroughly trained work force. In general, mechanical excavation requires more than twice the number of skilled operatives compared to conventional drill and blast techniques.

d) Ground support systems

With tunnel boring operations, a variety of ground support systems can be installed, including rock bolts, steel arches, pre-cast concrete members, etc. Where a significant proportion of the tunnel requires support, a reduction in the machine utilisation factor to around 50% to 60% can be expected, although this factor obviously depends upon the difficulty of the ground support.

Due to the significant reduced rock mass loosening and over-break experienced with tunnel boring machines compared to conventional drill and blast techniques, machine-bored tunnels generally require much less ground support. As one would expect, the factor is greater for small diameter tunnels than larger ones.

e) Line and grade control

Prior to the introduction of laser beam guidance, the maintenance of line and grade was always problematic. Adjustments of the grade and alignment of the machine can be made automatically or manually. Deviations can be easily kept within 25 mm.

f) Dust Control

The control of dust is a major factor in the operation of TBMs. This is commonly achieved by installing ventilation ducts mounted on suction type blowers, as close to the face as possible. In addition, the face is frequently sprayed with water or a wetting agent.

e) Geotechnical Factors

To a great extent, the efficiency and economy of any tunnelling machine is dependent upon the rock and rock structure through which it bores. Problems of a geological nature found only during actual tunnelling operations result in very costly downtime and must be prevented at all costs.

h) Rates of Advance

Penetration rates for full-face TBMs vary from 2 to 3 m/hr with the minimum rate required for economic machine boring operations being approximately 1 m/hr.

A – 8 Advantages of TBMs:

Advantages of Tunnel Boring Machines may be summarised as follows:

a) A negative feature of the drill and blast method is the delay caused by cyclic operation. In contrast, TBMs can operate on an almost continuous basis, the only unproductive time in the cycle is that required to advance the reaction frame at the end of each "stroke". The continuous advance results in higher hourly rates of advance and in optimum use of ancillary tunnelling equipment such as muck handling and ventilation systems.

b) TBMs have the great advantage that in good rock they produce a smooth bore with a diameter equal to the design diameter. Consequently, overbreak is practically eliminated, which results in a reduction in the quantities of muck to be handled and the amount of concrete used in the lining.

c) A further benefit, resulting from the smooth bore and from the elimination of blasting vibration, is that loosening of the rock is considerably reduced, so that the rock has a better self-supporting capacity. This in turn, means that the support requirements for machine excavated tunnels are significantly less than for drilled and blasted tunnels. This effects the economics not only in terms of

reduced quantities of support, but also in terms of shorter installation time for rock support and consequent faster rates of advance of the entire tunnelling operation.

d) A further advantage is that due to the absence of blast induced vibrations, TBMs are not as damaging to the local environment, hence special precautions need not be taken with regard to the effect of tunnelling vibrations on nearby structures.

A – 9 Disadvantages of TBMs:

Tunnel-boring machines pent some important disadvantages that may reduce their potential use under some conditions.

a) Geometric Constraints

Full-face TBMs can only excavate circular tunnel sections and a given TBM can bore only one size of tunnel.

A further geometric constraint in the use of TBMs is related to the minimum radius of curvature, the tightest practical curve which can be negotiated by a TBM is in the order of 100 metres. For maximum tunnel grades, the limitations are generally similar to those for the material handling system and, as such; do not introduce additional constraints to the alignment.

b) Limitations due to Rock Conditions

The limitations of TBM use are uniquely related to variations in the quality of the rock mass. Since TBMs are custom built for local rock conditions (i.e. their design is based on the strength and hardness of the rock expected), if the rock conditions are variable over the length of the tunnel, the operation of any TBM will be very difficult. The incapacity of TBMs to adapt to changes in rock quality can be even more severe and may force the contractor to use classical mining methods to overcome the difficulty.

A – 10 Mechanised Tunnelling verses Drilling and Blasting:

Full-face rock tunnelling machines produce a very smooth opening which reduces rock support requirements, and minimises overbreak and the distance

to the flow of ventilation. In addition, the smooth tunnel makes support installation much faster, gives improved support, and is much more cost effective. Rock sts concentrations are also reduced. The smooth tunnel and the absence of explosives make machine tunnelling operations safer and less unpleasant.

On the other hand, the drill and blast technique has a wealth of experience, and is frequently used as the last remaining solution when other methods have failed. For identical projects, tunnelling machines can develop at 3 to 10 times the rate of conventional drill and blast techniques.

Rules of thumb can sometimes be misleading but the following are pented as a list of the items to be evaluated when considering the use of tunnel boring techniques:

- The required tunnel length should be at least 2.0 km, with the tunnel diameter greater than 3.0m for full-face machines;
- The uni-axial compressive strength of the intact rock should be less than 275 MPa, with a geological structure that is preferably jointed or bedded;
- Tunnel curves should have a radius of at least 100m with the tunnel grade varying from -9% to +14%;
- The rate of water inflow at the tunnel face should not exceed 0.017 m^3/second (i.e. 17 lit/second) per metre of tunnel diameter. The maximum water pressure should be less than 1.5 MPa;
- The muck handling system must be capable of disposing of broken rock at the sustained production rate of the tunnelling machine; and
- The rock sts must not exceed the equivalent of two tunnel diameters.

Annexure 4 B – uMkhomazi – uMlaza Tunnel: Tunnel and shaft design

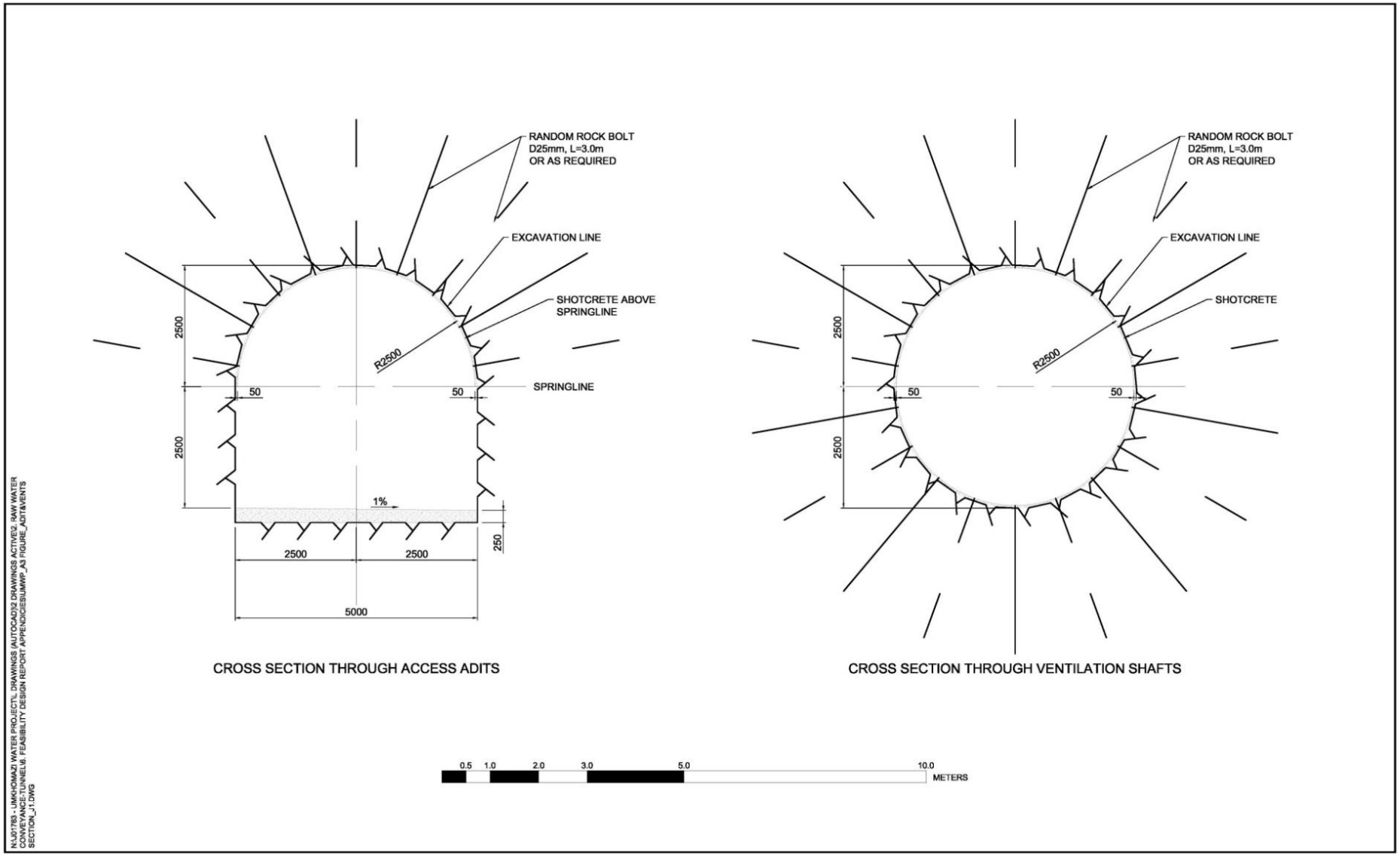


Figure 4.B.1: Cross sectional view through an access adit and a ventilation shaft

Annexure 4 C – uMkhomazi – uMlaza Tunnel: Hydraulic design

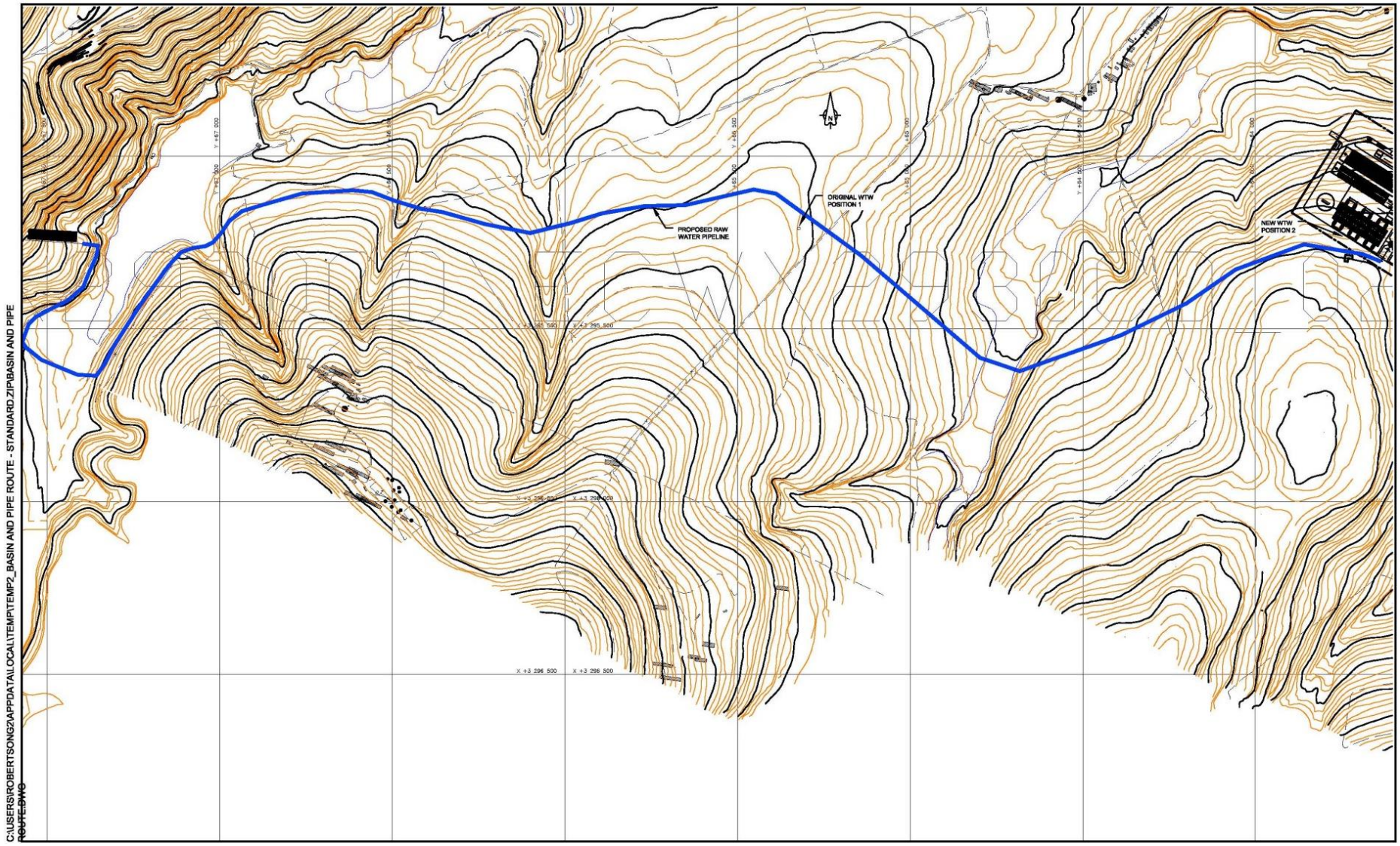


Figure 4.C.1: General layout of the raw water pipeline from tunnel outlet to Baynesfield WTW

Annexure 4 D – uMkhomazi – uMlaza Tunnel: Alignment

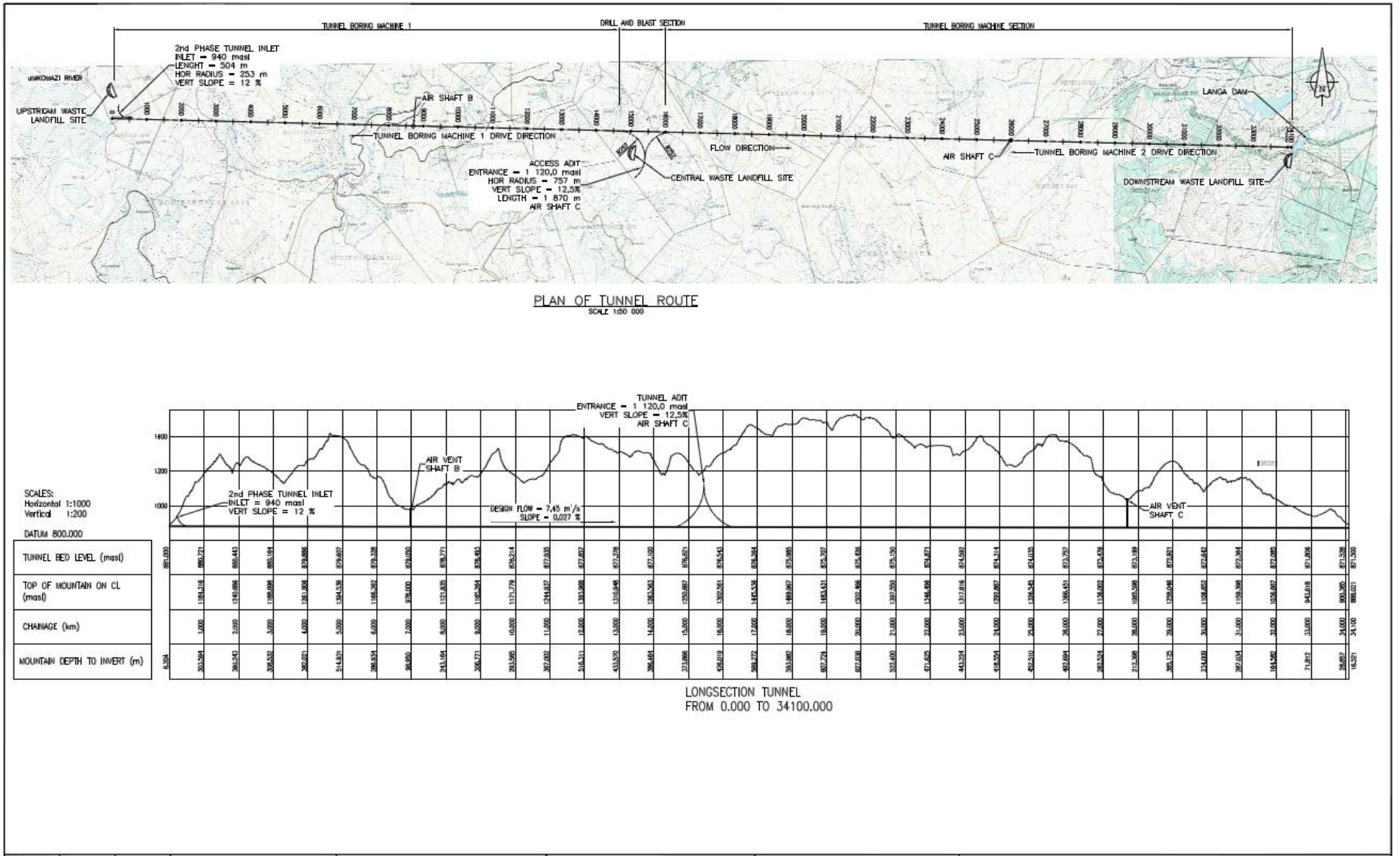


Figure 4.D.1: Long section and chainages of uMkhomazi – uMlaza Tunnel

Annexure 4 E – uMkhomazi – uMlaza Tunnel: Inlet and Outlet portals stability analysis

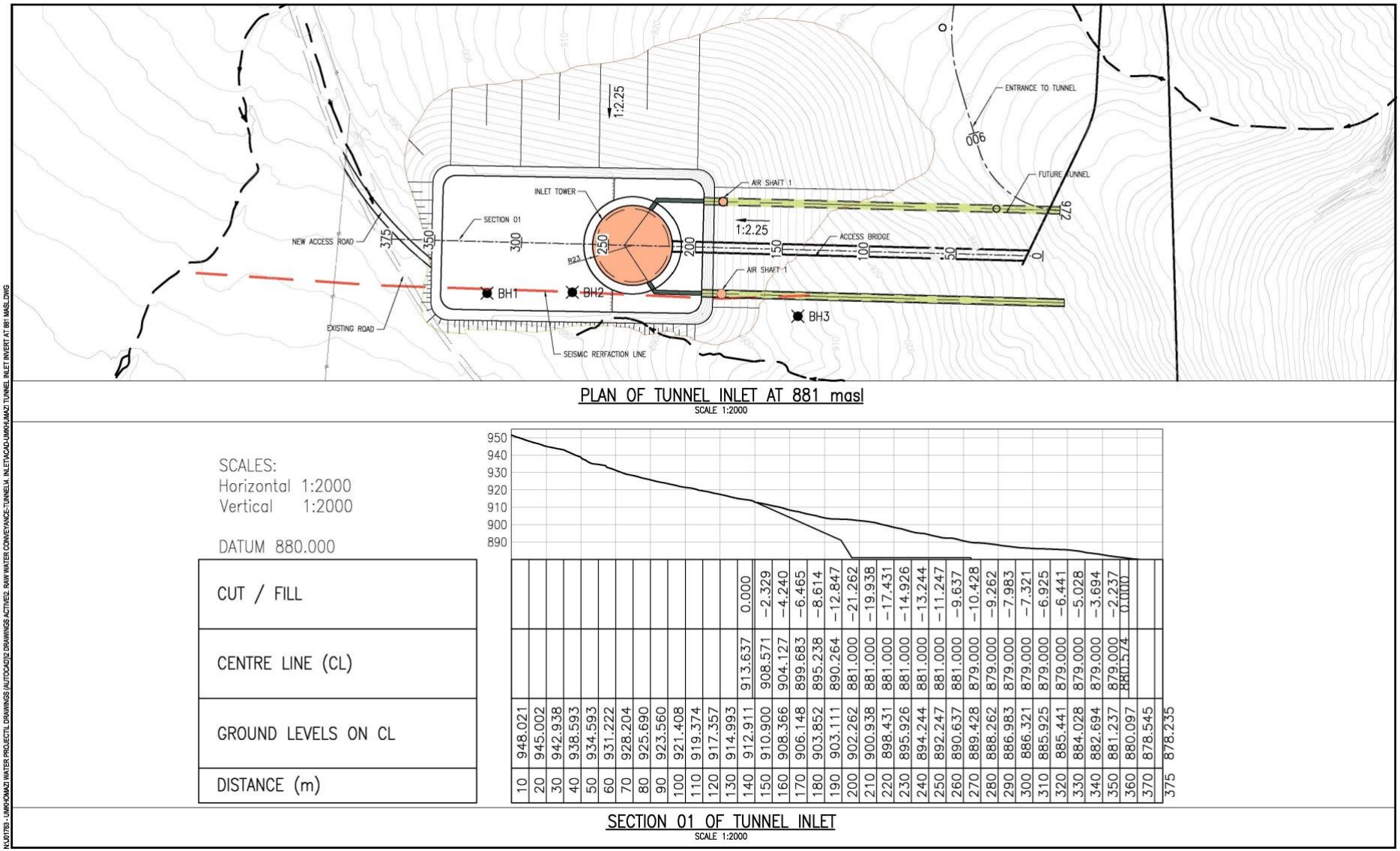
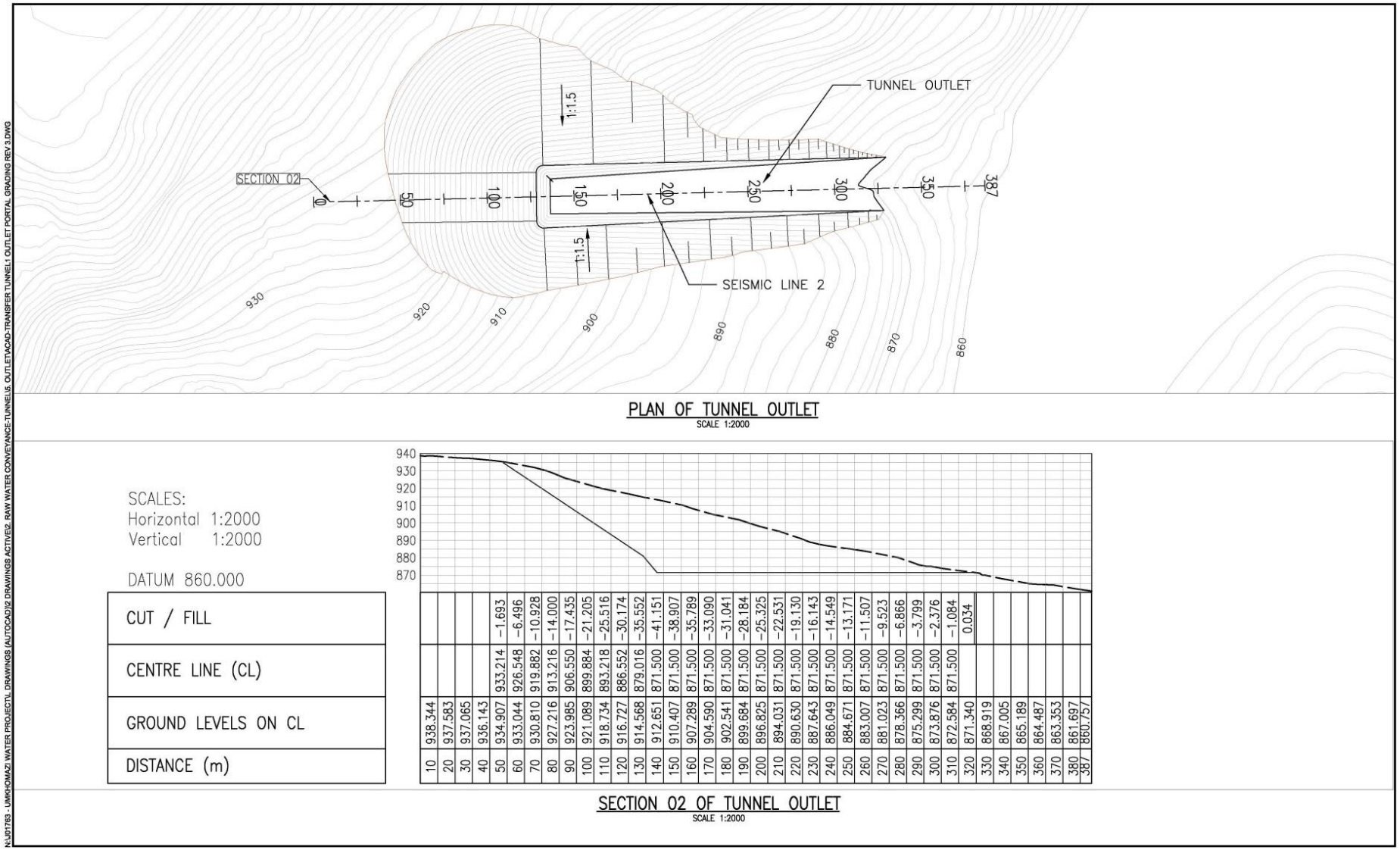


Figure 4.E.1: Tunnel Inlet Portal Excavation



DISTANCE (m)	GROUND LEVELS ON CL	CENTRE LINE (CL)	CUT / FILL
10	938.344		
20	937.583		
30	937.065		
40	936.143		
50	934.907	933.214	−1.693
60	933.044	926.548	−6.496
70	930.810	919.882	−10.928
80	927.216	913.216	−14.000
90	923.985	906.550	−17.435
100	921.089	899.884	−21.205
110	918.734	893.218	−25.516
120	916.727	886.552	−30.174
130	914.568	879.016	−35.552
140	912.651	871.500	−41.151
150	910.407	871.500	−38.907
160	907.289	871.500	−35.789
170	904.590	871.500	−33.090
180	902.541	871.500	−31.041
190	899.684	871.500	−28.184
200	896.825	871.500	−25.325
210	894.031	871.500	−22.531
220	890.630	871.500	−19.130
230	887.643	871.500	−16.143
240	886.049	871.500	−14.549
250	884.671	871.500	−13.171
260	883.007	871.500	−11.507
270	881.023	871.500	−9.523
280	878.366	871.500	−6.866
290	875.299	871.500	−3.799
300	873.876	871.500	−2.376
310	872.584	871.500	−1.084
320	871.340		0.034
330	868.919		
340	867.005		
350	865.189		
360	864.487		
370	863.353		
380	861.697		
387	860.757		

Figure 4.E.2: Tunnel Outlet Portal Excavation

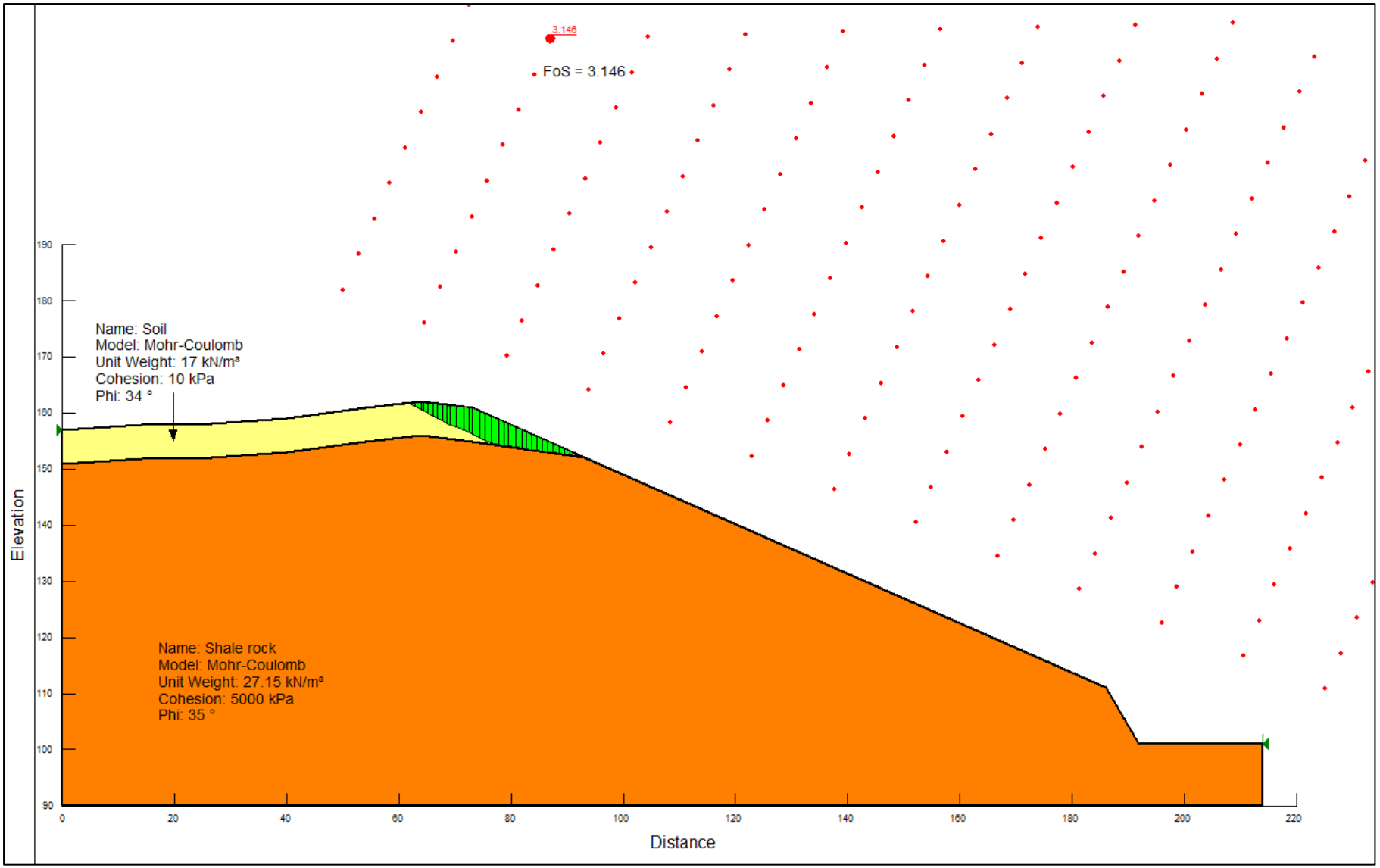


Figure 4.E.3: Inlet portal, Section 1, 1:1.5 excavation slope

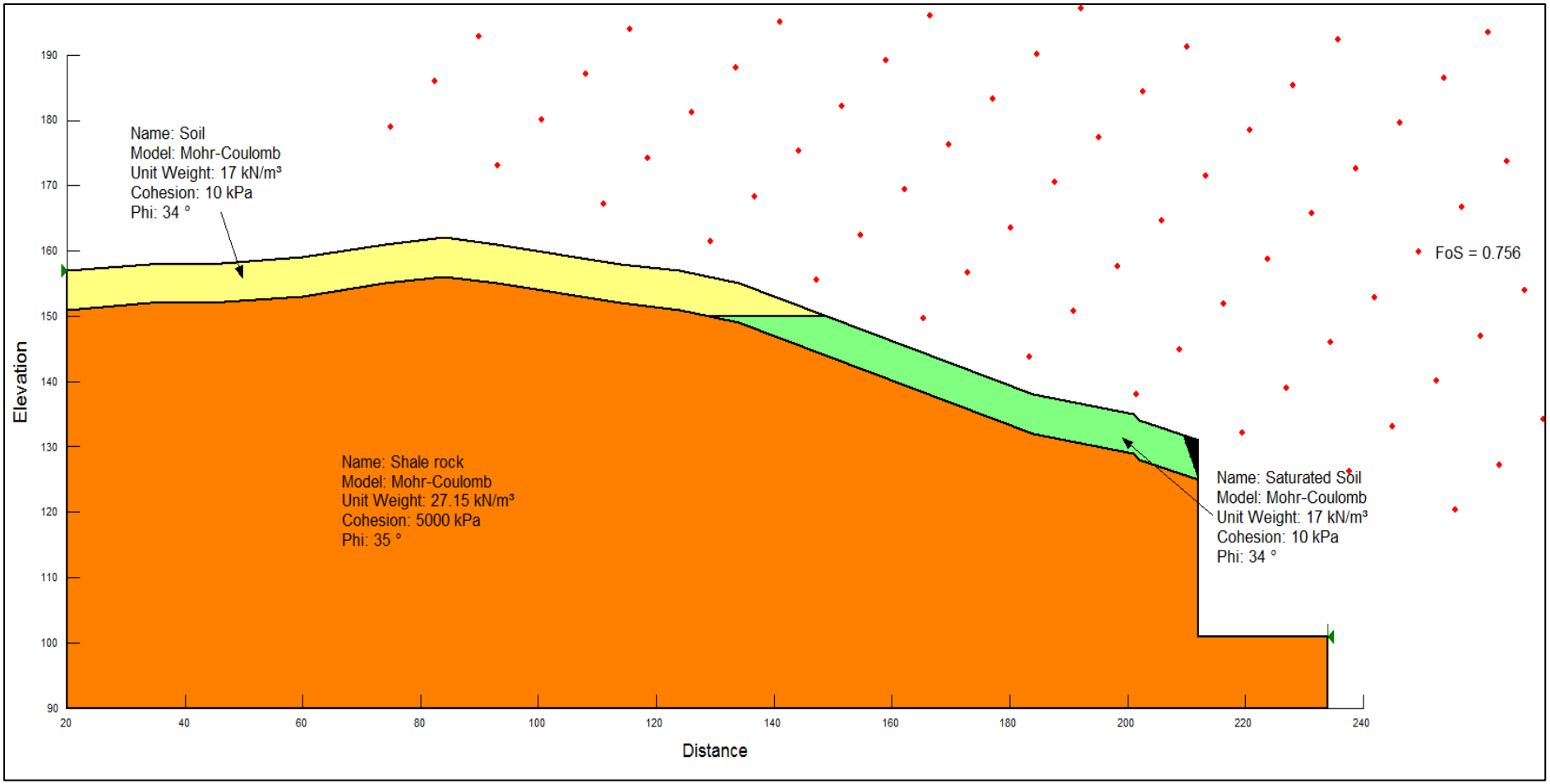


Figure 4.E.4: Inlet portal, Section 1, 90° excavation

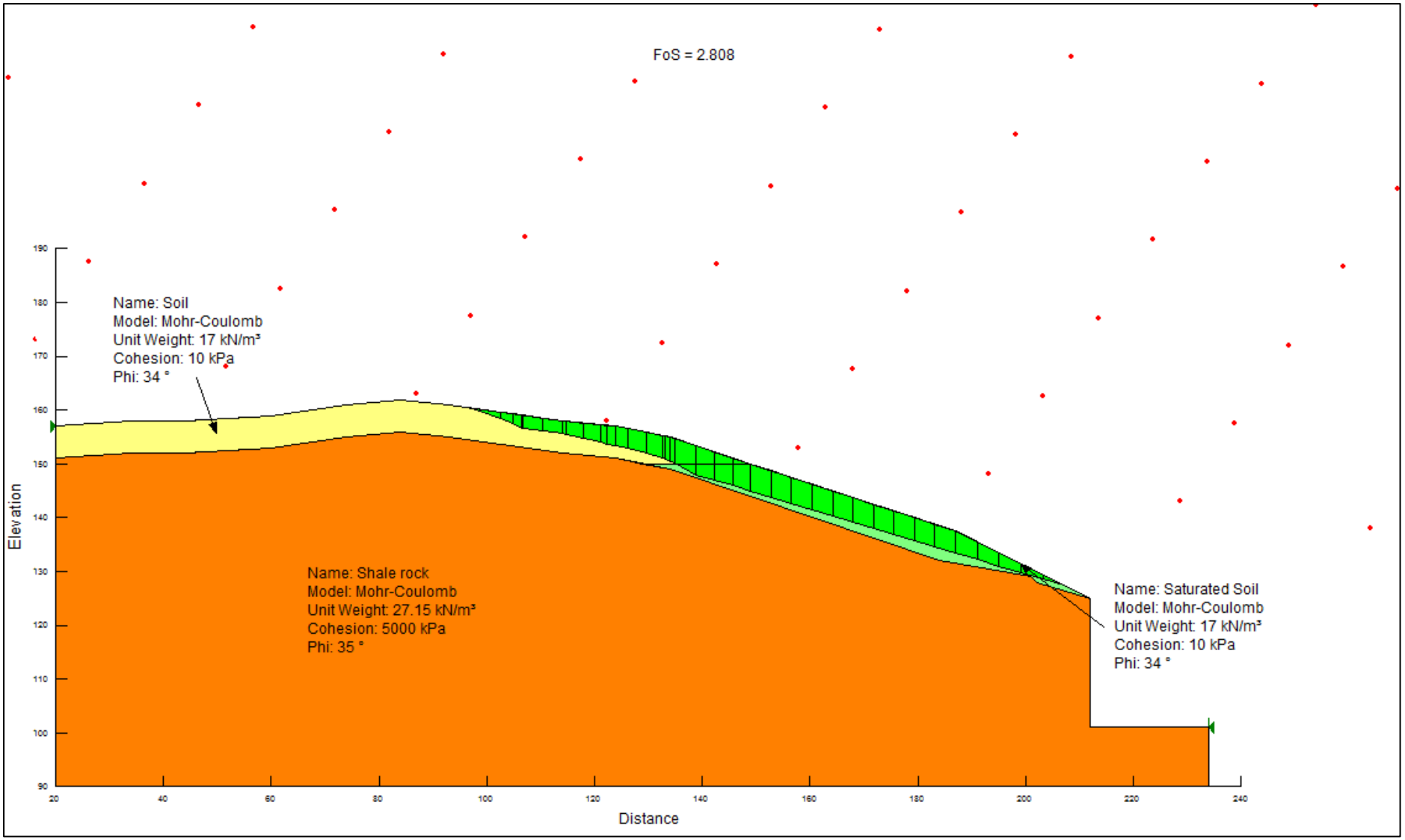


Figure 4.E.5: Inlet portal, Section 1, 90° excavation in shale, 1:2 excavation slope in soil

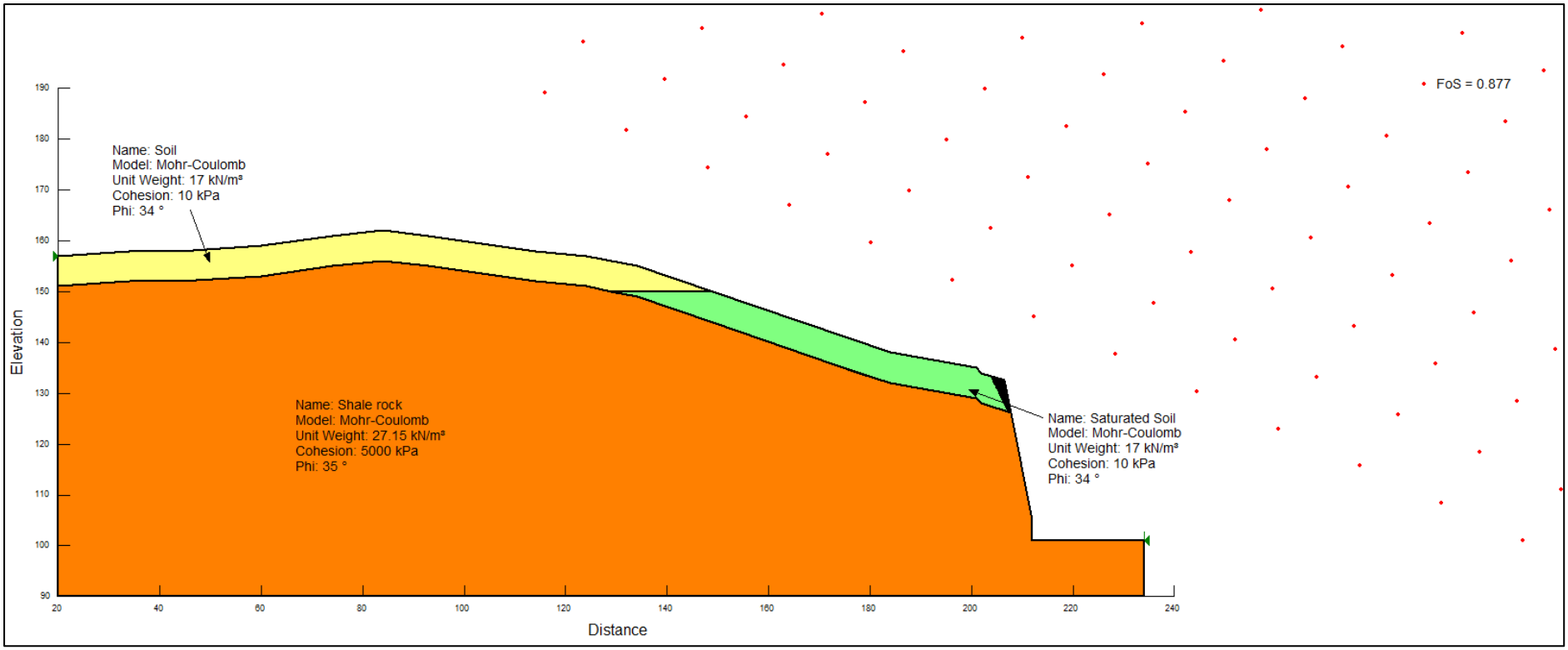


Figure 4.E.6: Inlet portal, Section 1, 1:0.2 excavation slope in shale, 1:2 excavation slope in soil

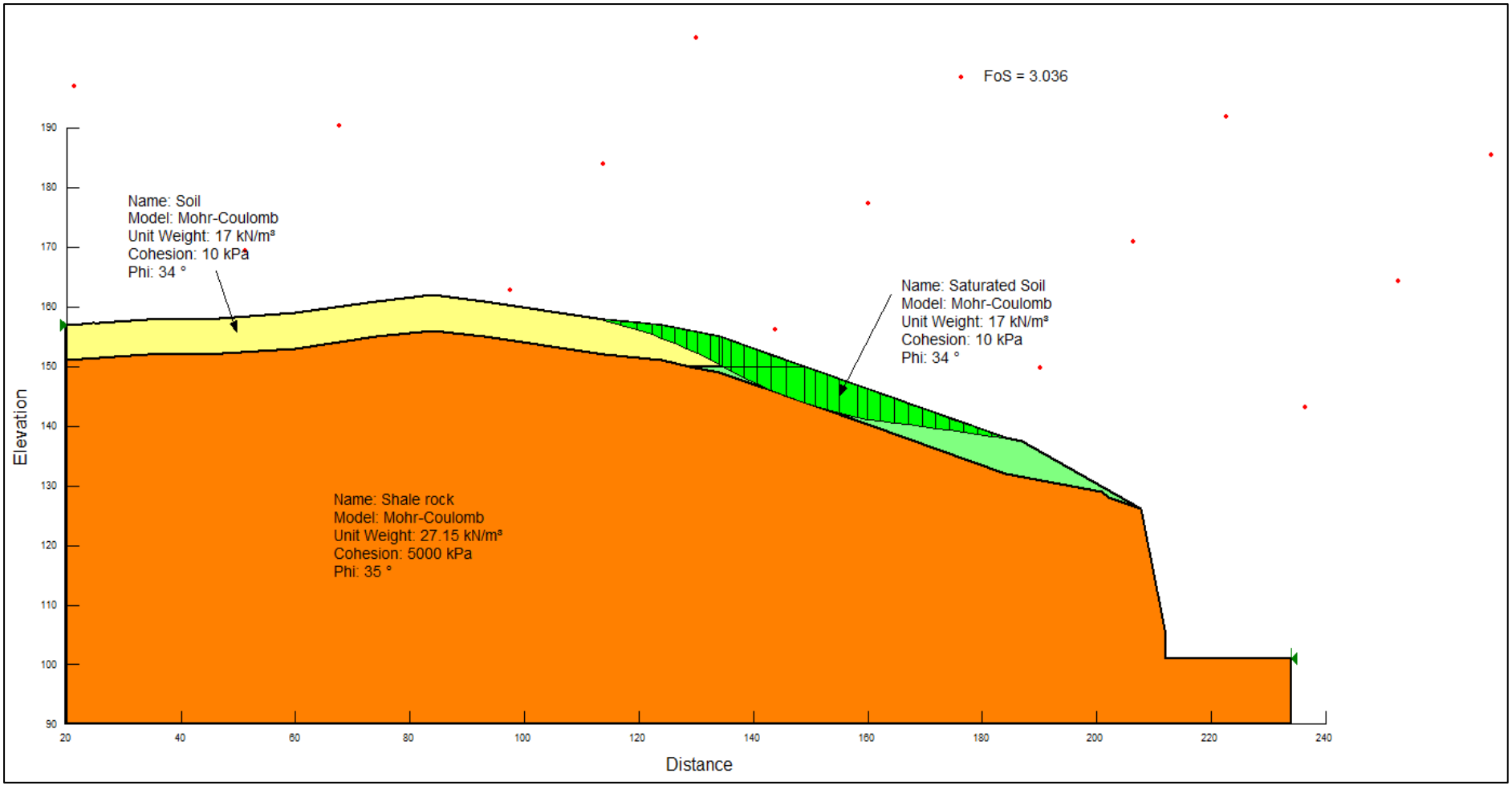


Figure 4.E.7: Inlet portal, Section 1, 1:0.2 excavation slope in shale, 1:2 excavation slope in soil

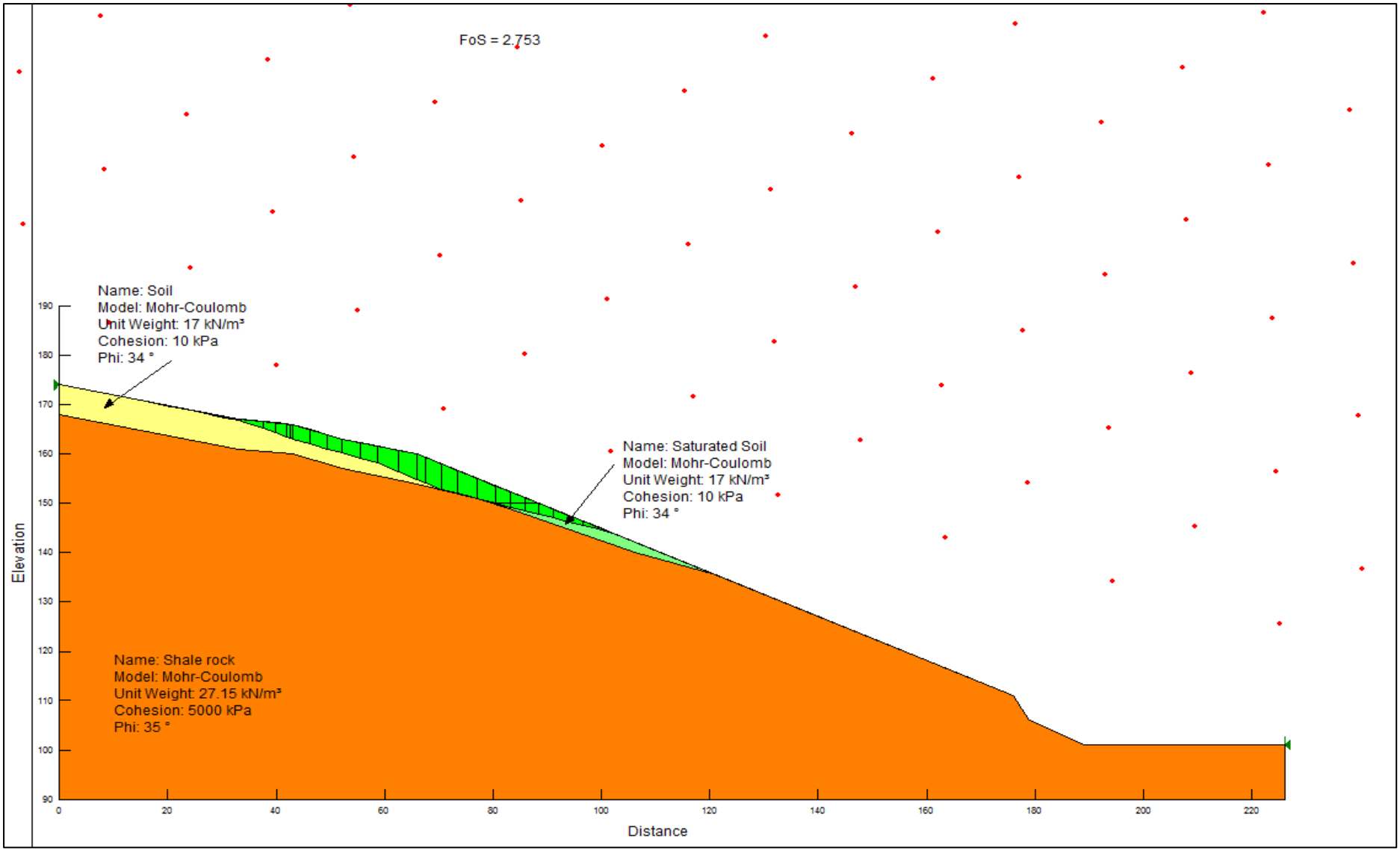


Figure 4.E.8: Inlet portal, Section 2, 1:1.5 excavation slope

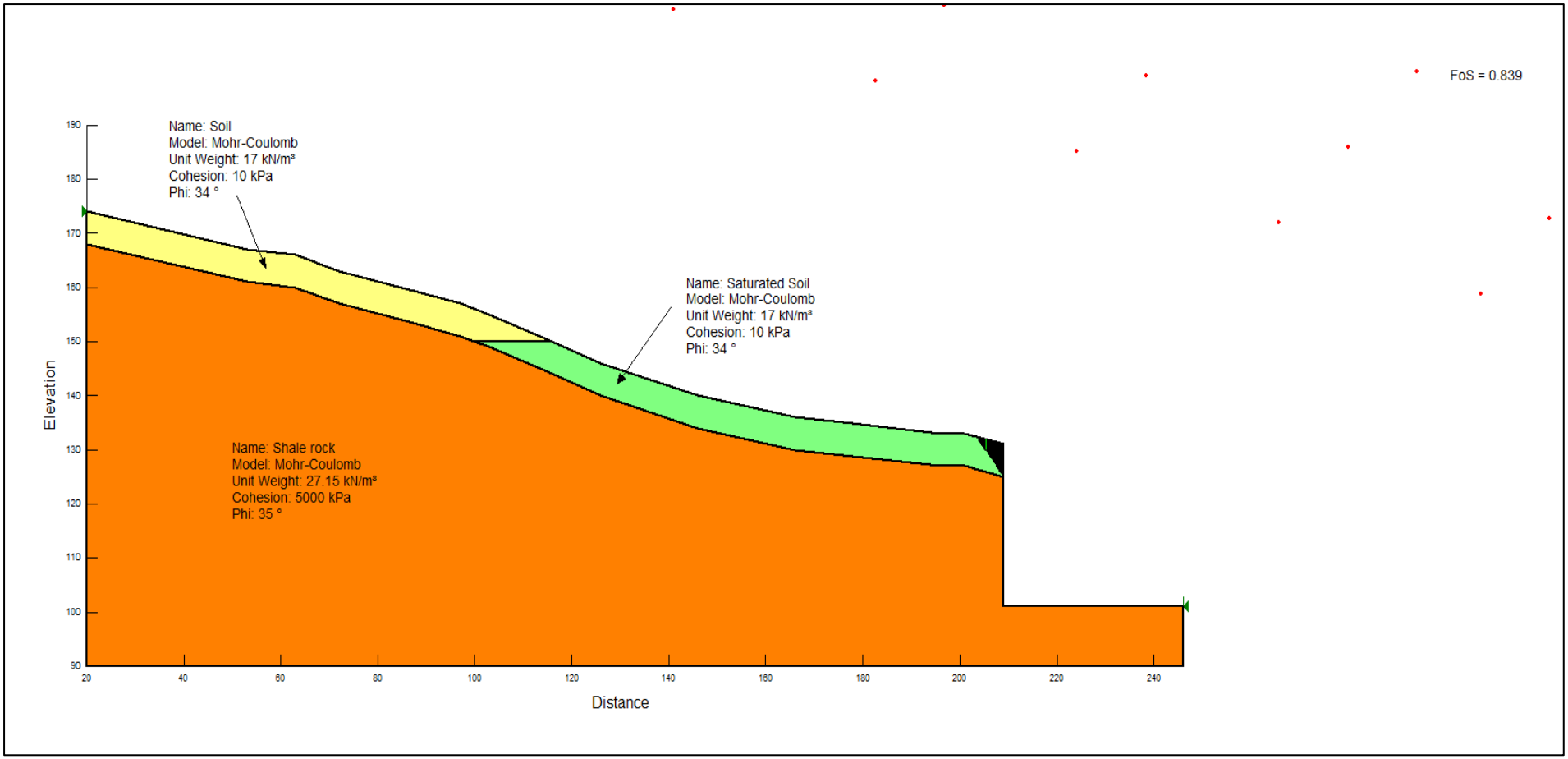


Figure 4.E.9: Inlet portal, Section 2, 90° excavation

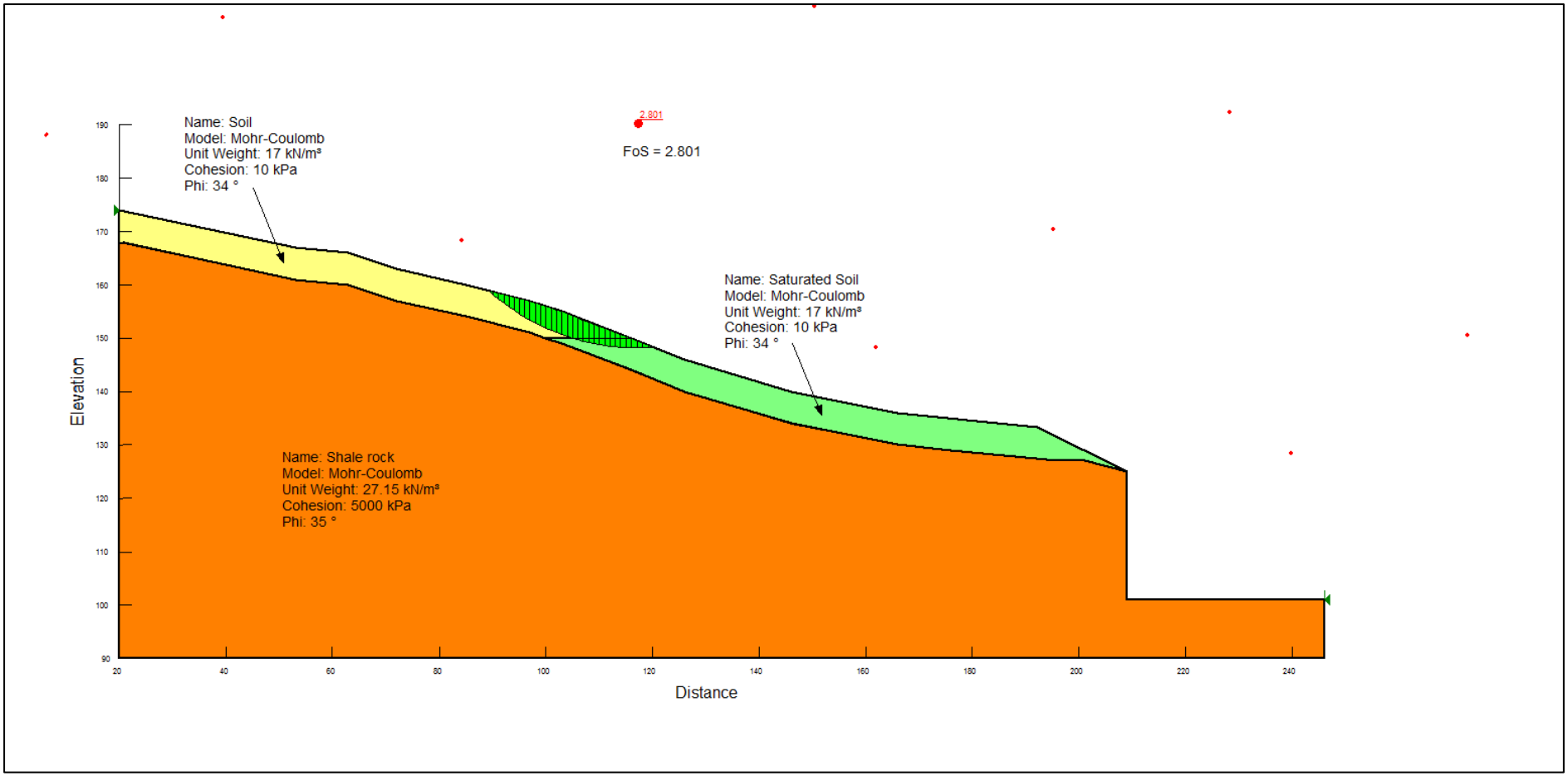


Figure 4.E.10: Inlet portal, Section 2, 90° excavation in shale, 1:2 excavation slope in soil

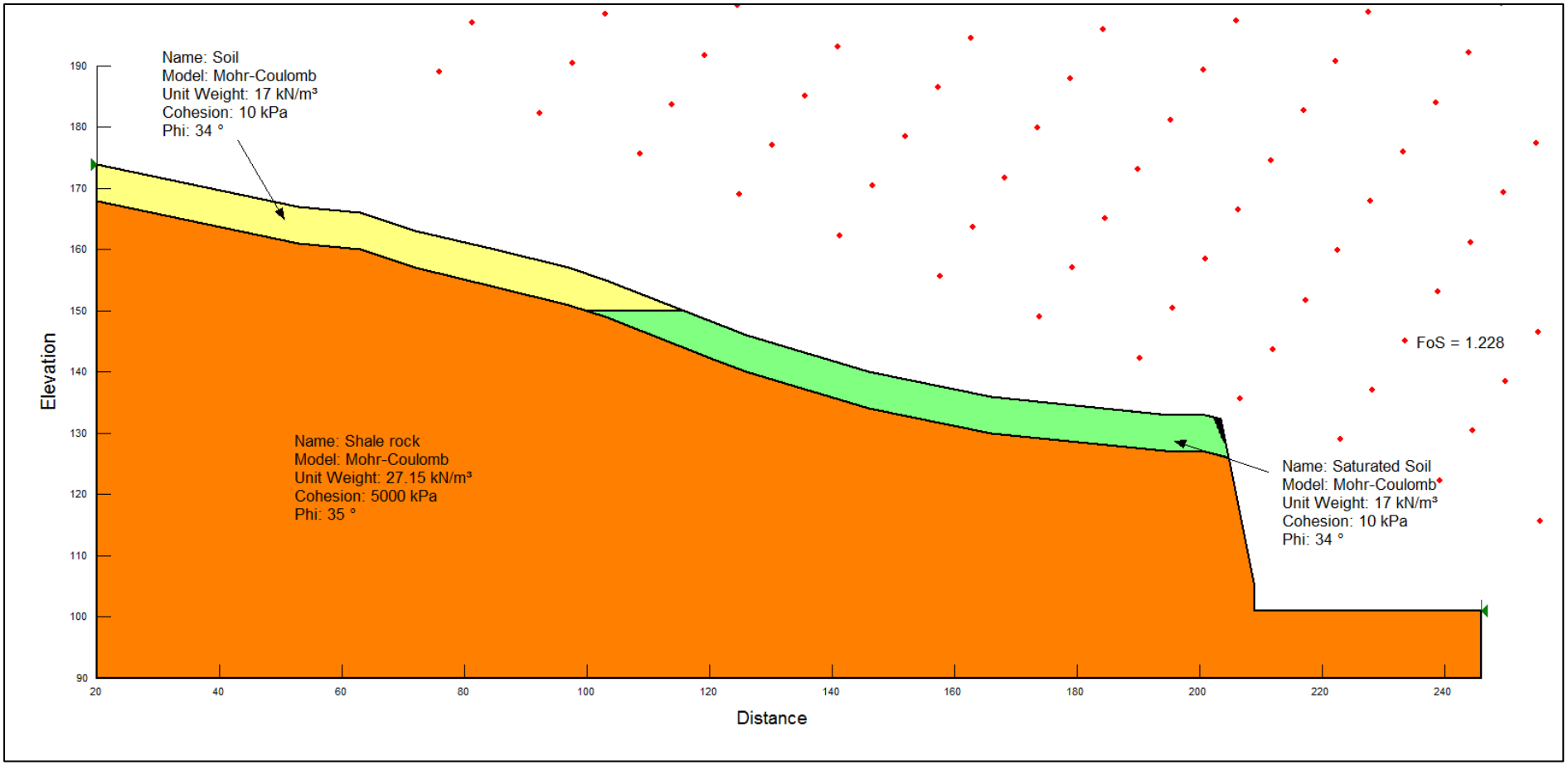


Figure 4.E.11: Inlet portal, Section 2, 1:0.2 excavation slope in shale, 1:2 excavation slope in soil

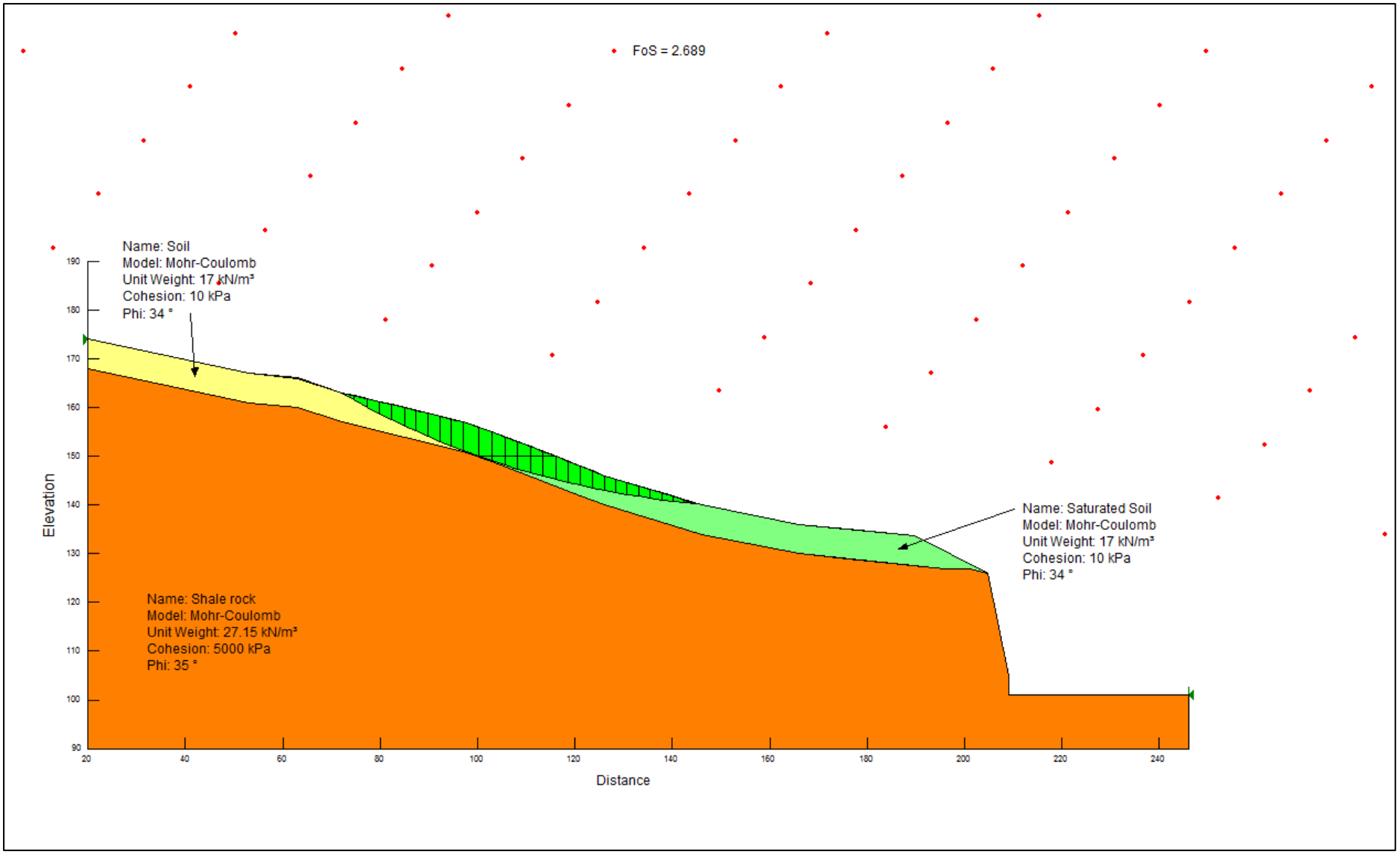


Figure 4.E.12: Inlet portal, Section 2, 1:0.2 excavation slope in shale, 1:2 excavation slope in soil

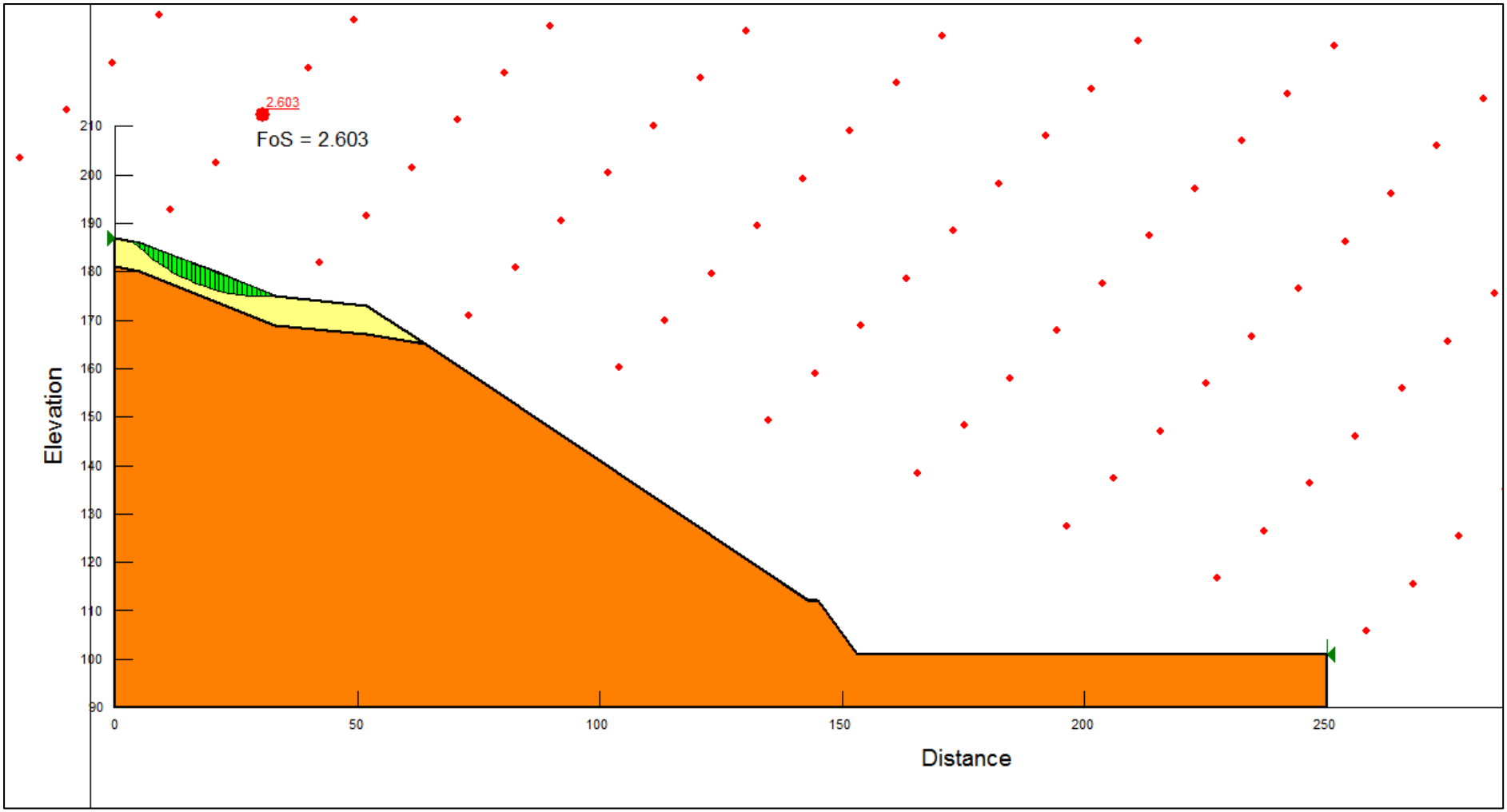


Figure 4.E.13: Outlet portal, Section 1, 1:1.5 excavation slope

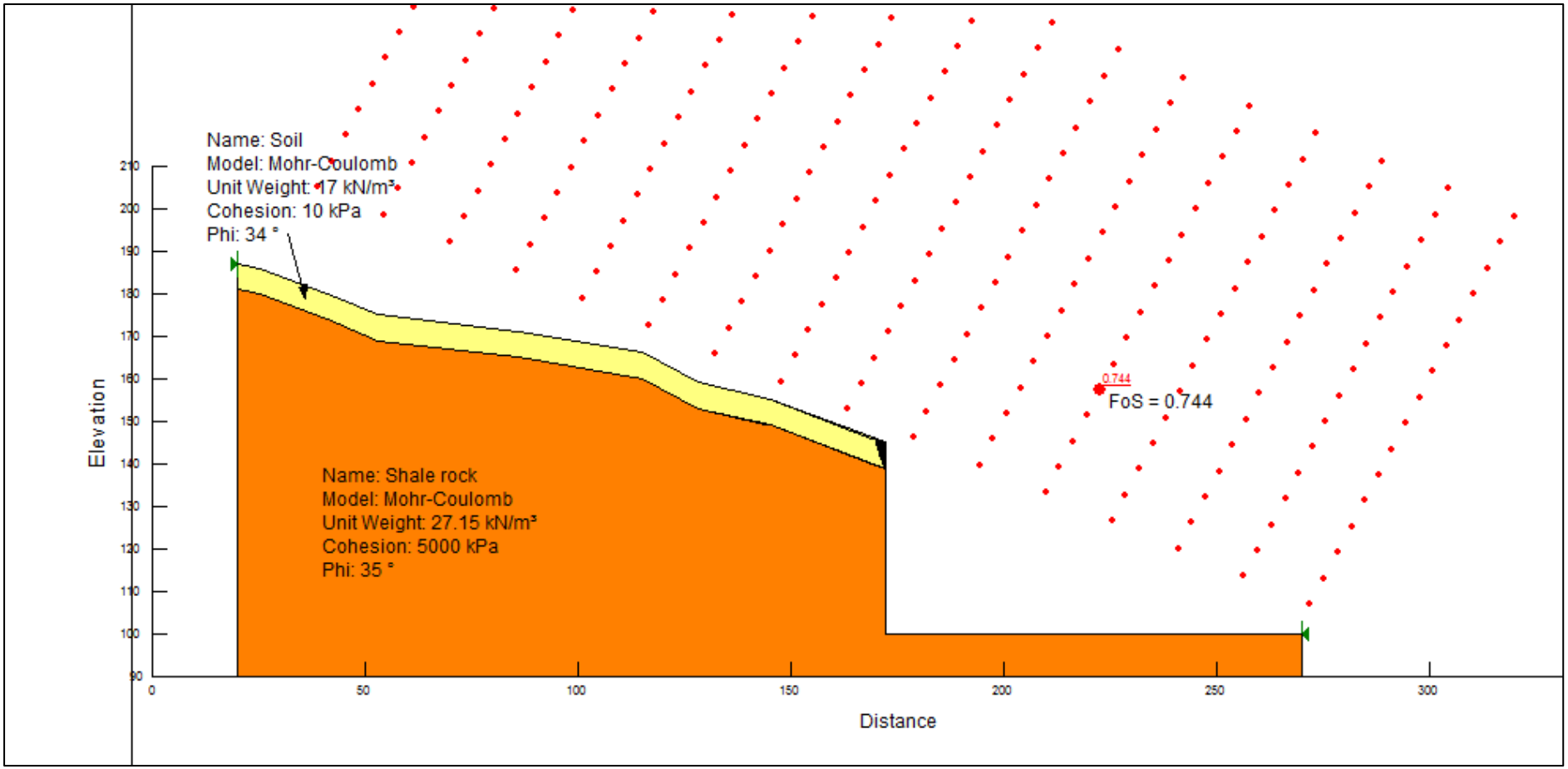


Figure 4.E.14: Outlet portal, Section 1, 90° excavation

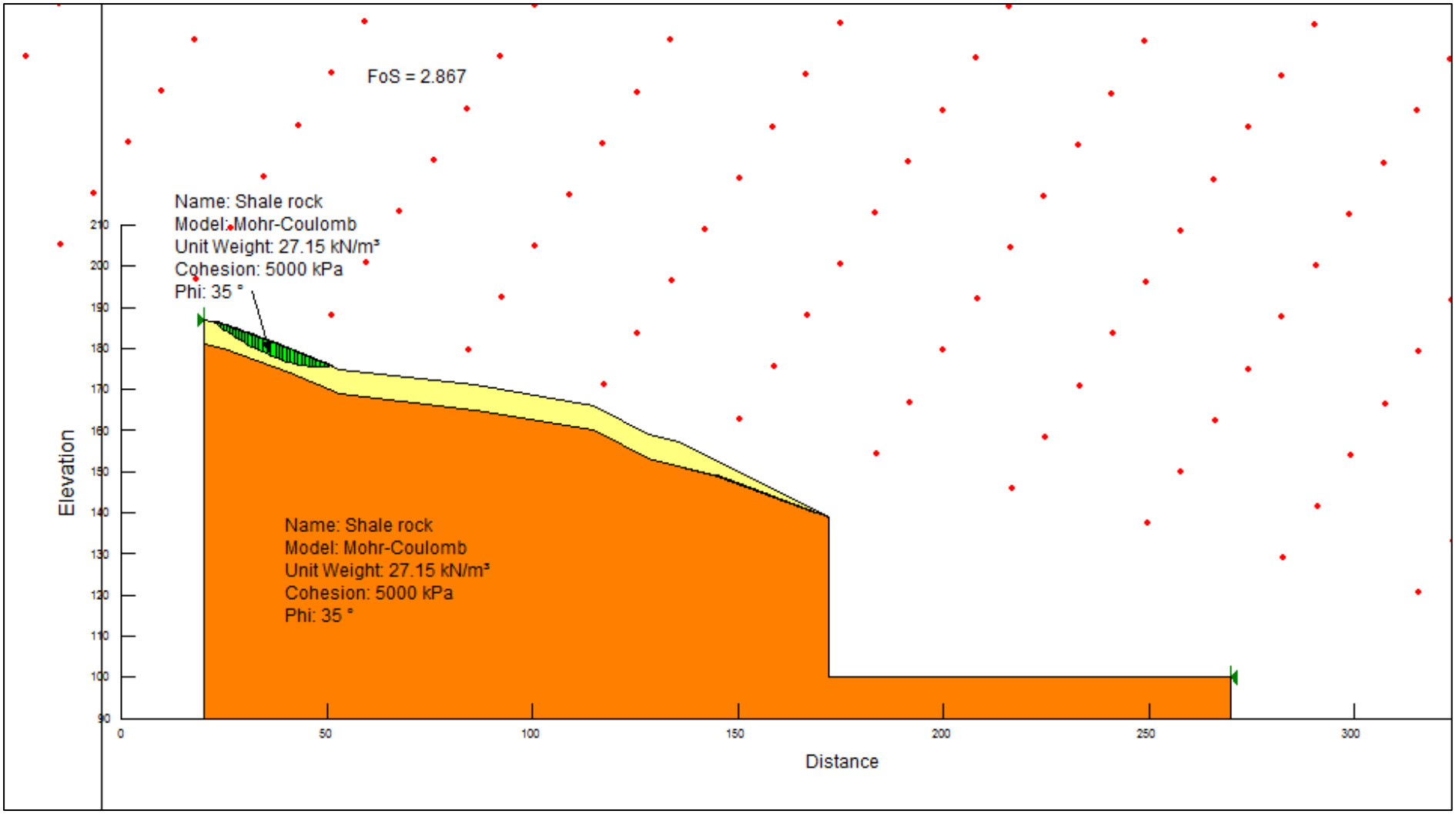


Figure 4.E.15: Outlet portal, Section 1, 90° excavation in shale, 1:2 excavation slope in soil

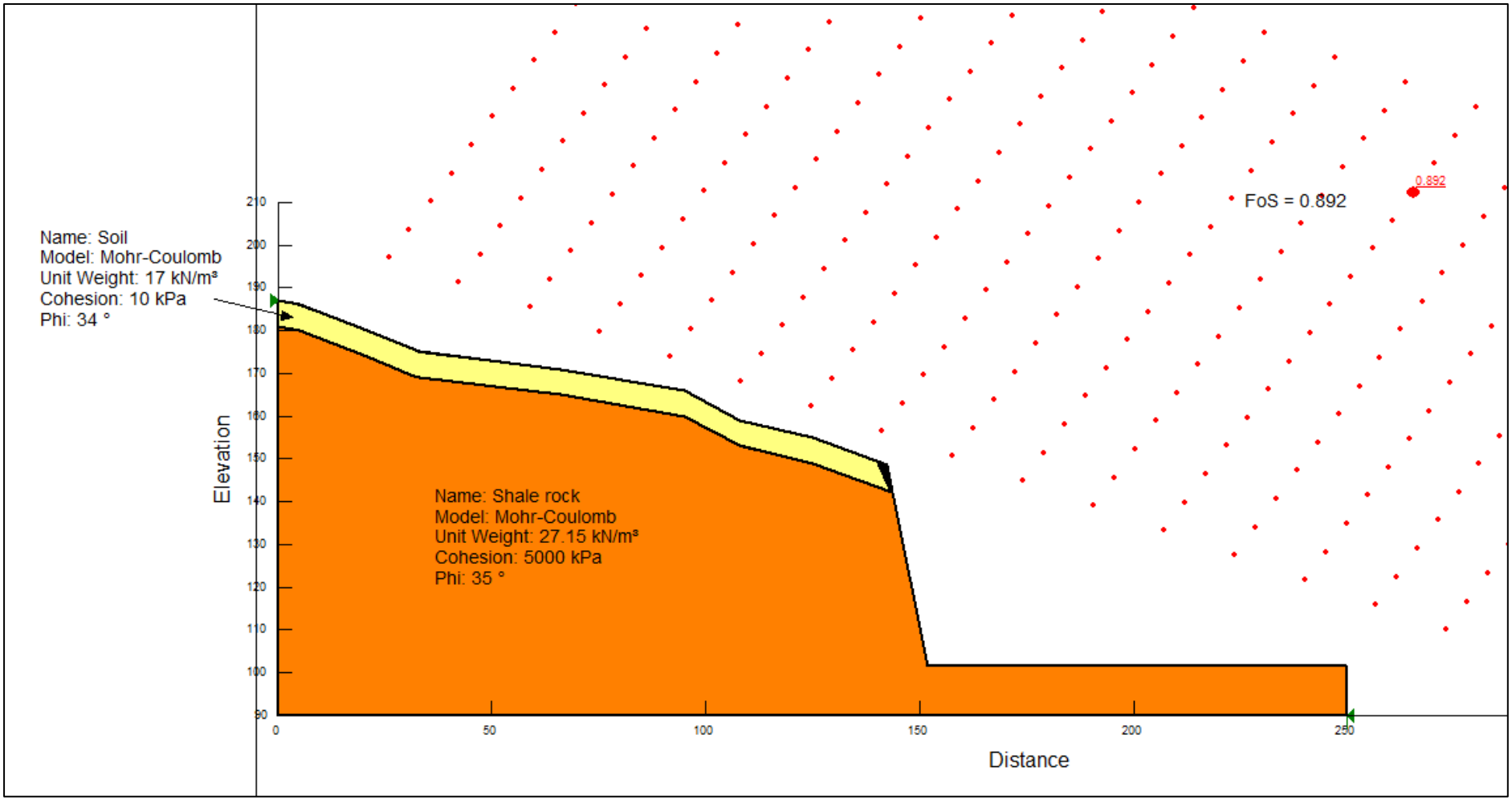


Figure 4.E.16: Outlet portal, Section 1, 1:0.2 excavation slope in shale, 1:2 excavation slope in soil

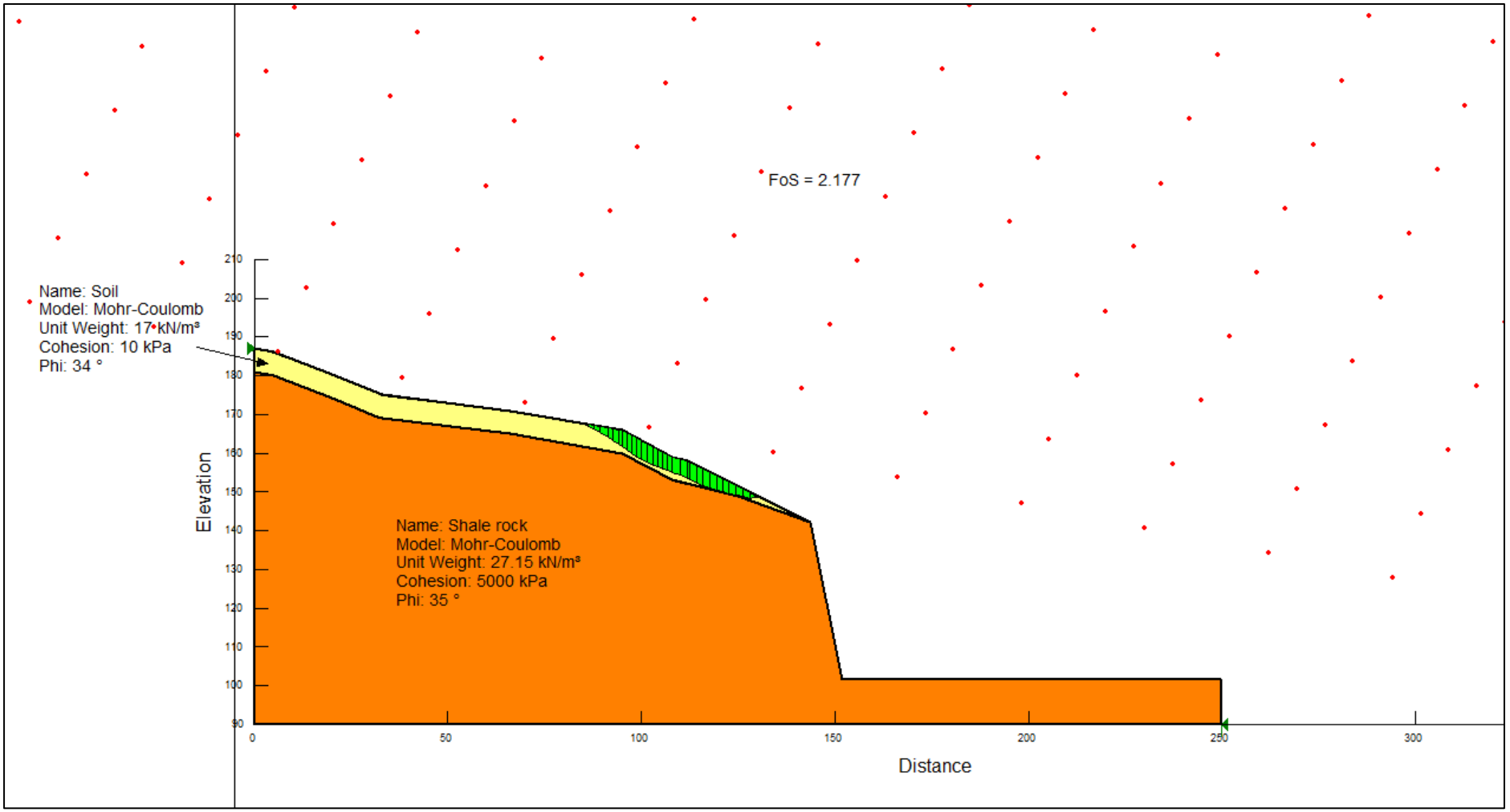


Figure 4.E.17: Outlet portal, Section 1, 1:0.2 excavation slope in shale, 1:2 excavation slope in soil

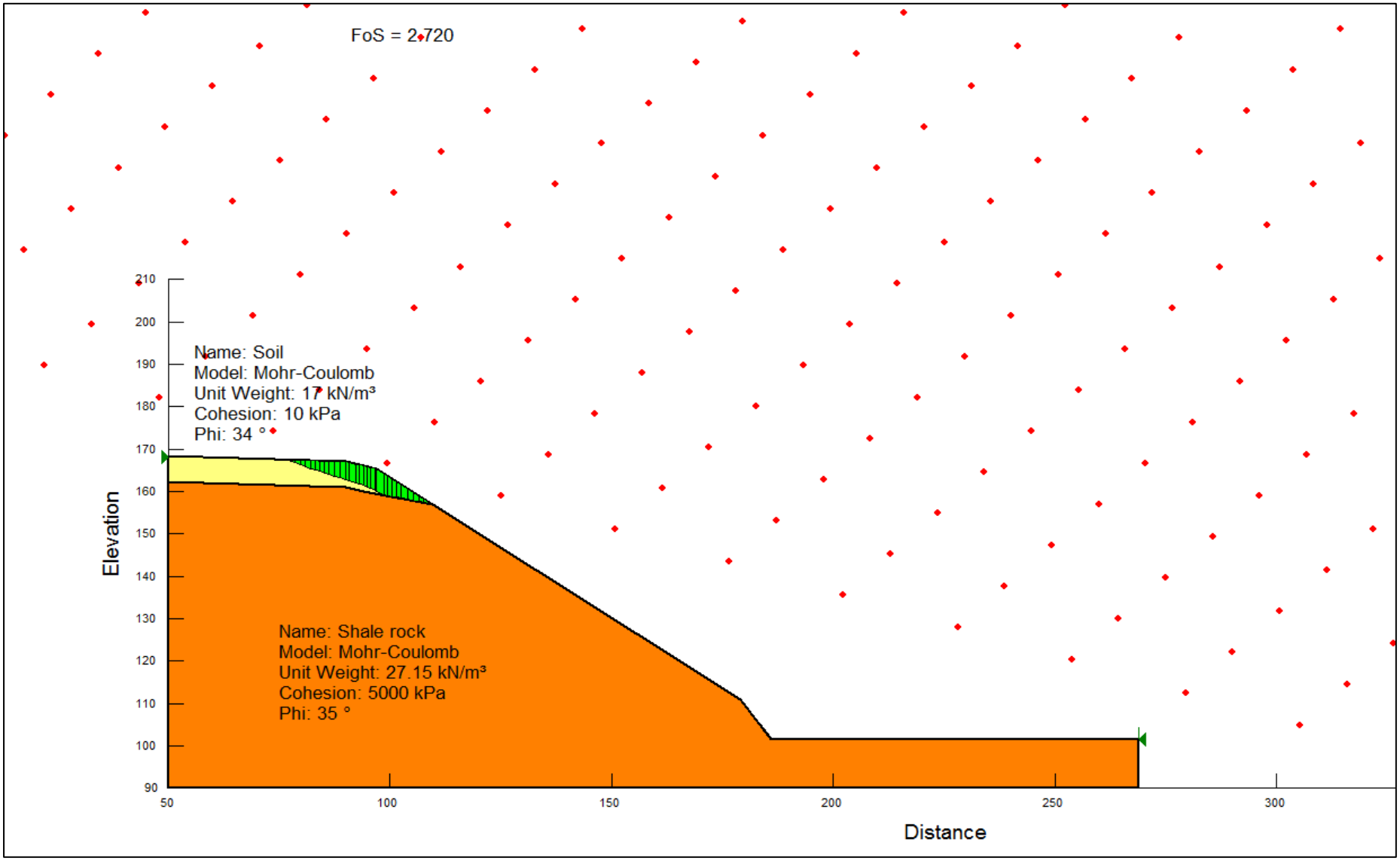


Figure 4.E.18: Outlet portal, Section 2, 1:1.5 excavation

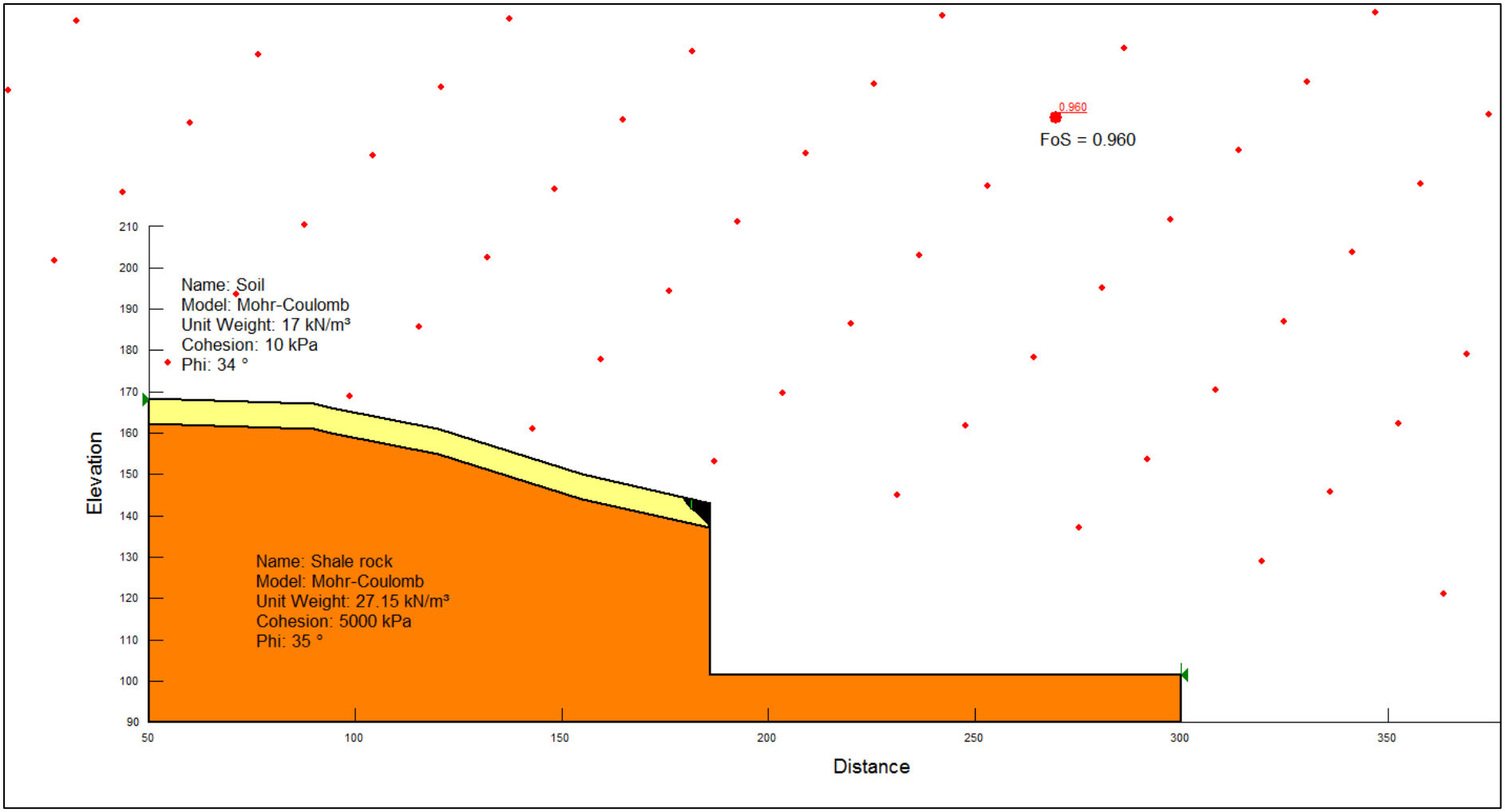


Figure 4.E.19: Outlet portal, Section 2, 90° excavation

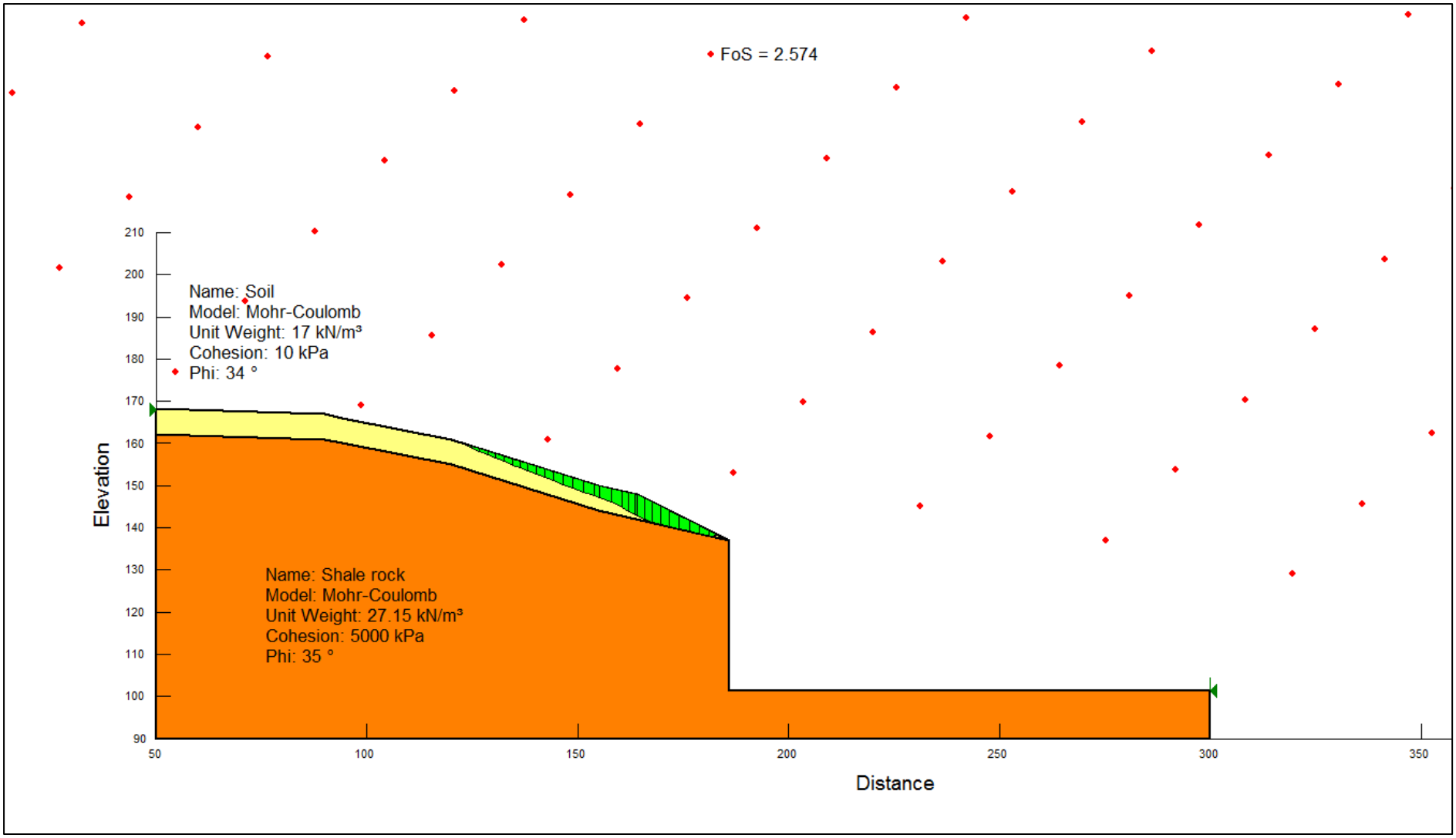


Figure 4.E.20: Outlet portal, Section 2, 90° excavation in shale, 1:2 excavation slope in soil

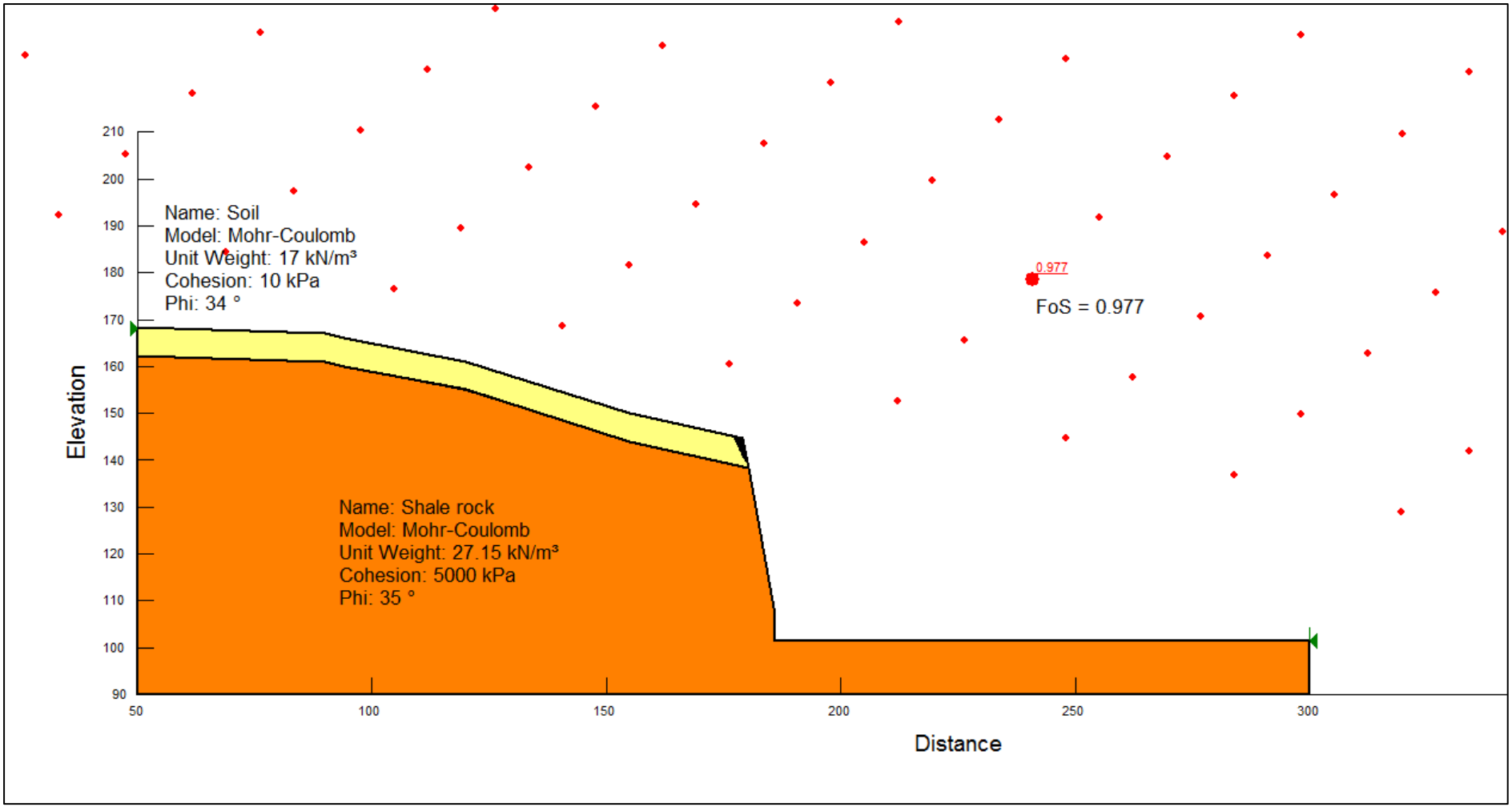


Figure 4.E.21: Outlet portal, Section 2, 1:0.2 excavation slope in shale, 1:2 excavation slope in soil

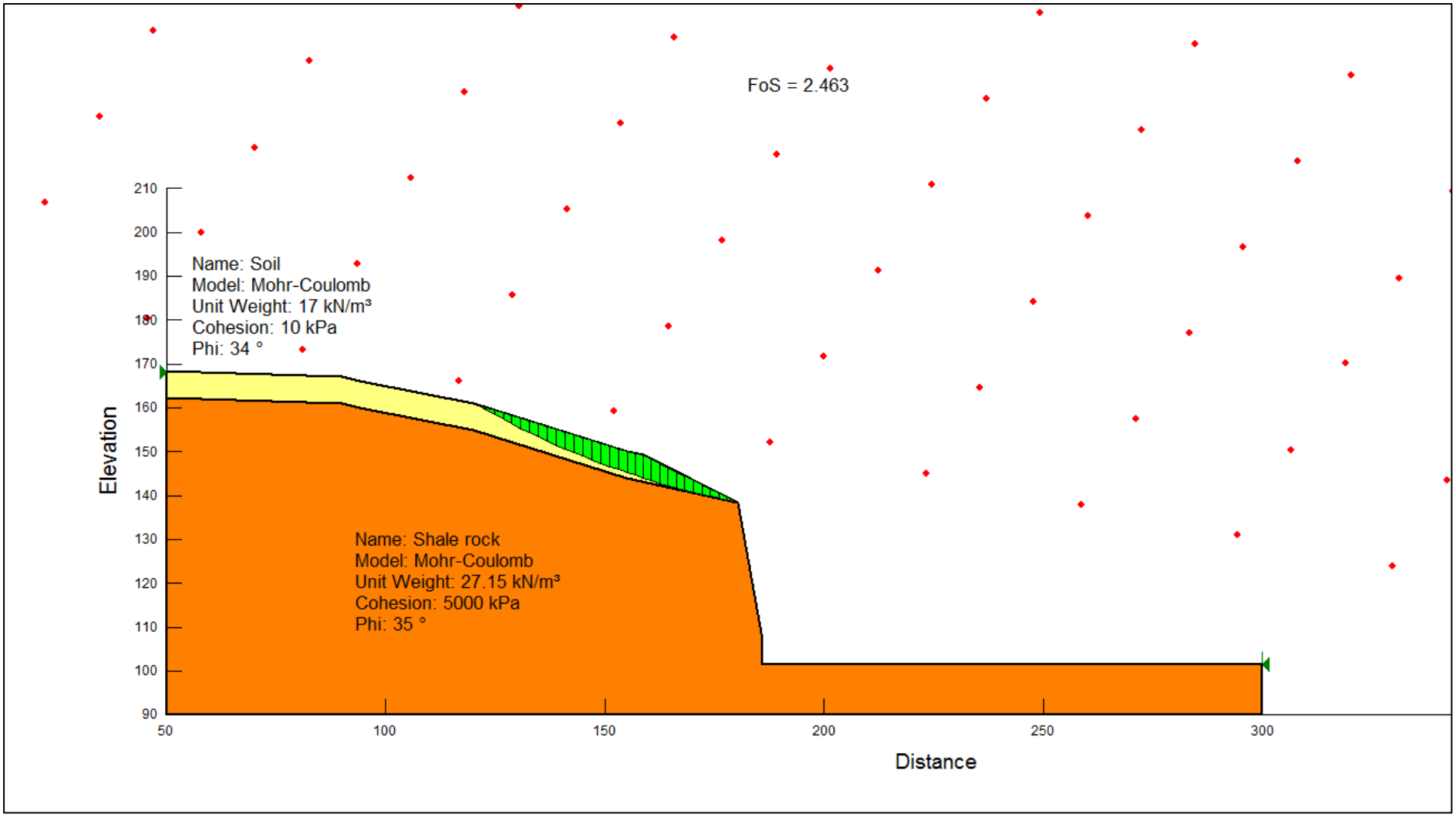


Figure 4.E.22: Outlet portal, Section 2, 1:0.2 excavation slope in shale, 1:2 excavation slope in soil

Annexure 4 F – uMkhomazi – uMlaza Tunnel: Cost estimate

Table 4.F.1: Cost estimate: uMkhomazi-uMlazi Tunnel: Transfer tunnel

TRANSFER TUNNEL					
ITEM NO	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
1	**PART 1: TRANSFER TUNNEL**				
1.1	**SECTION: TRANSFER TUNNEL: PHASE 1**				
	Tunnel Boring Machine (TBM)				
	(a) Plant	No.	2	219 287 000	438 574 000
	(a) Shipping	Sum	1	17 698 000	17 698 000
	Adit Excavation	m³	68 680	2 230	153 156 400
	Tunnel Excavation				
	(a) Rock Class I	m³	3 980	1 250	4 975 000
	(b) Rock Class II	m³	89 860	1 250	112 325 000
	(c) Rock Class III	m³	218 690	1 350	295 231 500
	(d) Rock Class IV	m³	54 080	1 500	81 120 000
	(e) Rock Class V	m³	95 440	1 650	157 476 000
	(f) Rock Class VI	m³	80 320	2 500	200 800 000
	(g) Rock Class VII	m³	0	900	0
	Ventilation Shafts				
	(a) Ventilation shaft 2	m	120	25 000	3 000 000
	(b) Ventilation shaft 3	m	166	25 000	4 150 000
	Rock Support				
	(a) Rockbolts				
	(i) Tunnel	m	387 120	285	110 329 200
	(ii) Central access adit	m	38 250	285	10 901 250
	(b) Shotcrete				
	(i) Tunnel	m³	11 360	5 885	66 853 600
	(ii) Central access adit	m³	1 200	5 885	7 062 000
	(c) Reinforcing mesh				
	(i) Tunnel	m²	188 700	85	16 039 500
	(ii) Central access adit	m²	10 690	85	908 650
	(d) Steel arches and lagging				
	(i) Tunnel	ton	510	28 445	14 506 950
	(ii) Central access adit	ton	0	28 445	0
	Concrete				
	(a) Linings				
	(i) Tunnel	m³	133 020	2 500	332 550 000
	(ii) Central access adit	m³	4 240	2 500	10 600 000
	(b) Overbreak concrete: TBM	m²	9 220	565	5 209 300
	(c) Overbreak concrete: DBT	m²	3 190	2 245	7 161 550
	(d) Concrete in structures	m³	0	1 405	0
	Formwork				
	(a) Smooth curved in tunnel	m²	482 120	730	351 947 600
	(b) Structures - intricate	m²	0	575	0
	Reinforcement	ton	2 270	14 000	31 780 000
	Pre-cast concrete inverts	m	0	1 405	0
	Grouting				
	(a) Tunnel	m²	482 120	485	233 828 200
	(b) Central access adit	m²	32 044	485	15 541 340
	Waterproof lining, sealing, pumping of water from centre of tunnel	m²	482 120	400	192 848 000

Table 4.F.1 (continued)

1.2	**SECTION: TRANSFER TUNNEL: FIRST SECTION OF PHASE 2**				
	Adit Excavation	m³	11 160	1 655	18 469 800
	Tunnel Excavation				
	(a) Rock Class I	m³	0	1 250	0
	(b) Rock Class II	m³	1 600	1 250	2 000 000
	(c) Rock Class III	m³	0	1 350	0
	(d) Rock Class IV	m³	0	1 500	0
	(e) Rock Class V	m³	0	1 650	0
	(f) Rock Class VI	m³	0	2 500	0
	(g) Rock Class VII	m³	0	900	0
	Rock Support				
	(a) Rockbolts				
	(i) Tunnel	m	750	285	213 750
	(ii) Access adit	m	3 750	285	1 068 750
	(b) Shotcrete				
	(i) Tunnel	m³	0	5 885	0
	(ii) Access adit	m³	0	5 885	0
	(c) Reinforcing mesh				
	(i) Tunnel	m²	0	85	0
	(ii) Access adit	m²	0	85	0
	(d) Steel arches and lagging				
	(i) Tunnel	ton	0	28 445	0
	(ii) Access adit	ton	0	28 445	0
	Concrete				0
	(a) Linings				
	(i) Tunnel	m³	430	2 500	1 075 000
	(ii) Access adit	m³	690	2 500	1 725 000
	(b) Overbreak concrete: TBM	m²	0	565	0
	(c) Overbreak concrete: DBT	m²	220	2 245	493 900
	(d) Concrete in structures	m³	0	1 405	0
	Formwork				
	(a) Smooth curved in tunnel	m²	1 420	730	1 036 600
	(b) Structures - intricate	m²	0	575	0
	Reinforcement	ton	0	14 000	0
	Pre-cast concrete inverts	m	0	1 405	0
	Grouting				
	(a) Tunnel	m²	1 420	485	688 700
	(b) Access adit	m²	7 860	485	3 812 100
	Waterproof lining, sealing, pumping of water from centre of tunnel	m²	1 420	400	568 000

Table 4.F.1 (continued)

1.3	**SECTION: PORTALS**				
	Excavation				
	(a) Bulk				
	(ii) Extra over for rock				
	(1) Tunnel inlet portal	m^3	365 000	440	160 600 000
	(2) Tunnel outlet portal	m^3	401 000	440	176 440 000
	(3) Adit portal	m^3	80 000	440	35 200 000
	Slope protection (shotcrete and anchors)				
	(a) Phase 1 tunnel inlet portal	m^2	42 710	960	41 001 600
	(b) Phase 1 tunnel outlet portal	m^2	32 590	960	31 286 400
	(c) Phase 2 tunnel inlet portal	m^2	1 420	960	1 363 200
	(d) Adit portal	m^2	6 500	961	6 246 500
	Concrete for retaining wall				
	(a) Phase 1 tunnel inlet portal	m^3	530	2 160	1 144 800
	(b) Phase 1 tunnel outlet portal	m^3	530	2 160	1 144 800
TOTAL CARRIED FORWARD TO SUMMARY					**3 362 151 940**

Table 4.F.2: Cost estimate: uMkhomazi-uMlazi Tunnel: Miscellaneous

SMITHFIELD DAM					
ITEM NO	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
2	**PART 2: MISCELLANEOUS**				
2.1	**SECTION: MISCELLANEOUS**				
	Work not mentioned, pre-grouting, delays for groundwater, additional concrete works, etc.	Sum	1	539 073 000	539 073 000
TOTAL CARRIED FORWARD TO SUMMARY					**539 073 000**

Table 4.F.3: Cost estimate: uMkhomazi-uMlazi Tunnel: Summary

SUMMARY: UMKHOMAZI-UMLAZI TUNNEL	
DESCRIPTION	AMOUNT
PART 1: TRANSFER TUNNEL	3 362 152 000
PART 2: MISCELLANEOUS	539 073 000
TOTAL	**3 901 225 000**

Annexure 4 G – uMkhomazi – uMlaza Tunnel: Outlet Structure and Access Arrangements

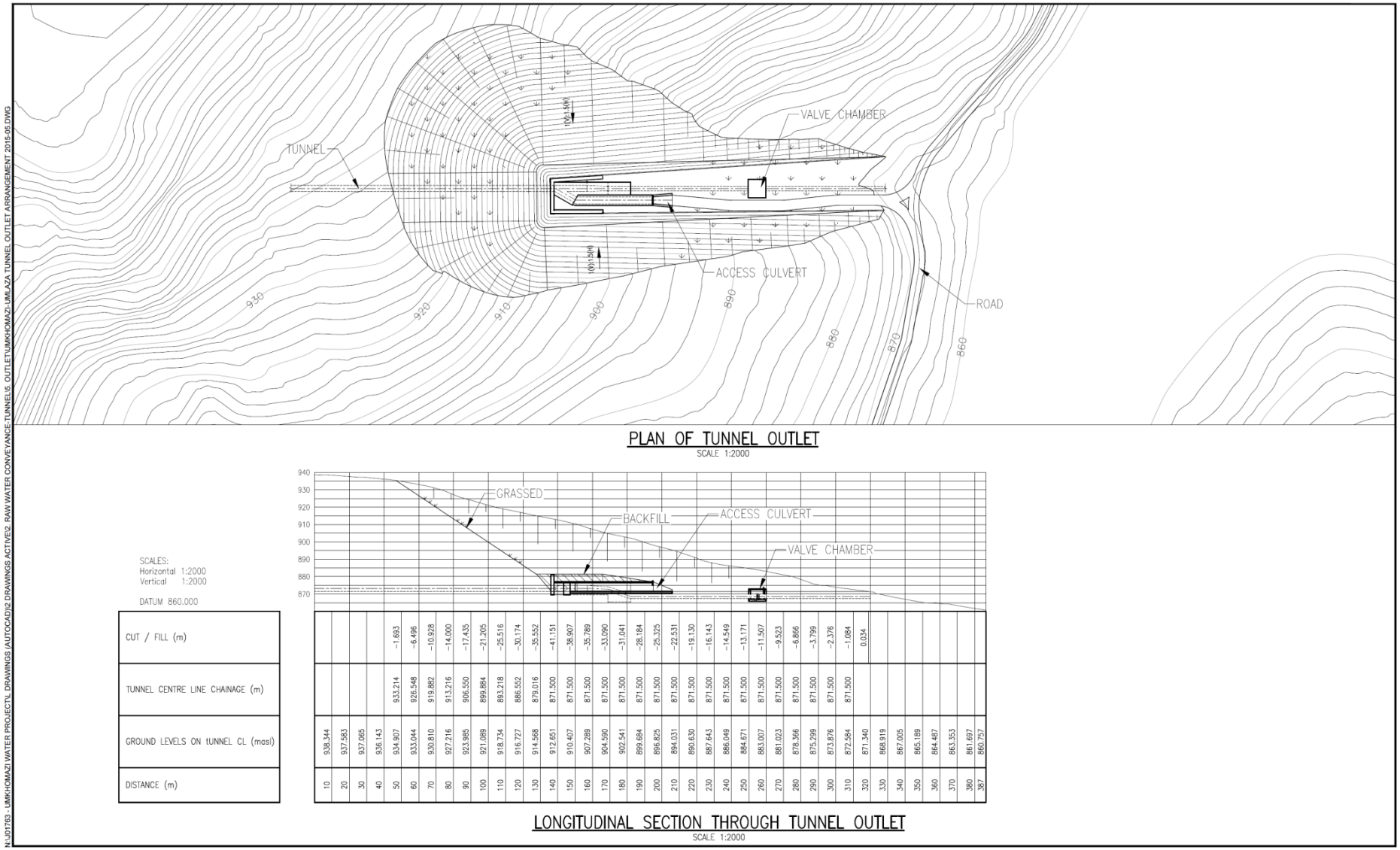


Figure 4.G.1: Tunnel Outlet Portal Excavation and Access Arrangements

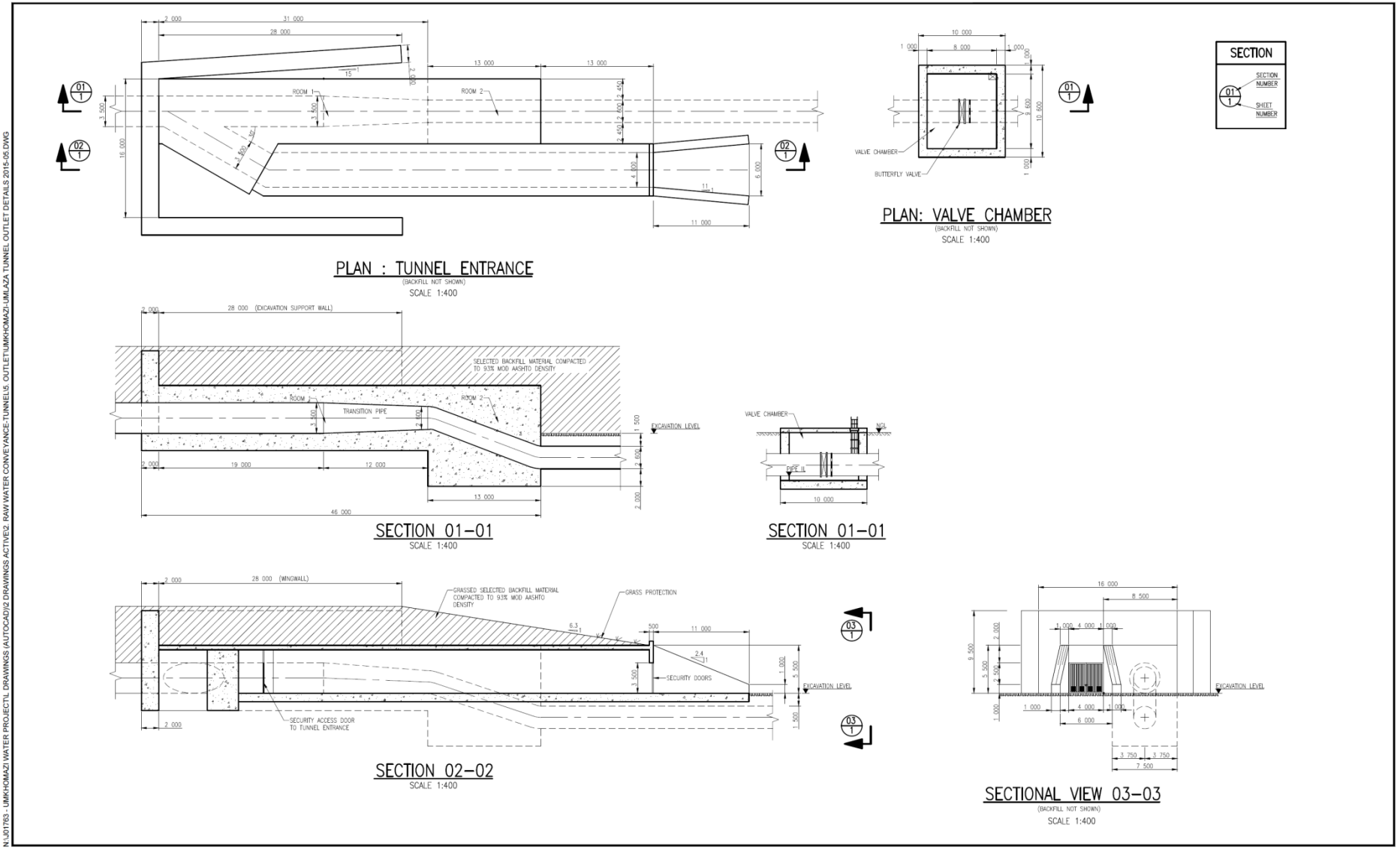


Figure 4.G.2: Details of Access Arrangements at Tunnel Outlet Portal

Annexure 5 A – Langa Dam: Layout and Typical Embankment Cross Sections

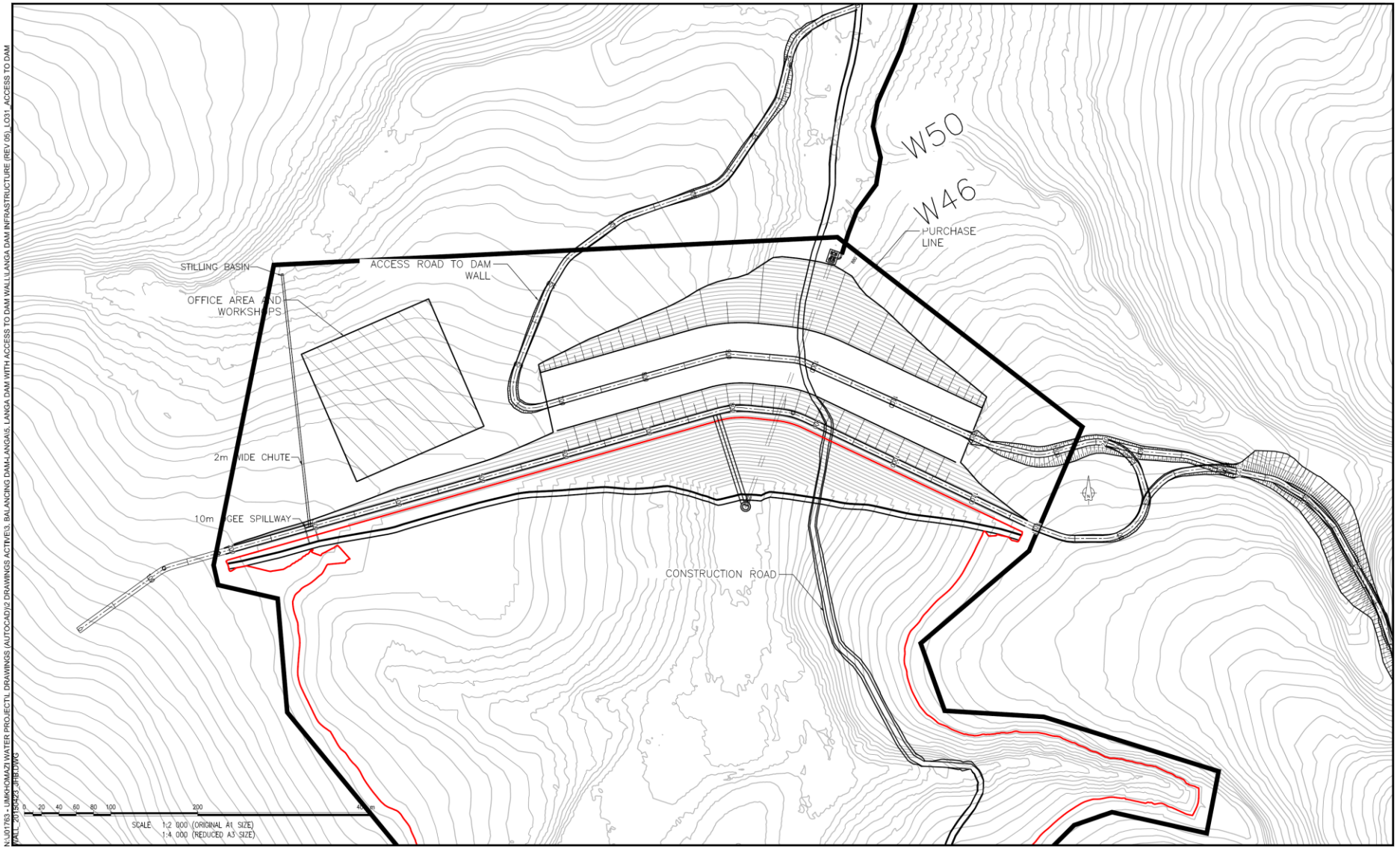


Figure 5.A.1: Langa Dam embankment and spillway layout

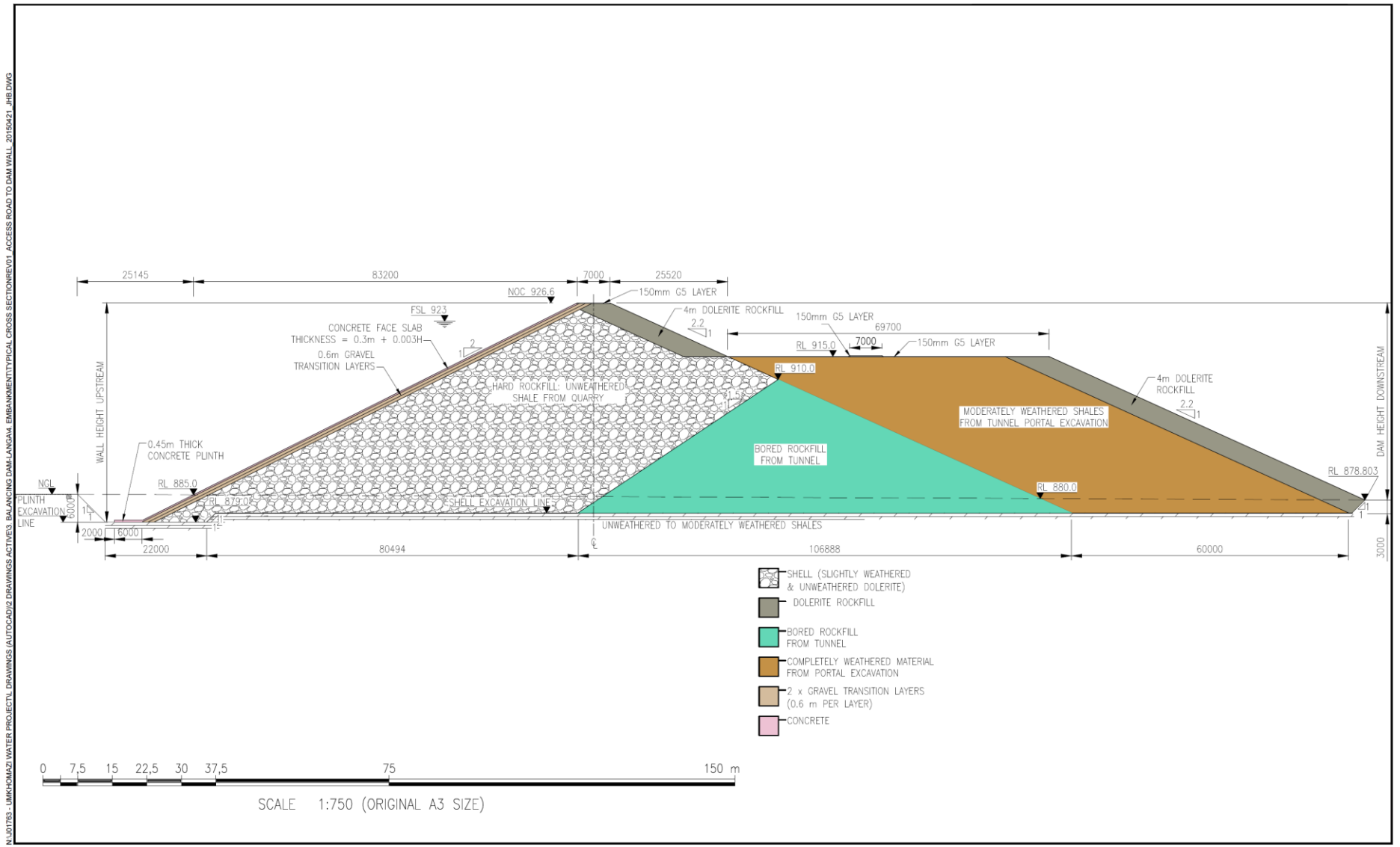


Figure 5.A.2: Langa Dam proposed embankment cross section with dolerite downstream protection layer

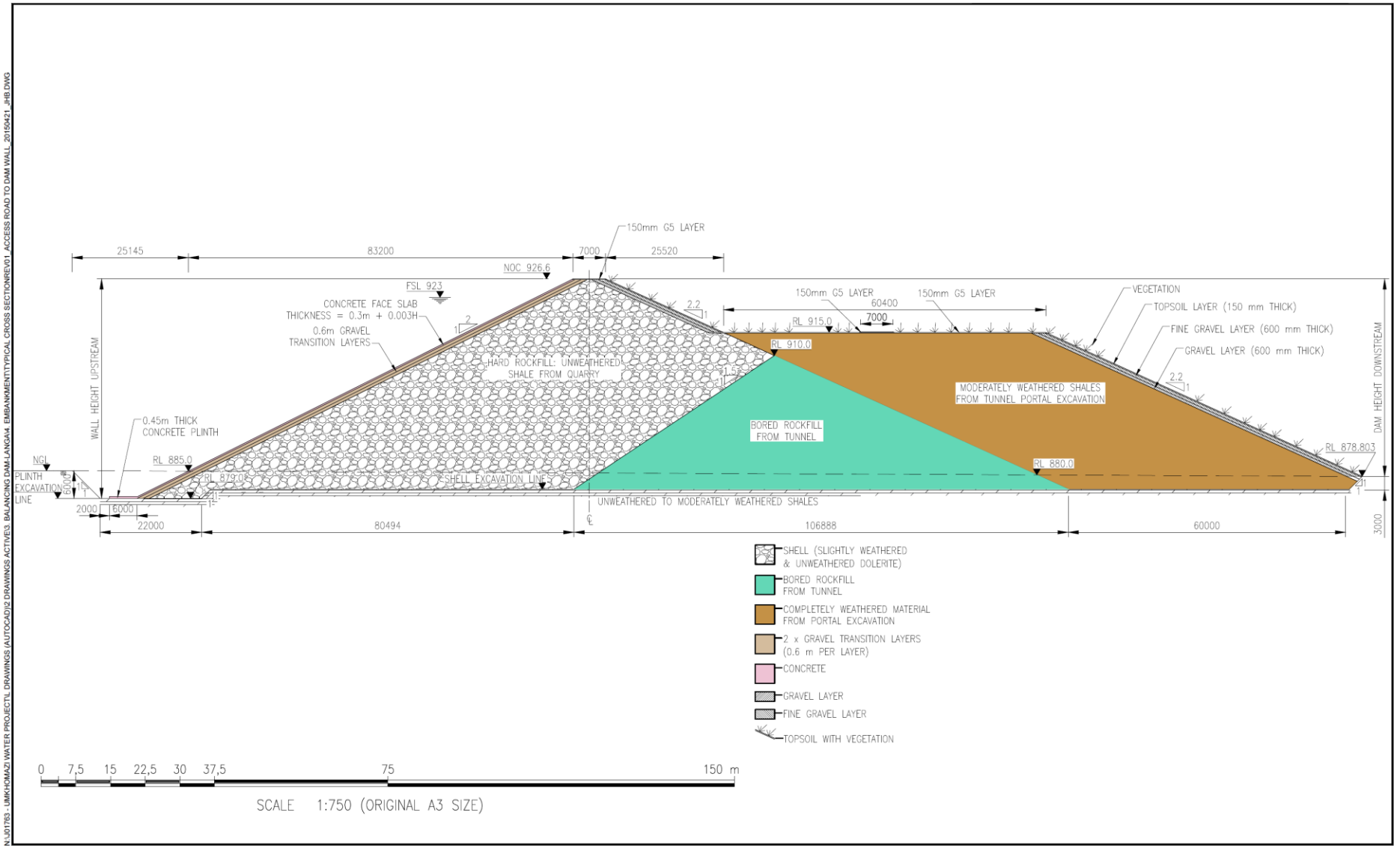


Figure 5.A.3: Langa Dam proposed embankment cross section with vegetated downstream slope

Annexure 5 B – Langa Dam: Embankment stability results

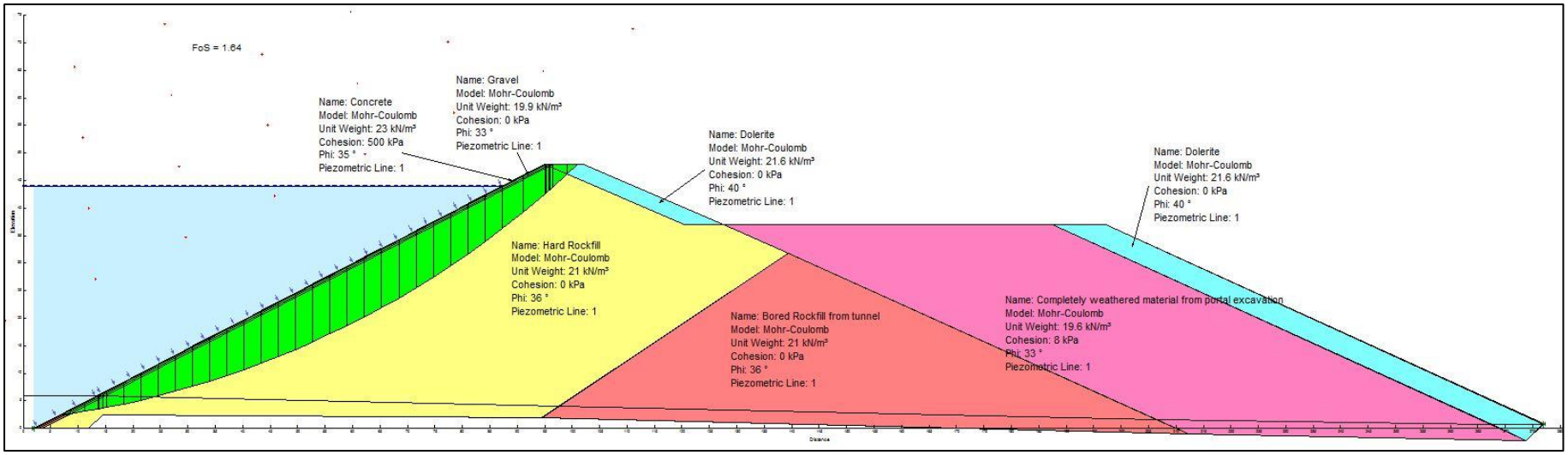


Figure 5.B.1: Water at FSL, downstream slope 1:2.2 with a FoS against upstream slip of 1.64

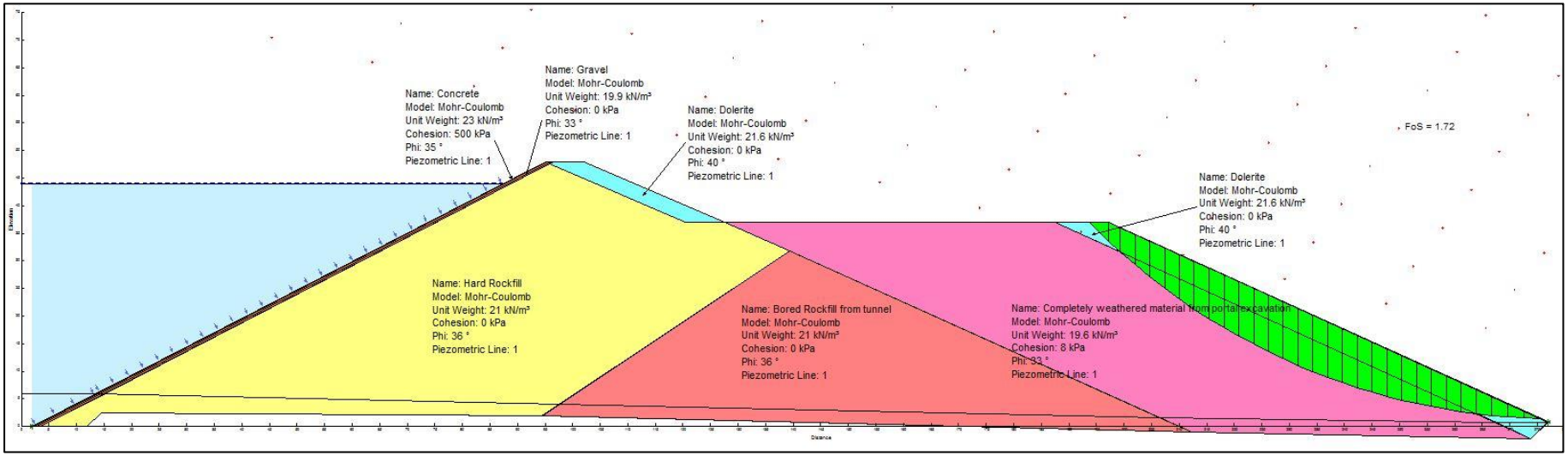


Figure 5.B.2: Water at FSL, downstream slope 1:2.2 with a FoS against downstream slip of 1.72

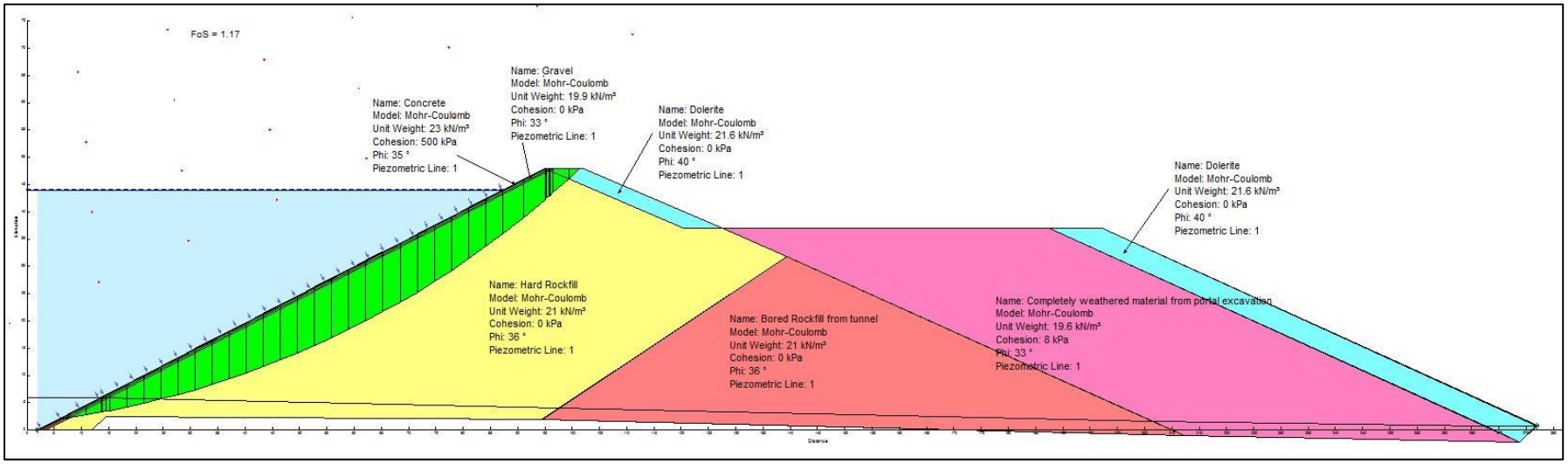


Figure 5.B.3: Seismic analysis - Water at FSL, downstream slope 1:2.2 with a FoS against upstream slip of 1.17

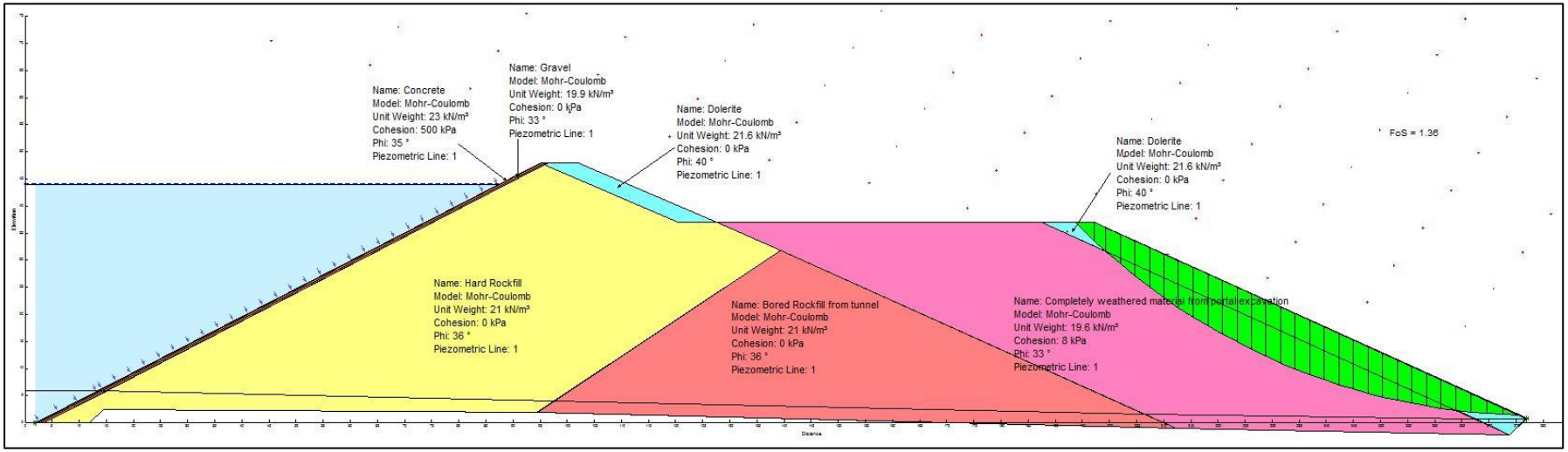


Figure 5.B.4: Seismic analysis - Water at FSL, downstream slope 1:2.2 with a FoS against downstream slip of 1.36

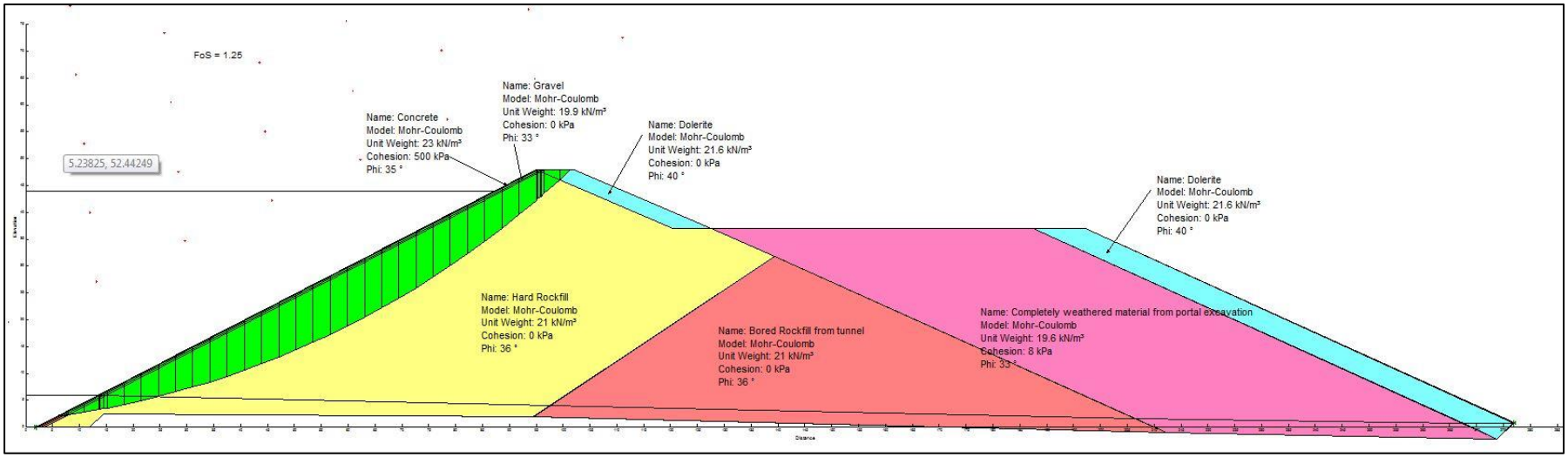


Figure 5.B.5: Seismic analysis - No Water, downstream slope 1:2.2 with a FoS against upstream slip of 1.25

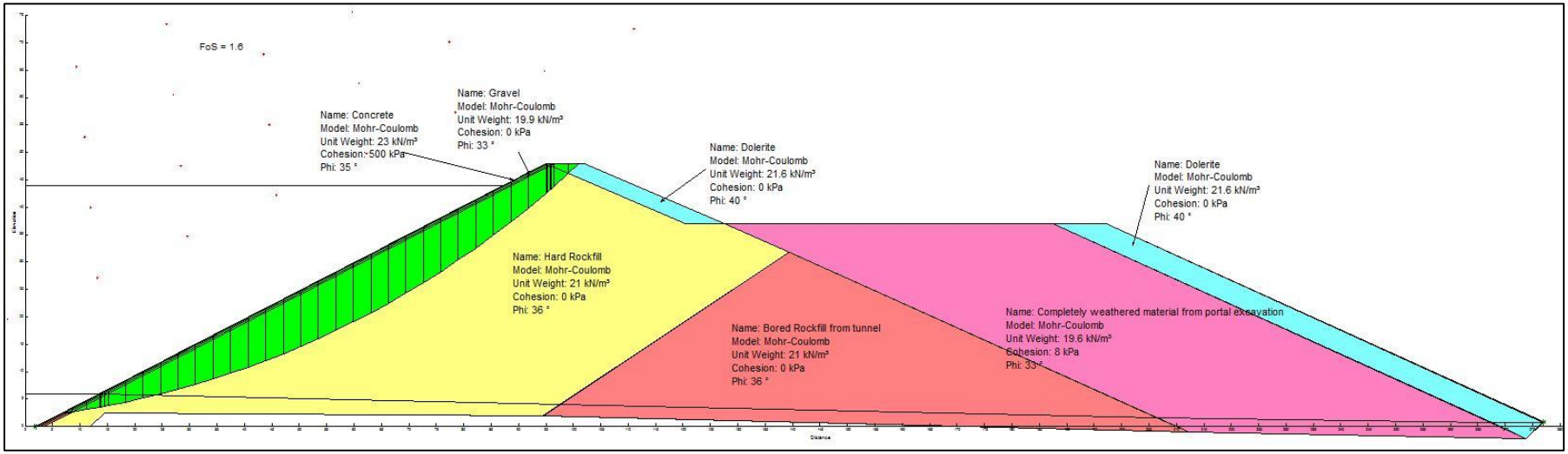


Figure 5.B.6: No Water, downstream slope 1:2.2 with a FoS against upstream slip of 1.6

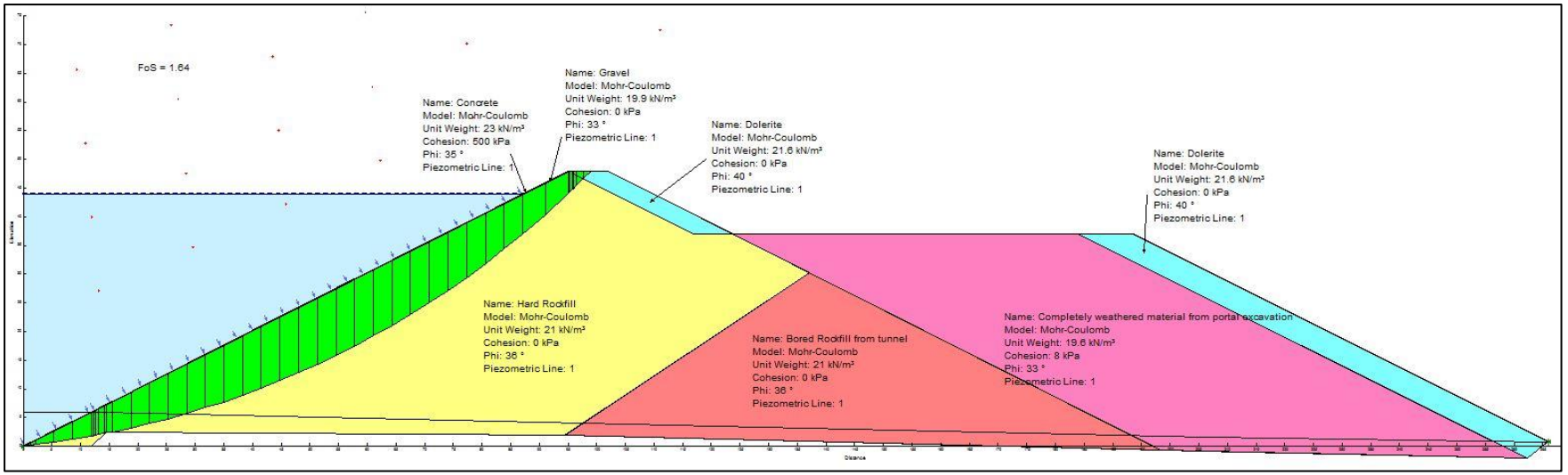


Figure 5.B.7: Water at FSL, downstream slope 1:2 with a FoS against upstream slip of 1.64

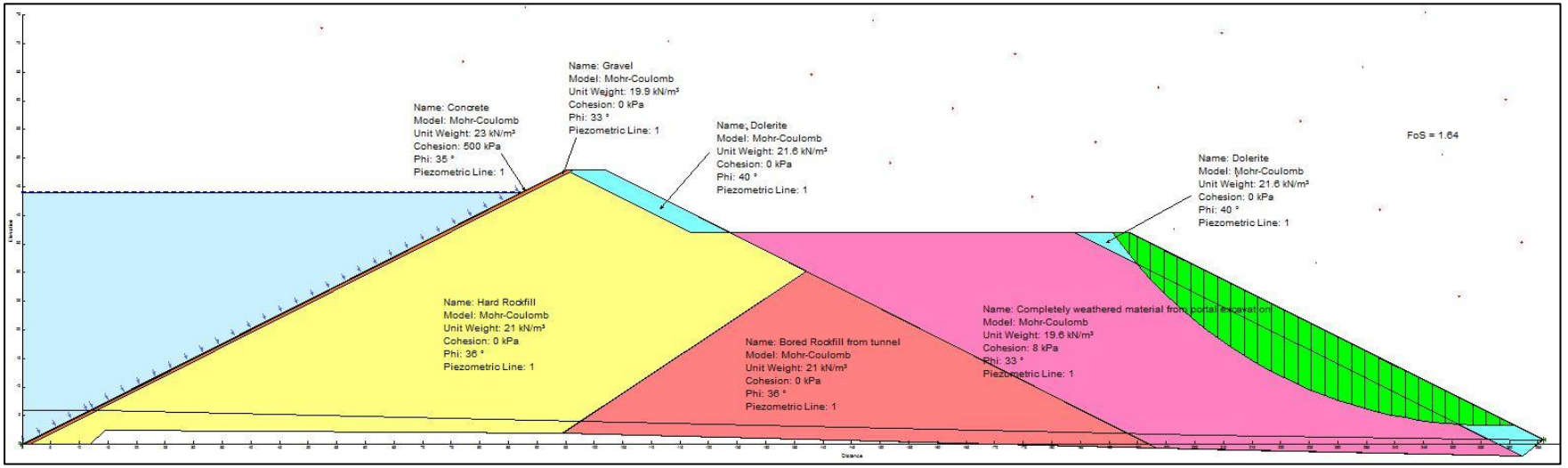


Figure 5.B.8: Water at FSL, downstream slope 1:2 with a FoS against downstream slip of 1.64

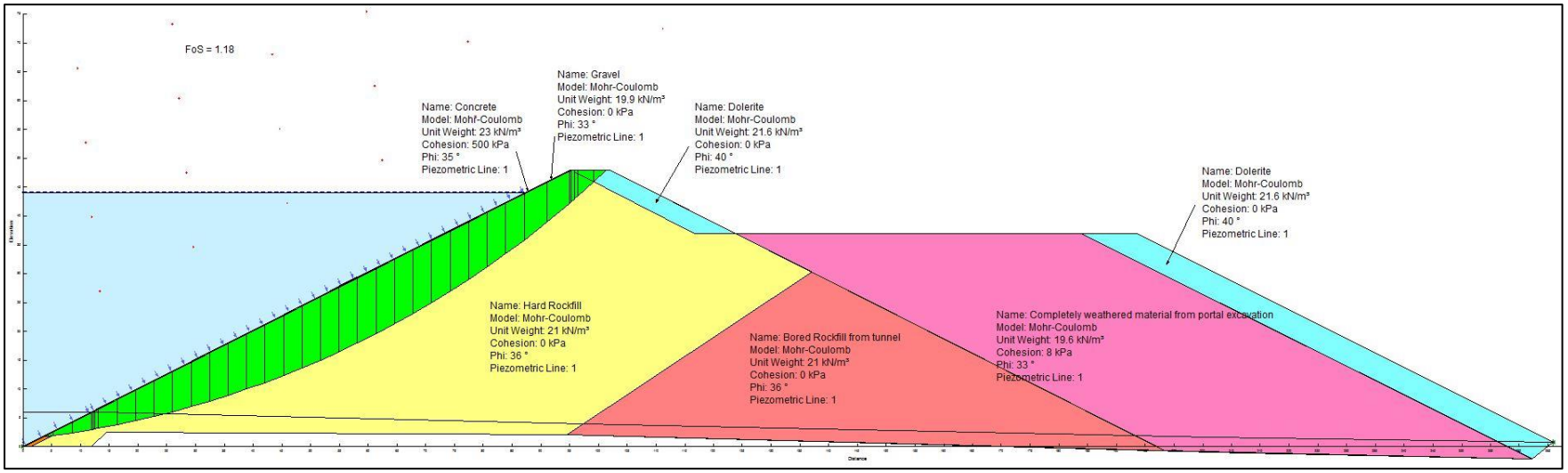


Figure 5.B.9: Seismic analysis - Water at FSL, downstream slope 1:2 with a FoS against uptream slip of 1.18

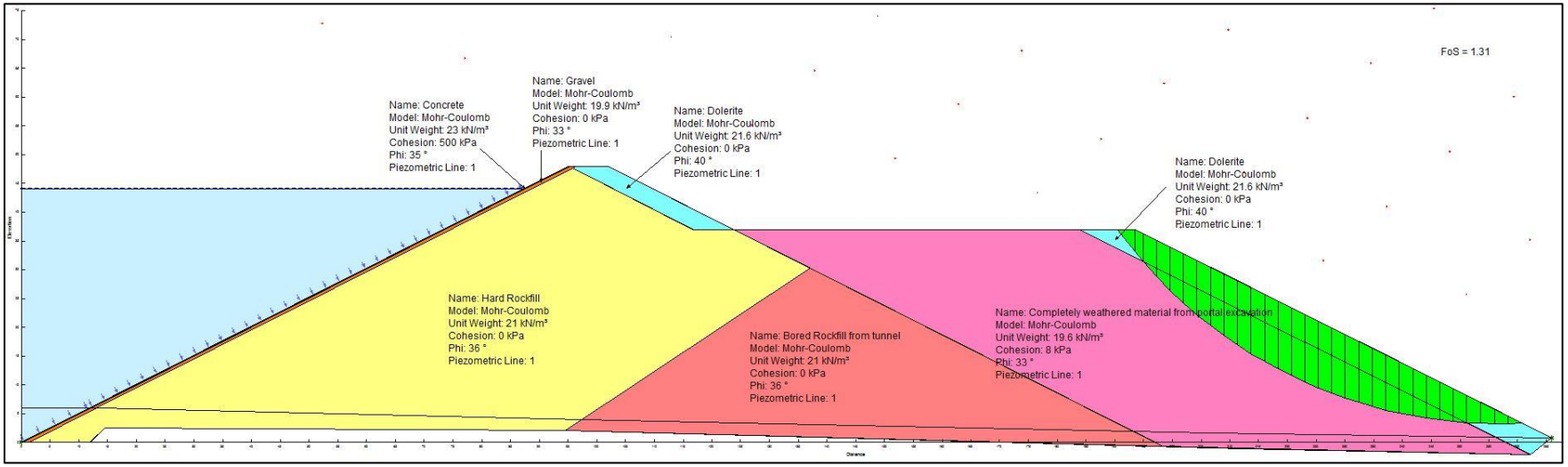


Figure 5.B.10: Seismic analysis - Water at FSL, downstream slope 1:2 with a FoS against downstream slip of 1.31

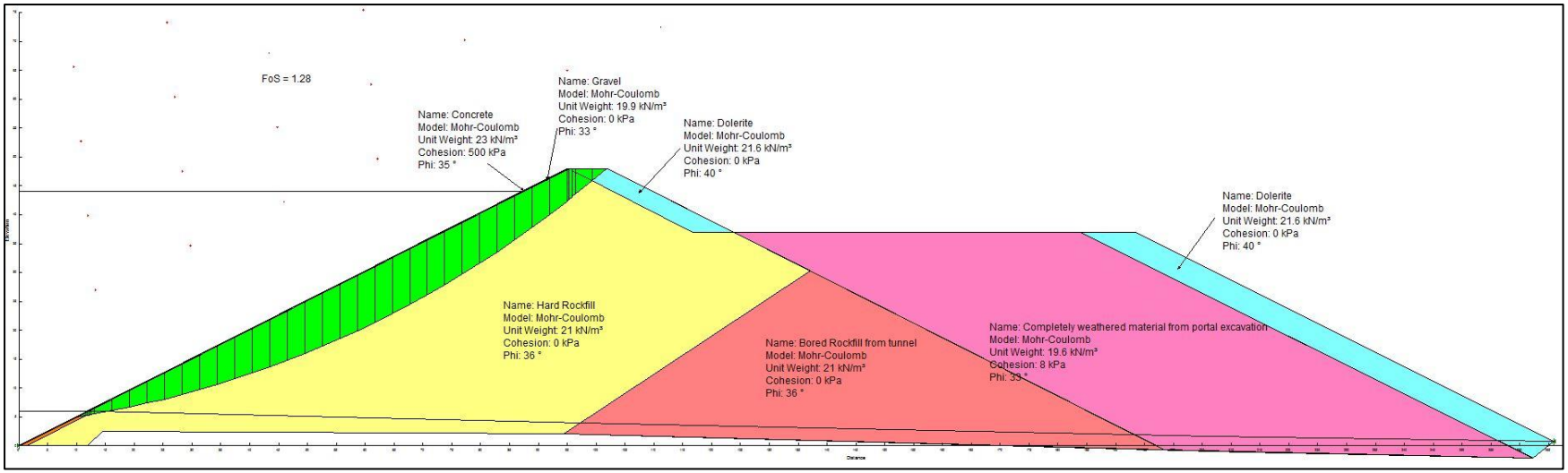


Figure 5.B.11: Seismic analysis - No Water, downstream slope 1:2 with a FoS against upstream slip of 1.28

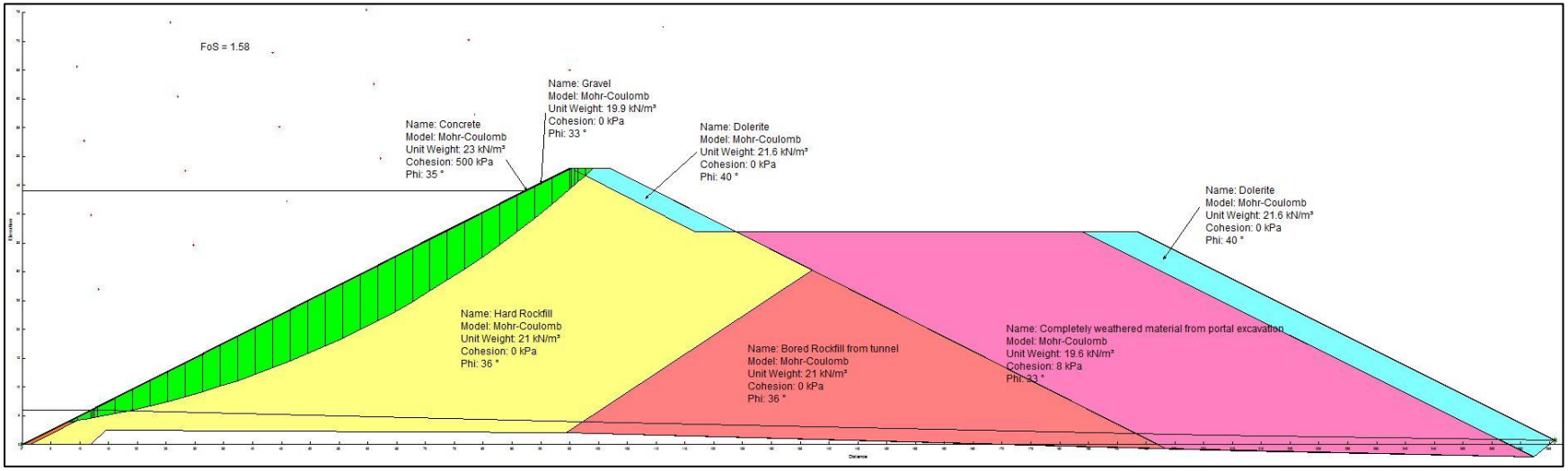


Figure 5.B.12: No Water, downstream slope 1:2 with a FoS against upstream slip of 1.58

Annexure 5 C – Langa Dam: Cost estimate

Table 5.C.1: Cost estimate: Langa Dam: River diversion

LANGA DAM					
ITEM NO	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
1	**PART 1: RIVER DIVERSION WORKS**				
1.1	**SECTION: CONSTRUCTION OF COFFER DAM 1**				
	Excavation				
	Excavation				
	(a) Material unsuitable for embankment	m³	3 680	35	128 800
	(b) Material suitable for embankment from essential excavations	m³	0	34	0
	(c) Extra-over item (b) for excavation in:				
	(1) Intermediate material	-	-	-	Incl. in (a)
	(2) Hard rock material	m³	190	40	7 600
	Preparation of exposed surfaces				
	(a) All materials	m²	3 680	105	386 400
	(b) Extra over for rock	m²	190	120	22 800
	Embankment construction				
	Forming embankment				
	(a) Earthfill	m³	11 600	55	638 000
1.2	**SECTION: CONSTRUCTION OF COFFER DAM 2**				
	Excavation				
	Excavation				
	(a) Material unsuitable for embankment	m³	550	35	19 250
	(b) Material suitable for embankment from essential excavations	m³	0	34	0
	(c) Extra-over item (b) for excavation in:				
	(1) Intermediate material	-		-	Incl. in (a)
	(2) Hard rock material	m³	30	40	1 200
	Preparation of exposed surfaces				
	(a) All materials	m²	550	105	57 750
	(b) Extra over for rock	m²	30	120	3 600
	Embankment construction				
	Forming embankment				
	(a) Earthfill	m³	1 700	55	93 500
TOTAL CARRIED FORWARD TO SUMMARY					**1 358 900**

Table 5.C.2: Cost estimate: Langa Dam: Development of quarry

LANGA DAM					
ITEM NO	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
2	**PART 2: DEVELOPMENT OF QUARRY**				
2.1	**SECTION: SITE CLEARANCE**				
	Clear and grub (a) Quarry I	ha	10.0	10 430	104 300
	Remove topsoil to nominal depth of 150 mm and stockpile (a) Quarry I	m^3	15 000	27	405 000
TOTAL CARRIED FORWARD TO SUMMARY					**509 300**

Table 5.C.3: Cost estimate: Langa Dam: Embankment

LANGA DAM					
ITEM NO	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
3	**PART 3: LANGA DAM MAIN EMBANKMENT CONSTRUCTION**				
3.1	**SECTION: SITE CLEARANCE**				
	Site clearance				
	Clear and strip site	ha	12.0	41 900	502 800
	Remove topsoil to 150 mm, stockpile, and maintain	m³	18 000	27	486 000
3.2	**SECTION: EXCAVATION**				
	Excavation				
	(a) Material unsuitable for embankment	m³	92 460	35	3 236 100
	(b) Material suitable for embankment from essential excavations	m³	215 740	34	7 335 160
	(c) Extra-over item (b) for excavation in:				
	(1) Intermediate material	-	-	-	Incl. in (a)
	(2) Hard rock material	m³	31 000	40	1 240 000
	Preparation of exposed surfaces				
	(a) All materials	m²	93 800	105	9 849 000
	(b) Extra over for rock	m²	940	120	112 800
3.3	**SECTION: EMBANKMENT CONSTRUCTION**				
	Forming embankment				
	(a) Earthfill				
	(1) Semi-pervious fill (residual silty clayey sand and sandy silty clay)	m³	230 000	55	12 650 000
	(2) Semi-pervious fill (highly weathered shale)	m³	70 000	55	3 850 000
	(b) Rockfill				
	(1) Soft rockfill (bored rockfill from tunnel)	m³	97 100	120	11 652 000
	(2) Hard rockfill (unweathered shale from dolerite)	m³	1 278 000	120	153 360 000
	(c) Filters				
	(1) Upstream gravel layers (imported dolerite)	m³	41 390	310	12 830 900
	(2) Downstream protection layer (imported dolerite)	m³	144 620	310	44 832 200
	(d) Gravel capping				
	(1) Road on crest	m³	1 030	100	103 000
	(2) Downstream embankment	m³	5 870	100	587 000
	Scheduled Formwork items				
	Smooth				
	(a) Vertical	m²	346	650	224 900
	Scheduled concrete items				
	Strength concrete				
	(a) Mass concrete	m³	15 920	2 160	34 387 200
	(b) 30MPa structural concrete	m³	2 350	2 160	5 076 000
	Scheduled reinforcement items				
	Steel bars	t	62	14 000	868 000
3.4	**SECTION: DRILLING AND GROUTING**				
	Curtain grouting	m	6 080	1 150	6 992 000
	Consolidation grouting	m	4 890	1 150	5 623 500
TOTAL CARRIED FORWARD TO SUMMARY					**315 798 560**

Table 5.C.4: Cost estimate: Langa Dam: Spillway

LANGA DAM					
ITEM NO	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
4	**PART 4: SPILLWAY**				
4.1	**SECTION: SITE PREPARATION**				
	Site clearance				
	Clear and strip site	ha	0.3	41 900	12 570
	Remove topsoil to 150 mm, stockpile, and maintain	m³	450	27	12 150
	Benching (forming the terrace)				
	(a) All materials	m³	380	105	39 900
	(b) Extra over for rock	m³	60	70	4 200
4.2	**SECTION: EXCAVATION**				
	Excavation				
	(a) Material unsuitable for embankment	m³	6 450	56	361 200
	(b) Material suitable for embankment from essential excavations	m³	0	54	0
	(c) Extra-over item (b) for excavation in				
	(1) Intermediate material	-	-	-	Incl. in (a)
	(2) Hard rock material	m³	380	65	24 700
4.3	**SECTION: CONSTRUCTION OF SPILLWAY**				
	Canal fill				
	(a) From excavation	m³	2 850	55	156 750
	(b) Selected layer to 90% Mod. AASHTO	m³	190	88	16 720
	Scheduled Formwork items				
	Smooth				
	(a) Sloped (ogee of spillway)				
	(1) Ogee spillway	m²	20	650	13 000
	(b) Intricate				
	(1) Transition and stilling basin	m²	165	730	120 450
	Scheduled reinforcement items				
	Steel bars				
	(1) Ogee spillway	t	0.2	14 000	2 800
	(2) Transition and stilling basin	t	2	14 000	21 000
	High tensile welded mesh				
	(2) Spillway chute	m²	1 140	50	57 000
	Scheduled concrete items				
	Strength concrete				
	(a) 25MPa mass concrete				
	(1) Ogee spillway	m³	25	2 160	54 000
	(2) Spillway chute	m³	740	2 160	1 598 400
	(3) Transition and stilling basin	m³	45	2 160	97 200
4.4	**SECTION: DRILLING AND GROUTING**				
	Curtain grouting	m	250	1 150	287 500
	Consolidation grouting	m	250	1 150	287 500

Table 5.C.4 (continued)

4.5	**SECTION: WATERSTOPS, JOINTING AND BEARINGS**				
	Waterstops, joints and sealing				
	(1) Ogee spillway	m	20	800	16 000
	(2) Spillway chute	m	260	800	208 000
	(3) Transition and stilling basin	m	10	800	8 000
4.6	**SECTION: SUB-SOIL DRAINAGE**				
	Ground water drainage under canal lining	m	560	330	184 800
TOTAL CARRIED FORWARD TO SUMMARY					**3 583 840**

Table 5.C.5: Cost estimate: Langa Dam: Outlet pipes

LANGA DAM					
ITEM NO	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
5	**PART 5: OUTLET PIPES**				
5.1	**SECTION: TRENCH EXCAVATION AND BACKFILLING**				
	Excavation				
	(a) Excavate in all materials for trenches, backfill, compact and dispose of surplus material	-	-	-	Incl. in main excavation
	(b) Extra-over for				
	(1) Intermediate excavation	-	-	-	Incl. in (a)
	(2) Hard rock excavation	m³	2 190	40	87 600
	(c) Bed preparation	m²	1 690	105	177 450
5.2	**SECTION: INSTALLATION OF PIPELINE**				
	Supply, lay and bed pipes complete with couplings				
	(a) 1 600 mm diameter	m	470	7 370	3 463 900
	Concrete, incl. formwork				
	(a) Encasing	m³	3 440	2 300	7 912 000
	Reinforcing	t	30	14 000	420 000
	Hydro-mechanical				
	(a) Valves	Sum	1	750 000	750 000
TOTAL CARRIED FORWARD TO SUMMARY					**12 810 950**

Table 5.C.6: Cost estimate: Langa Dam: Outlet works, intake structure

LANGA DAM					
ITEM NO	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
6	**PART 6: OUTLET WORKS, INTAKE STRUCTURE**				
6.1	**SECTION: EXCAVATION**				
	Excavation				
	(a) Material unsuitable for embankment	m³	4 700	35	164 500
	(b) Material suitable for embankment from essential excavations	m³	0	34	0
	(c) Extra-over item (b) for excavation in:				
	(1) Intermediate material	-	-	-	Incl. in (a)
	(2) Hard rock material	m³	680	40	27 200
	(3) Rockfill to abutments	m³	990	100	99 000
6.2	**SECTION: ROCK SUPPORT**				
	Shotcrete and mesh	m²	150	300	45 000
6.3	**SECTION: INTAKE TOWER**				
	Drilling and grouting				
	(a) Consolidation grouting	m	700	1 150	805 000
	Scheduled Formwork items				
	Smooth				
	(a) Vertical	m²	4 800	650	3 120 000
	(b) Horizontal	m²	950	730	693 500
	(c) Intricate	m²	55	730	40 150
	(d) Form openings	m²	100	730	73 000
	Scheduled concrete items				
	Strength concrete				
	(a) 25MPa mass concrete	m³	450	2 160	972 000
	(a) 30MPa structural concrete	m³	7 200	2 160	15 552 000
	Scheduled reinforcement items				
	Steel bars	t	1 200	14 000	16 800 000
	Mesh	t	600	14 000	8 400 000
	Waterstops, joints and bearings	m	390	800	312 000
6.4	**SECTION: ACCESS BRIDGE**				
	Scheduled Formwork items				
	Smooth				
	(a) Vertical	m²	960	500	480 000
	(b) Horizontal	m²	190	650	123 500
	Scheduled concrete items				
	Strength concrete				
	(a) 30MPa structural concrete	m³	1 200	2 160	2 592 000
	Scheduled reinforcement items				
	Steel bars	t	220	14 000	3 080 000

Table 5.C.6 (continued)

6.5	**SECTION: HYDRO-MECHANICAL**				
	Mechanical items				
	(a) Gates and screens	Sum	1	145 000	145 000
	(b) Lifting equipment - cranes and gate hoists	Sum	1	5 000 000	5 000 000
	(c) Pipework and valves	Sum	1	1 850 000	1 850 000
	Electrical installation	Sum	1	1 200 000	1 200 000
TOTAL CARRIED FORWARD TO SUMMARY					**47 103 350**

Table 5.C.7: Cost estimate: Langa Dam: Miscellaneous

LANGA DAM					
ITEM NO	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
7	**PART 7: MISCELLANEOUS**				
7.1	**SECTION: MISCELLANEOUS**				
	Electrical	Sum	1	3 943 000	3 943 000
	Telemetry	Sum	1	3 033 000	3 033 000
	Monitoring instrumentation	Sum	1	493 000	493 000
	Finishing and rehabilitation	Sum	1	3 079 000	3 079 000
	Miscellaneous steelworks	Sum	1	1 643 000	1 643 000
	Permanent infrastructure (incl. housing)	Sum	1	27 648 000	27 648 000
	Permanent fence	Sum	1	2 000 000	2 000 000
	Floating boom	Sum	1	113 000	113 000
	Dayworks	Sum	1	15 700 000	15 700 000
TOTAL CARRIED FORWARD TO SUMMARY					**57 652 000**

Table 5.C.8: Cost estimate: Langa Dam: Summary

SUMMARY: LANGA DAM	
DESCRIPTION	**AMOUNT**
PART 1: RIVER DIVERSION WORKS	1 359 000
PART 2: DEVELOPMENT OF QUARRY	510 000
PART 3: LANGA DAM MAIN EMBANKMENT CONSTRUCTION	315 799 000
PART 4: SPILLWAY	3 584 000
PART 5: OUTLET PIPES	12 811 000
PART 6: OUTLET WORKS, INTAKE STRUCTURE	47 104 000
PART 7: MISCELLANEOUS	57 652 000
TOTAL	**438 819 000**

Annexure 5 D – Langa Dam: Spillway sizing and design

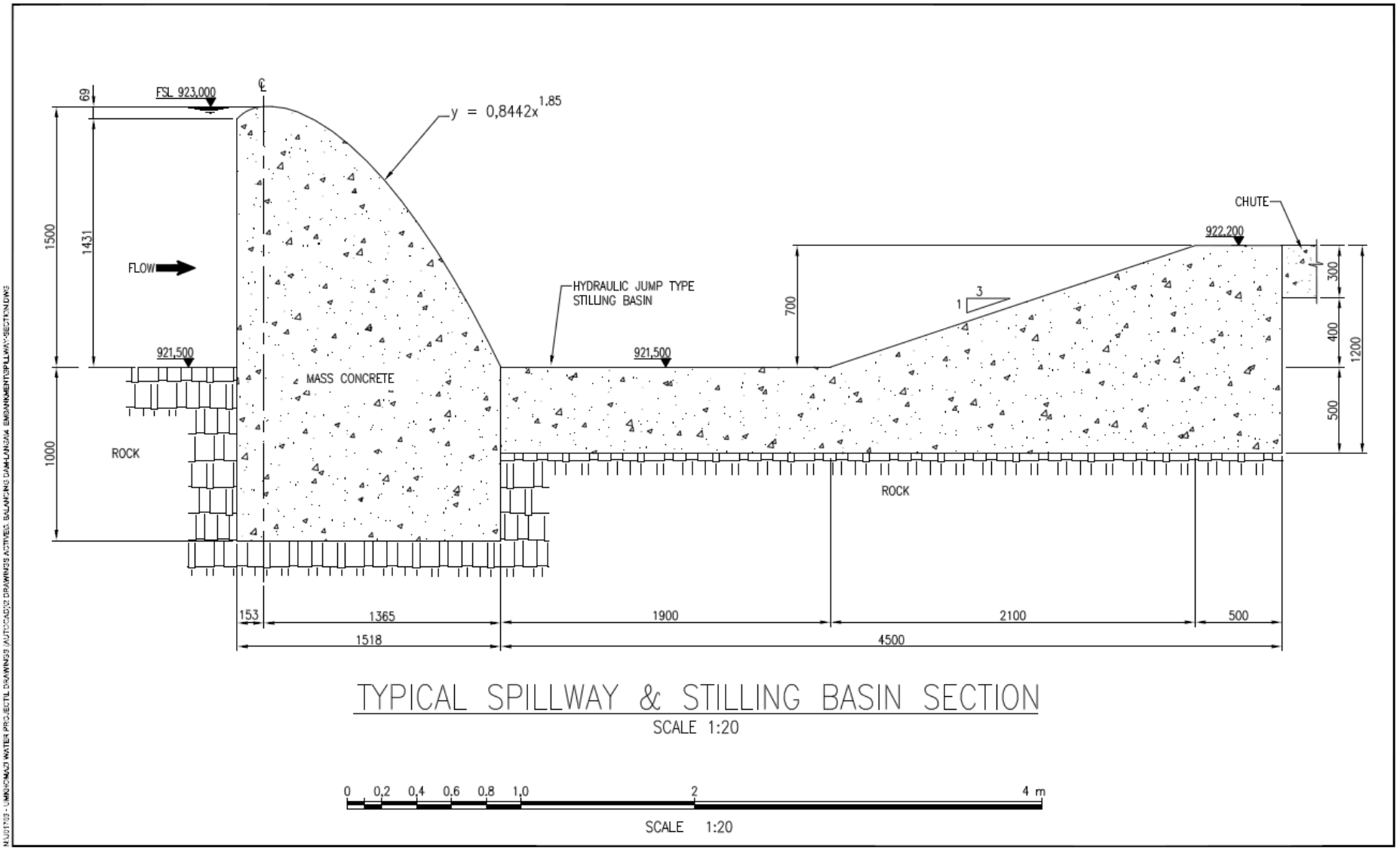


Figure 5.D.1: Typical spillway and stilling basin section

Annexure 6 A – Raw Water Pipeline: Drawings

Figure 6.A.1: General layout of the raw water pipeline

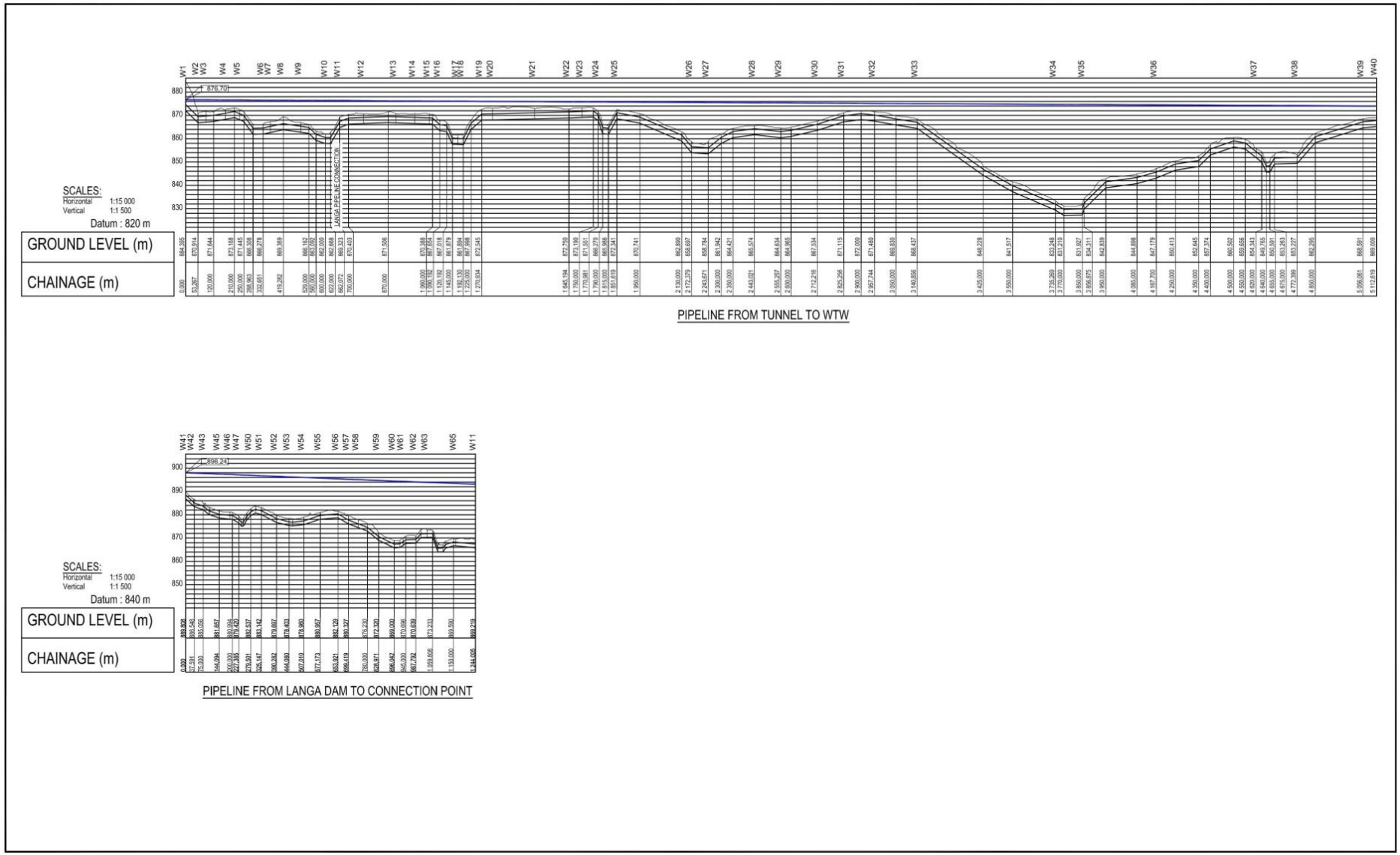


Figure 6.A.2: Longitudinal sections of the raw water pipeline

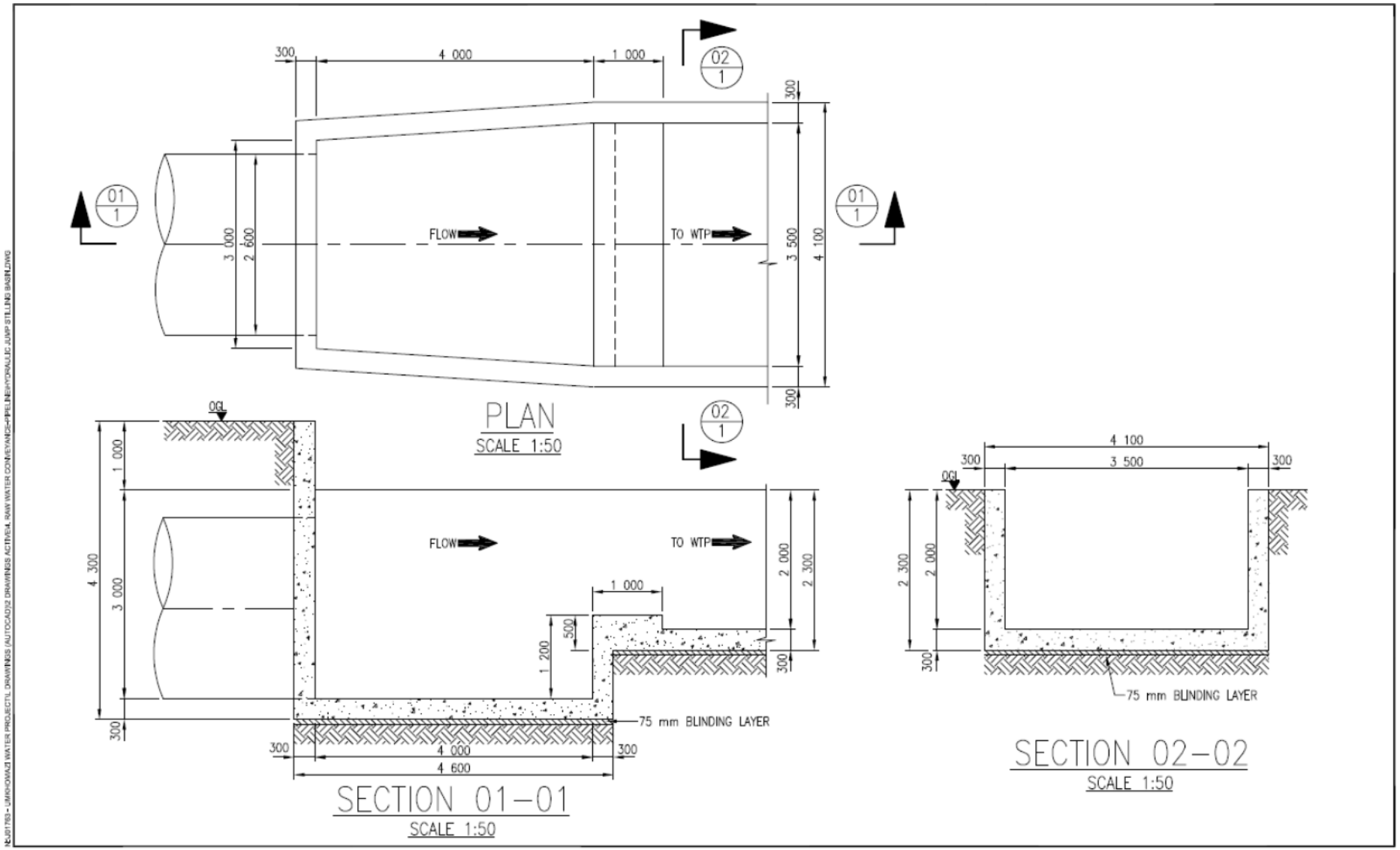


Figure 6.A.3: Hydraulic jump stilling basin at the end of the raw water pipeline

Annexure 6 B – Raw Water Pipeline: Cost estimate

Table 6.B.1: Cost estimate: Tunnel-Langa Dam-Baynesfield Pipeline: 2.6 m diameter section

TUNNEL-LANGA DAM-BAYNESFIELD PIPELINE					
ITEM NO	**DESCRIPTION**	**UNIT**	**QTY**	**RATE**	**AMOUNT**
1	**PART 1: PIPELINE - 2.6 m DIAMETER SECTION**				
1.1	**SECTION: SITE PREPARATION**				
	Site clearance				
	Clear and strip site	ha	3.6	41 900	150 840
	Remove topsoil to nominal depth of 150 mm and stockpile	m³	5 400	27	145 800
	River and road crossings	Sum	1	3 000 000	3 000 000
1.2	**SECTION: INSTALLATION OF PIPELINE**				
	Pipes, complete with couplings				
	(a) 2 600 mm diameter	m	5 120	23 750	121 600 000
	Transport of pipes	%	5%	121 600 000	6 080 000
	Excavation, installation and backfilling of pipe	m	5 120	23 750	121 600 000
	Fittings (including chambers)	%	20%	121 600 000	24 320 000
	Cathodic protection	km	5.1	77 000	392 700
TOTAL CARRIED FORWARD TO SUMMARY					**277 289 340**

Table 6.B.2: Cost estimate: Tunnel-Langa Dam-Baynesfield Pipeline: 1.6 m diameter section

TUNNEL-LANGA DAM-BAYNESFIELD PIPELINE					
ITEM NO	**DESCRIPTION**	**UNIT**	**QTY**	**RATE**	**AMOUNT**
2	**PART 2: PIPELINE - 1.6 m DIAMETER SECTION**				
2.1	**SECTION: SITE PREPARATION**				
	Site clearance				
	Clear and strip site	ha	0.8	41 900	33 520
	Remove topsoil to nominal depth of 150 mm and stockpile	m³	1 200	27	32 400
	River and road crossings	Sum	1	500 000	500 000
2.2	**SECTION: INSTALLATION OF PIPELINE**				
	Pipes, complete with couplings				
	(a) 1 600 mm diameter	m	1 250	9 375	11 718 750
	Transport of pipes	%	5%	11 718 750	585 938
	Excavation, installation and backfilling of pipe	m	1 250	9 375	11 718 750
	Fittings (including chambers)	%	20%	11 718 750	2 343 750
	Cathodic protection	km	1.3	77 000	100 100
TOTAL CARRIED FORWARD TO SUMMARY					**27 033 208**

Table 6.B.3: Cost estimate: Tunnel-Langa Dam-Baynesfield Pipeline: Miscellaneous

TUNNEL-LANGA DAM-BAYNESFIELD PIPELINE					
ITEM NO	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
3	**PART 3: MISCELLANEOUS**				
3.1	**SECTION: MISCELLANEOUS**				
	Establishment of sub-consultant (for pipeline)	%	20%	304 322 548	60 864 510
TOTAL CARRIED FORWARD TO SUMMARY					**60 864 510**

Table 6.B.4: Cost estimate: Tunnel-Langa Dam-Baynesfield Pipeline: Summary

SUMMARY: TUNNEL-LANGA DAM-BAYNESFIELD PIPELINE	
DESCRIPTION	**AMOUNT**
PART 1: PIPELINE - 2.6 m DIAMETER SECTION	277 290 000
PART 2: PIPELINE - 1.6 m DIAMETER SECTION	27 034 000
PART 3: MISCELLANEOUS	60 865 000
TOTAL	**365 189 000**

Annexure 7 A – Hydropower Plant: Powerhouse layout

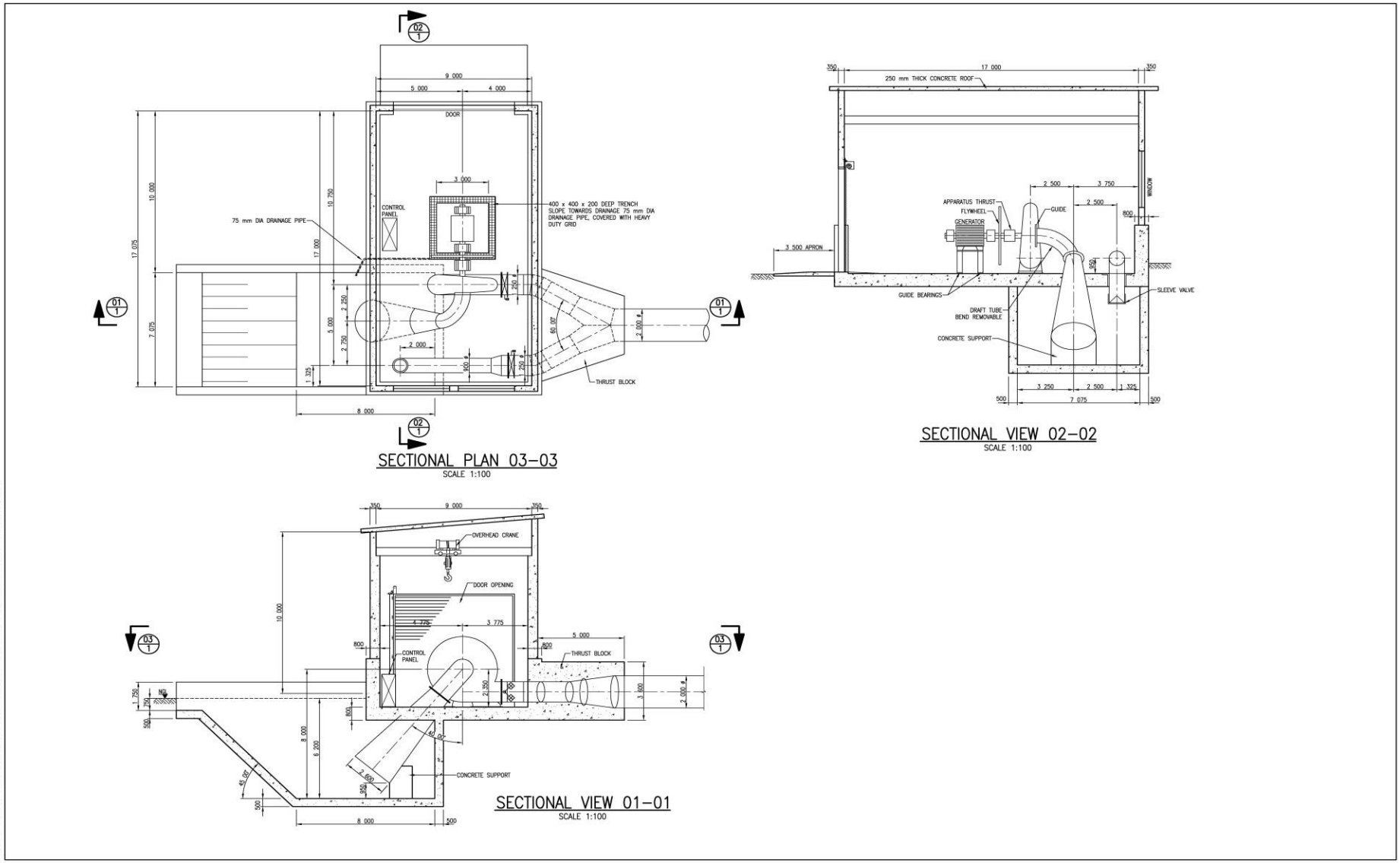


Figure 7.A.1: Powerhouse layout

Annexure 7 B – Hydropower Plants: Cost estimate

Table 7.B.1: Cost estimate: Hydropower Plants: Baynesfield HPP alternative 1

HYDROPOWER PLANTS					
ITEM NO	**DESCRIPTION**	**UNIT**	**QTY**	**RATE**	**AMOUNT**
1	**PART 1: BAYNESFIELD HPP (ALTERNATIVE 1)**				
1.1	**SECTION: CIVIL WORKS**				
	Excavation	m^3	600	150	90 000
	Concrete (in structures)	m^3	600	1 980	1 188 000
	Reinforcement	ton	190	13 000	2 470 000
1.2	**SECTION: HYDRO-MECHANICAL**				
	Hydro-generating set (quotation by Gilbert Gilkes & Gordon Ltd)	Sum	1	35 696 000	35 696 000
	Shipping of hydro-generating set (quotation by Gilbert Gilkes & Gordon Ltd)	Sum	1	547 000	547 000
	0.65 m diameter sleeve valve (quotation by Ithuba Valves and Industrial Supplies cc)	No.	1	469 000	469 000
	1.25 m diameter butterfly valve (quotation by Ithuba Valves and Industrial Supplies cc)	No.	1	256 000	256 000
1.3	**SECTION: POWER TRANSMISSION**				
	Power transformation infrastructure	Sum	1	2 000 000	2 000 000
	Transmission lines: Cables	m	50	1 500	75 000
TOTAL CARRIED FORWARD TO SUMMARY					**42 791 000**

Table 7.B.2: Cost estimate: Hydropower Plants: Smithfield Dam HPP alternative 2

HYDROPOWER PLANTS					
ITEM NO	**DESCRIPTION**	**UNIT**	**QTY**	**RATE**	**AMOUNT**
2	**PART 2: SMITHFIELD DAM HPP (ALTERNATIVE 2)**				
2.1	**SECTION: CIVIL WORKS**				
	Excavation	m^3	600	150	90 000
	Concrete (in structures)	m^3	600	1 980	1 188 000
	Reinforcement	ton	190	13 000	2 470 000
2.2	**SECTION: HYDRO-MECHANICAL**				
	Hydro-generating set (quotation by Gilbert Gilkes & Gordon Ltd)	Sum	1	22 435 000	22 435 000
	Shipping of hydro-generating set (quotation by Gilbert Gilkes & Gordon Ltd)	Sum	1	547 000	547 000
	Estimate of additional pipework and valves needed for Smithfield Dam outlet works	Sum	1	7 100 000	7 100 000
2.3	**SECTION: POWER TRANSMISSION**				
	Power transformation infrastructure	Sum	1	2 000 000	2 000 000
	Transmission lines: Cables	m	500	1 500	750 000
TOTAL CARRIED FORWARD TO SUMMARY					**36 580 000**

Table 7.B.3: Cost estimate: Hydropower Plants: Miscellaneous

HYDROPOWER PLANTS					
ITEM NO	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
3	**PART 3: MISCELLANEOUS**				
3.1	**SECTION: MISCELLANEOUS**				
	Miscellaneous	%	5%	79 371 000	3 968 550
TOTAL CARRIED FORWARD TO SUMMARY					**3 968 550**

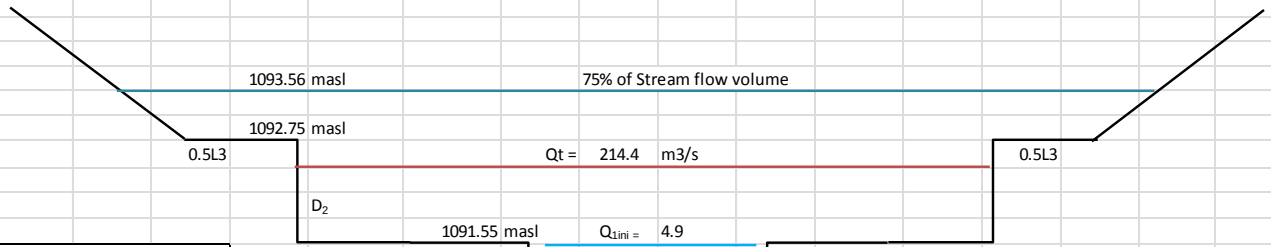
Table 7.B.4: Cost estimate: Hydropower Plants: Summary

SUMMARY: HYDROPOWER PLANTS	
DESCRIPTION	AMOUNT
PART 1: BAYNESFIELD HPP (ALTERNATIVE 1)	42 791 000
PART 2: SMITHFIELD DAM HPP (ALTERNATIVE 2)	36 580 000
PART 3: MISCELLANEOUS	3 969 000
TOTAL	**83 340 000**

Annexure 8 A – Flow gauging weirs: Calculations

Figure 8.A.1: Downstream of Impendle gauging weir: Catchment characteristics and flow calculations

Catchment Characteristics			
Description			Impendle Dam
Flood Peak Q_T (m^3/s)	Reurn Period T (years)	2	320
		10	830
		20	1080
		50	1460
		100	
		RMF	3760
Size of catchment (km^2)			1422
Longest river course (km)			75.9
Average watercourse Slope (%)			0.8%
Total stream length (m)			308773
River density (m/km^2)			217.40



Symbol	Description
L1	Width of weir level 1
T1	Thickness or height of step
Q1ini	Flow in Notch 1
Qt	Total required flow
P	Crest height
B	Water surface top width

NGL	1089.55	
L_1	15	
L_2	18	
L3	6	
Ltotal	44	Includes 5m for splitting walls
L_2/L_1 - ratio	1.20	
L3/L2 - ratio	0.33	
%Error (L2/L1)	5.3%	**read off graph**
T_1	0.3	
Q_t initial (m^3/s	**4.9**	EWR
Qt (m^3/s)	**214.4**	

Table 8.A.1: Downstream of Impendle gauging weir calculations to determine the downstream water level and dimensions of the weir

Level	Chosen Po	Step Thickness	Crump height	ha	Q_{I1}	Qmax	Qtmax	D/S WL	hb	hb<0.9ha	Aa	va	$v^2/2g$	Ha	Po>0.33Ha
	(m)	(masl)	(masl)	(m)	(m^3/s)	(m^3/s)	(m^3/s)	(masl)	(m)		(m^2)	(m/s)	(m)		
	1.7		1091.25	2.3083										2.46	OK
1		0.3	1091.55	2.0083	4.9	104.3								2.16	OK
2		1.2	1092.75	0.8083		101.5								0.96	OK
3		0.8083	1093.5583	0		8.6	214.4	1093.4	1.82	OK	125.79	1.70	0.15	0.15	OK

Check Froude number:			
B	Y	Fr	Check Fr
52.42	2.40	0.35	OK

Accurately Measures Flows > x		
x	0.332	m^3/s
x	332	l/s

Dimensions of Crump Weir:								
Centre Crump - Level 1			Side Crump - Level 2			Side Crump - Level 3		
Up (m)	Down (m)	Total (m)	Up (m)	Down (m)	Total (m)	Up (m)	Down (m)	Total (m)
2.46	4.91	7.37	2.16	4.31	6.47	0.96	1.91	2.87

Table 8.A.2: Downstream of Impendle gauging weir: Upstream river station

Reach	River Station	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
					ha		Ha					
Impendle weir	30	PF 1	10	1089.54	1091.14	0	1091.15	0.000116	0.36	27.8	27.48	0.11
Impendle weir	30	PF 2	50	1089.54	1091.97	0	1092.01	0.000435	0.91	55.02	38.33	0.24
Impendle weir	30	PF 3	100	1089.54	1092.52	0	1092.61	0.000617	1.34	77.37	43.31	0.3
Impendle weir	30	PF 4	150	1089.54	1092.9	0	1093.04	0.00077	1.67	94.85	46.35	0.34
Impendle weir	30	PF 5	160	1089.54	1092.97	0	1093.12	0.000796	1.73	98.06	46.59	0.35
Impendle weir	30	PF 6	170	1089.54	1093.04	0	1093.2	0.000821	1.79	101.19	46.83	0.36
Impendle weir	30	PF 7	180	1089.54	1093.11	0	1093.28	0.000845	1.85	104.24	47.06	0.36
Impendle weir	30	PF 8	190	1089.54	1093.17	0	1093.35	0.000868	1.9	107.23	47.28	0.37
Impendle weir	30	PF 9	200	1089.54	1093.23	0	1093.42	0.000889	1.95	110.15	47.5	0.37
Impendle weir	30	PF 10	205	1089.54	1093.26	0	1093.46	0.0009	1.98	111.59	47.6	0.38
Impendle weir	30	PF 11	210	1089.54	1093.29	0	1093.49	0.00091	2.01	113.01	47.71	0.38
Impendle weir	30	PF 12	214	1089.54	1093.31	0	1093.52	0.000919	2.03	114.14	47.79	0.38
Impendle weir	30	PF 13	214.4	1089.54	1093.32	0	1093.52	0.00092	2.03	114.25	47.8	0.38
Impendle weir	30	PF 14	215	1089.54	1093.32	0	1093.53	0.000921	2.03	114.42	47.81	0.38
Impendle weir	30	PF 15	220	1089.54	1093.35	0	1093.56	0.000931	2.06	115.81	47.93	0.39
Impendle weir	30	PF 16	225	1089.54	1093.38	0	1093.59	0.000941	2.08	117.19	48.06	0.39
Impendle weir	30	PF 17	230	1089.54	1093.41	0	1093.63	0.000951	2.11	118.56	48.2	0.39
Impendle weir	30	PF 18	235	1089.54	1093.43	0	1093.66	0.000961	2.13	119.92	48.33	0.39
Impendle weir	30	PF 19	240	1089.54	1093.46	0	1093.69	0.00097	2.15	121.27	48.46	0.4
Impendle weir	30	PF 20	245	1089.54	1093.49	0	1093.72	0.00098	2.18	122.6	48.59	0.4
Impendle weir	30	PF 21	250	1089.54	1093.52	0	1093.76	0.000989	2.2	123.93	48.72	0.4
Impendle weir	30	PF 22	260	1089.54	1093.57	0	1093.82	0.001008	2.25	126.54	48.97	0.41
Impendle weir	30	PF 23	270	1089.54	1093.62	0	1093.88	0.001025	2.29	129.12	49.18	0.41
Impendle weir	30	PF 24	280	1089.54	1093.67	0	1093.94	0.001042	2.34	131.65	49.21	0.41
Impendle weir	30	PF 25	290	1089.54	1093.73	0	1094	0.001058	2.38	134.16	49.25	0.42
Impendle weir	30	PF 26	300	1089.54	1093.78	0	1094.06	0.001074	2.42	136.62	49.28	0.42
Impendle weir	30	PF 27	350	1089.54	1094.01	0	1094.35	0.00115	2.62	148.27	49.44	0.44
Impendle weir	30	PF 28	400	1089.54	1094.23	0	1094.61	0.001222	2.81	159.03	49.59	0.46
Impendle weir	30	PF 29	500	1089.54	1094.62	0	1095.1	0.001355	3.16	178.48	49.85	0.49
Impendle weir	30	PF 30	600	1089.54	1094.96	0	1095.55	0.001485	3.49	195.5	50.08	0.52

Table 8.A.3: Downstream of Impendle gauging weir: Downstream river station

Reach	River Station	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev		E.G. Slope	Vel Chnl	Flow Area	Top Width
			(m3/s)	(m)	(m)	(m)	(m)		(m/m)	(m/s)	(m2)	(m)
					ha		Ha					
Impendle weir	20	PF 1	10	1089.42	1091.14	0	1091.15		0.000112	0.34	29	29.78
Impendle weir	20	PF 2	50	1089.42	1091.97	0	1092.01		0.000379	0.88	56.88	36.74
Impendle weir	20	PF 3	100	1089.42	1092.51	0	1092.6		0.000571	1.31	78.35	41.75
Impendle weir	20	PF 4	150	1089.42	1092.9	0	1093.04		0.000729	1.65	95.19	44.8
Impendle weir	20	PF 5	160	1089.42	1092.97	0	1093.12		0.000756	1.71	98.28	45.08
Impendle weir	20	PF 6	170	1089.42	1093.03	0	1093.19		0.000782	1.77	101.29	45.36
Impendle weir	20	PF 7	180	1089.42	1093.1	0	1093.27		0.000807	1.83	104.23	45.62
Impendle weir	20	PF 8	190	1089.42	1093.16	0	1093.34		0.000832	1.89	107.11	45.85
Impendle weir	20	PF 9	200	1089.42	1093.22	0	1093.41		0.000855	1.94	109.93	46.08
Impendle weir	20	PF 10	205	1089.42	1093.25	0	1093.45		0.000866	1.97	111.32	46.19
Impendle weir	20	PF 11	210	1089.42	1093.28	0	1093.48		0.000877	1.99	112.69	46.29
Impendle weir	20	PF 12	214	1089.42	1093.31	0	1093.51		0.000886	2.01	113.77	46.38
Impendle weir	20	PF 13	214.4	1089.42	1093.31	0	1093.51		0.000887	2.02	113.88	46.39
Impendle weir	20	PF 14	215	1089.42	1093.31	0	1093.52		0.000888	2.02	114.05	46.4
Impendle weir	20	PF 15	220	1089.42	1093.34	0	1093.55		0.000899	2.04	115.39	46.51
Impendle weir	20	PF 16	225	1089.42	1093.37	0	1093.58		0.00091	2.07	116.72	46.61
Impendle weir	20	PF 17	230	1089.42	1093.4	0	1093.62		0.00092	2.09	118.04	46.72
Impendle weir	20	PF 18	235	1089.42	1093.43	0	1093.65		0.00093	2.12	119.34	46.82
Impendle weir	20	PF 19	240	1089.42	1093.45	0	1093.68		0.000941	2.14	120.64	46.92
Impendle weir	20	PF 20	245	1089.42	1093.48	0	1093.71		0.000951	2.17	121.92	47.02
Impendle weir	20	PF 21	250	1089.42	1093.51	0	1093.75		0.000961	2.19	123.2	47.12
Impendle weir	20	PF 22	260	1089.42	1093.56	0	1093.81		0.00098	2.24	125.71	47.32
Impendle weir	20	PF 23	270	1089.42	1093.61	0	1093.87		0.000999	2.28	128.18	47.51
Impendle weir	20	PF 24	280	1089.42	1093.66	0	1093.93		0.001018	2.33	130.6	47.69
Impendle weir	20	PF 25	290	1089.42	1093.71	0	1093.99		0.001036	2.38	133	47.88
Impendle weir	20	PF 26	300	1089.42	1093.76	0	1094.05		0.001054	2.42	135.35	48.06
Impendle weir	20	PF 27	350	1089.42	1094	0	1094.34		0.00114	2.63	146.62	49.04
Impendle weir	20	PF 28	400	1089.42	1094.21	0	1094.6		0.001217	2.82	157.19	49.29
Impendle weir	20	PF 29	500	1089.42	1094.6	0	1095.09		0.001359	3.18	176.3	49.57
Impendle weir	20	PF 30	600	1089.42	1094.93	0	1095.53		0.001499	3.51	192.98	49.81

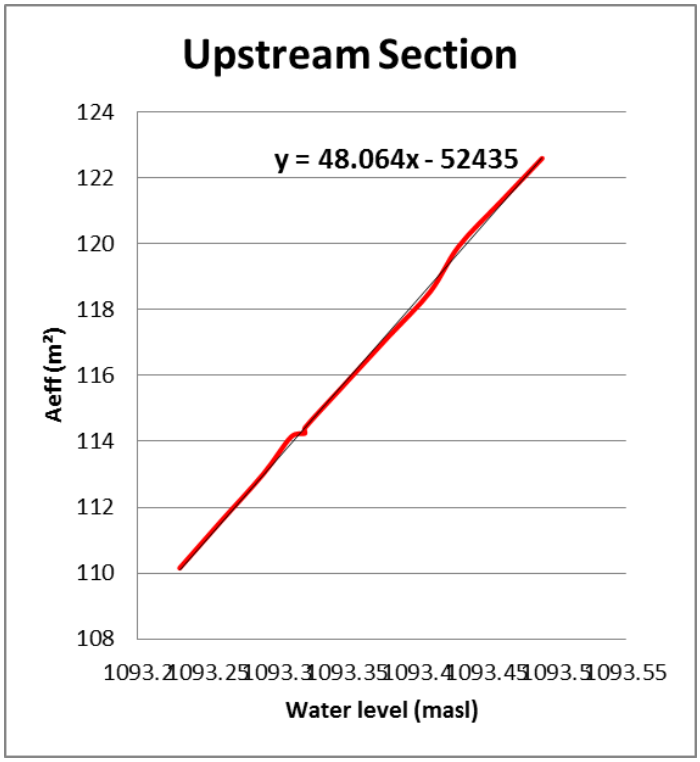


Figure 8.A.2: Downstream of Impendle gauging weir: Area of flow for upstream river station

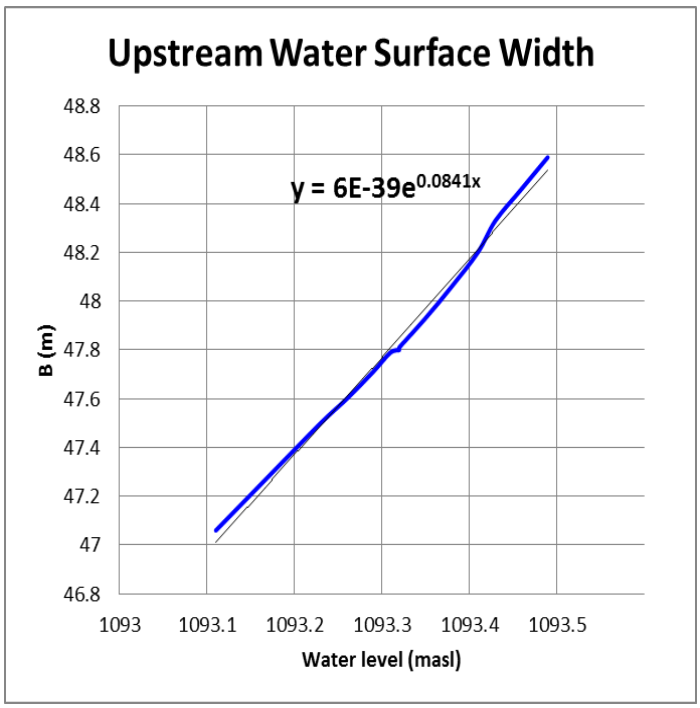


Figure 8.A.3: Downstream of Impendle gauging weir: Top width of water surface of upstream river section

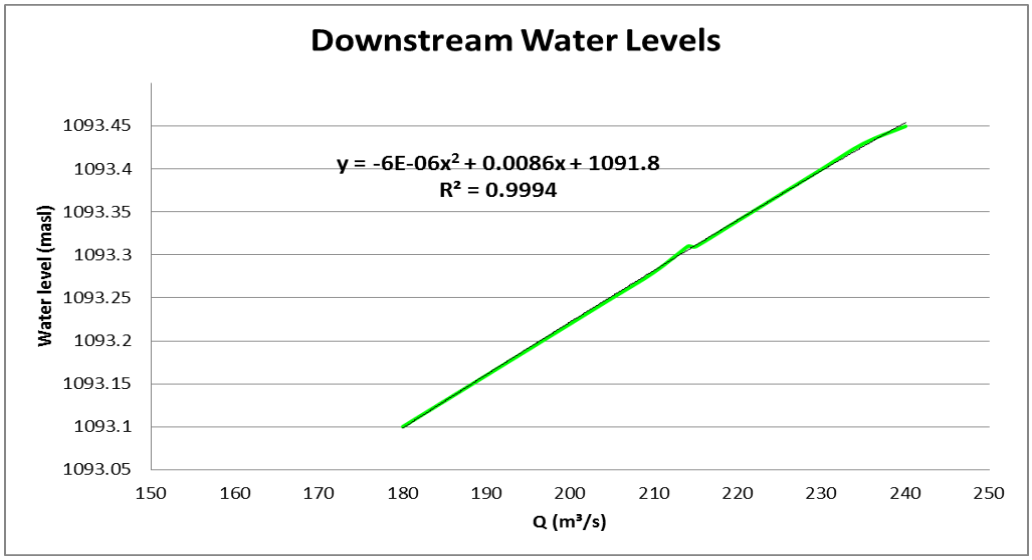
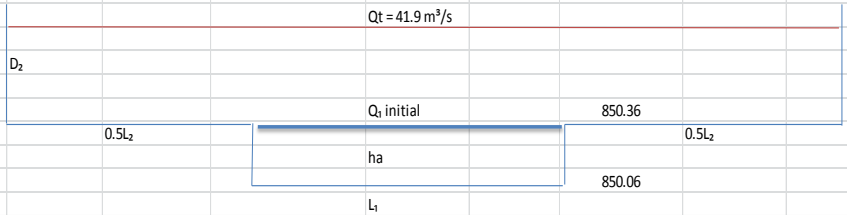


Figure 8.A.4: Downstream of Impendle gauging weir: Downstream water level against flows

Cogee	2.18	
Flow height over ogee	0.3	
Length of spillway	150	
RL bottom	523	
L_1	15	
L_2	40	
Ltotal	55	
L_2/L_1 - ratio	2.67	
%Error	7.9%	read off graph
T_1	0.3	
Q_t initial (m^3/s)	**4.9**	EWR
Qt (m^3/s)	**53.7**	



Level	Chosen Po	NGL	Crump height	D_2	Q_{i1}	Qmax	Qtmax	ha	D/S WL	hb	hb<0.9ha	Aa	va	$v^2/2g$	Ha	Po>0.33Ha
	(m)	(masl)	(masl)		(m^3/s)	(m^3/s)	(m^3/s)	(m)	(masl)	(m)		(m^2)	(m/s)	(m)		
	1.6	848.46	850.06					0.835							0.90	
1		0.3	850.36		4.9	22.7		0.535							0.60	
2		0.535	850.895	0.3		31.0	53.7	0	850.40	0.34	OK	47.75	1.12	0.06	0.06	OK

Check Froude number:			
B	Y	Fr	Check Fr
51.45	0.93	0.37	OK

Can measure accurately flows larger than:	
0.332	m^3/s
332	l/s

Dimensions of weir:					
Centre crump weir			Side crump weir		
Up (m)	Down (m)	Total (m)	Up (m)	Down (m)	Total (m)
0.90	1.80	2.70	0.60	1.20	1.80

Figure 8.A.5: Downstream of Smithfield gauging weir: Design flow calculations and dimensions of weir

Table 8.A.4: Downstream of Smithfield gauging weir: Upstream river station

Upstream of weir												
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
					ha		Ha					
HA-River Center	10	PF 1	5	848.46	849.11	849.11	849.28	0.013427	1.8	2.78	8.66	1.01
HA-River Center	10	PF 2	10	848.46	849.32	849.32	849.53	0.012117	2.04	4.9	11.69	1.01
HA-River Center	10	PF 3	15	848.46	849.43	849.47	849.72	0.013531	2.36	6.35	13.19	1.09
HA-River Center	10	PF 4	20	848.46	849.53	849.59	849.88	0.014145	2.6	7.7	14.36	1.13
HA-River Center	10	PF 5	25	848.46	849.62	849.69	850.01	0.014473	2.78	8.99	15.39	1.16
HA-River Center	10	PF 6	30	848.46	849.69	849.78	850.14	0.014864	2.95	10.18	16.28	1.19
HA-River Center	10	PF 7	35	848.46	849.77	849.87	850.25	0.014893	3.07	11.39	17.14	1.2
HA-River Center	10	PF 8	40	848.46	849.84	849.95	850.35	0.014871	3.18	12.58	17.98	1.21
HA-River Center	10	PF 9	45	848.46	849.91	850.01	850.44	0.01432	3.23	13.93	18.89	1.2
HA-River Center	10	PF 10	50	848.46	850.3		850.55	0.005712	2.24	22.34	26.38	0.78
HA-River Center	10	PF 11	53.7	848.46	850.38		850.62	0.006018	2.15	24.93	32.47	0.78
HA-River Center	10	PF 12	55	848.46	850.41		850.64	0.005828	2.13	25.83	33.42	0.77
HA-River Center	10	PF 13	60	848.46	850.5		850.72	0.005433	2.09	28.73	36.32	0.75
HA-River Center	10	PF 14	65	848.46	850.57		850.79	0.005167	2.07	31.43	38.82	0.73
HA-River Center	10	PF 15	70	848.46	850.64		850.85	0.00537	2.04	34.39	44.91	0.74
HA-River Center	10	PF 16	75	848.46	850.7		850.91	0.005048	2.01	37.31	47.82	0.72
HA-River Center	10	PF 17	80	848.46	850.76		850.96	0.004724	1.99	40.25	50.24	0.7
HA-River Center	10	PF 18	85	848.46	850.84		851.03	0.003908	1.92	44.43	51.28	0.65
HA-River Center	10	PF 19	90	848.46	850.87		851.07	0.00391	1.96	46.08	51.69	0.65
HA-River Center	10	PF 20	95	848.46	850.91		851.11	0.003913	2	47.7	52.08	0.66
HA-River Center	10	PF 21	100	848.46	850.94		851.15	0.003906	2.04	49.31	52.4	0.66
HA-River Center	10	PF 22	105	848.46	850.97		851.19	0.003905	2.08	50.87	52.66	0.66
HA-River Center	10	PF 23	110	848.46	851		851.22	0.003895	2.12	52.43	52.92	0.66
HA-River Center	10	PF 24	115	848.46	851.03		851.26	0.003885	2.15	53.98	53.17	0.67
HA-River Center	10	PF 25	120	848.46	851.05		851.3	0.003874	2.18	55.52	53.38	0.67
HA-River Center	10	PF 26	125	848.46	851.08		851.33	0.003865	2.22	57.02	53.53	0.67
HA-River Center	10	PF 27	130	848.46	851.11		851.37	0.003855	2.25	58.51	53.67	0.67
HA-River Center	10	PF 28	135	848.46	851.14		851.4	0.003847	2.28	59.98	53.81	0.67
HA-River Center	10	PF 29	140	848.46	851.16		851.44	0.003837	2.31	61.44	53.95	0.67
HA-River Center	10	PF 30	145	848.46	851.19		851.47	0.003833	2.34	62.87	54.12	0.68

Table 8.A.5: Downstream of Smithfield gauging weir: Downstream river station

Downstream of weir												
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
					ha		Ha					
HA-River Center	20	PF 1	5	848.51	849.26	849.2	849.39	0.008768	1.58	3.17	8.7	0.83
HA-River Center	20	PF 2	10	848.51	849.43	849.43	849.65	0.011201	2.05	4.89	10.92	0.98
HA-River Center	20	PF 3	15	848.51	849.58	849.58	849.84	0.011196	2.27	6.61	12.63	1
HA-River Center	20	PF 4	20	848.51	849.71	849.71	850	0.010759	2.41	8.28	13.99	1
HA-River Center	20	PF 5	25	848.51	849.82	849.82	850.14	0.010413	2.53	9.88	15.18	1
HA-River Center	20	PF 6	30	848.51	849.91	849.91	850.27	0.010152	2.63	11.41	16.23	1
HA-River Center	20	PF 7	35	848.51	850	850	850.38	0.009971	2.72	12.87	17.18	1
HA-River Center	20	PF 8	40	848.51	850.08	850.08	850.48	0.009911	2.8	14.29	18.17	1.01
HA-River Center	20	PF 9	45	848.51	850.2	850.2	850.57	0.009979	2.7	16.65	22.46	1
HA-River Center	20	PF 10	50	848.51	850.32	850.29	850.65	0.009444	2.55	19.62	27.8	0.97
HA-River Center	20	PF 11	53.7	848.51	850.42	850.34	850.71	0.0082	2.36	22.76	32.58	0.9
HA-River Center	20	PF 12	55	848.51	850.45	850.36	850.72	0.007949	2.32	23.66	33.86	0.89
HA-River Center	20	PF 13	60	848.51	850.53	850.42	850.79	0.00733	2.25	26.7	37.85	0.85
HA-River Center	20	PF 14	65	848.51	850.61		850.85	0.006949	2.19	29.67	42	0.83
HA-River Center	20	PF 15	70	848.51	850.69		850.91	0.006451	2.11	33.13	47.27	0.8
HA-River Center	20	PF 16	75	848.51	850.74		850.97	0.005847	2.09	35.92	48.67	0.77
HA-River Center	20	PF 17	80	848.51	850.8		851.02	0.00528	2.08	38.58	49.15	0.74
HA-River Center	20	PF 18	85	848.51	850.87		851.08	0.004488	2.03	42.15	49.78	0.69
HA-River Center	20	PF 19	90	848.51	850.9		851.12	0.004479	2.07	43.72	50.05	0.7
HA-River Center	20	PF 20	95	848.51	850.93		851.16	0.004474	2.11	45.25	50.32	0.7
HA-River Center	20	PF 21	100	848.51	850.96		851.2	0.004463	2.15	46.77	50.58	0.7
HA-River Center	20	PF 22	105	848.51	850.99		851.24	0.004462	2.19	48.24	50.84	0.7
HA-River Center	20	PF 23	110	848.51	851.02		851.27	0.004455	2.23	49.71	51.09	0.71
HA-River Center	20	PF 24	115	848.51	851.05		851.31	0.004446	2.27	51.17	51.34	0.71
HA-River Center	20	PF 25	120	848.51	851.08		851.35	0.004436	2.31	52.61	51.59	0.71
HA-River Center	20	PF 26	125	848.51	851.1		851.38	0.004429	2.34	54.03	51.83	0.71
HA-River Center	20	PF 27	130	848.51	851.13		851.42	0.004422	2.38	55.43	52.06	0.72
HA-River Center	20	PF 28	135	848.51	851.16		851.45	0.004415	2.41	56.82	52.3	0.72
HA-River Center	20	PF 29	140	848.51	851.18		851.49	0.004405	2.44	58.2	52.53	0.72
HA-River Center	20	PF 30	145	848.51	851.21		851.52	0.0044	2.47	59.56	52.75	0.72

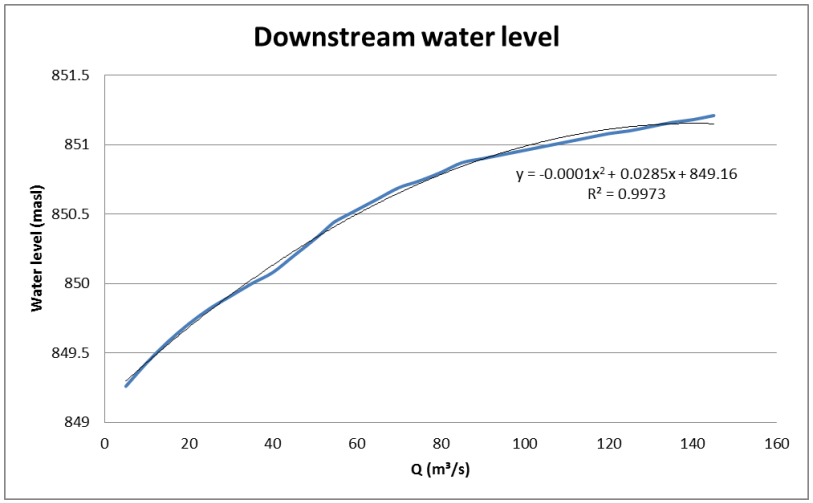


Figure 8.A.6: Downstream of Smithfield gauging weir: Downstream water level against flows

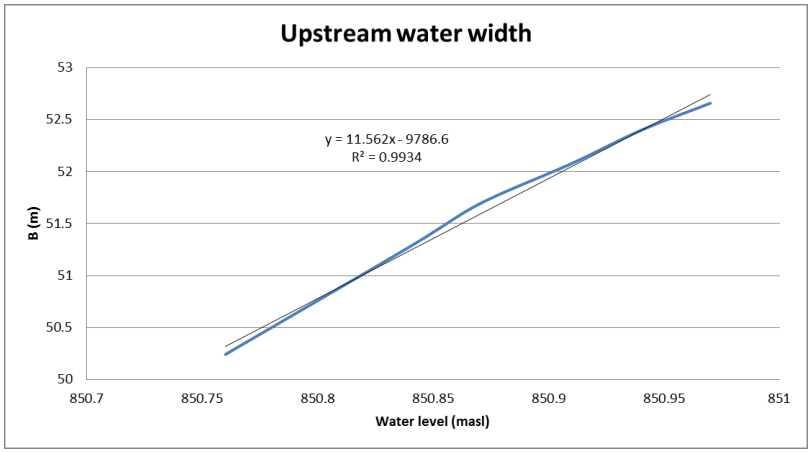


Figure 8.A.7: Downstream of Smithfield gauging weir: Top width of water surface of upstream river section

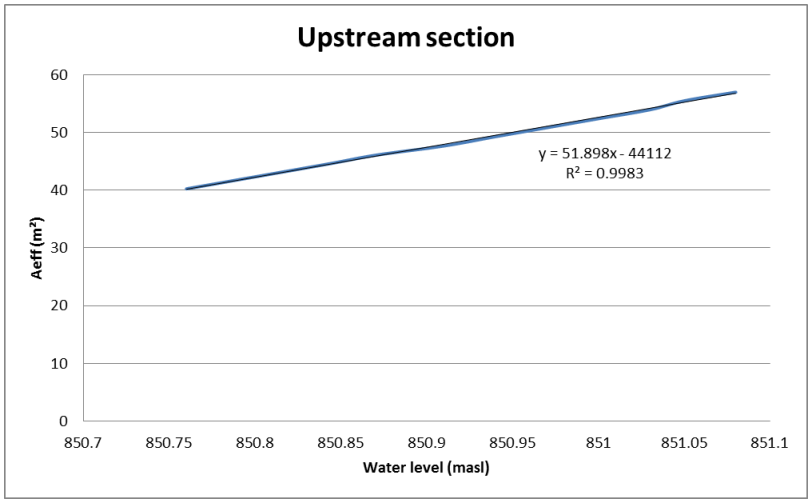
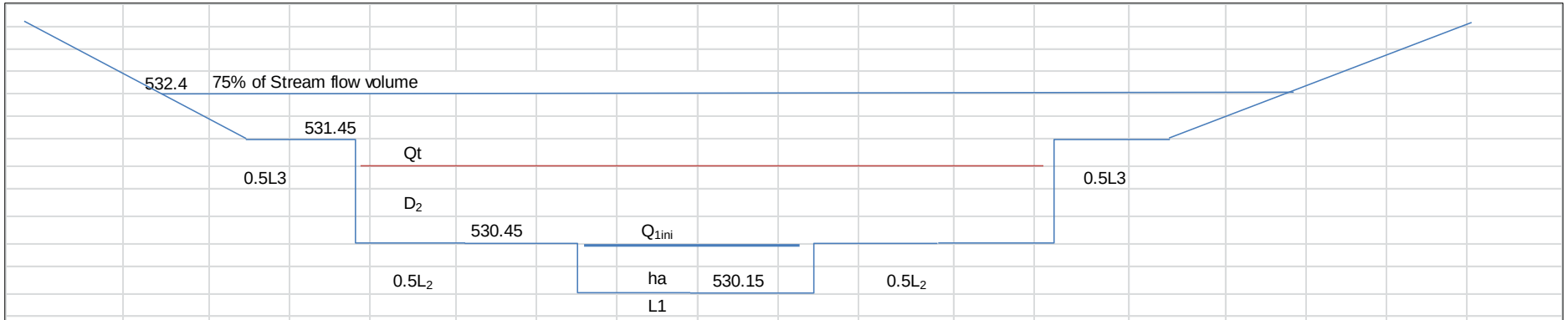


Figure 8.A.8: Downstream of Smithfield gauging weir: Area of flow for upstream river station



L1	L2	L2/L1	% Err	L3/L2	L3	Lt	Q_{1ini}	Q U1H005	IFR2 site
(m)	(m)				(m)	(m)	(m³/s)	(m³/s)	(m³/s)
15	30	2.00	7.8	1	10	55	4.9	124	273.0

Level			Po	NGL	Crump height	Q_{l1}	Qmax	Qtmax	ha	D/S WL	hb	hb<0.9ha	Aa	va	$v^2/2g$	Ha	Po>0.33Ha
			(m)	(masl)	(masl)	(m³/s)	(m³/s)	(m³/s)	(m)	(masl)	(m)		(m²)	(m/s)	(m)		
			1.7	528.45	530.15				2.22				163	1.67	0.14	2.36	
1	d1	(m)		0.3	530.45	4.9	98.0		1.92				163	1.67	0.14	2.06	
2	d2	(m)		1	531.45		157.6		0.92				163	1.67	0.14	1.06	
3	d3	(m)		0.92	532.37		17.4	273.0	0.00	531.26	1.11	OK	163	1.67	0.14	0.14	OK

Upstream F — Make Po = 1.7 due to uncertainties

Top width	ym	Fa	Fa<0.4			1.70
(m)	(m)					
58.64	2.78	0.32	OK			

Lowest			D1 or second height			D2 or third height		
Width of centre crump weir			Width of side crump weir			Width of side crump weir		
Up	Down	Total	Up	Down	Total	Up	Down	Total
2.36	4.72	7.07	2.06	4.12	6.17	1.06	2.12	3.17

Can measure accurate	
m³/s	L/s
0.332	332

Figure 8.A.9: IFR weir site: Design flow calculations and dimensions of weir

Table 8.A.6: IFR weir site: Upstream river station

DATA FOR SECTION UPSTREAM OF WEIR												
River Sta	Profile	Hydr Radius	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
		(m)	(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
4	PF 1	0.2	3	528.45	528.84		528.9	0.00843	1.06	2.83	13.83	0.75
4	PF 2	0.26	4.8	528.45	528.94		529	0.006695	1.1	4.37	17.03	0.69
4	PF 3	0.28	6	528.45	529		529.06	0.00607	1.12	5.34	18.75	0.67
4	PF 4	0.36	10	528.45	529.14		529.21	0.004995	1.19	8.39	23.3	0.63
4	PF 5	0.58	25	528.45	529.49		529.59	0.003649	1.4	17.88	30.81	0.59
4	PF 6	0.63	30	528.45	529.58		529.69	0.003541	1.46	20.59	32.64	0.59
4	PF 7	0.67	35	528.45	529.66		529.77	0.003486	1.51	23.18	34.38	0.59
4	PF 8	0.71	40	528.45	529.73		529.85	0.003448	1.56	25.66	36	0.59
4	PF 9	0.75	45	528.45	529.79		529.92	0.003424	1.6	28.05	37.5	0.59
4	PF 10	0.78	50	528.45	529.85		529.99	0.003408	1.65	30.36	38.89	0.59
4	PF 11	0.81	55	528.45	529.91		530.05	0.003421	1.69	32.52	40.15	0.6
4	PF 12	0.84	60	528.45	529.96		530.11	0.003419	1.73	34.68	41.36	0.6
4	PF 13	0.86	65	528.45	530.01		530.17	0.003418	1.77	36.8	42.52	0.61
4	PF 14	0.89	70	528.45	530.06		530.22	0.003423	1.8	38.85	43.61	0.61
4	PF 15	0.91	75	528.45	530.1		530.27	0.003432	1.84	40.84	44.66	0.61
4	PF 16	0.93	80	528.45	530.15		530.32	0.003442	1.87	42.8	45.66	0.62
4	PF 17	0.96	85	528.45	530.19		530.37	0.003446	1.9	44.75	46.64	0.62
4	PF 18	0.98	90	528.45	530.23		530.42	0.003451	1.93	46.66	47.58	0.62
4	PF 19	1	95	528.45	530.27		530.46	0.003453	1.96	48.56	48.51	0.62
4	PF 20	1.02	100	528.45	530.31		530.51	0.003457	1.98	50.44	49.42	0.63
4	PF 21	1.14	120	528.45	530.45		530.67	0.003286	2.08	57.65	50.5	0.62
4	PF 22	1.25	140	528.45	530.58		530.82	0.003171	2.18	64.22	51.04	0.62
4	PF 23	1.36	160	528.45	530.7		530.96	0.003086	2.27	70.45	51.55	0.62
4	PF 24	1.46	180	528.45	530.82		531.1	0.003024	2.36	76.38	52.03	0.62
4	PF 25	1.76	250	528.45	531.18		531.53	0.002895	2.62	95.45	53.54	0.63
4	PF 26	1.85	271	528.45	531.28		531.65	0.002862	2.69	100.87	53.96	0.63
4	PF 27	1.96	300	528.45	531.41		531.8	0.002836	2.78	108	54.51	0.63
4	PF 28	2.13	350	528.45	531.62		532.06	0.002802	2.92	119.74	55.4	0.63
4	PF 29	2.29	400	528.45	531.82		532.3	0.00278	3.06	130.89	56.24	0.64
4	PF 30	2.44	450	528.45	532.01		532.53	0.002765	3.18	141.57	57.02	0.64
4	PF 31	2.58	500	528.45	532.19		532.74	0.002753	3.29	151.86	57.77	0.65
4	PF 32	2.72	550	528.45	532.36		532.95	0.002738	3.4	161.78	58.47	0.65
4	PF 33	2.84	600	528.45	532.52		533.15	0.00271	3.5	171.38	59.09	0.65
4	PF 34	2.96	650	528.45	532.68		533.34	0.002689	3.6	180.69	59.69	0.66
4	PF 35	3.08	700	528.45	532.83		533.53	0.002675	3.7	189.71	60.27	0.66
4	PF 36	3.19	750	528.45	532.98		533.71	0.002664	3.79	198.5	60.82	0.66
4	PF 37	3.29	800	528.45	533.11		533.88	0.002663	3.88	206.88	61.35	0.67
4	PF 38	3.39	850	528.45	533.25		534.05	0.002661	3.97	215.19	61.87	0.67
4	PF 39	3.49	900	528.45	533.38		534.22	0.002655	4.05	223.37	62.35	0.67
4	PF 40	3.59	950	528.45	533.51		534.38	0.002637	4.13	231.47	62.74	0.67
4	PF 41	3.69	1000	528.45	533.64		534.54	0.002618	4.2	239.51	63.12	0.67
4	PF 42	3.78	1050	528.45	533.76		534.69	0.002601	4.28	247.42	63.49	0.68
4	PF 43	3.88	1100	528.45	533.89		534.85	0.002586	4.35	255.21	63.86	0.68
4	PF 44	3.97	1150	528.45	534.01		535	0.00257	4.42	262.94	64.22	0.68
4	PF 45	4.06	1200	528.45	534.12		535.15	0.002556	4.49	270.59	64.57	0.68
4	PF 46	4.14	1250	528.45	534.24		535.3	0.002542	4.55	278.16	64.92	0.68
4	PF 47	4.23	1300	528.45	534.36		535.44	0.002529	4.62	285.62	65.26	0.68
4	PF 48	4.31	1350	528.45	534.47		535.58	0.002517	4.68	293.03	65.6	0.68
4	PF 49	4.39	1400	528.45	534.58		535.72	0.002505	4.74	300.34	65.93	0.68
4	PF 50	4.47	1450	528.45	534.69		535.86	0.002495	4.8	307.6	66.26	0.68

Table 8.A.7: IFR weir site: Downstream river station

DATA FOR SECTION DOWNSTREAM OF WEIR												
River Sta	Profile	Hydr Radius	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
		(m)	(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
3	PF 1	0.28	3	528.34	528.82		528.85	0.002666	0.73	4.08	14.6	0.44
3	PF 2	0.33	4.8	528.34	528.92		528.96	0.002836	0.85	5.62	16.79	0.47
3	PF 3	0.36	6	528.34	528.98		529.02	0.002916	0.92	6.55	17.99	0.48
3	PF 4	0.44	10	528.34	529.12		529.18	0.003102	1.07	9.33	21.19	0.52
3	PF 5	0.6	25	528.34	529.46		529.56	0.003365	1.38	18.09	29.85	0.57
3	PF 6	0.64	30	528.34	529.55		529.65	0.003387	1.45	20.73	32.08	0.57
3	PF 7	0.68	35	528.34	529.62		529.74	0.003411	1.5	23.28	34.19	0.58
3	PF 8	0.71	40	528.34	529.7		529.82	0.003435	1.55	25.76	36.26	0.59
3	PF 9	0.74	45	528.34	529.76		529.89	0.003449	1.6	28.2	38.2	0.59
3	PF 10	0.76	50	528.34	529.82		529.96	0.003469	1.63	30.59	40.13	0.6
3	PF 11	0.78	55	528.34	529.88		530.02	0.003502	1.67	32.85	41.88	0.6
3	PF 12	0.8	60	528.34	529.93		530.08	0.003506	1.71	35.15	43.59	0.61
3	PF 13	0.83	65	528.34	529.98		530.14	0.003506	1.74	37.44	45.25	0.61
3	PF 14	0.85	70	528.34	530.03		530.19	0.003477	1.76	39.69	46.56	0.61
3	PF 15	0.88	75	528.34	530.08		530.24	0.003421	1.79	41.88	47.41	0.61
3	PF 16	0.91	80	528.34	530.12		530.29	0.003378	1.82	44	48.23	0.61
3	PF 17	0.94	85	528.34	530.16		530.34	0.003346	1.85	46.05	49	0.61
3	PF 18	0.96	90	528.34	530.21		530.38	0.003314	1.87	48.1	49.76	0.61
3	PF 19	0.99	95	528.34	530.25		530.43	0.003281	1.9	50.12	50.48	0.61
3	PF 20	1.02	100	528.34	530.29		530.47	0.003218	1.92	52.09	50.71	0.6
3	PF 21	1.15	120	528.34	530.43		530.64	0.003034	2.01	59.59	51.6	0.6
3	PF 22	1.26	140	528.34	530.56		530.79	0.002937	2.11	66.43	52.41	0.6
3	PF 23	1.36	160	528.34	530.69		530.93	0.002865	2.19	72.94	53.16	0.6
3	PF 24	1.46	180	528.34	530.8		531.07	0.00281	2.27	79.18	53.87	0.6
3	PF 25	1.76	250	528.34	531.17		531.49	0.002686	2.51	99.43	56.11	0.6
3	PF 26	1.84	271	528.34	531.27		531.61	0.002654	2.58	105.22	56.73	0.6
3	PF 27	1.94	300	528.34	531.41		531.77	0.002625	2.66	112.87	57.53	0.61
3	PF 28	2.12	350	528.34	531.63		532.02	0.002555	2.79	125.49	58.39	0.61
3	PF 29	2.29	400	528.34	531.83		532.26	0.002493	2.91	137.46	59.21	0.61
3	PF 30	2.45	450	528.34	532.02		532.49	0.002447	3.03	148.9	59.98	0.61
3	PF 31	2.6	500	528.34	532.2		532.7	0.002407	3.14	159.86	60.54	0.61
3	PF 32	2.74	550	528.34	532.38		532.91	0.002379	3.24	170.37	61.08	0.61
3	PF 33	2.87	600	528.34	532.54		533.11	0.002358	3.34	180.51	61.59	0.61
3	PF 34	3	650	528.34	532.7		533.3	0.002343	3.44	190.31	62.08	0.62
3	PF 35	3.12	700	528.34	532.85		533.49	0.002332	3.53	199.8	62.56	0.62
3	PF 36	3.24	750	528.34	533		533.67	0.002322	3.62	209.02	63.01	0.62
3	PF 37	3.35	800	528.34	533.14		533.84	0.002315	3.71	217.81	63.44	0.63
3	PF 38	3.45	850	528.34	533.27		534.01	0.002306	3.8	226.48	63.87	0.63
3	PF 39	3.56	900	528.34	533.41		534.17	0.002298	3.88	234.99	64.28	0.63
3	PF 40	3.66	950	528.34	533.54		534.33	0.00229	3.96	243.42	64.69	0.63
3	PF 41	3.76	1000	528.34	533.67		534.49	0.00228	4.04	251.79	65.09	0.63
3	PF 42	3.85	1050	528.34	533.79		534.65	0.002271	4.11	260.02	65.48	0.64
3	PF 43	3.95	1100	528.34	533.92		534.8	0.002263	4.18	268.13	65.86	0.64
3	PF 44	4.04	1150	528.34	534.04		534.95	0.002254	4.25	276.18	66.24	0.64
3	PF 45	4.13	1200	528.34	534.16		535.1	0.002246	4.32	284.14	66.62	0.64
3	PF 46	4.21	1250	528.34	534.28		535.25	0.002238	4.38	292.02	66.98	0.64
3	PF 47	4.3	1300	528.34	534.39		535.39	0.002231	4.45	299.8	67.34	0.65
3	PF 48	4.38	1350	528.34	534.51		535.54	0.002223	4.51	307.52	67.69	0.65
3	PF 49	4.47	1400	528.34	534.62		535.68	0.002217	4.57	315.14	68.04	0.65
3	PF 50	4.55	1450	528.34	534.73		535.81	0.00221	4.63	322.71	68.38	0.65

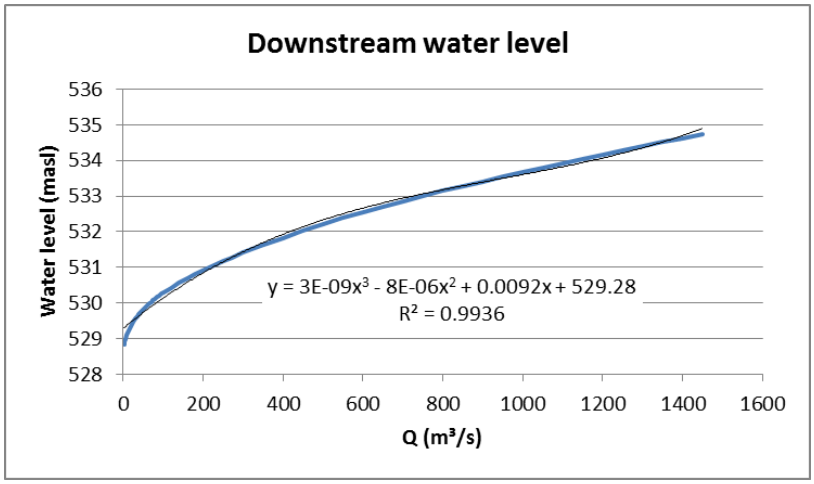


Figure 8.A.10: IFR weir site: Downstream water level against flows

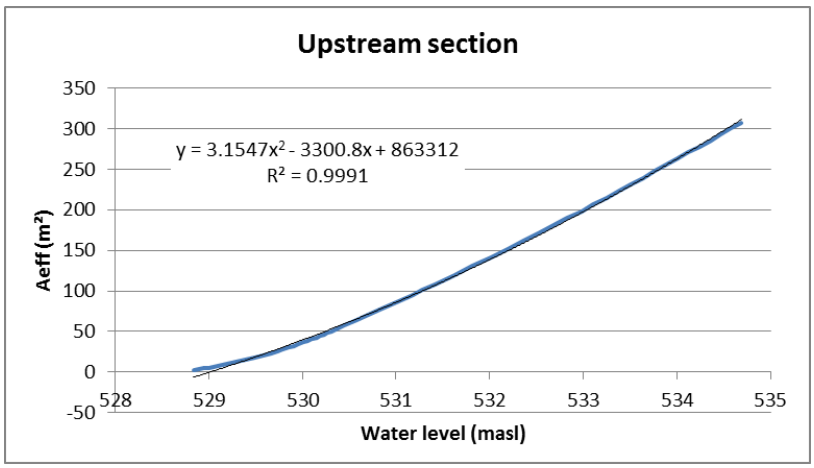


Figure 8.A.11: IFR weir site: Area of flow for upstream river station

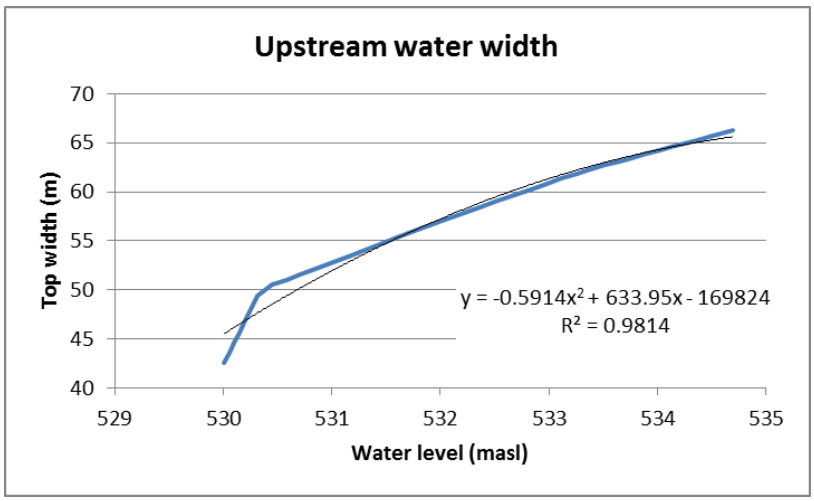


Figure 8.A.12: IFR weir site: Top width of water surface of upstream river section

Annexure 8 B – Flow gauging weirs: Cost estimate

Table 8.B.1: Cost estimate: Flow gauging weirs: Weir 1: Upstream of Smithfield Dam

FLOW GAUGING WEIRS					
ITEM NO	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
1	**PART 1: WEIR 1: UPSTREAM OF SMITHFIELD DAM**				
1.1	**SECTION: EARTHWORKS**				
	Site Preparation				
	Clear and strip site	m²	3 500	19	65 170
	Bulk Excavation				
	(a) Excavate in all materials and use for embankment as ordered				
	(1) Weir and wingwall footprint	m³	499	106	53 050
	(b) Extra over for				
	(2) hard rock excavation	m³	50	612	30 500
	(3) boulder excavation, class A	m³	5	633	3 170
	Restricted Excavation				
	(a) Excavate for restricted foundations, footings and pipe trenches in all materials and dispose				
	(1) Conduit pipes at bottom of weir	m³	10	170	1 710
	(b) Extra-over for				
	(2) hard rock excavation	m³	2	648	1 300
	Importing of Materials				
	(a) Extra-over for importation of materials from from borrow pits for use in:				
	(1) Construction of Coffer Dams	m³	4 800	161	772 470
	Overhaul				
	(a) Limited overhaul (provisional)	m³	200	60	11 970
	Remove material on upstream side	Sum	1	90 000	90 000
1.2	**SECTION: CONCRETE (STRUCTURAL)**				
	SCHEDULED FORMWORK ITEMS				
	Rough				
	(a) Vertical				
	(1) Sides of concrete weir between joints	m²	54	376	20 330

Table 8.B.1 (continued)

	Smooth				
	(a) Vertical				
	(1) Upstream side of weir	m^2	14	650	9 100
	(2) Downstream side of weir	m^2	15	650	9 750
	(3) Sides of wingwalls	m^2	249	650	161 850
	(4) At Instrumentation Hut	m^2	9	650	5 850
	SCHEDULED REINFORCEMENT ITEMS				
	Steel bars				
	(a) High tensile reinforcement				
	(1) Concrete crump weir				
	(i) Y25 Dowels @ 1000 mm c/c	t	0.3	10 680	3 210
	(2) Wing Walls				
	(i) Y25 @ 500 mm c/c	t	1.7	10 680	18 160
	(ii) Y16 @ 300 mm c/c	t	1.2	10 680	12 820
	(iii) Y25 Dowels at 1000 mm c/c	t	0.2	10 680	2 140
	(3) Instrumentation Hut				
	(i) Y12 reinforcement as shown on drawings	t	0.7	10 680	7 480
	100 x 100 x 8 mm Stainless Steel angle welded to dowel at weir crest as shown on drawings	m	39	928	36 210
	SCHEDULED CONCRETE ITEMS				
	Blinding Layer				
	(a) 75 mm minimum thickness grade 15 MPa/19mm concrete underneath concrete sections	m^2	332	1 869	620 400
	Strength Concrete				
	Grade 25/19 in:				
	(a) Weir	m^3	212	2 160	457 920
	(b) Wing walls	m^3	136	2 160	293 420
	(c) Instrumentation hut	m^3	20	2 160	43 200
	Unformed surface finishes				
	(b) Steel-floated finish				
	(i) Weir surface	m^2	220	286	62 910
	(ii) Wingwalls	m^2	82	286	23 450
	(iii) Instrumentation hut	m^2	7	286	2 010
	MANUFACTURE (OR SUPPLY) AND ERECT PRECAST ELEMENTS				
	(a) At instrumentation hut as shown on drawings	No	2	55 269	110 540

Table 8.B.1 (continued)

	GROUTING				
	(c) Grouting of dowels in crump weir with shrinkage compensated cementitious grout	ℓ	25	642	16 060
1.3	**SECTION: MEDIUM PRESSURE PIPELINES**				
	Supply, lay and bed pipes complete with couplings				
	(a) 65 mm Nominal diameter Stainless Steel pipe 1,6 mm minimum thickness as shown on the drawings	m	30	1 107	33 200
	(b) 350 mm Stainless Steel pipe with blank end flanges through crump weir as shown on the drawings	m	11	3 389	37 280
	(c) 90 mm nominal diameter HDPE pipe PE 100 PN8 as shown on the drawings	m	30	599	17 960
	(d) 250 mm OD Class 4 UPVC Pipes as shown on the drawings	m	20	791	15 830
	Extra-over 8.2.1 for the supplying, laying and bedding of specials complete with couplings				
	(a) 65 mm Nominal diameter Stainless Steel pipe	No	10	6 308	63 090
	(b) 350 mm Stainless Steel Pipe	No	6	26 117	156 710
	(c) 90 mm nominal diameter HDPE pipe	No	10	4 404	44 040
	(d) 250 mm OD Class 4 UPVC Pipe	No	10	6 923	69 230
	Extra over 8.2.1 for the supplying, fixing and bedding of valves				
	(a) 65 mm Nominal diameter Stainless Steel pipe	No	1	9 799	9 800
	(b) 350 mm Stainless Steel Pipe	No	1	30 320	30 330
	(c) 90 mm nominal diameter HDPE pipe	No	1	6 606	6 610
	(d) 250 mm OD Class 4 UPVC pipe	No	1	12 890	12 900
	Instrumentation and Specialized Items				
	(a) Allowance for Instrumentation and Specialized Items	Prov Sum	1		5 650 000
	(b) Handling Costs and charges on the above item	%	565 000	15%	84 750
TOTAL CARRIED FORWARD TO SUMMARY					**9 177 880**

Table 8.B.2: Cost estimate: Flow gauging weirs: Weir 2: Downstream of Smithfield Dam

FLOW GAUGING WEIRS					
ITEM NO	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
2	**PART 2: WEIR 2: DOWNSTREAM OF SMITHFIELD DAM**				
2.1	**SECTION: EARTHWORKS**				
	Site Preparation				
	Clear and strip site	m²	3 500	19	65 170
	Bulk Excavation				
	(a) Excavate in all materials and use for embankment as ordered				
	(1) Weir and wingwall footprint	m³	154	106	16 390
	(2) Coffer dams (base)	m³	2	138	280
	(b) Extra over for				
	(2) hard rock excavation	m³	15	612	9 180
	(3) boulder excavation, class A	m³	0	633	0
	Restricted Excavation				
	(a) Excavate for restricted foundations, footings and pipe trenches in all materials and dispose				
	(1) Conduit pipes at bottom of weir	m³	10	170	1 710
	(b) Extra-over for				
	(2) hard rock excavation	m³	2	648	1 300
	Importing of Materials				
	(a) Extra-over for importation of materials from from borrow pits for use in:				
	(1) Construction of Coffer Dams	m³	960	161	154 500
	Overhaul				
	(a) Limited overhaul (provisional)	m³	200	60	11 970
	Remove material on upstream side	Sum	1	93 670	93 670
2.2	**SECTION: CONCRETE (STRUCTURAL)**				
	SCHEDULED FORMWORK ITEMS				
	Rough				
	(a) Vertical				
	(1) Sides of concrete weir between joints	m²	68	376	25 590

Table 8.B.2 (continued)

	Smooth				
	(a) Vertical				
	(1) Upstream side of weir	m^2	112	650	72 800
	(2) Downstream side of weir	m^2	112	650	72 800
	(3) Sides of wingwalls	m^2	155	650	100 750
	(4) At Instrumentation Hut	m^2	25	650	16 250
	SCHEDULED REINFORCEMENT ITEMS				
	Steel bars				
	(a) High tensile reinforcement				
	(1) Concrete crump weir				
	(i) Y25 Dowels @ 1000 mm c/c	t	0.2	10 680	2 140
	(2) Wing Walls				
	(i) Y25 @ 500 mm c/c	t	2.2	10 680	23 500
	(ii) Y16 @ 300 mm c/c	t	1.4	10 680	14 960
	(iii) Y25 Dowels at 1000 mm c/c	t	0.2	10 680	2 140
	(3) Instrumentation Hut				
	(i) Y12 reinforcement as shown on drawings	t	0.7	10 680	7 480
	100 x 100 x 8 mm Stainless Steel angle welded to dowel at weir crest as shown on drawings	m	35	928	32 500
	SCHEDULED CONCRETE ITEMS				
	Blinding Layer				
	(a) 75 mm minimum thickness grade 15 MPa/19mm concrete underneath concrete sections	m^2	326	1 869	609 180
	Strength Concrete				
	Grade 25/19 in:				
	(a) Weir	m^3	163	2 160	352 080
	(b) Wing walls	m^3	97	2 160	209 520
	(c) Instrumentation hut	m^3	10	2 160	21 600
	Unformed surface finishes				
	(b) Steel-floated finish				
	(i) Weir surface	m^2	123	286	35 180
	(ii) Wingwalls	m^2	48	286	13 730
	(iii) Instrumentation hut	m^2	20	286	5 720
	MANUFACTURE (OR SUPPLY) AND ERECT PRECAST ELEMENTS				
	(a) At instrumentation hut as shown on drawings	No	2	55 270	110 540

Table 8.B.2 (continued)

	GROUTING				
	(c) Grouting of dowels in crump weir with shrinkage compensated cementitious grout	ℓ	20	645	12 900
2.3	**SECTION: MEDIUM PRESSURE PIPELINES**				
	Supply, lay and bed pipes complete with couplings				
	(a) 65 mm Nominal diameter Stainless Steel pipe 1,6 mm minimum thickness as shown on the drawings	m	30	1 107	33 200
	(b) 350 mm Stainless Steel pipe with blank end flanges through crump weir as shown on the drawings	m	11	3 389	37 280
	(c) 90 mm nominal diameter HDPE pipe PE 100 PN8 as shown on the drawings	m	30	599	17 960
	(d) 250 mm OD Class 4 UPVC Pipes as shown on the drawings	m	20	791	15 830
	Extra-over 8.2.1 for the supplying, laying and bedding of specials complete with couplings				
	(a) 65 mm Nominal diameter Stainless Steel pipe	No	10	6 308	63 090
	(b) 350 mm Stainless Steel Pipe	No	6	26 117	156 710
	(c) 90 mm nominal diameter HDPE pipe	No	10	4 404	44 040
	(d) 250 mm OD Class 4 UPVC Pipe	No	10	6 923	69 230
	Extra over 8.2.1 for the supplying, fixing and bedding of valves				
	(a) 65 mm Nominal diameter Stainless Steel pipe	No	1	9 799	9 800
	(b) 350 mm Stainless Steel Pipe	No	1	30 320	30 330
	(c) 90 mm nominal diameter HDPE pipe	No	1	6 606	6 610
	(d) 250 mm OD Class 4 UPVC pipe	No	1	12 890	12 900
	Instrumentation and Specialized Items				
	(a) Allowance for Instrumentation and Specialized Items	Prov Sum	1		5 650 000
	(b) Handling Costs and charges on the above item	%	565 000	15%	84 750
TOTAL CARRIED FORWARD TO SUMMARY					**8 327 260**

Table 8.B.3: Cost estimate: Flow gauging weirs: Weir 3: Near EWR/IFR2

FLOW GAUGING WEIRS					
ITEM NO	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
3	**PART 3: WEIR 3: NEAR EWR/IFR2**				
3.1	**SECTION: EARTHWORKS**				
	Site Preparation				
	Clear and strip site	m²	3 500	19	65 170
	Bulk Excavation				
	(a) Excavate in all materials and use for embankment as ordered				
	(1) Weir and wingwall footprint	m³	644	106	68 530
	(2) Coffer dams (base)	m³	1 305	138	180 090
	(b) Extra over for				
	(2) hard rock excavation	m³	64	612	39 160
	(3) boulder excavation, class A	m³	261	633	165 240
	Restricted Excavation				
	(a) Excavate for restricted foundations, footings and pipe trenches in all materials and dispose				
	(1) Conduit pipes at bottom of weir	m³	10	170	1 710
	(b) Extra-over for				
	(2) hard rock excavation	m³	2	648	1 300
	Importing of Materials				
	(a) Extra-over for importation of materials from from borrow pits for use in:				
	(1) Construction of Coffer Dams	m³	3 012	161	484 730
	Overhaul				
	(a) Limited overhaul (provisional)	m³	200	60	11 970
	Remove material on upstream side	Sum	1	90 000	90 000
3.2	**SECTION: CONCRETE (STRUCTURAL)**				
	SCHEDULED FORMWORK ITEMS				
	Rough				
	(a) Vertical				
	(1) Sides of concrete weir between joints	m^2	165	376	62 090

Table 8.B.3 (continued)

	Smooth				
	(a) Vertical				
	(1) Upstream side of weir	m^2	103	650	66 950
	(2) Downstream side of weir	m^2	130	650	84 500
	(3) Sides of wingwalls	m^2	324	650	210 600
	(4) At Instrumentation Hut	m^2	25	650	16 250
	SCHEDULED REINFORCEMENT ITEMS				
	Steel bars				
	(a) High tensile reinforcement				
	(1) Concrete crump weir				
	(i) Y25 Dowels @ 1000 mm c/c	t	0.7	10 680	7 480
	(2) Wing Walls				
	(i) Y25 @ 500 mm c/c	t	4.9	10 680	52 340
	(ii) Y16 @ 300 mm c/c	t	3.3	10 680	35 250
	(iii) Y25 Dowels at 1000 mm c/c	t	0.5	10 680	5 340
	(3) Instrumentation Hut				
	(i) Y12 reinforcement as shown on drawings	t	0.7	10 680	7 480
	100 x 100 x 8 mm Stainless Steel angle welded to dowel at weir crest as shown on drawings	m	35	928	32 500
	SCHEDULED CONCRETE ITEMS				
	Blinding Layer				
	(a) 75 mm minimum thickness grade 15 MPa/19mm concrete underneath concrete sections	m^2	399	1 869	745 600
	Strength Concrete				
	Grade 25/19 in:				
	(a) Weir	m^3	693	2 160	1 496 880
	(b) Wing walls	m^3	393	2 160	848 880
	(c) Instrumentation hut	m^3	10	2 160	21 600
	Unformed surface finishes				
	(b) Steel-floated finish				
	(i) Weir surface	m^2	247	286	70 630
	(ii) Wingwalls	m^2	78	286	22 310
	(iii) Instrumentation hut	m^2	20	286	5 720
	MANUFACTURE (OR SUPPLY) AND ERECT PRECAST ELEMENTS				
	(a) At instrumentation hut as shown on drawings	No	2	55 270	110 540

Table 8.B.3 (continued)

	GROUTING				
	(c) Grouting of dowels in crump weir with shrinkage compensated cementitious grout	ℓ	20	645	12 900
3.3	**SECTION: MEDIUM PRESSURE PIPELINES**				
	Supply, lay and bed pipes complete with couplings				
	(a) 65 mm Nominal diameter Stainless Steel pipe 1,6 mm minimum thickness as shown on the drawings	m	30	1 107	33 200
	(b) 350 mm Stainless Steel pipe with blank end flanges through crump weir as shown on the drawings	m	11	3 389	37 280
	(c) 90 mm nominal diameter HDPE pipe PE 100 PN8 as shown on the drawings	m	30	599	17 960
	(d) 250 mm OD Class 4 UPVC Pipes as shown on the drawings	m	20	791	15 830
	Extra-over 8.2.1 for the supplying, laying and bedding of specials complete with couplings				
	(a) 65 mm Nominal diameter Stainless Steel pipe	No	10	6 308	63 090
	(b) 350 mm Stainless Steel Pipe	No	6	26 117	156 710
	(c) 90 mm nominal diameter HDPE pipe	No	10	4 404	44 040
	(d) 250 mm OD Class 4 UPVC Pipe	No	10	6 923	69 230
	Extra over 8.2.1 for the supplying, fixing and bedding of valves				
	(a) 65 mm Nominal diameter Stainless Steel pipe	No	1	9 799	9 800
	(b) 350 mm Stainless Steel Pipe	No	1	30 320	30 330
	(c) 90 mm nominal diameter HDPE pipe	No	1	6 606	6 610
	(d) 250 mm OD Class 4 UPVC pipe	No	1	12 890	12 900
	Instrumentation and Specialized Items				
	(a) Allowance for Instrumentation and Specialized Items	Prov Sum	1		5 650 000
	(b) Handling Costs and charges on the above item	%	565 000	15%	84 750
TOTAL CARRIED FORWARD TO SUMMARY					**11 255 470**

Table 8.B.4: Cost estimate: Flow gauging weirs: Miscellaneous costs

FLOW GAUGING WEIRS					
ITEM NO	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
4	**PART 4: MISCELLANEOUS**				
4.1	**SECTION: MISCELLANEOUS**				
	General	%	5%	28 762 000	1 438 100
TOTAL CARRIED FORWARD TO SUMMARY					**1 438 100**

Table 8.B.5: Cost estimate: Flow gauging weirs: Cost summary

SUMMARY: FLOW GAUGING WEIRS	
DESCRIPTION	AMOUNT
PART 1: WEIR 1: UPSTREAM OF SMITHFIELD DAM	9 178 000
PART 2: WEIR 2: DOWNSTREAM OF SMITHFIELD DAM	8 328 000
PART 3: WEIR 3: NEAR EWR/IFR2	11 256 000
PART 4: MISCELLANEOUS	1 439 000
TOTAL	**30 201 000**

Annexure 8 C – Flow gauging weirs: Layouts

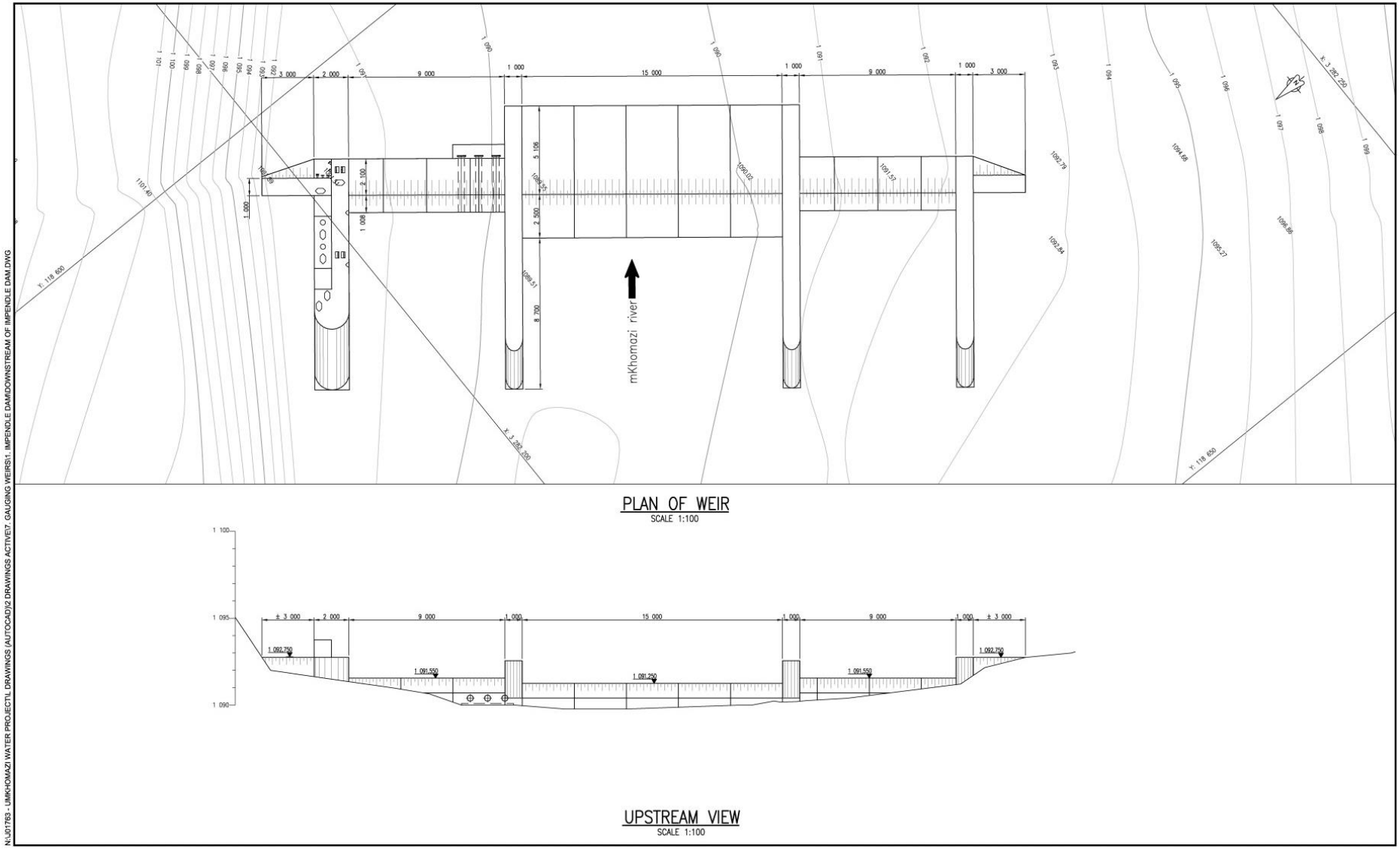


Figure 8.C.1: Plan and cross-sectional view of gauging weir upstream of Smithfield Dam

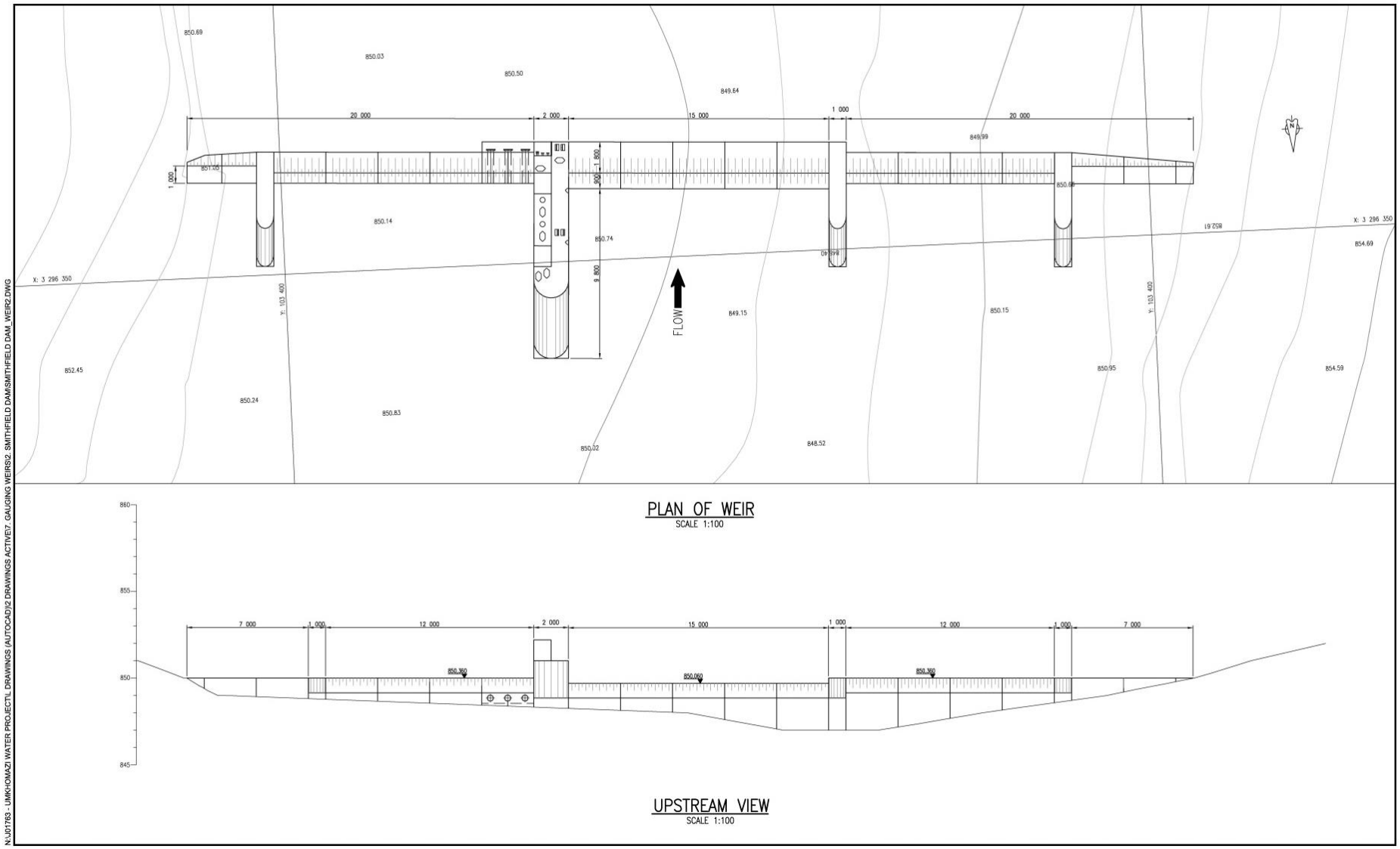


Figure 8.C.2: Plan and cross-sectional view of gauging weir downstream of Smithfield Dam

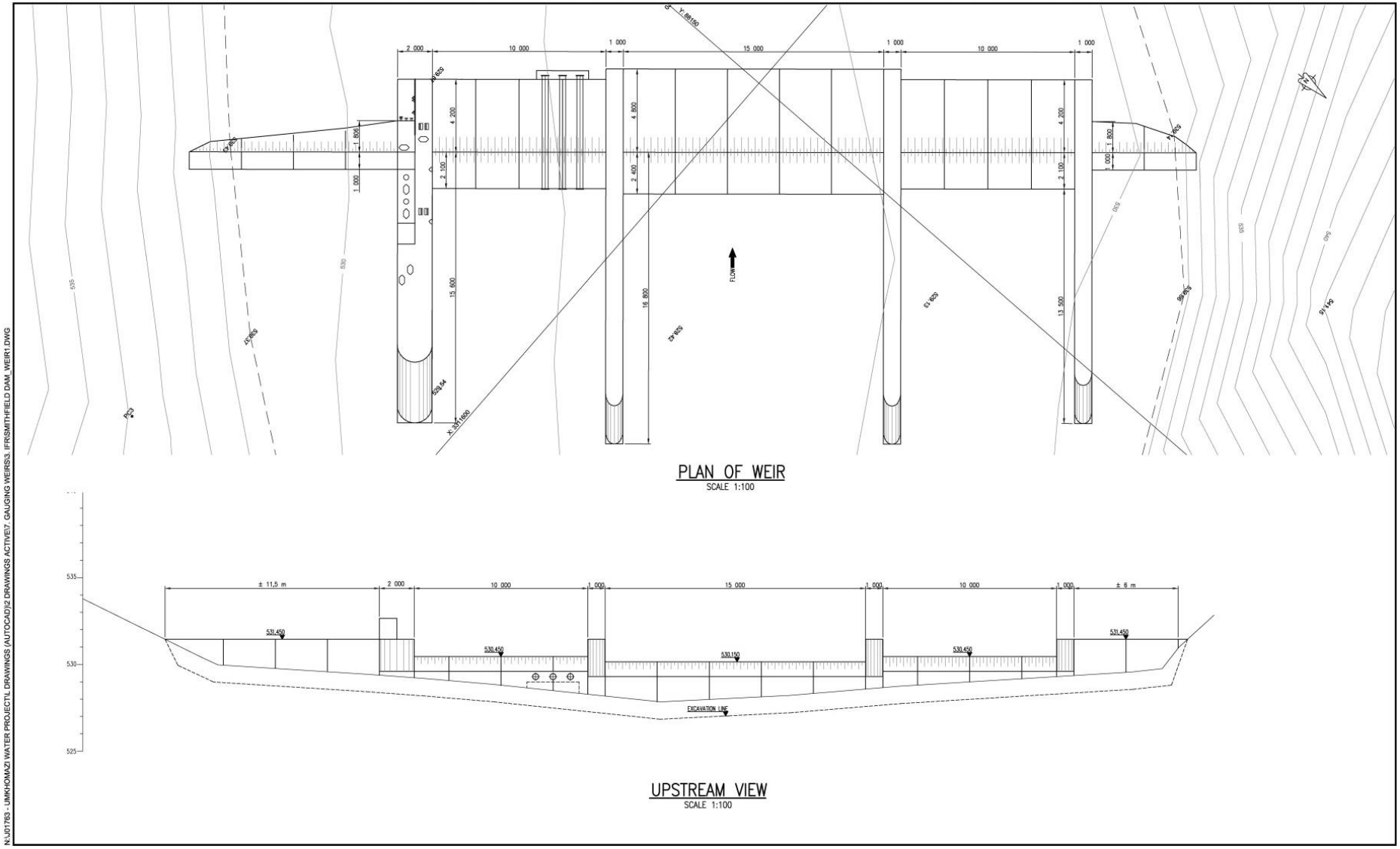


Figure 8.C.3: Plan and cross-sectional view of gauging weir near EWR/IFR2, further downstream of Smithfield Dam

Annexure 9 A – Roads: Layouts

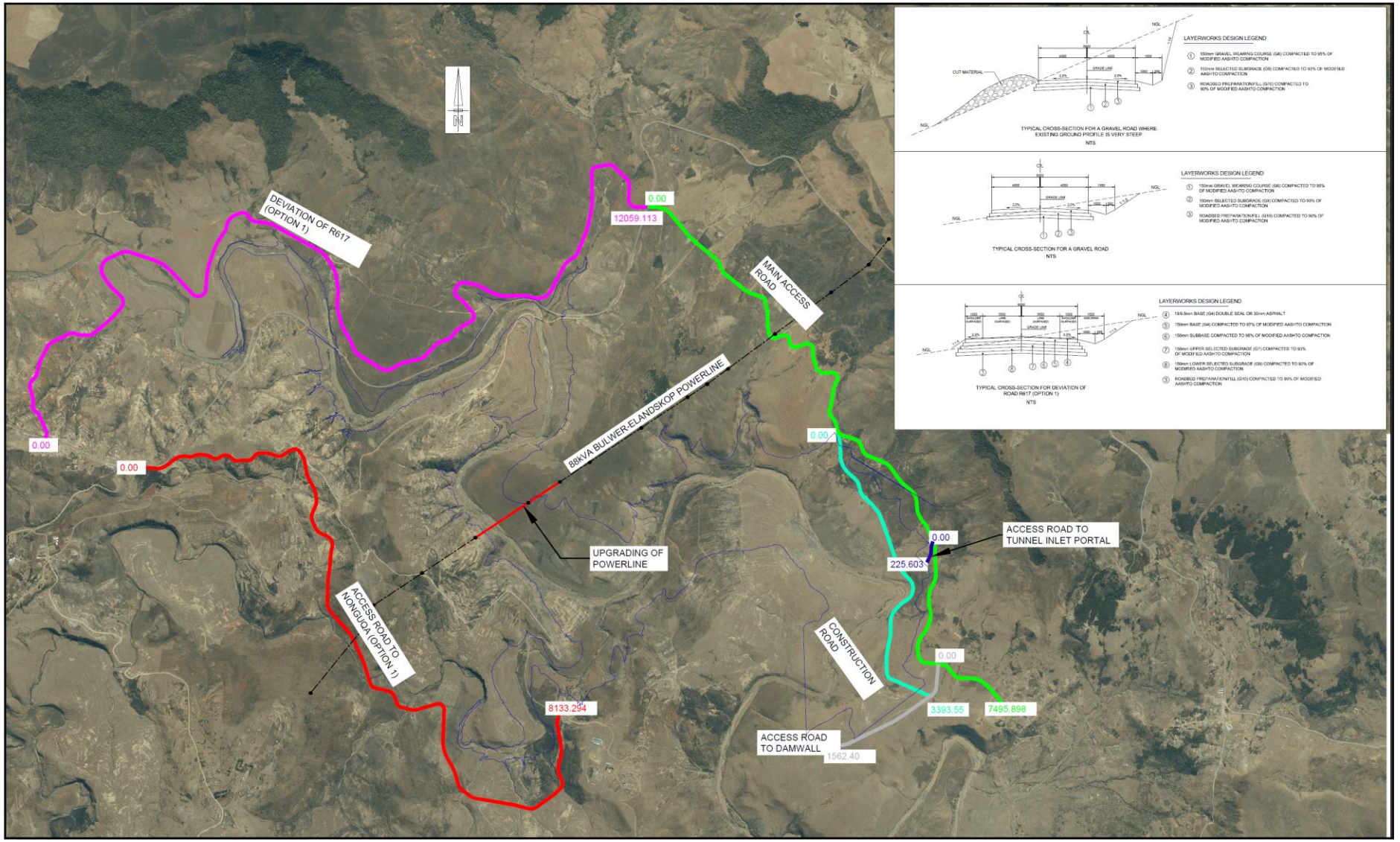


Figure 9.A.1: Smithfield Dam – Key plan of road deviation and upgrading of powerline

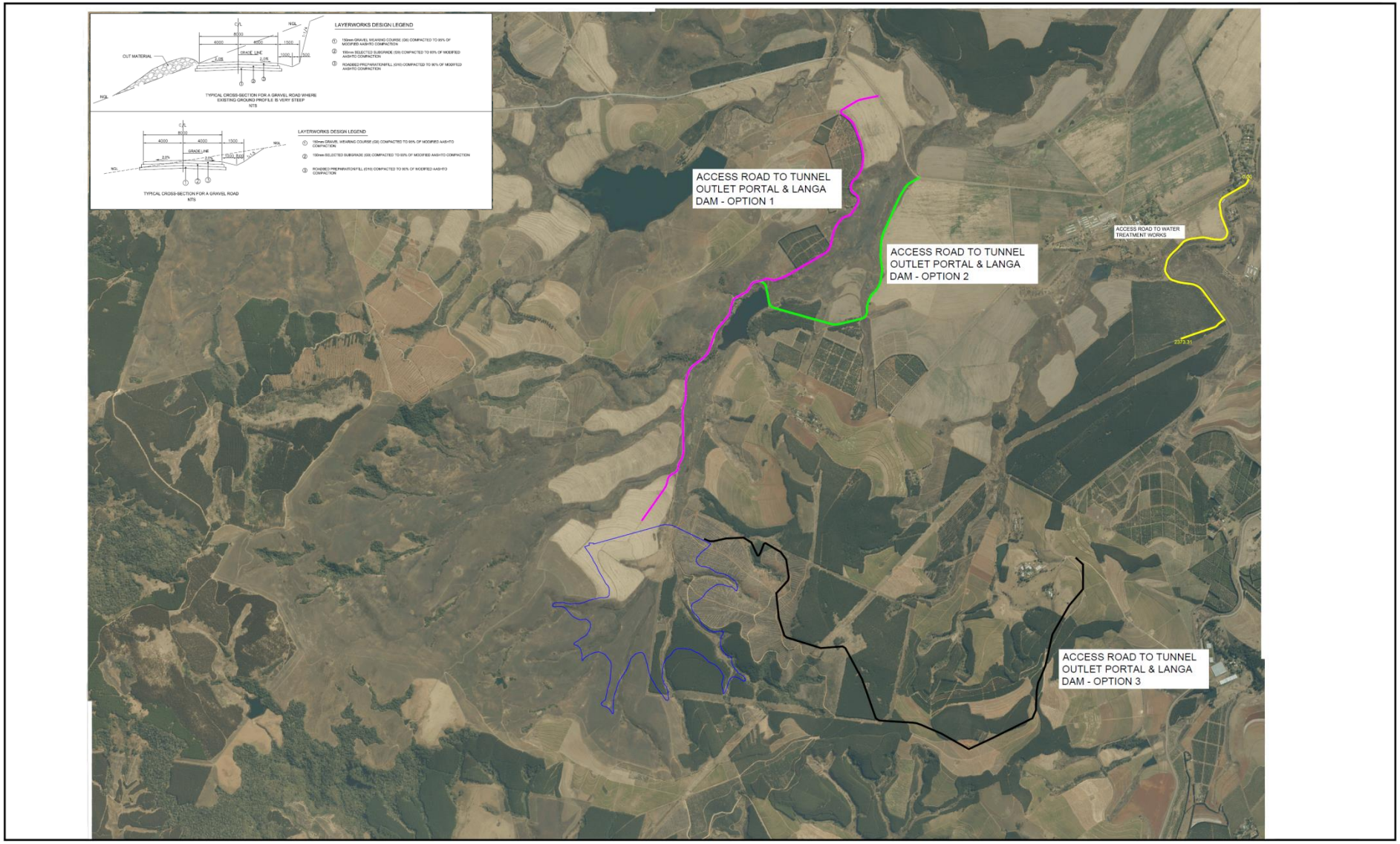


Figure 9.A.2: Langa Dam – Key plan of access roads

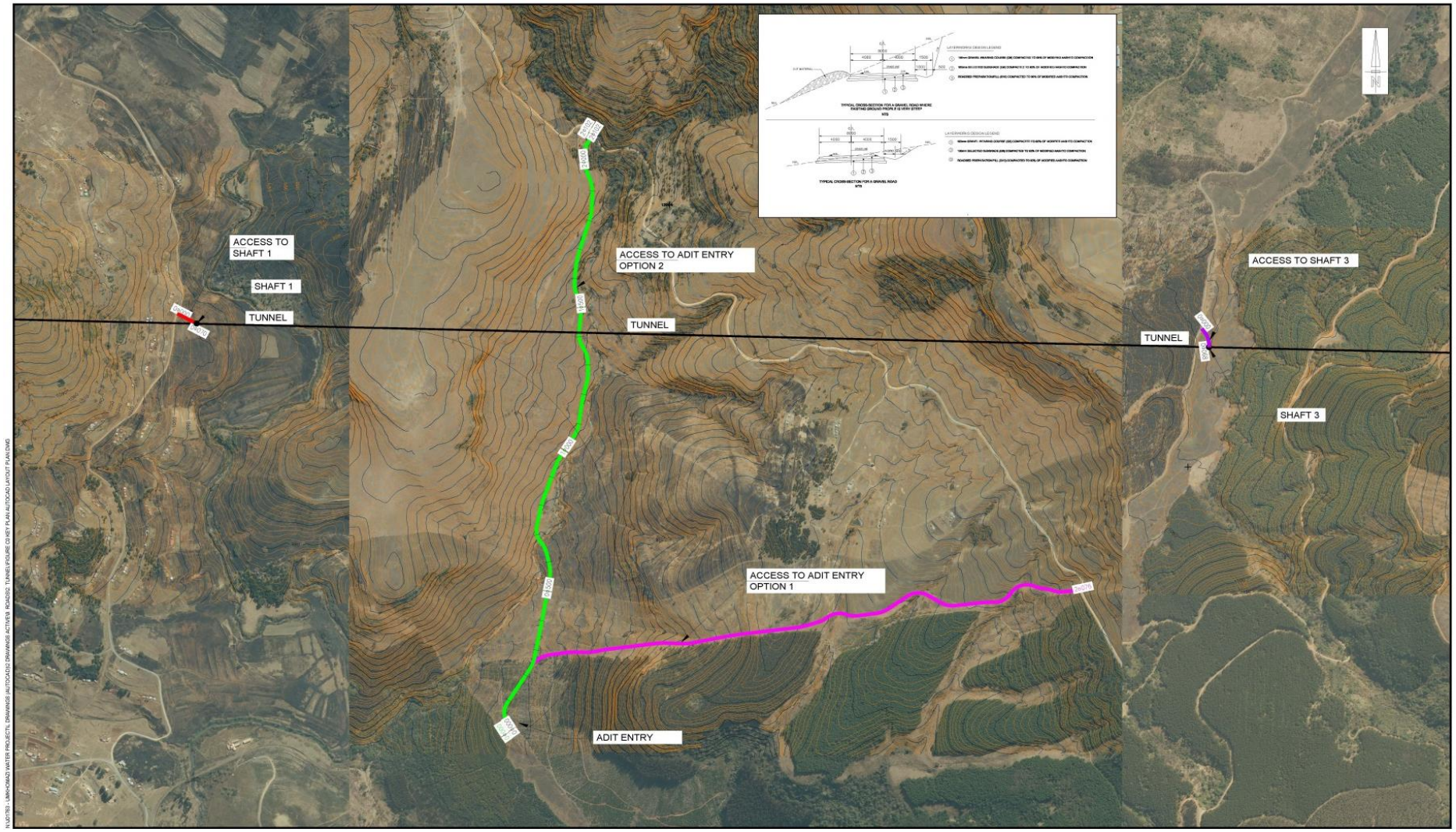


Figure 9.A.3: Transfer tunnel – Layout of access roads to shaft 1, adit entry and shaft 3

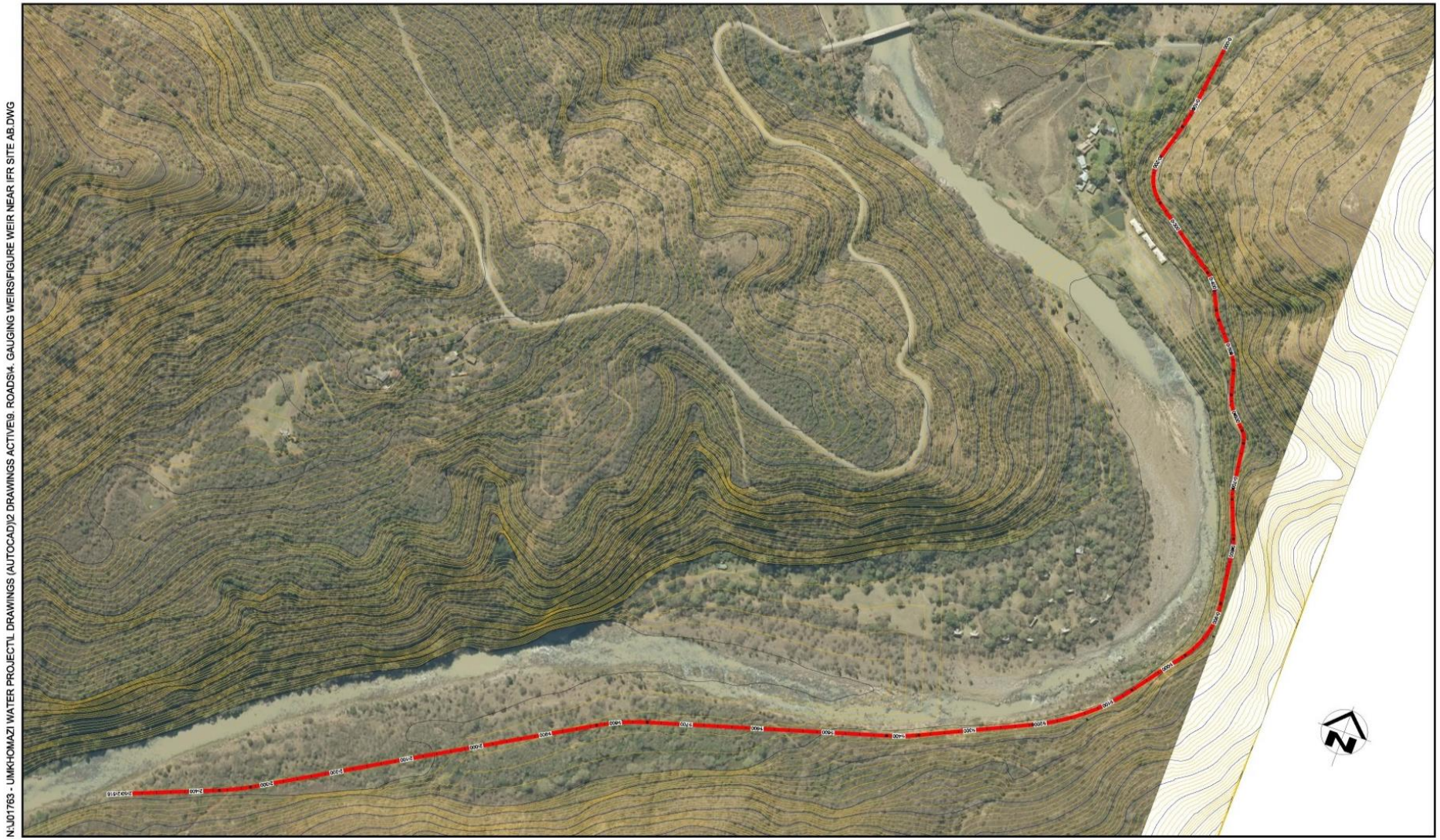


Figure 9.A.4: Smithfield Dam – Contour plan of the gauging weir at the IFR site

Figure 9.A.5: Smithfield Dam – Contour plan of the gauging weir downstream of Smithfield Dam

Figure 9.A.6: Smithfield Dam – Contour plan of gauging weir upstream of Smithfield Dam

Annexure 9 B – Roads: Cross-sections

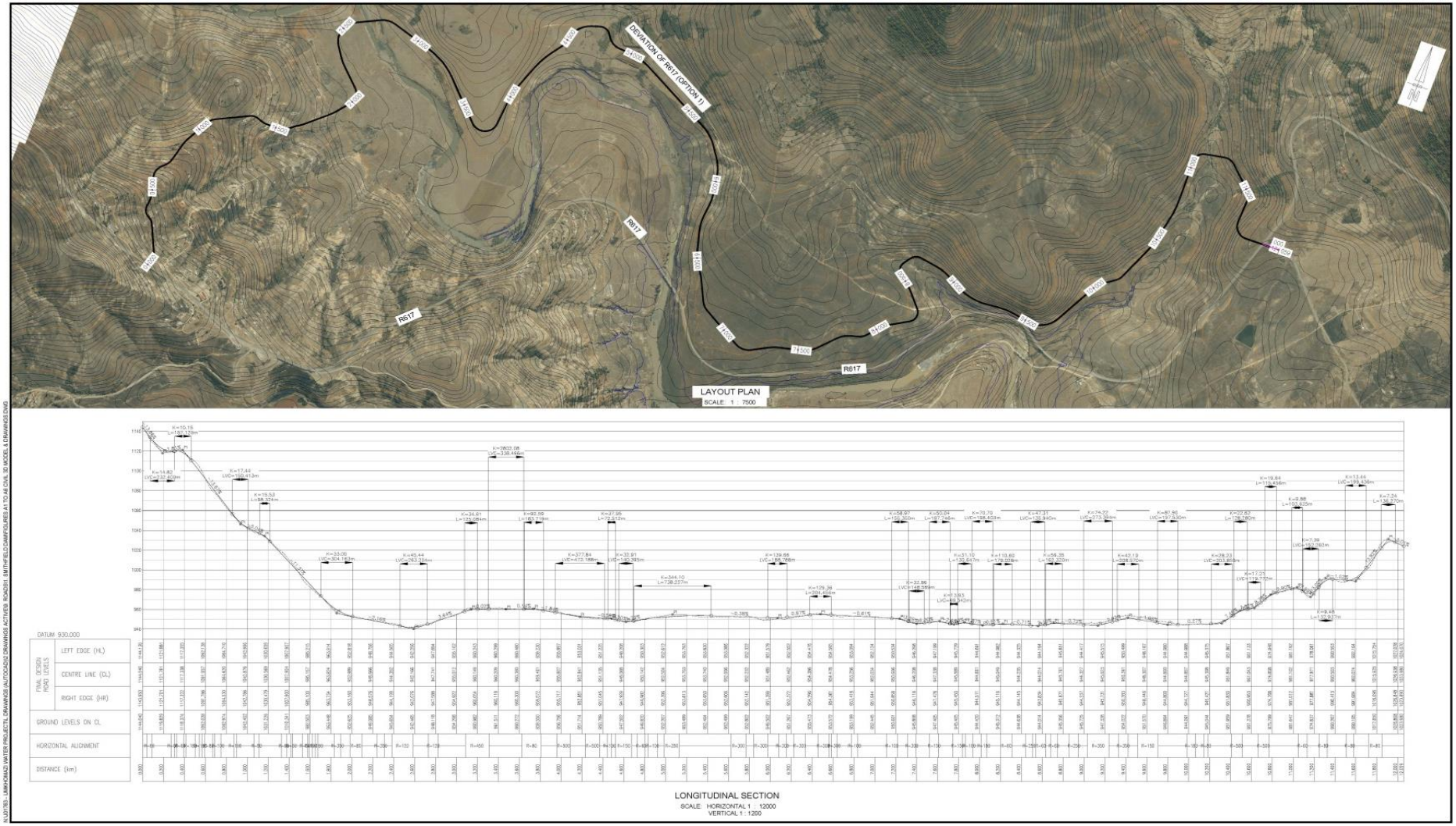


Figure 9.B.1: Smithfield Dam – Layout plan and longitudinal section of the deviation of road R617

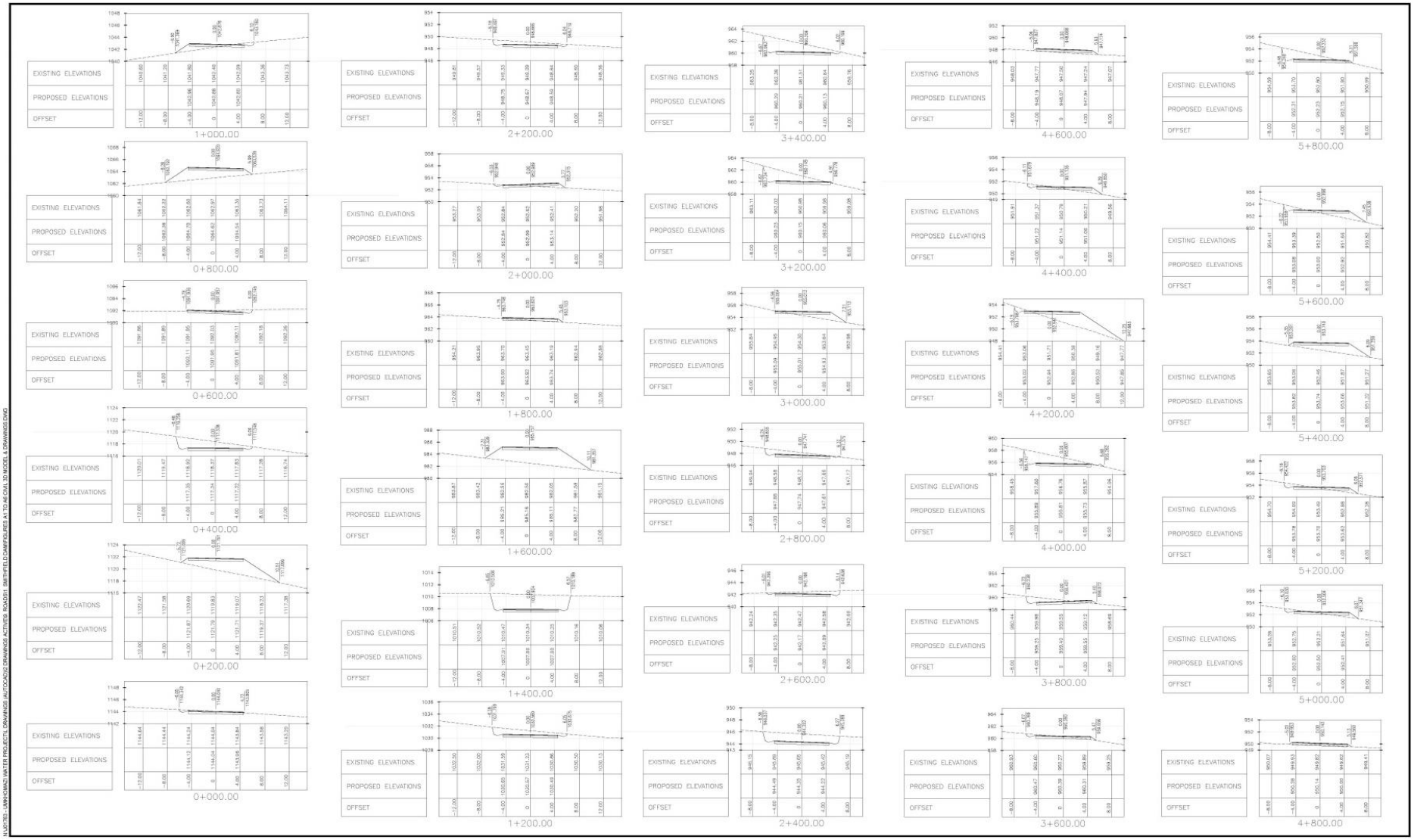


Figure 9.B.2: Smithfield Dam - Deviation of road R617 with cross sections

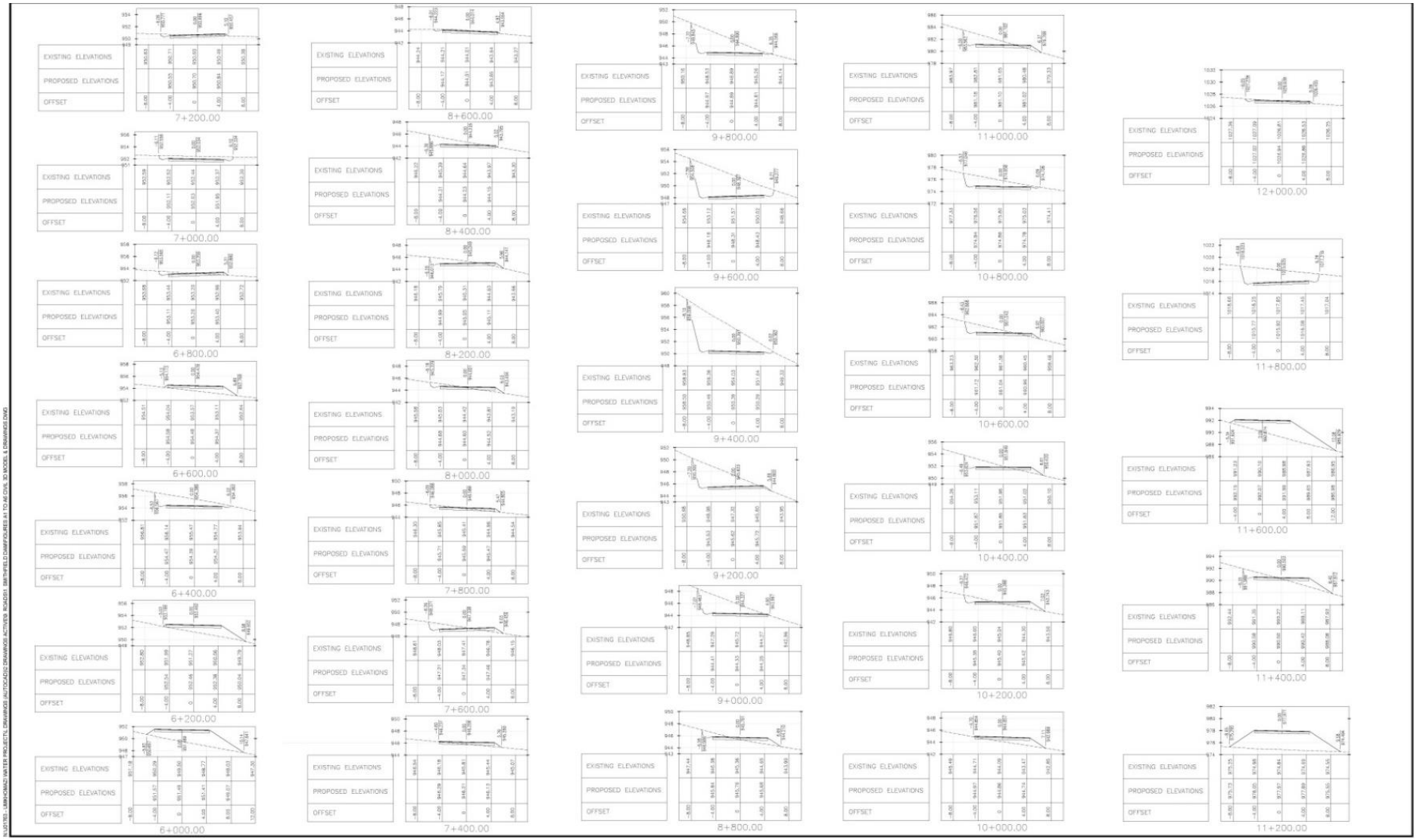


Figure 9.B.3: Smithfield Dam - Deviation of road R617 with cross sections

Annexure 9 C – Roads: Routes investigated

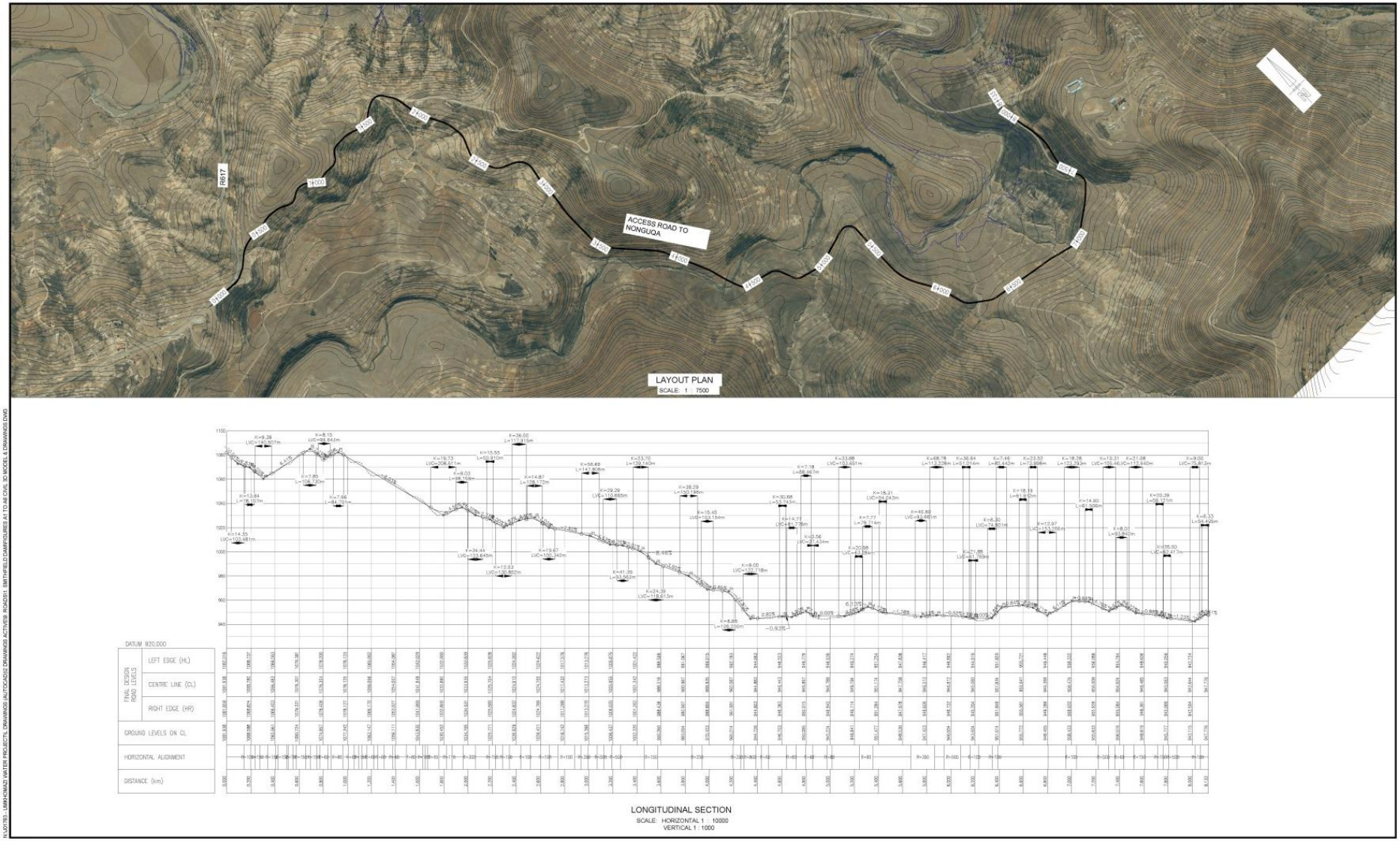


Figure 9.C.1: Smithfield Dam – Layout plan and longitudinal section of access road to Nonguqa

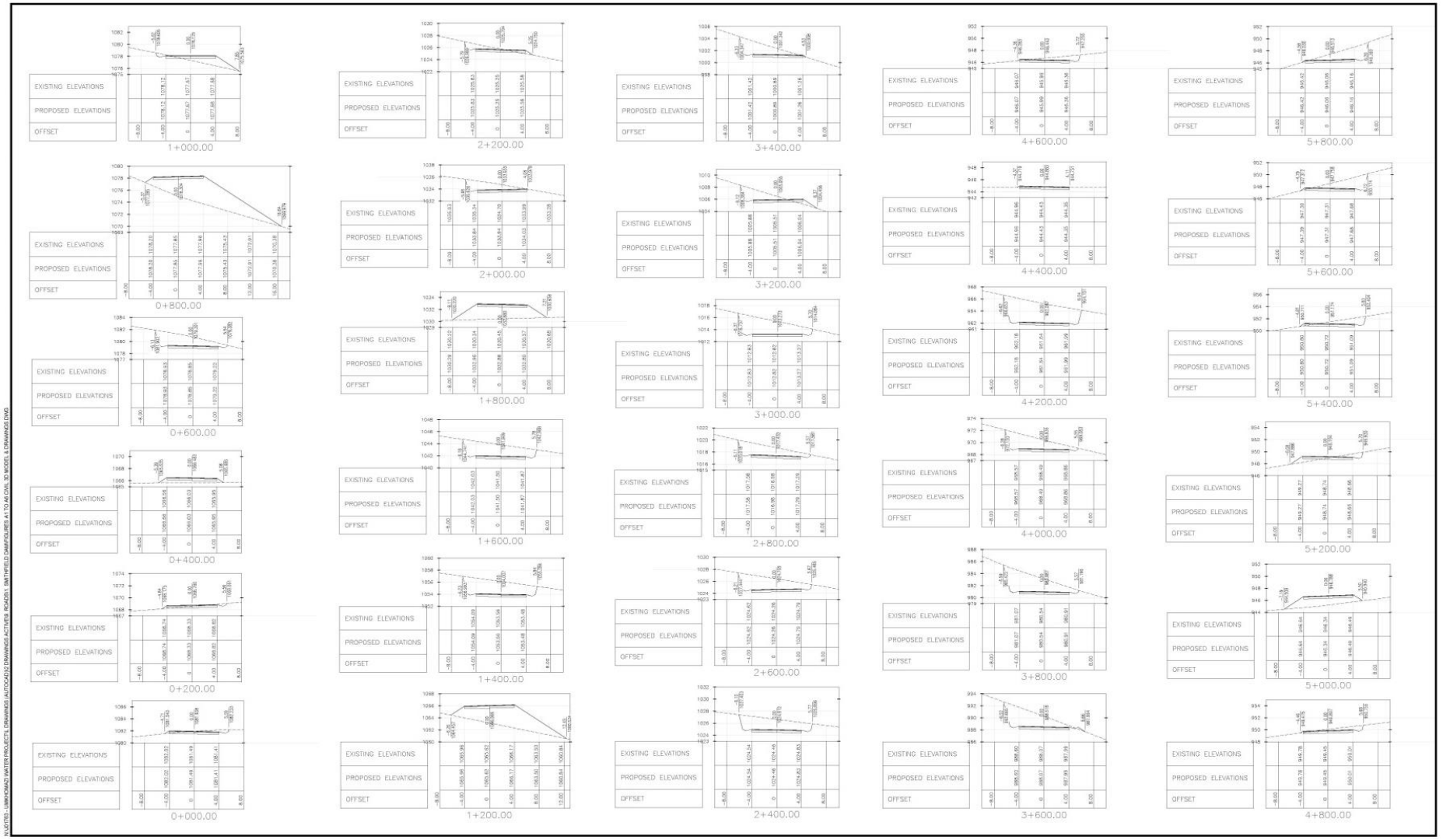


Figure 9.C.2: Smithfield Dam – Cross sections of access road to Nonguqa

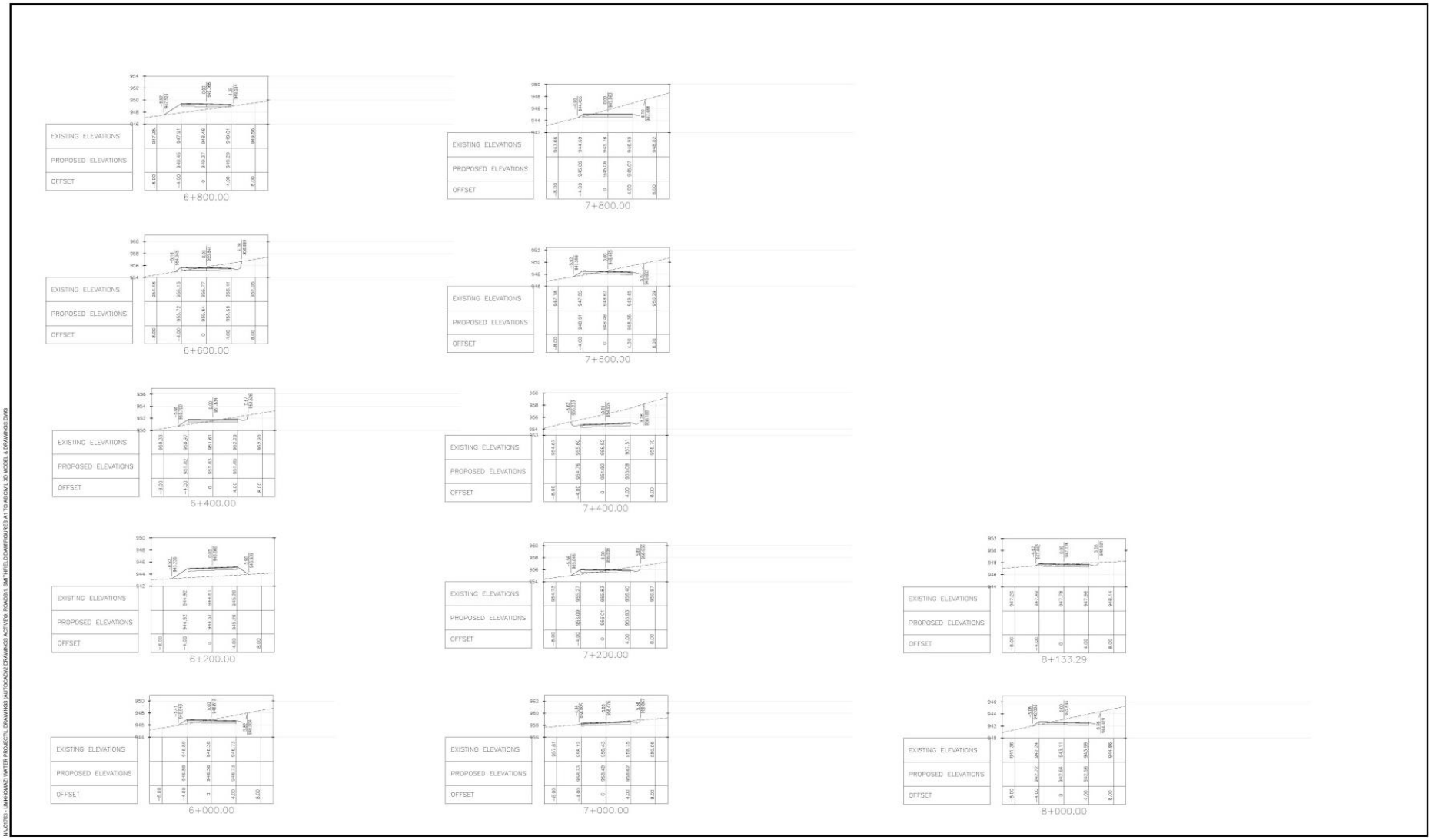


Figure 9.C.3: Smithfield Dam – Cross sections of access road to Nonguqa

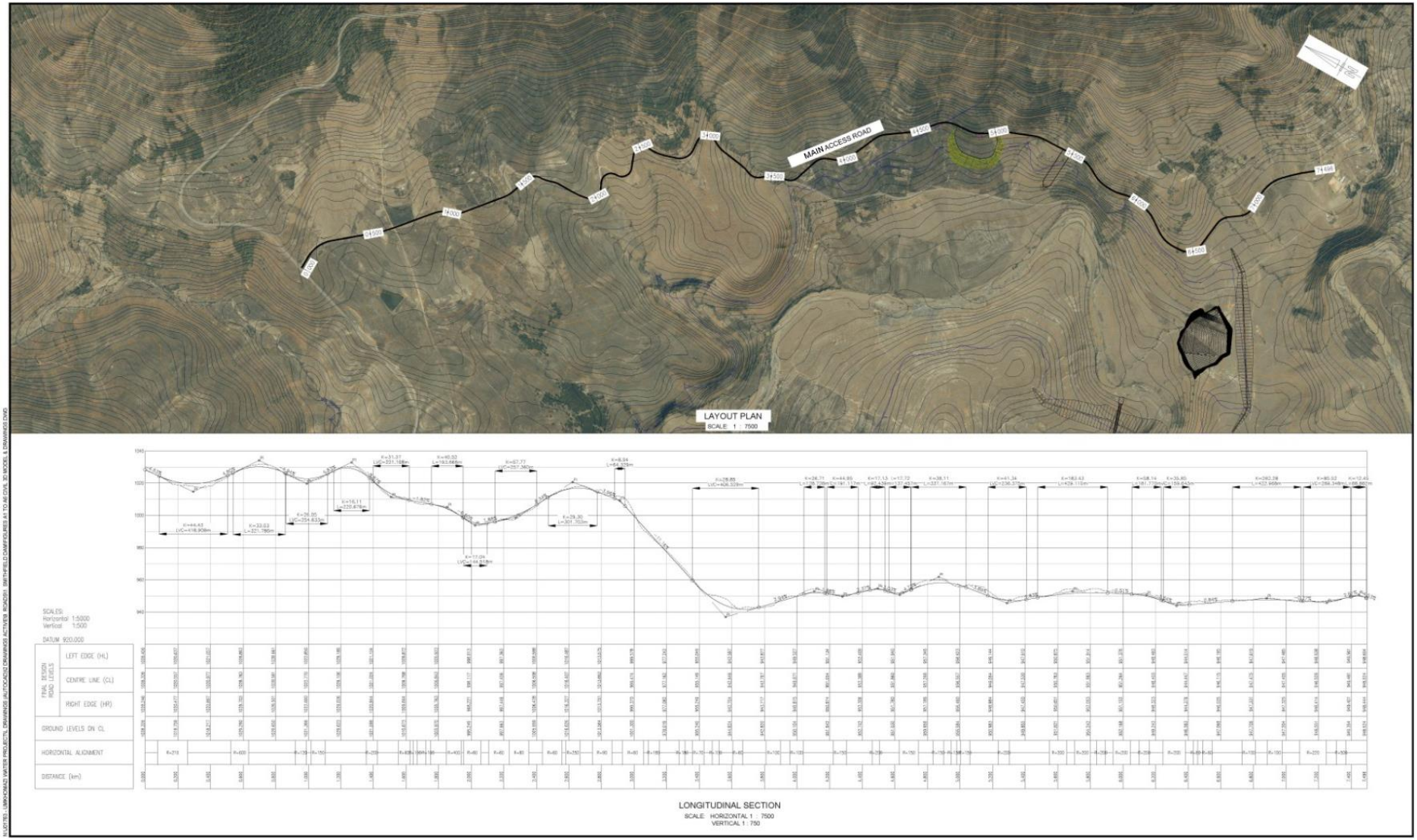


Figure 9.C.4: Smithfield Dam – Layout plan and longitudinal section of main access road

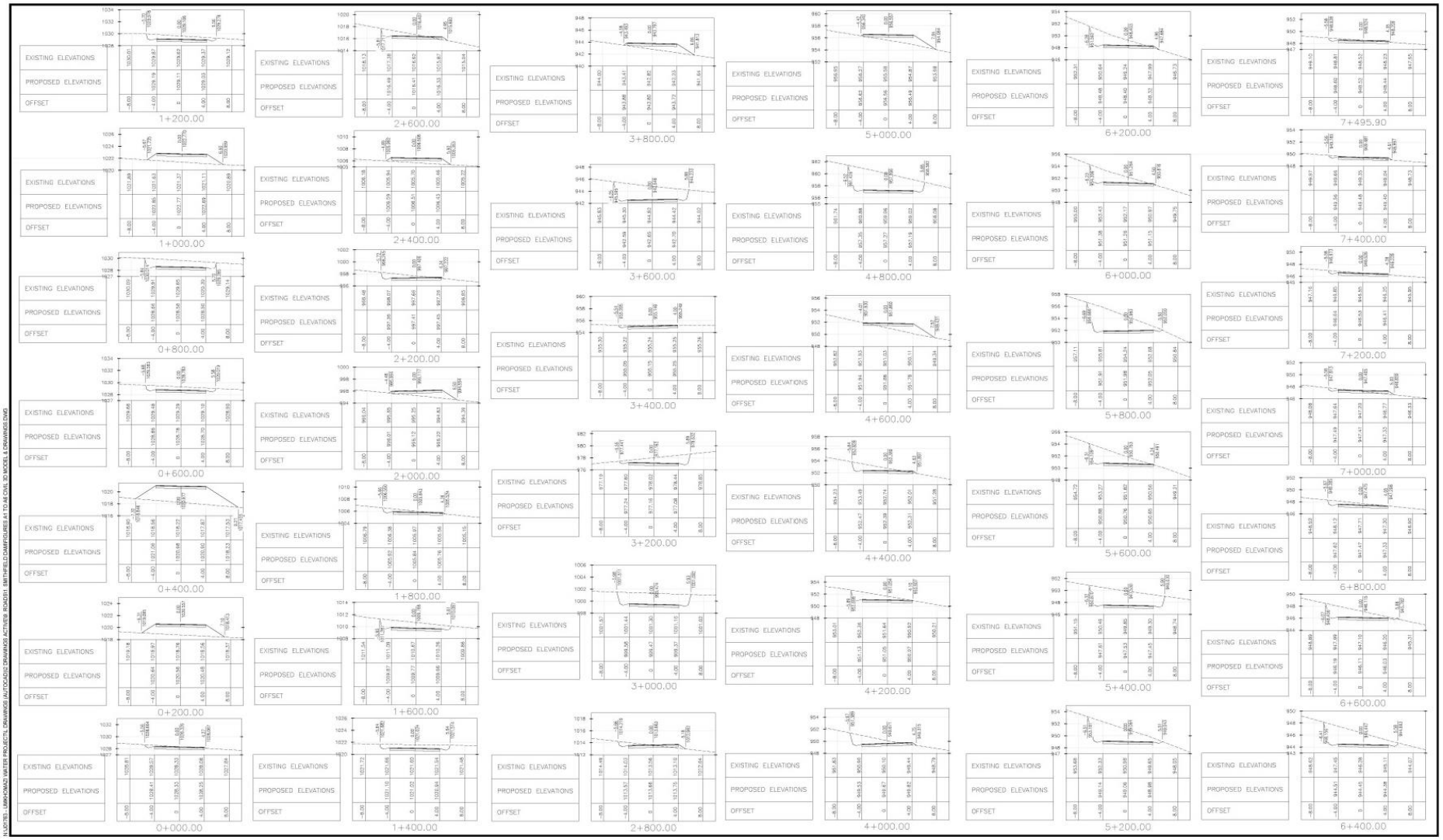


Figure 9.C.5: Smithfield Dam – Cross sections of main access road

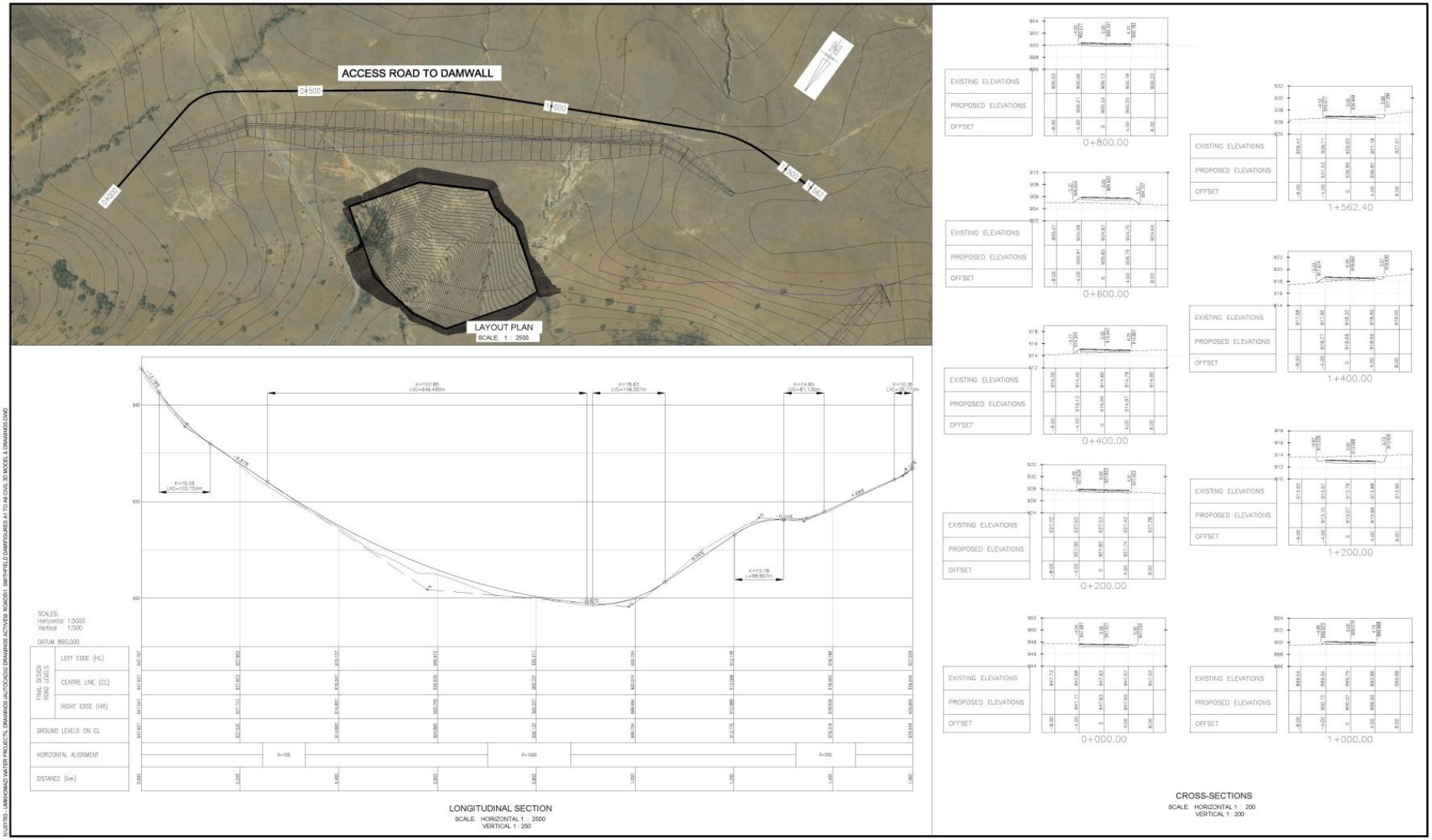


Figure 9.C.6: Smithfield Dam – Layout plan, longitudinal section and cross sections of access road to damwall

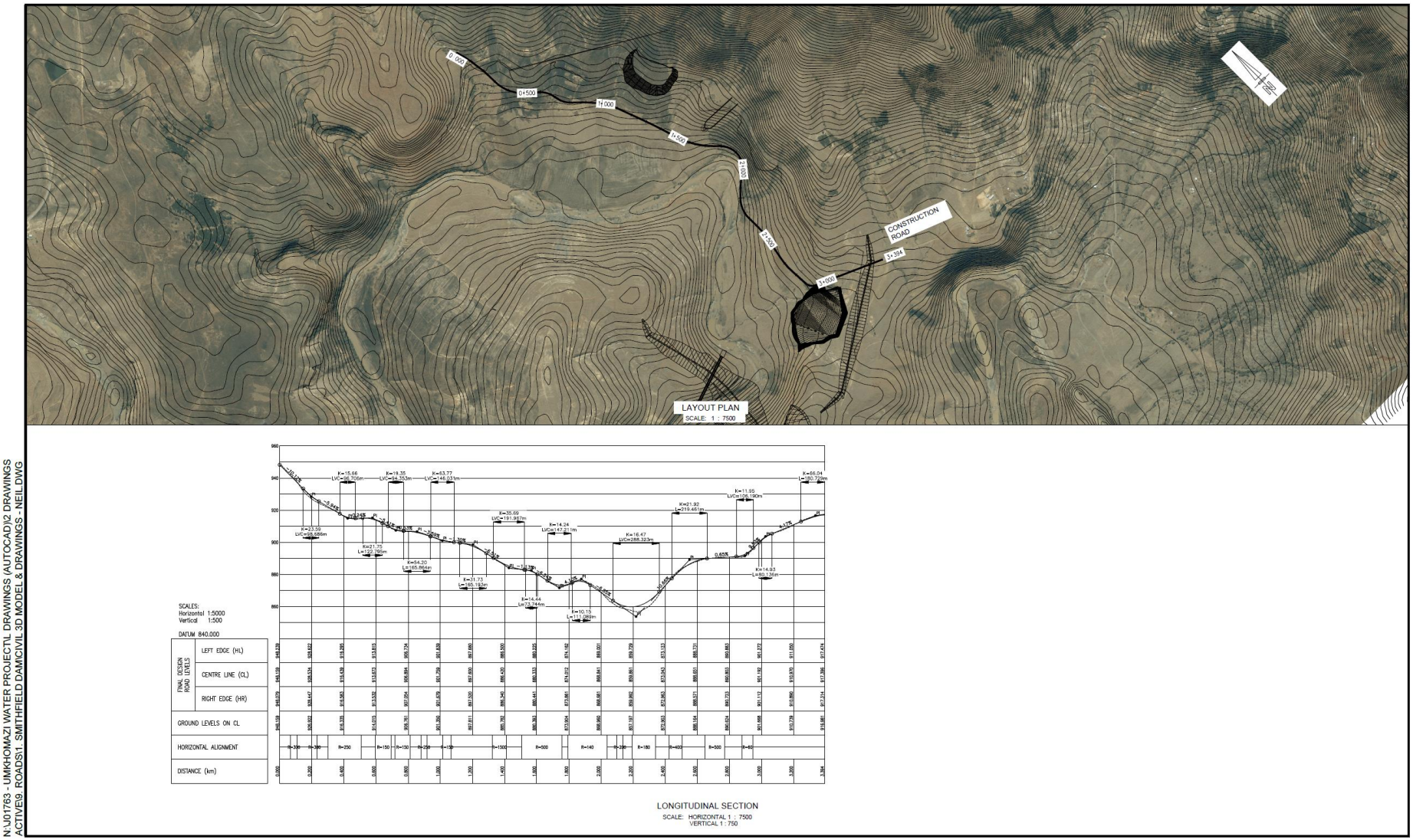


Figure 9.C.7: Smithfield Dam – Layout plan and longitudinal section of construction road

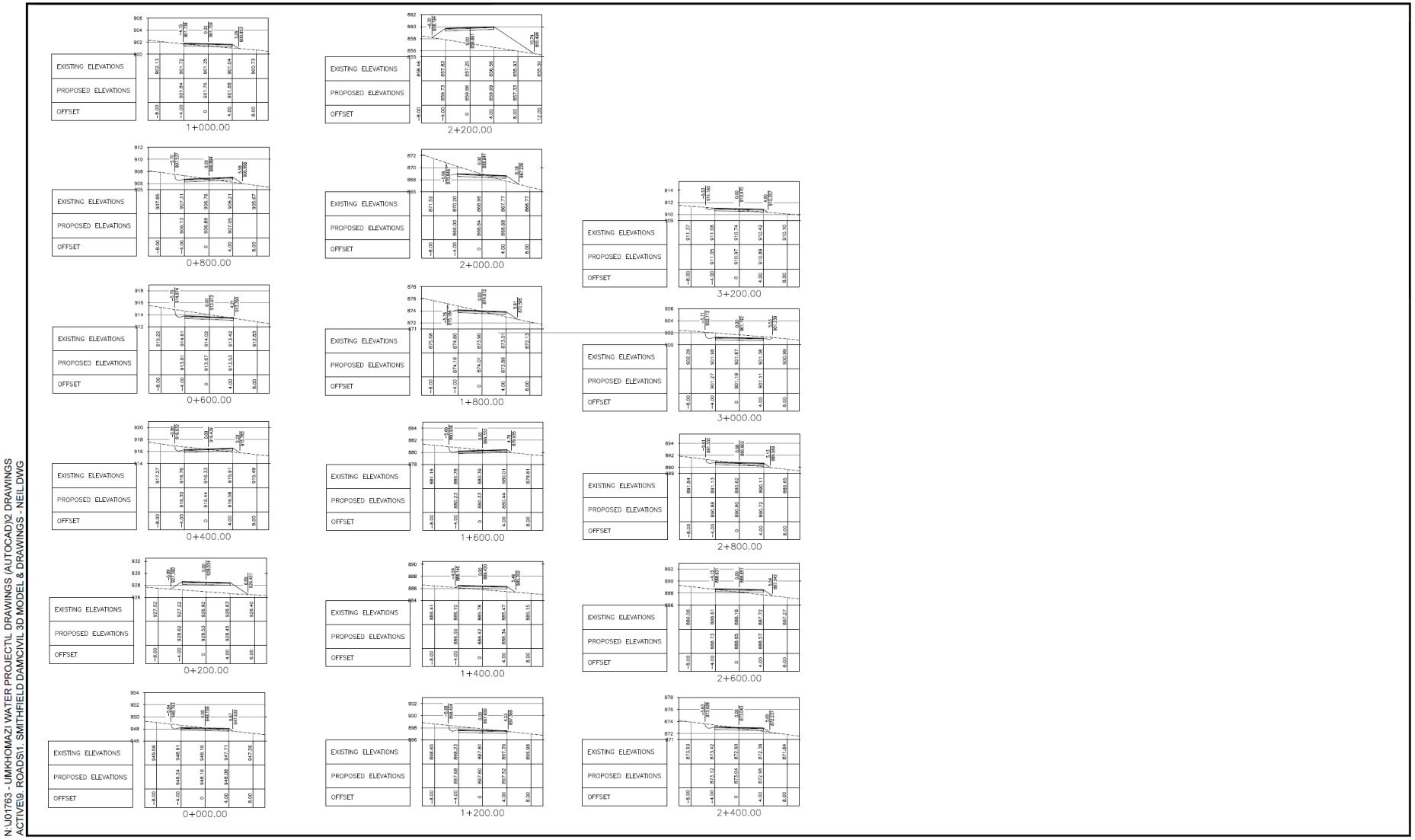


Figure 9.C.8: Smithfield Dam – Cross sections of construction road

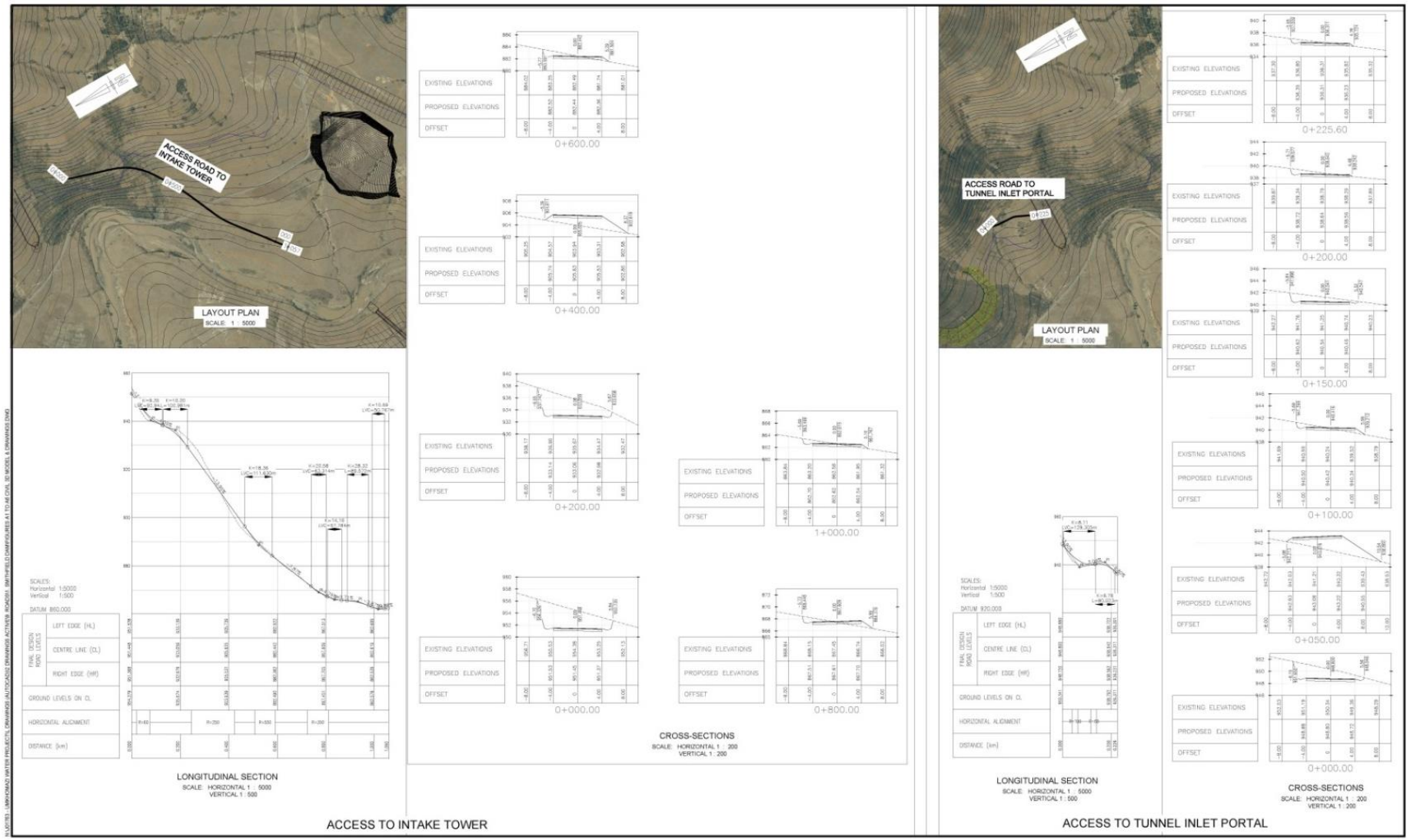


Figure 9.C.9: Smithfield Dam – Layout plan, longitudinal sections and cross sections of access road to intake tower and tunnel inlet portal

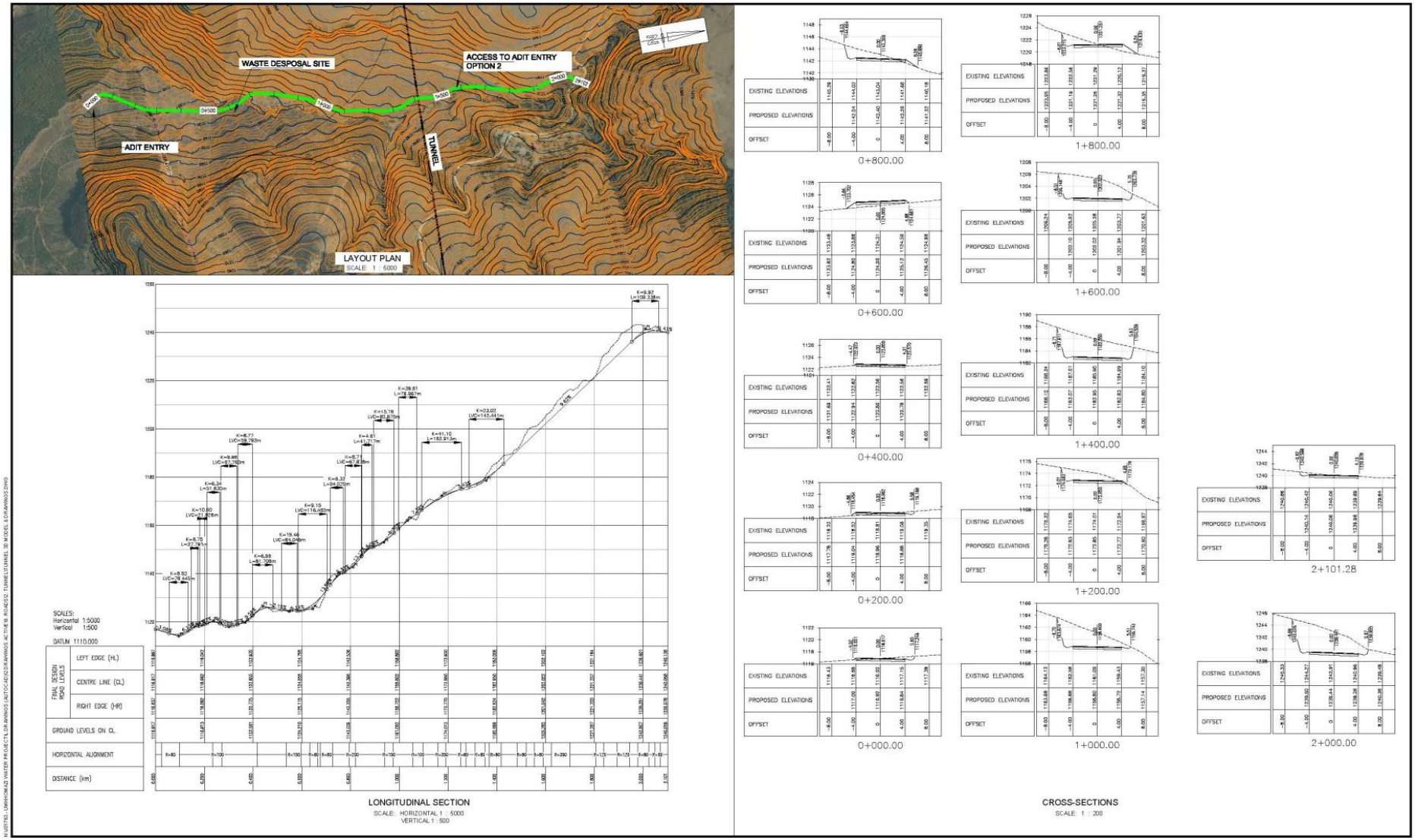


Figure 9.C.10: Transfer Tunnel – Layout plan, longitudinal section and cross sections of access road to adit entry

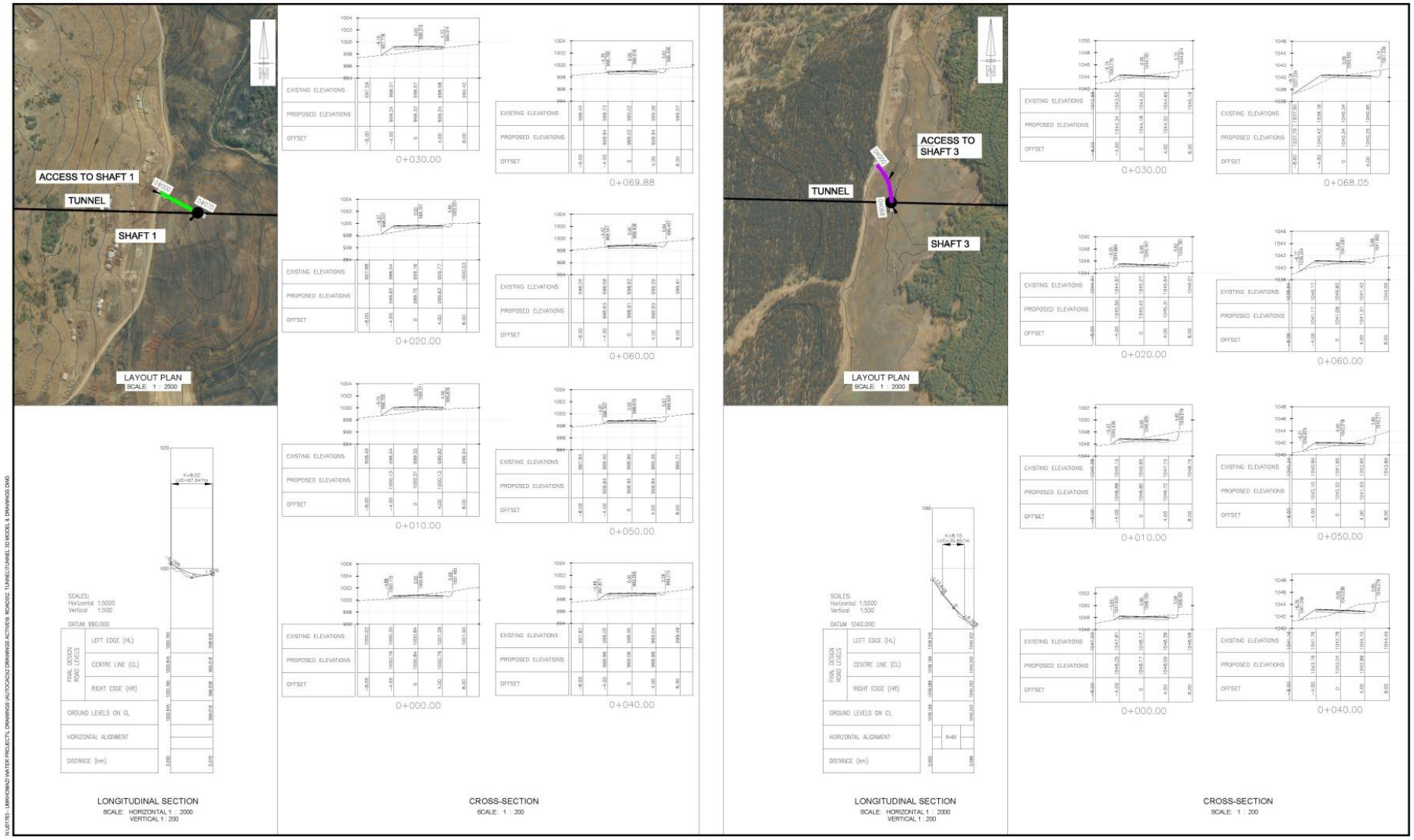


Figure 9.C.11: Transfer Tunnel – Layout plan, longitudinal section and cross sections of access road to shaft 1 and shaft 2

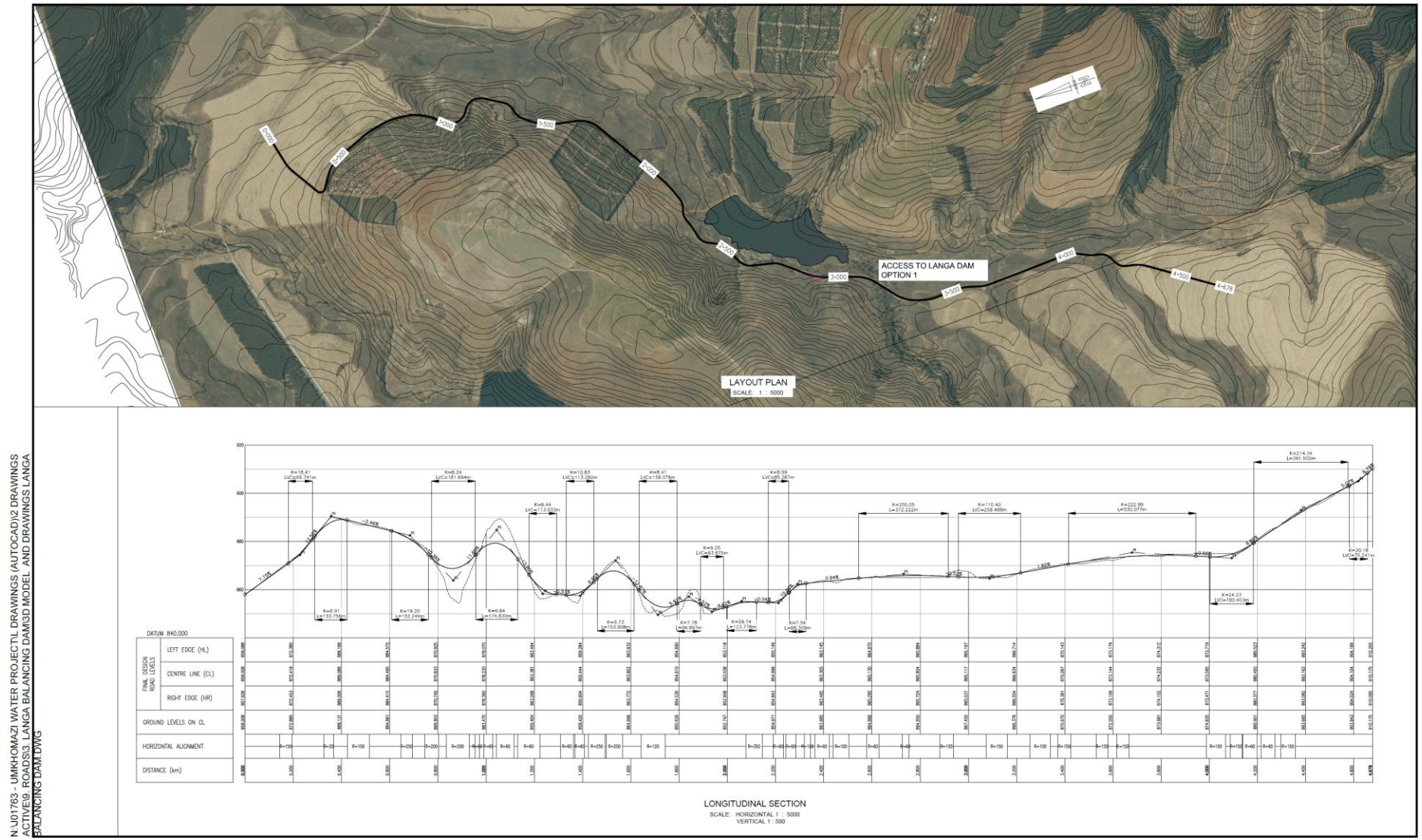


Figure 9.C.12: Langa Dam – Layout plan and longitudinal section of access road to tunnel outlet portal and Langa Dam Option 1

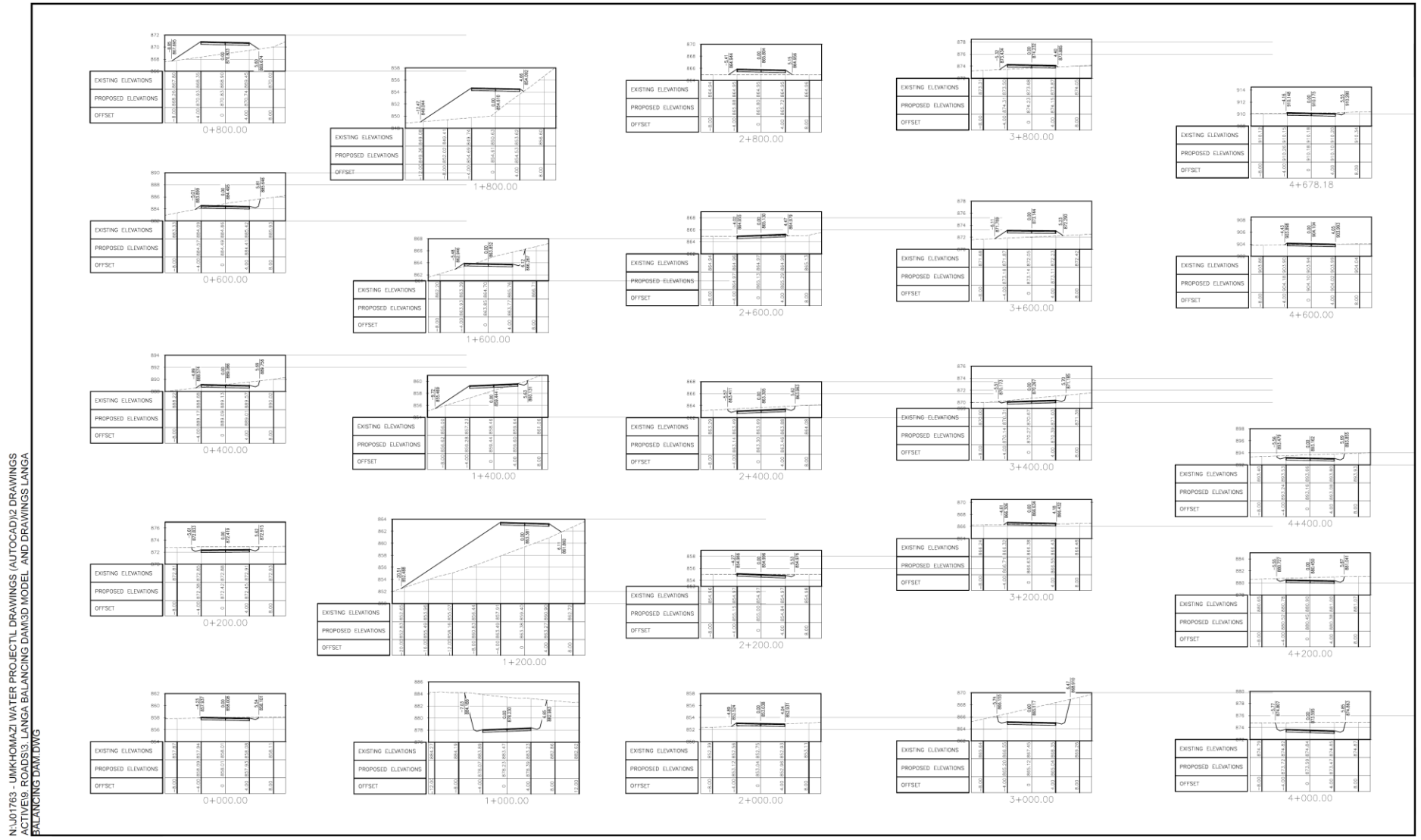


Figure 9.C.13: Langa Dam – Cross sections of access road to tunnel outlet portal and Langa Dam Option 1

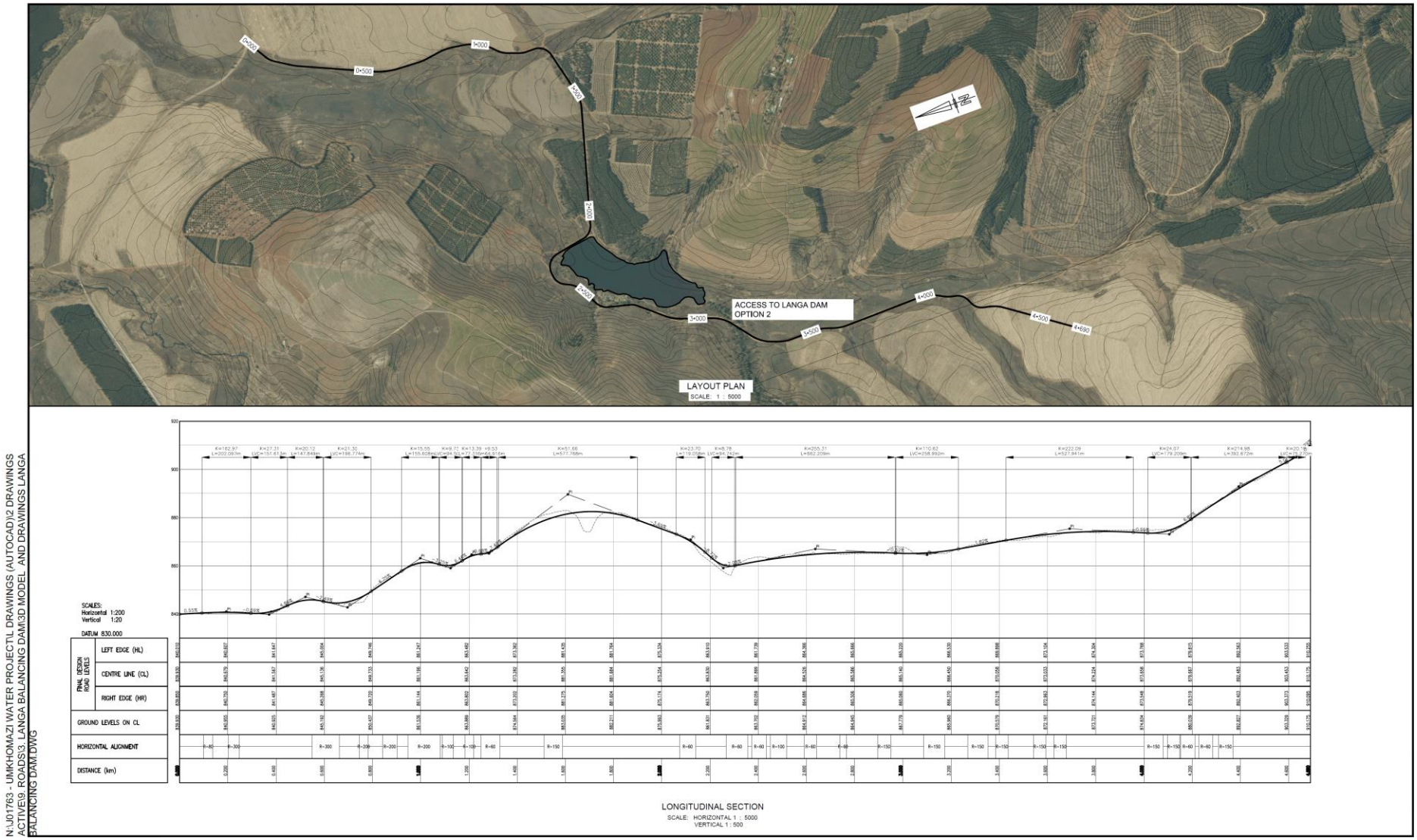


Figure 9.C.14: Langa Dam – Layout plan and longitudinal section of access road to tunnel outlet portal and Langa Dam Option 2

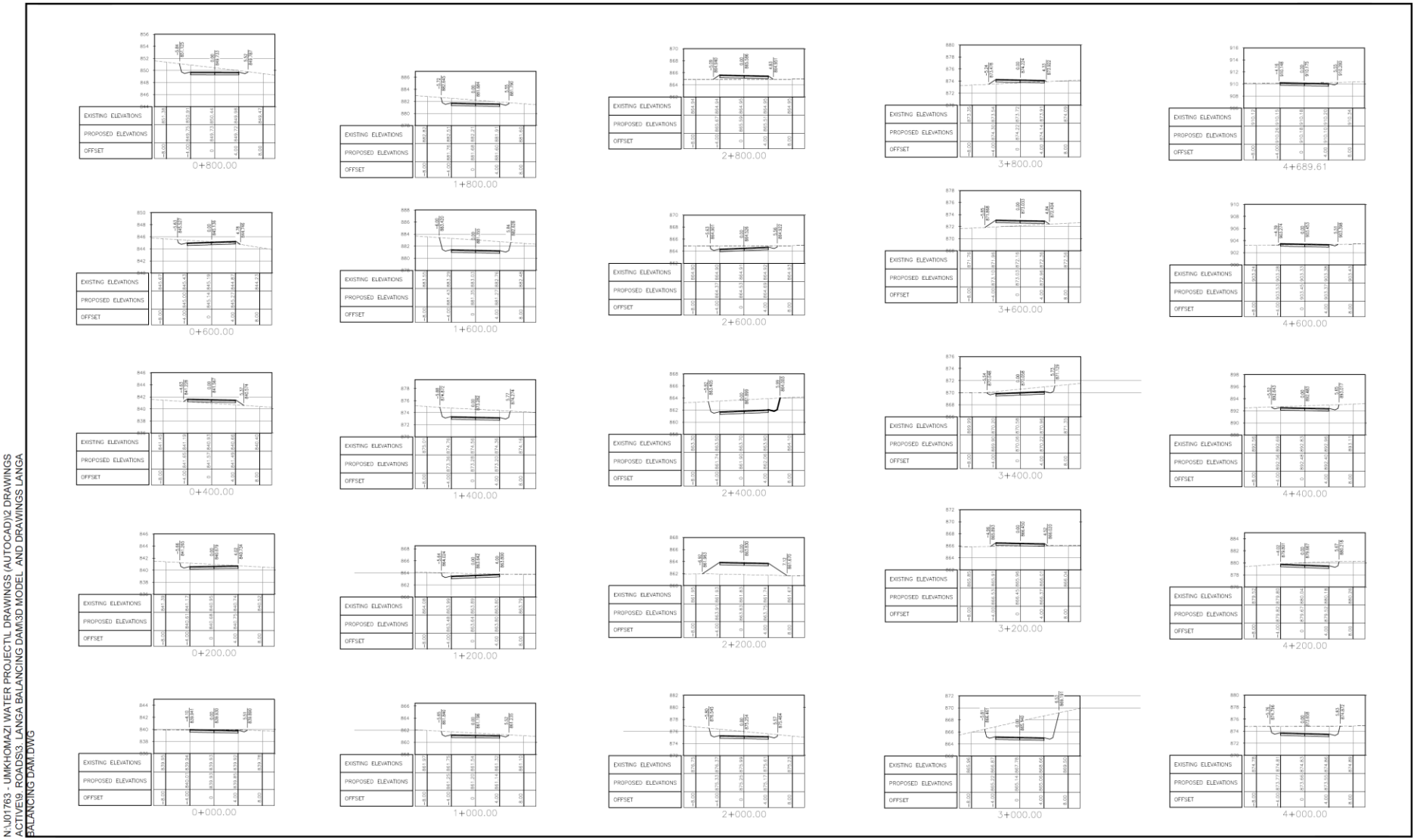


Figure 9.C.15: Langa Dam – Cross sections of access road to tunnel outlet portal and Langa Dam Option 2

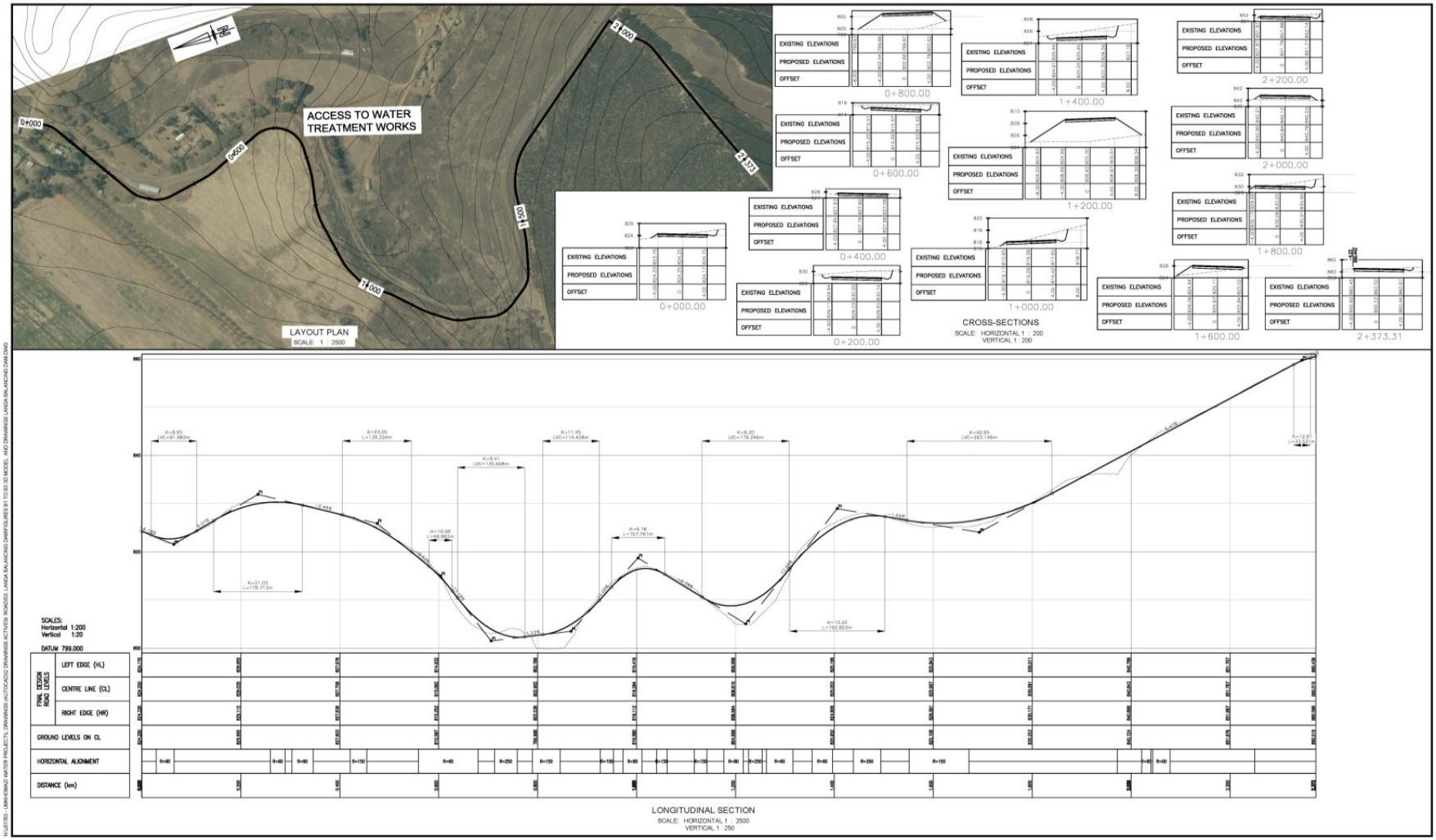


Figure 9.C.16: Langa Dam – Layout plan, longitudinal section and cross sections of access road to water treatment works

Annexure 9 D – Roads: Cost estimate

Table 9.D.1: Cost estimate: Access and deviation of roads: Smithfield Dam

ACCESS AND DEVIATION OF ROADS					
ITEM NO	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
1	**PART 1: SMITHFIELD DAM**				
1.1	**SECTION: DEVIATION OF R617**				
	Accommodation of traffic	km	12.059	40 000	482 360
	Clearing and grubbing	m²	120 590	10	1 205 900
	Cut to fill	m³	250 000	80	20 000 000
	Cut to spoil	m³	60 000	75	4 500 000
	Import	m³	0	80	0
	Extra-over for excavation in hard material	m³	50 000	350	17 500 000
	Formation preparation	m²	120 590	5	602 950
	Selected layer	m³	34 730	180	6 251 386
	Subbase	m³	16 931	220	3 724 784
	Wearing course/base course	m³	16 280	280	4 558 302
	Surfacing	m²	84 413	200	16 882 600
	Stormwater drainage	km	12.059	200 000	2 411 800
	Bridges (1:5 year flood)	m²	1 160	18 000	20 880 000
	Erosion protection, landscaping and finishing	km	12.059	50 000	602 950
	Erosion protection to high fill slopes	km	12.059	50 000	602 950
	Road markings and road furniture	km	12.059	20 000	241 180
1.2	**SECTION: NONGUQA**				
	Accommodation of traffic	km	8.133	20 000	162 660
	Clearing and grubbing	m²	81 330	15	1 219 950
	Cut to fill	m³	28 812	90	2 593 051
	Cut to spoil	m³	43 827	90	3 944 470
	Import	m³	0	200	0
	Extra-over for excavation in hard material	m³	5 000	350	1 750 000
	Formation preparation	m²	81 330	5	406 650
	Selected layer	m³	10 126	150	1 518 838
	Subbase	m³	10 126	150	1 518 838
	Wearing course/base course	m³	9 760	100	975 960
	Surfacing	m²	0	200 000	0
	Stormwater drainage	km	8.133	200 000	1 626 600
	Bridges (1:5 year flood)	m²	0	50 000	0
	Erosion protection, landscaping and finishing	km	8.133	50 000	406 650
	Erosion protection to high fill slopes	km	8.133	20 000	162 660
	Road markings and road furniture	km	8.133	2 000	16 266
1.3	**SECTION: TUNNEL INLET PORTAL**				
	Accommodation of traffic	km	0.226	40 000	9 040
	Clearing and grubbing	m²	2 260	3	6 780
	Cut to fill	m³	1 565	80	125 229
	Cut to spoil	m³	0	75	0
	Import	m³	439	80	35 129
	Extra-over for excavation in hard material	m³	40	350	14 000
	Formation preparation	m²	2 260	5	11 300
	Selected layer	m³	281	180	50 647
	Subbase	m³	281	220	61 901
	Wearing course/base course	m³	271	300	81 360
	Surfacing	m²	0	240	0
	Stormwater drainage	km	0.226	200 000	45 200
	Bridges (1:5 year flood)	m²	0	20 000	0
	Erosion protection, landscaping and finishing	km	0.226	50 000	11 300
	Erosion protection to high fill slopes	km	0.226	50 000	11 300
	Road markings and road furniture	km	0.226	20 000	4 520

Table 9.D.1 (continued)

1.4	**SECTION: TO DAM WALL**				
	Accommodation of traffic	km	1.562	40 000	62 480
	Clearing and grubbing	m²	15 620	3	46 860
	Cut to fill	m³	6 866	80	549 270
	Cut to spoil	m³	0	75	0
	Import	m³	4 321	80	345 682
	Extra-over for excavation in hard material	m³	1 500	350	525 000
	Formation preparation	m²	15 620	5	78 100
	Selected layer	m³	1 945	180	350 044
	Subbase	m³	1 945	220	427 832
	Wearing course/base course	m³	1 874	300	562 320
	Surfacing	m²	0	240	0
	Stormwater drainage	km	1.562	200 000	312 400
	Bridges (1:5 year flood)	m²	0	20 000	0
	Erosion protection, landscaping and finishing	km	1.562	50 000	78 100
	Erosion protection to high fill slopes	km	1.562	50 000	78 100
	Road markings and road furniture	km	1.562	20 000	31 240
1.5	**SECTION: CONSTRUCTION ROAD**				
	Accommodation of traffic	km	5.818	40 000	232 720
	Clearing and grubbing	m²	58 180	3	174 540
	Cut to fill	m³	34 198	80	2 735 840
	Cut to spoil	m³	0	75	0
	Import	m³	10 764	80	861 130
	Extra-over for excavation in hard material	m³	1 500	350	525 000
	Formation preparation	m²	58 180	5	290 900
	Selected layer	m³	7 243	180	1 303 814
	Subbase	m³	7 243	220	1 593 550
	Wearing course/base course	m³	6 982	300	2 094 480
	Surfacing	m²	0	240	0
	Stormwater drainage	km	5.818	200 000	1 163 600
	Bridges (1:5 year flood)	m²	0	20 000	0
	Erosion protection, landscaping and finishing	km	5.818	50 000	290 900
	Erosion protection to high fill slopes	km	5.818	50 000	290 900
	Road markings and road furniture	km	5.818	20 000	116 360
1.6	**SECTION: MAIN ACCESS ROAD**				
	Accommodation of traffic	km	7.496	40 000	299 840
	Clearing and grubbing	m²	74 960	3	224 880
	Cut to fill	m³	25 402	80	2 032 178
	Cut to spoil	m³	48 251	75	3 618 839
	Import	m³	0	80	0
	Extra-over for excavation in hard material	m³	1 500	350	525 000
	Formation preparation	m²	74 960	5	374 800
	Selected layer	m³	9 333	180	1 679 854
	Subbase	m³	9 333	220	2 053 154
	Wearing course/base course	m³	8 995	300	2 698 560
	Surfacing	m²	90 000	240	21 600 000
	Stormwater drainage	km	7.496	200 000	1 499 200
	Bridges (1:5 year flood)	m²	0	20 000	0
	Erosion protection, landscaping and finishing	km	7.496	50 000	374 800
	Erosion protection to high fill slopes	km	7.496	50 000	374 800
	Road markings and road furniture	km	7.496	20 000	149 920
TOTAL CARRIED FORWARD TO SUMMARY					**169 844 445**

Table 9.D.2: Cost estimate: Access and deviation of roads: uMkhomazi-uMlazi Tunnel

ACCESS AND DEVIATION OF ROADS					
ITEM NO	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
2	**PART 2: UMKHOMAZI-UMLAZI TUNNEL**				
2.1	**SECTION: VENTILATION SHAFT 1**				
	Accommodation of traffic	km	2.102	40 000	84 080
	Clearing and grubbing	m²	21 020	3	63 060
	Cut to fill	m³	69	80	5 558
	Cut to spoil	m³	0	75	0
	Import	m³	194	80	15 503
	Extra-over for excavation in hard material	m³	1 500	350	525 000
	Formation preparation	m²	21 020	5	105 100
	Selected layer	m³	2 617	180	471 058
	Subbase	m³	2 617	220	575 738
	Wearing course/base course	m³	2 522	300	756 720
	Surfacing	m²	0	240	0
	Stormwater drainage	PS	2.102	200 000	420 400
	Bridges (1:5 year flood)	m²	0	20 000	0
	Erosion protection, landscaping and finishing	km	2.102	50 000	105 100
	Erosion protection to high fill slopes	km	2.102	50 000	105 100
	Road markings and road furniture	km	2.102	20 000	42 040
2.2	**SECTION: VENTILATION SHAFT 3**				
	Accommodation of traffic	km	0.068	40 000	2 720
	Clearing and grubbing	m²	680	3	2 040
	Cut to fill	m³	184	80	14 708
	Cut to spoil	m³	0	75	0
	Import	m³	46	80	3 686
	Extra-over for excavation in hard material	m³	100	350	35 000
	Formation preparation	m²	680	5	3 400
	Selected layer	m³	85	180	15 239
	Subbase	m³	85	220	18 625
	Wearing course/base course	m³	82	300	24 480
	Surfacing	m²	0	240	0
	Stormwater drainage	km	0.068	200 000	13 600
	Bridges (1:5 year flood)	m²	0	20 000	0
	Erosion protection, landscaping and finishing	km	0.068	50 000	3 400
	Erosion protection to high fill slopes	km	0.068	50 000	3 400
	Road markings and road furniture	km	0.068	20 000	1 360
2.3	**SECTION: CENTRAL ADIT ENTRY**				
	Accommodation of traffic	km	2.102	40 000	84 080
	Clearing and grubbing	m²	21 020	3	63 060
	Cut to fill	m³	37 249	80	2 979 955
	Cut to spoil	m³	13 708	75	1 028 096
	Import	m³	0	80	0
	Extra-over for excavation in hard material	m³	5 000	350	1 750 000
	Formation preparation	m²	21 020	5	105 100
	Selected layer	m³	2 617	180	471 058
	Subbase	m³	2 617	220	575 738
	Wearing course/base course	m³	2 522	300	756 720
	Surfacing	m²	0	240	0
	Stormwater drainage	km	2.102	200 000	420 400
	Bridges (1:5 year flood)	m²	0	20 000	0
	Erosion protection, landscaping and finishing	km	2.102	50 000	105 100
	Erosion protection to high fill slopes	km	2.102	50 000	105 100
	Road markings and road furniture	km	2.102	20 000	42 040
TOTAL CARRIED FORWARD TO SUMMARY					**11 902 563**

Table 9.D.3: Cost estimate: Access and deviation of roads: Langa Dam

ACCESS AND DEVIATION OF ROADS					
ITEM NO	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
3	**PART 3: LANGA DAM**				
3.1	**SECTION: TUNNEL OUTLET PORTAL AND LANGA DAM (OPTION 2)**				
	Accommodation of traffic	km	4.690	20 000	93 800
	Clearing and grubbing	m²	46 900	15	703 500
	Cut to fill	m³	21 943	90	1 974 870
	Cut to spoil	m³	5 847	90	526 230
	Import	m³	0	200	0
	Extra-over for excavation in hard material	m³	1 500	30	45 000
	Formation preparation	m²	46 900	150	7 035 000
	Selected layer	m³	5 839	150	875 858
	Subbase	m³	5 839	150	875 858
	Wearing course/base course	m³	5 628	100	562 800
	Surfacing	m²	65 660	240	15 758 400
	Stormwater drainage	km	4.690	20 000	93 800
	Bridges (1:5 year flood)	m²	0	50 000	0
	Erosion protection, landscaping and finishing	km	4.690	50 000	234 500
	Erosion protection to high fill slopes	km	4.690	20 000	93 800
	Road markings and road furniture	km	4.690	2 000	9 380
TOTAL CARRIED FORWARD TO SUMMARY					**28 882 795**

Table 9.D.4: Cost estimate: Access and deviation of roads: Flow gauging weirs

ACCESS AND DEVIATION OF ROADS					
ITEM NO	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
4	**PART 4: FLOW GAUGING STATIONS**				
4.1	**SECTION: UPSTREAM OF SMITHFIELD DAM**				
	Accommodation of traffic	km	0.170	20 000	3 400
	Clearing and grubbing	m²	1 700	15	25 500
	Cut to fill	m³	307	90	27 630
	Cut to spoil	m³	0	90	0
	Import	m³	97	200	19 400
	Extra-over for excavation in hard material	m³	200	350	70 000
	Formation preparation	m²	1 700	5	8 500
	Selected layer	m³	212	150	31 748
	Subbase	m³	212	150	31 748
	Wearing course/base course	m³	204	100	20 400
	Surfacing	m²	0	240	0
	Stormwater drainage	km	0.170	20 000	3 400
	Bridges (1:5 year flood)	m²	0	50 000	0
	Erosion protection, landscaping and finishing	km	0.170	50 000	8 500
	Erosion protection to high fill slopes	km	0.170	20 000	3 400
	Road markings and road furniture	km	0.170	2 000	340
4.2	**SECTION: DOWNSTREAM OF SMITHFIELD DAM**				
	Accommodation of traffic	km	2.165	20 000	43 300
	Clearing and grubbing	m²	21 650	15	324 750
	Cut to fill	m³	8 513	90	766 170
	Cut to spoil	m³	0	90	0
	Import	m³	247	200	49 400
	Extra-over for excavation in hard material	m³	1 000	350	350 000
	Formation preparation	m²	21 650	5	108 250
	Selected layer	m³	2 695	150	404 314
	Subbase	m³	2 695	150	404 314
	Wearing course/base course	m³	2 598	100	259 800
	Surfacing	m²	0	240	0
	Stormwater drainage	km	2.165	20 000	43 300
	Bridges (1:5 year flood)	m²	0	50 000	0
	Erosion protection, landscaping and finishing	km	2.165	50 000	108 250
	Erosion protection to high fill slopes	km	2.165	20 000	43 300
	Road markings and road furniture	km	2.165	2 000	4 330
4.3	**SECTION: NEAR IFR SITE**				
	Accommodation of traffic	km	2.516	20 000	50 320
	Clearing and grubbing	m²	25 160	15	377 400
	Cut to fill	m³	26 656	90	2 399 040
	Cut to spoil	m³	1 184	90	106 560
	Import	m³	0	200	0
	Extra-over for excavation in hard material	m³	1 500	350	525 000
	Formation preparation	m²	25 160	5	125 800
	Selected layer	m³	3 132	150	469 863
	Subbase	m³	3 132	150	469 863
	Wearing course/base course	m³	3 019	100	301 920
	Surfacing	m²	0	240	0
	Stormwater drainage	km	2.516	20 000	50 320
	Bridges (1:5 year flood)	m²	0	50 000	0
	Erosion protection, landscaping and finishing	km	2.516	50 000	125 800
	Erosion protection to high fill slopes	km	2.516	20 000	50 320
	Road markings and road furniture	km	2.516	2 000	5 032
TOTAL CARRIED FORWARD TO SUMMARY					**8 220 681**

Table 9.D.5: Cost estimate: Access and deviation of roads: Miscellaneous

ACCESS AND DEVIATION OF ROADS					
ITEM NO	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
5	**PART 5: MISCELLANEOUS**				
5.1	**SECTION: MISCELLANEOUS**				
	Miscellaneous	%	5%	218 852 000	10 942 600
TOTAL CARRIED FORWARD TO SUMMARY					**10 942 600**

Table 9.D.6: Cost estimate: Access and deviation of roads: Miscellaneous

SUMMARY: ACCESS AND DEVIATION OF ROADS	
DESCRIPTION	AMOUNT
PART 1: ROADS APPLICABLE TO SMITHFIELD DAM	178 066 000
PART 2: ROADS APPLICABLE TO UMKHOMAZI-UMLAZI TUNNEL	11 903 000
PART 3: ROADS APPLICABLE TO LANGA DAM	28 883 000
PART 4.1: MISCELLANEOUS (SMITHFIELD DAM)	8 904 000
PART 4.2: MISCELLANEOUS (UMKHOMAZI-UMLAZI TUNNEL)	596 000
PART 4.3: MISCELLANEOUS (LANGA DAM)	1 445 000
TOTAL	**229 797 000**

Annexure 10 A – Waste Disposal Sites: Design Drawings

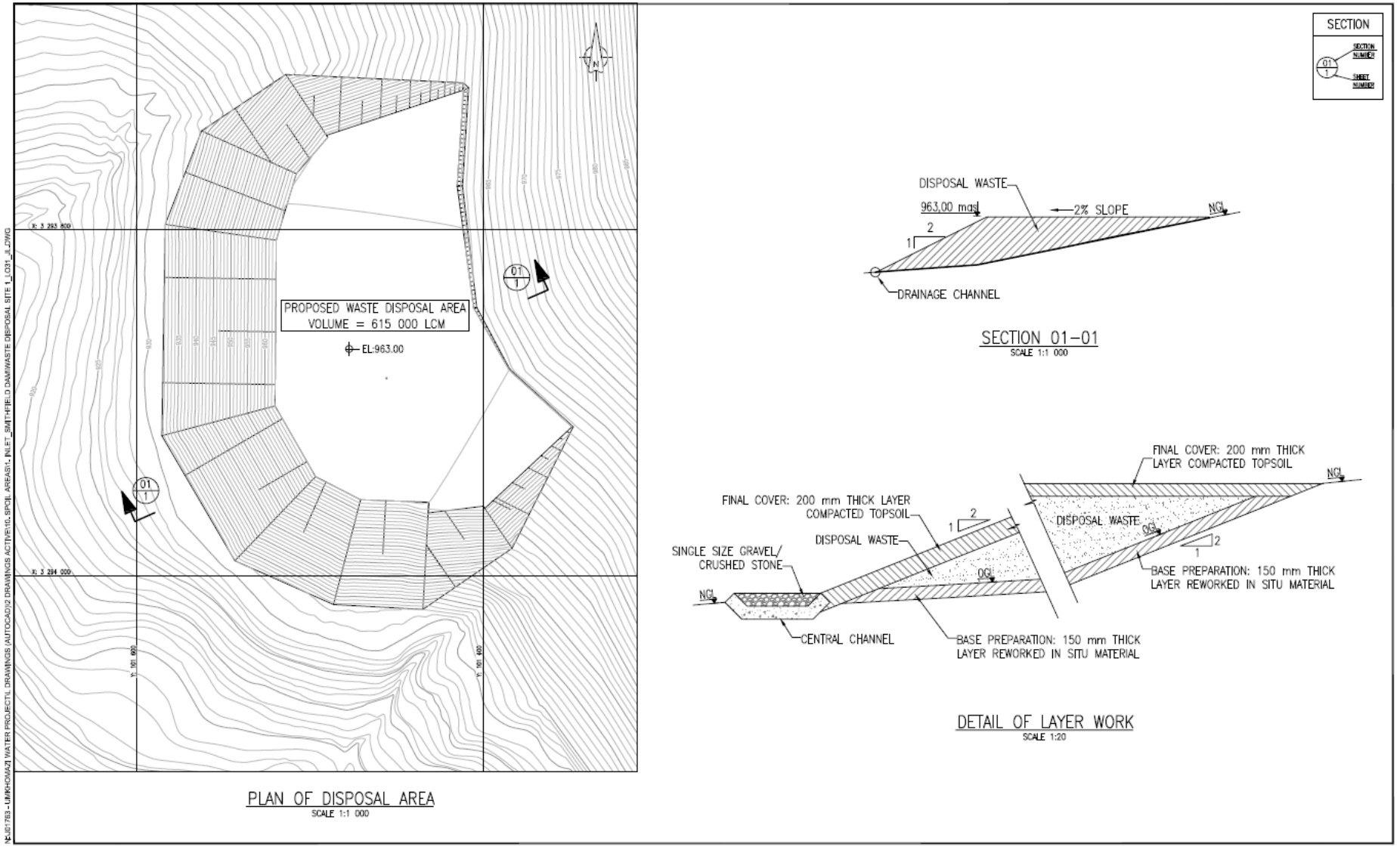


Figure 10.A.1: Plan and sections of waste disposal site 1

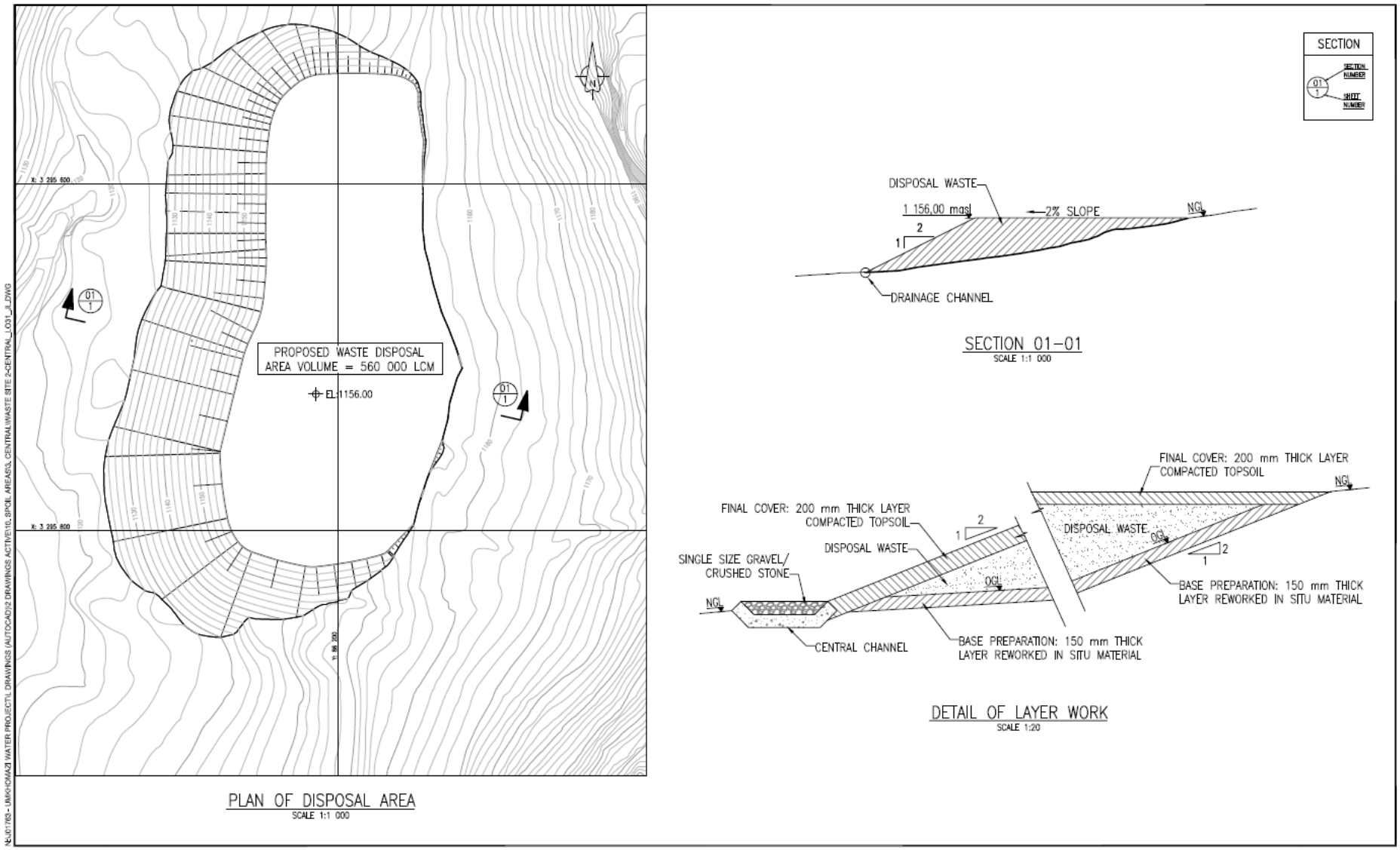


Figure 10.A.2: Plan and sections of waste disposal site 2

Annexure 10 B – Waste Disposal Site: Cost estimate

Table 10.B.1: Cost estimate: Waste disposal sites: Site 1

DEVELOPMENT OF WASTE DISPOSAL SITES					
ITEM NO	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
	PART 1: WASTE DISPOSAL SITE 1				
	SECTION: SITE PREPARATION				
	Site clearance				
	Clear and strip site	ha	5.4	10 430	56 322
	Remove topsoil to 200 mm, stockpile, and maintain	m^3	10 660	27	287 820
	SECTION: CREATION OF PLATFORM				
	Creation of platform				
	(a) Base preparation layer (preparation of exposed surfaces)	m^3	8 000	700	5 600 000
	(b) Final cover topsoil layer (topsoiling)	m^3	10 660	45	479 700
	SECTION: DRAINAGE CHANNEL				
	Concrete, reinforcing, formwork, jointing and waterstops	m	680	940	639 200
	Gravel / crushed stone	m	680	100	68 000
TOTAL CARRIED FORWARD TO SUMMARY					**7 131 042**

Table 10.B.2: Cost estimate: Waste disposal sites: Site 2

DEVELOPMENT OF WASTE DISPOSAL SITES					
ITEM NO	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
	PART 2: WASTE DISPOSAL SITE 2				
	SECTION: SITE PREPARATION				
	Site clearance				
	Clear and strip site	ha	5.4	10 430	56 322
	Remove topsoil to 150 mm, stockpile, and maintain	m³	10 630	27	287 010
	SECTION: CREATION OF PLATFORM				
	Creation of platform				
	(a) Base preparation layer (preparation of exposed surfaces)	m³	7 980	700	5 586 000
	(b) Final cover topsoil layer (topsoiling)	m³	10 630	45	478 350
	SECTION: DRAINAGE CHANNEL				
	Concrete, reinforcing, formwork, jointing and waterstops	m	660	940	620 400
	Gravel / crushed stone	m	660	100	66 000
TOTAL CARRIED FORWARD TO SUMMARY					**7 094 082**

Table 10.B.3: Cost estimate: Waste disposal sites: Miscellaneous

DEVELOPMENT OF WASTE DISPOSAL SITES					
ITEM NO	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
3	**PART 3: MISCELLANEOUS**				
3.1	**SECTION: MISCELLANEOUS**				
	Miscellaneous	%	5%	14 227 000	711 350
TOTAL CARRIED FORWARD TO SUMMARY					**711 350**

Table 10.B.4: Cost estimate: Waste disposal sites: Summary

SUMMARY: DEVELOPMENT OF WASTE DISPOSAL SITES	
DESCRIPTION	AMOUNT
PART 1: WASTE DISPOSAL SITE 1	7 132 000
PART 2: WASTE DISPOSAL SITE 2	7 095 000
PART 3: MISCELLANEOUS	712 000
TOTAL	**14 939 000**

Annexure 11 A – Land acquisition: Drawings of purchase lines

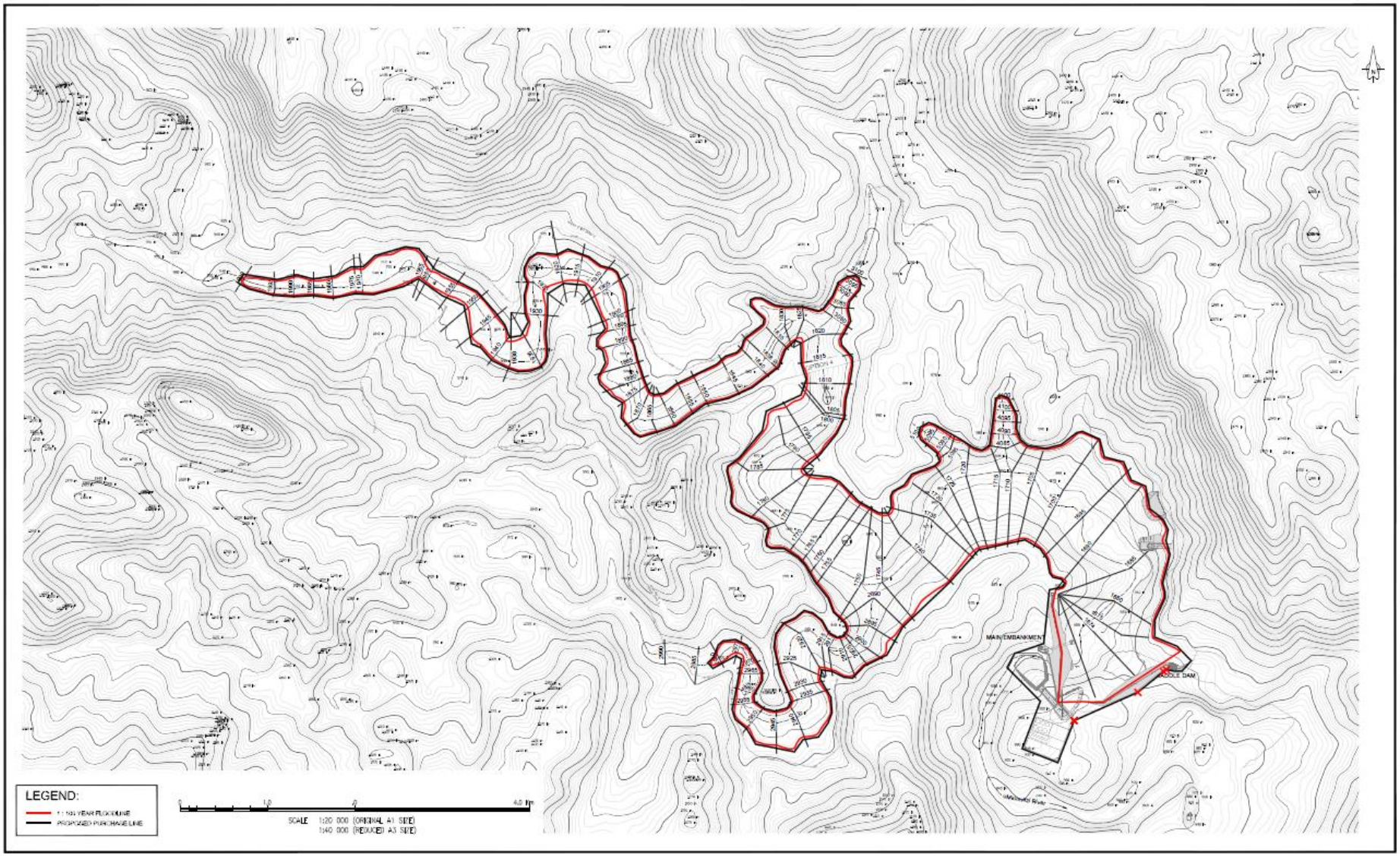


Figure 11.A.1: Land acquisition pertaining to Smithfield Dam

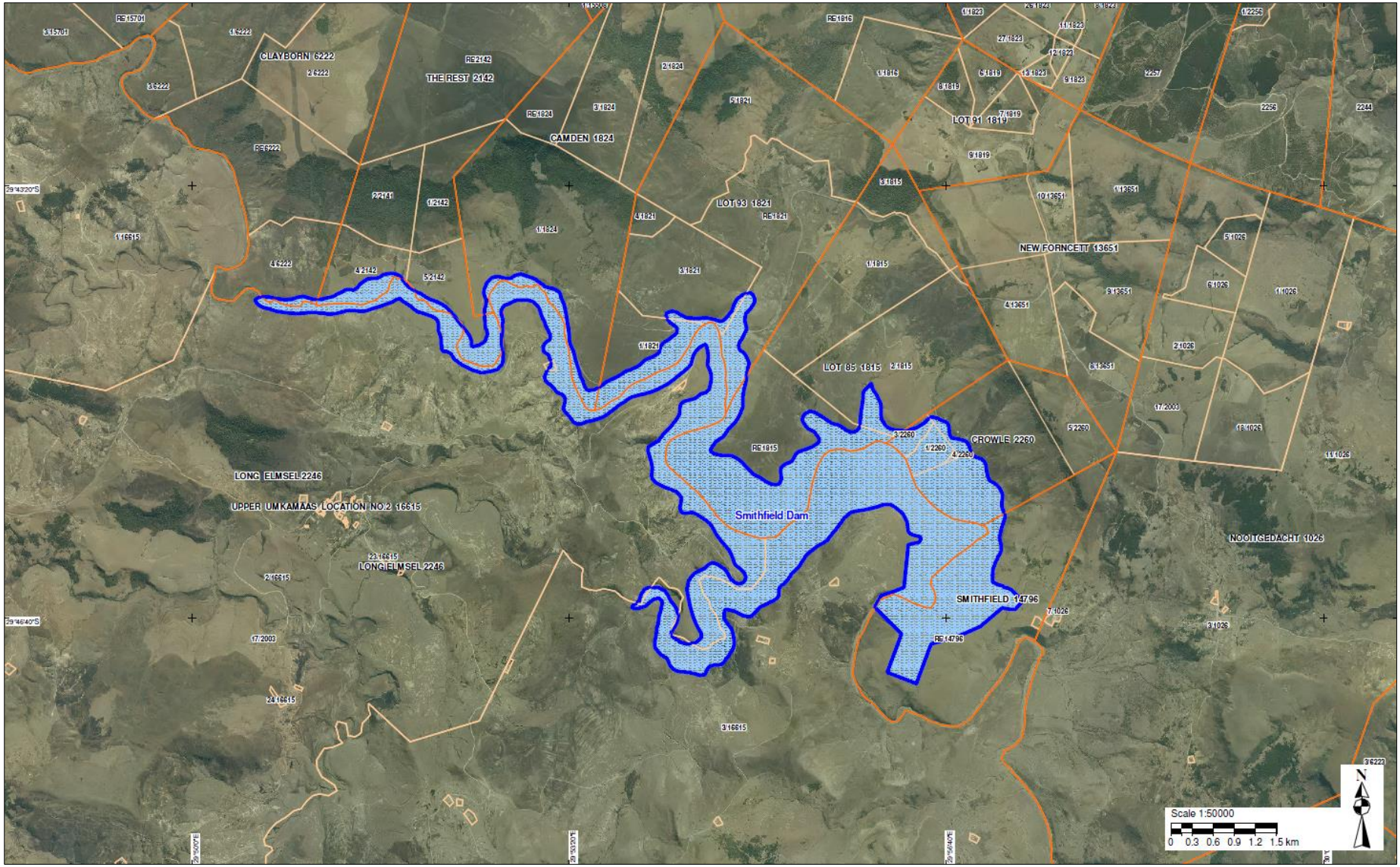


Figure 11.A.2: Land acquisition pertaining to Smithfield Dam (with orthophoto)

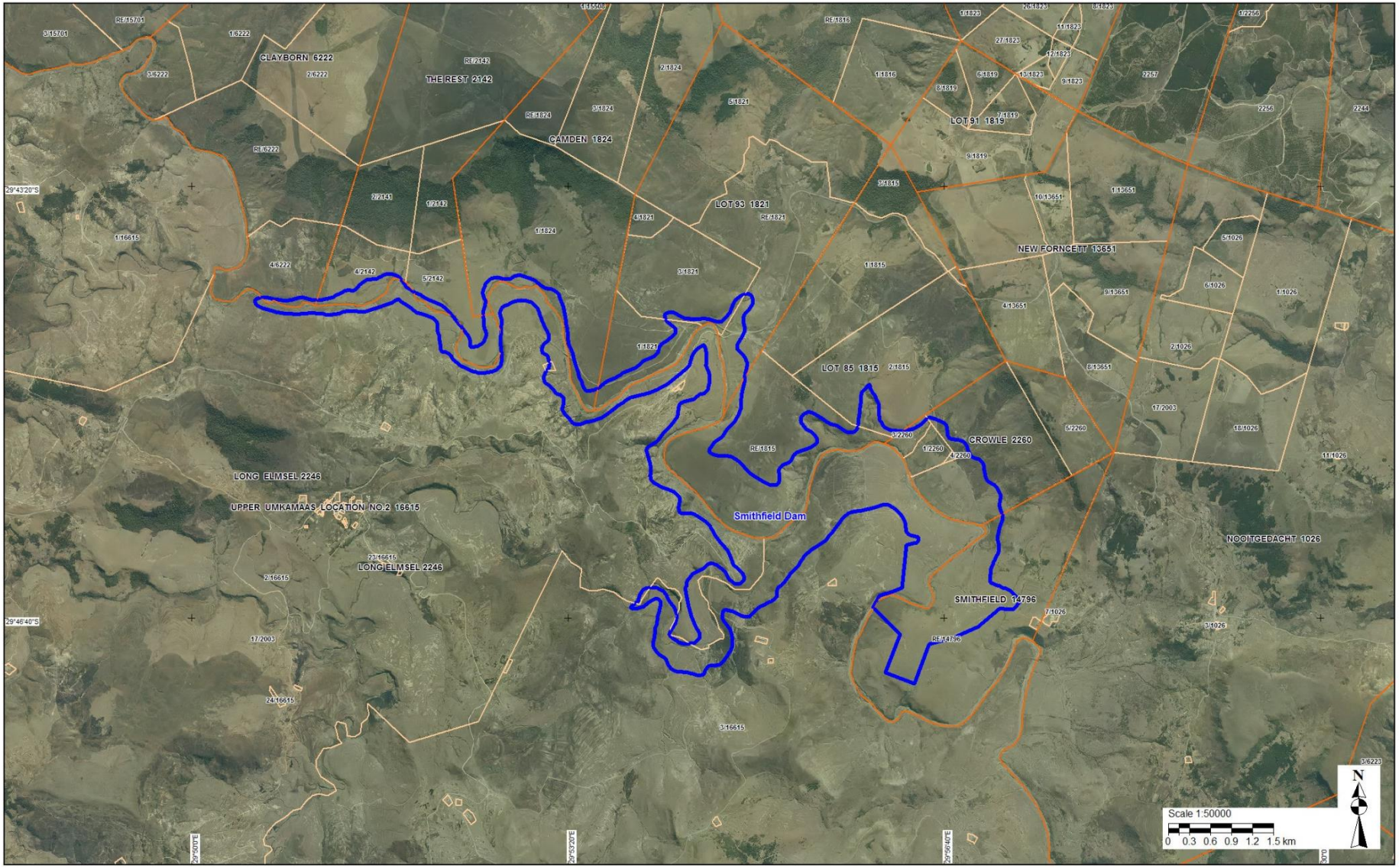


Figure 11.A.3: Land acquisition pertaining to Smithfield Dam (with orthophoto, without water level shading shown)

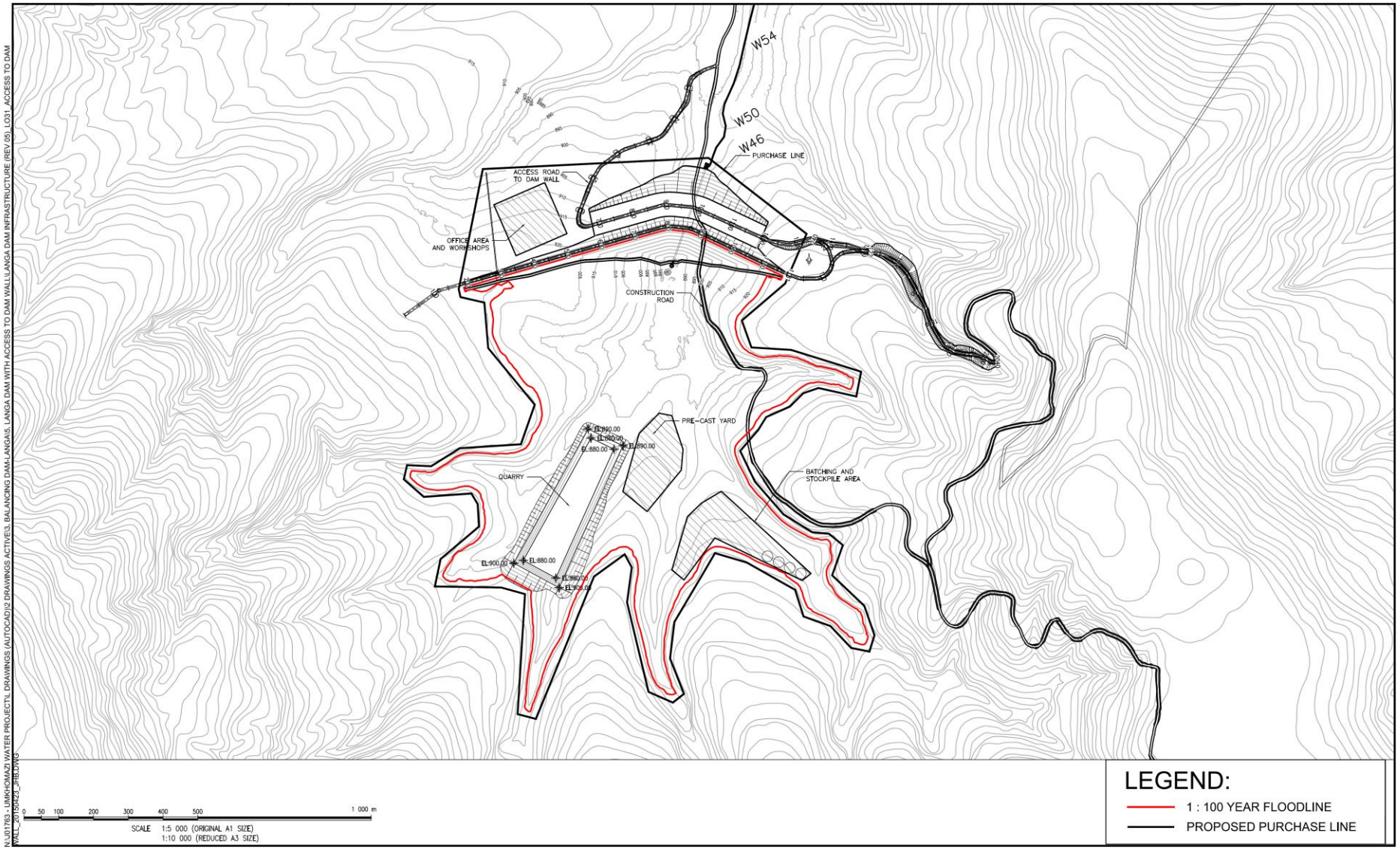


Figure 11.A.4: Land acquisition pertaining to Langa Dam

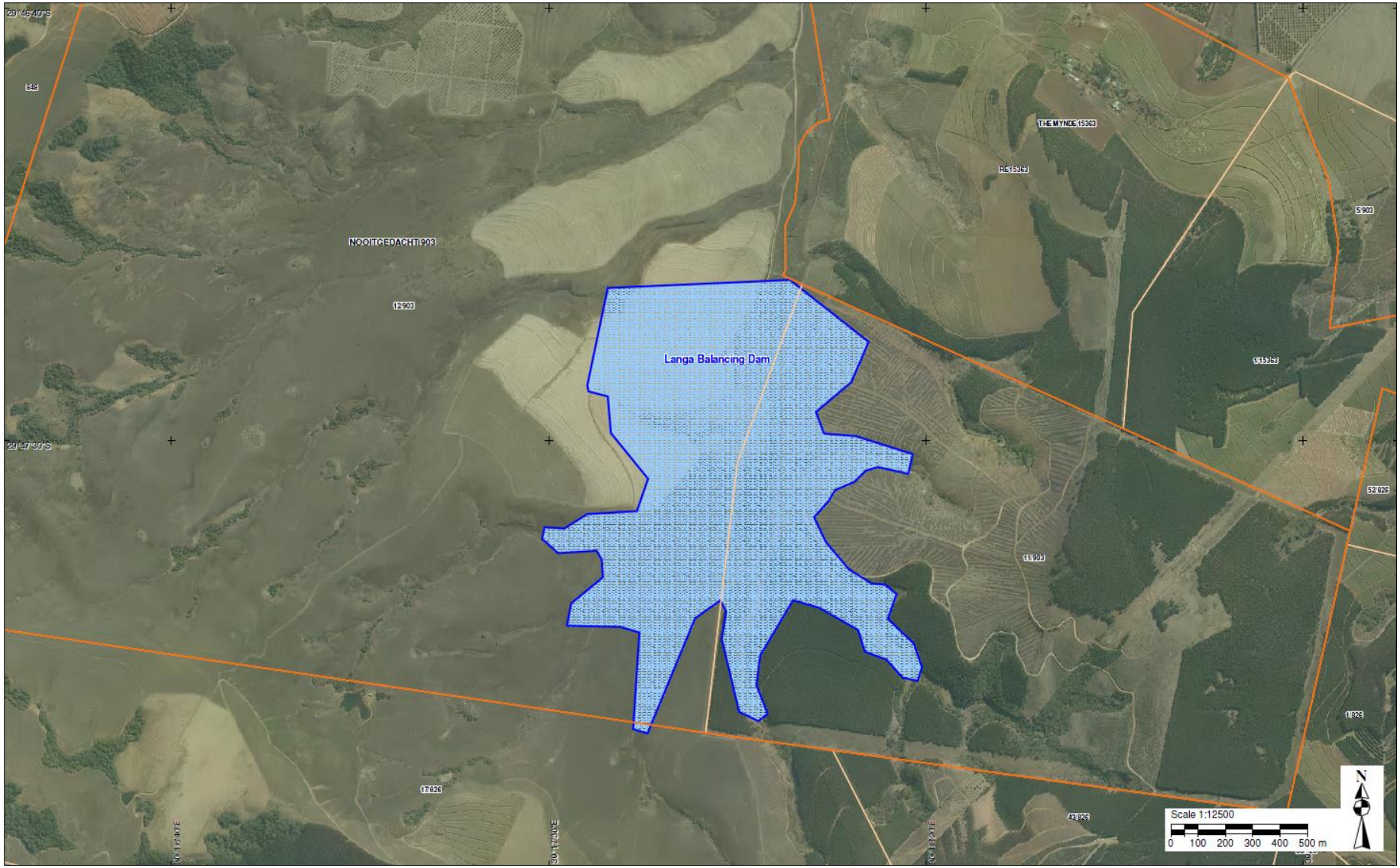


Figure 11.A.5: Land acquisition pertaining to Langa Dam (with orthophoto)

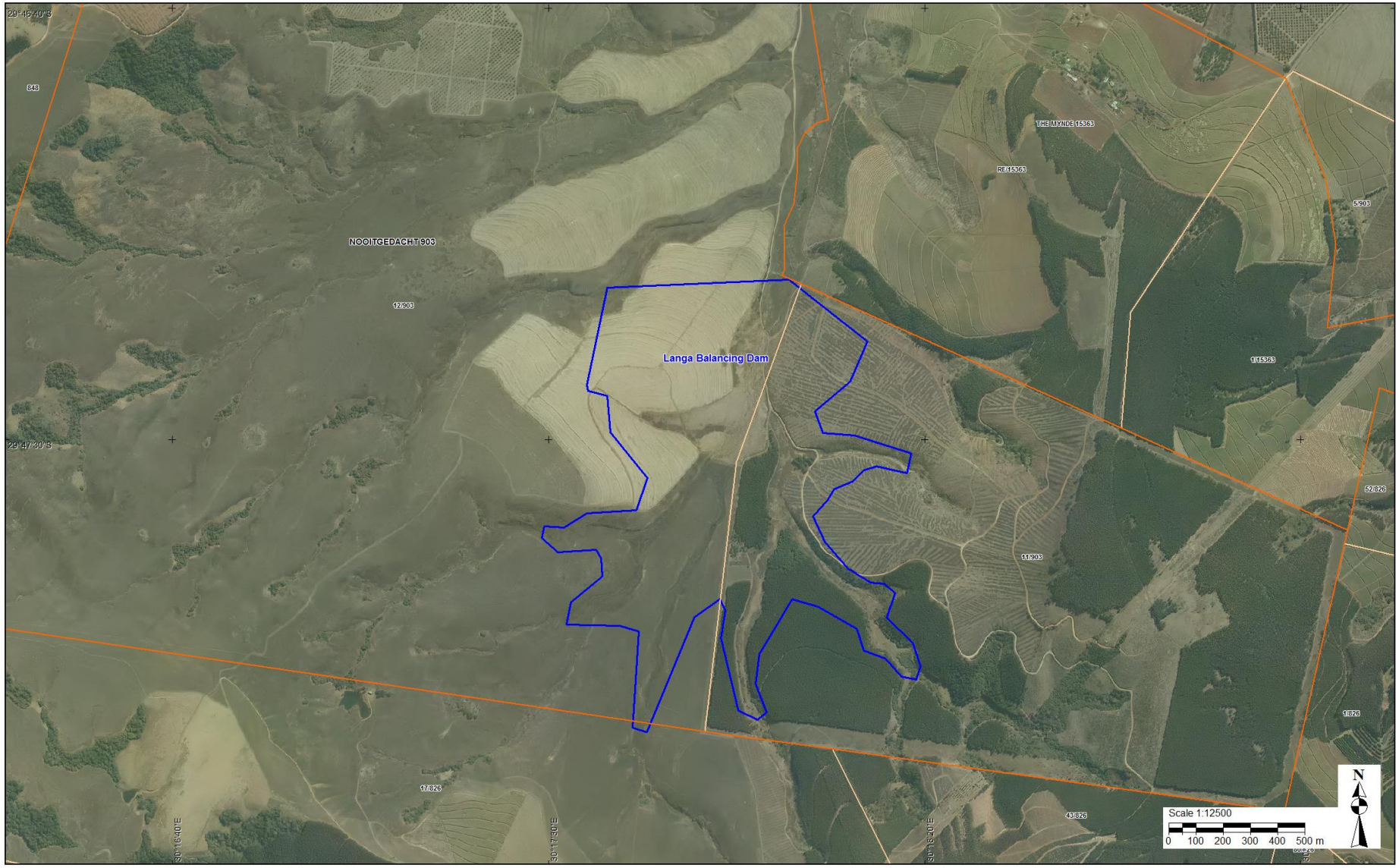


Figure 11.A.6: Land acquisition pertaining to Langa Dam (with orthophoto, without water level shading shown)

Annexure 11 B – Land acquisition: Cost estimate

Table 11.B.1: Cost estimate: Land acquisition

LAND ACQUISITION					
ITEM NO	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
1	**PART 1: LAND ACQUISITION**				
1.1	**SECTION: SMITHFIELD DAM**				
	Non-cultivated land				
	(a) Title deed land	ha	725.7	20 000	14 514 000
	(b) Tribal land	ha	761.3	20 000	15 226 000
1.2	**SECTION: LANGA DAM**				
	Non-cultivated land				
	(a) Title deed land	ha	42.5	20 000	850 000
	(b) Tribal land	ha	0.0	20 000	0
	Cultivated land (forest and agricultural)				
	(a) Title deed land	ha	74.7	40 000	2 988 000
	(b) Tribal land	ha	0.0	40 000	0
1.3	**SECTION: UMKHOMAZI-UMLAZA TUNNEL**				
	Servitude	ha	88.0	10 000	880 000
1.4	**SECTION: TUNNEL-LANGA DAM-BAYNESFIELD PIPELINE**				
	Permanent servitude	ha	12.7	10 000	127 000
	Additional temporary servitude	ha	15.3	5 000	76 500
1.5	**SECTION: FLOW GAUGING STATIONS**				
	Non-cultivated land				
	(a) Title deed land	ha	0.0	20 000	0
	(b) Tribal land	ha	56.8	20 000	1 136 000
1.6	**SECTION: ACCESS AND DEVIATION OF ROADS**				
	Servitude	ha	59.3	20 000	1 186 000
TOTAL CARRIED FORWARD TO SUMMARY					**36 983 500**

Annexure 12 A – Accommodation and related structures: Cost estimate

Table 12.A.1: Cost estimate: Accommodation and related structures

ACCOMMODATION AND RELATED STRUCTURES					
ITEM NO	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
1	**PART 1: SMITHFIELD DAM**				
1.1	**SECTION: ALL ITEMS**				
	Offices	m²	40	5 886	235 440
	3 Bedroom house	m²	230	5 668	1 303 640
	Workers house (1)	m²	92	4 142	381 064
	Workers house (2)	m²	92	4 142	381 064
	Workers house (3)	m²	92	4 142	381 064
	Carports	unit	5	3 597	17 985
	Boat garage	m²	40	3 052	122 080
	Workshop	m²	100	3 052	305 200
TOTAL CARRIED FORWARD TO SUMMARY					**3 127 537**