



**water affairs**

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REPUBLIC OF SOUTH AFRICA



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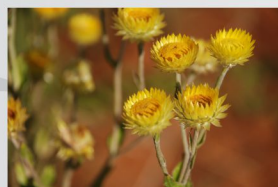
# The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study: Raw Water

**ENGINEERING FEASIBILITY DESIGN REPORT**

**WRITE-UP 4:  
ROUTE INVESTIGATION FOR VARIOUS  
ROAD ALIGNMENTS ON THE  
UMKHOMAZI-UMLAZA TRANSFER SCHEME**

**FINAL**

**APRIL 2015**



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

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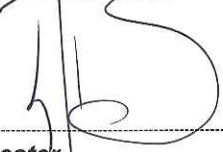
  
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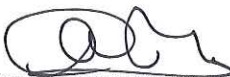
  
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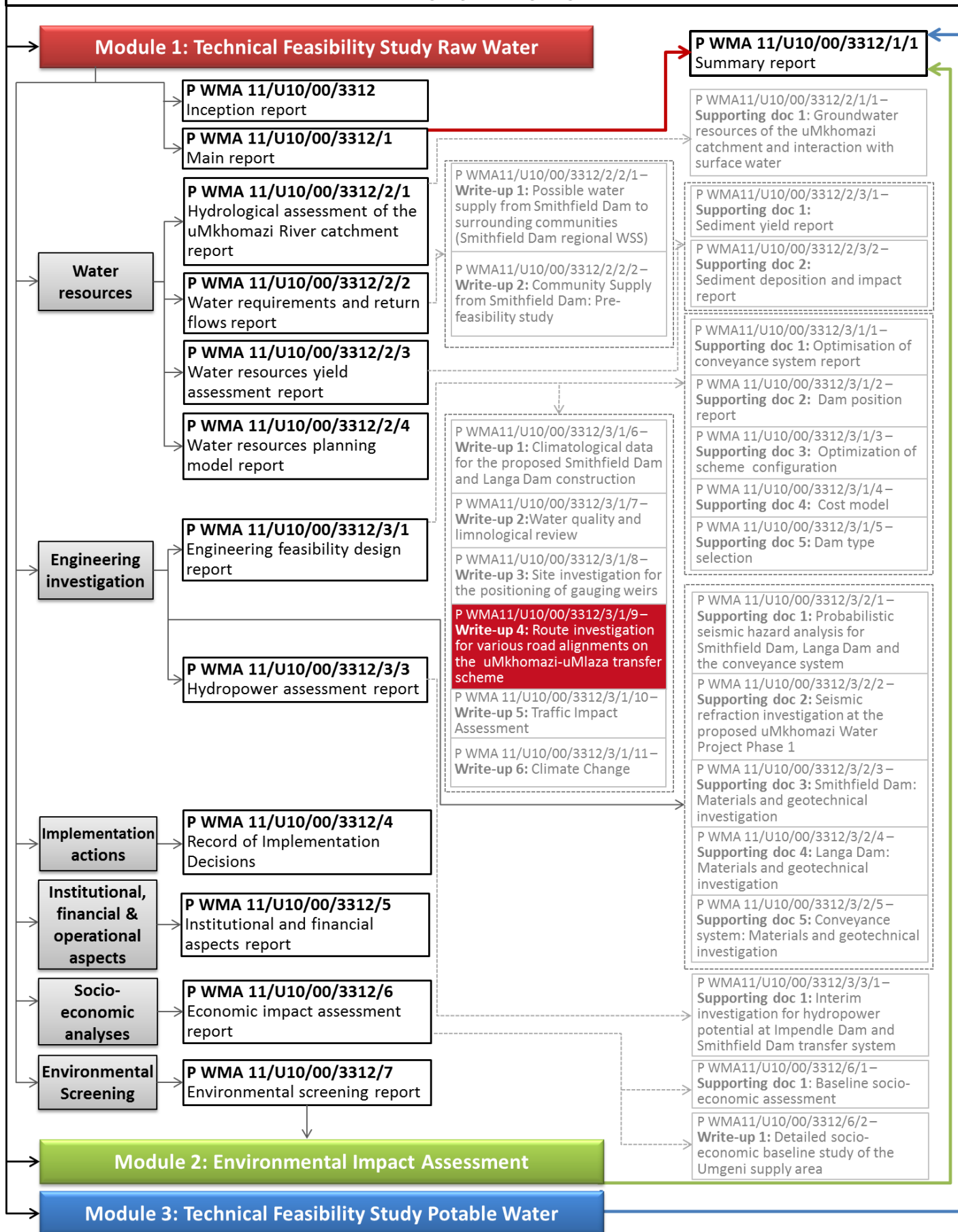
# PREAMBLE

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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.

## The uMkhomazi Water Project Phase 1 LIST OF REPORTS



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## APPENDICES

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# 1 INTRODUCTION

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## 1.1 PROJECT REQUIREMENTS

The aim of this section is to investigate options for the realignment of various roads that will be flooded by the proposed Smithfield Dam as well as route determination for new access roads to different components of this project.

The following roads were identified, for which route determination is addressed in this report:

♦ Smithfield Dam:

- ♦ Deviation of the R617;
- ♦ Access road to Nonguqa;
- ♦ Access road to tunnel inlet portal;
- ♦ Access road to dam wall;
- ♦ Construction road; and
- ♦ Main access road.

♦ Tunnel:

- ♦ Access road to Ventilation/air shaft 1;
- ♦ Access road to Ventilation/air shaft 3; and
- ♦ Access road to centre adit entry.

♦ Langa Dam:

- ♦ Access road to tunnel outlet portal and Langa Dam (Option 1); and
- ♦ Access road to tunnel outlet portal and Langa Dam (Option 2).

♦ Gauging weirs:

- ♦ Access road to gauging weir 1;
- ♦ Access road to gauging weir 2; and
- ♦ Access road to gauging weir 3.



## 1.2 OBJECTIVES

The objectives of the route investigation for the access road are as follows:

- ◆ Establish a road centre line;
- ◆ Develop a preliminary longitudinal section;
- ◆ Quantify the scope of the construction works including pavement layers and fills;
- ◆ Investigate design criteria for stormwater drainage structures; and
- ◆ Estimate the design and construction cost.

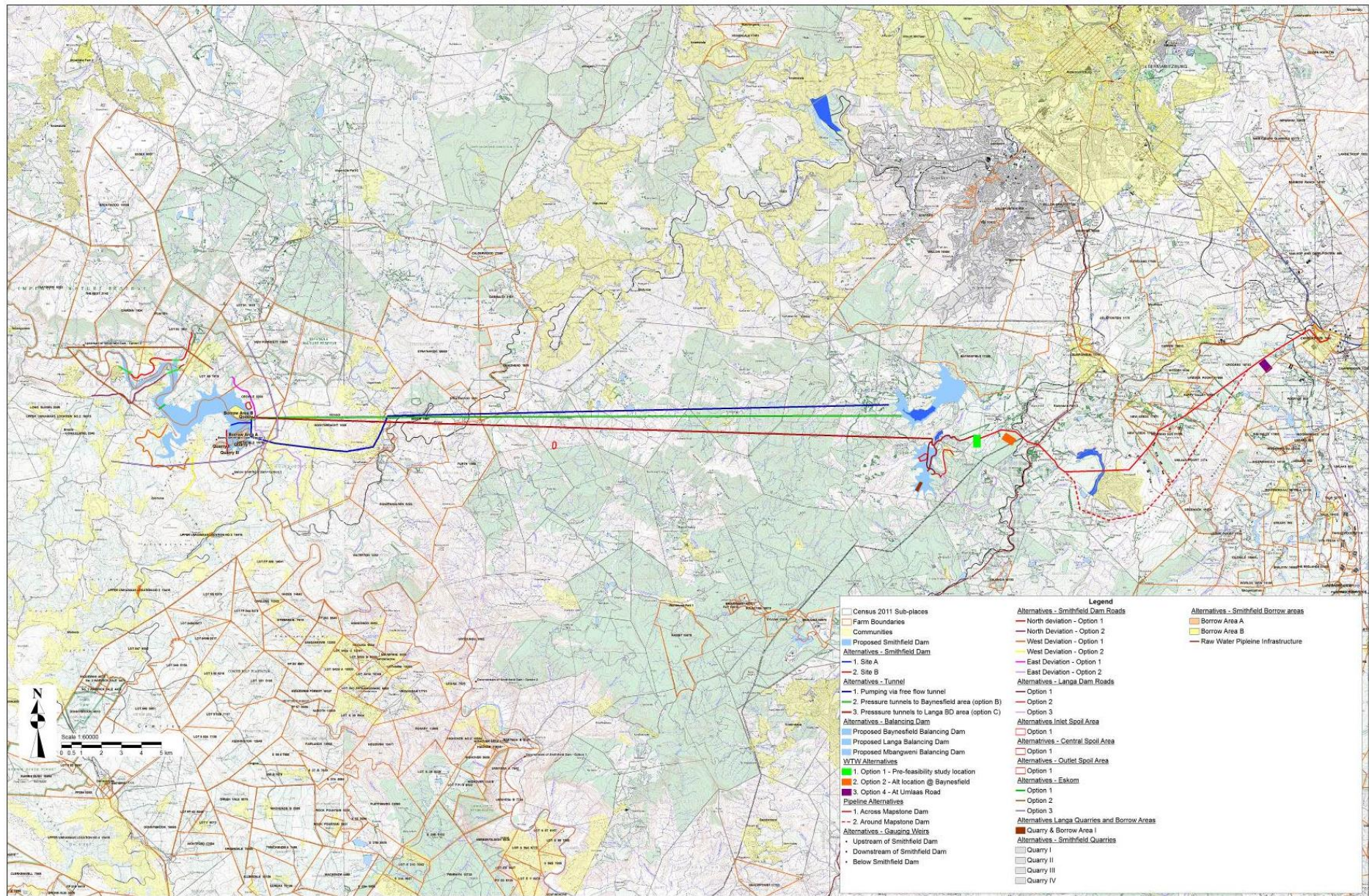


Figure 1: Location of roads to be realigned

## 2 DESIGN METHODOLOGY AND ASSUMPTIONS

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### 2.1 BASE INFORMATION

A digital terrain model was created from a 5 m contour plan received from a DWA survey. Topography information such as existing roads and water courses was provided in the form of images.

### 2.2 DESIGN STANDARDS

#### 2.2.1 Geometric design standards

The approach was to apply horizontal, vertical and cross-sectional design standards to the permanent road which would accommodate a typical heavy haulage vehicle, rather than applying an arbitrary design speed. The geometric design standards used are therefore as follows:

- ◆ Minimum horizontal curve radius: 50 – 60 m
- ◆ Maximum grade: 14%
- ◆ Vertical curve sag K-Value: 8 (Corresponds to 40km/h)
- ◆ Vertical curve crest K-Value: 6 (Corresponds to 40km/h)

#### 2.2.2 Design vehicle

The horizontal alignment and road width was checked by simulating an AASHTO WB-50 5-axle Semitrailer 16,76m long.

#### 2.2.3 Typical cross section

The deviation of road R617 will be a paved road with a 3.5 m lane in each direction and a 1.0 m shoulder on either side, therefore a 9 m formation. For the gravel roads, a width of 8 m is proposed. Typical cross sections of the paved and unpaved roads are shown in **Figure A1.0** in **Appendix A**.

### 2.3 FACTORS AFFECTING ROAD ALIGNMENT

The following factors were taken into consideration during the alignment of the road:

- Geometric Design Standards as mentioned above;
- The 1:100 year floodline;
- Areas of steep natural cross-fall; and
- The alignment of existing Provincial Road R617.

## 3 GEOTECHNICAL INVESTIGATION

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### 3.1 GEOLOGY

The area of interest is underlain by rocks of the Volksrust Formation of the Ecca Group, comprising shales (mudrocks) with sub-ordinate sandstones. The sedimentary strata are essentially horizontal, and largely undisturbed. Regional dips of 3 – 7 degrees are recorded, while locally steeper dips are recognised and are ascribed to the intrusion of dolerites. Three near-horizontal dolerite sills have intruded mainly concordantly into the sedimentary strata and are responsible for the narrow river valley at the dam site and the presence of good quality rock for concrete aggregate and rockfill. A few faults with throws of up to 10m have been mapped and one dolerite dyke traverses the left flank quarry area.

### 3.2 SOURCES OF CONSTRUCTION MATERIAL

It is likely that fills and the selected layers would be able to be constructed from material obtained from cut during road construction.

Material for the sub-base layer and wearing course will have to be obtained from borrow areas. Material may have to be modified by means of stabilization if required.

### 3.3 SLOPE STABILITY

Due to the steep natural cross-falls, high cut and fill slopes are inevitable.

#### 3.3.1 Cut slopes

A cut slope of 1V:1H has been applied throughout for the purposes of determining earthwork volumes as the locations of hard material, where steeper slopes may be used, are not accurately known at this stage. Cut slopes for

detailed design will have to be analysed for stability using soil properties determined during a detailed geotechnical investigation.

### 3.3.2 Fill slopes

If a fill slope of 1V:1.5H is applied throughout, the fill toe in sections with a steep cross-fall becomes located at excessive distances from the road edge. This will result in a large footprint for the road which may be found to be environmentally unacceptable. The fill volume will be further increased by the benching operation which will be required on steep slopes.

## 4 PRELIMINARY PAVEMENT DESIGN

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The following preliminary pavement designs are foreseen for the different roads:

- ◆ Gravel roads
  - ◆ 150 mm Gravel wearing course (G6) compacted to 95% of modified AASHTO compaction;
  - ◆ 150 mm Selected subgrade (G9) compacted to 93% of modified AASHTO compaction; and
  - ◆ Roadbed preparation/fill (G10) compacted to 90% of modified AASHTO compaction.
  
- ◆ Surfaced road
  - ◆ 19/9.5 mm double seal or 30mm asphalt;
  - ◆ 150 mm Base (G4) compacted to 97% of modified AASHTO compaction;
  - ◆ 150 mm Sub-base compacted to 95% of modified AASHTO compaction;
  - ◆ 150 mm Upper selected subgrade (G7) compacted to 93% of modified AASHTO compaction;
  - ◆ 150 mm Lower selected subgrade (G9) compacted to 90% of modified AASHTO compaction; and
  - ◆ Roadbed preparation/fill (G10) compacted to 90% of modified AASHTO compaction.

## 5 STORMWATER DRAINAGE

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All of the access roads under discussion are situated in the catchment of the uMkhomazi River, characterised by steep, rocky terrain and mountain grassland with scattered bush. The soils are easily eroded so great care needs to be taken in the design of drainage structures. The average annual precipitation for this area is 810 mm.

The following stormwater design standards are proposed:

- ◆ Minor catchments
  - ◆ Pipe and box culverts: 1:2 year flood return period
  - ◆ Side drains: 1:2 year flood return period
- ◆ Major catchments
  - ◆ Low water bridges: 1:5 year flood return period
  - ◆ Major bridges: 1:50 year flood return period



## 6 ALTERNATIVE ROUTES INVESTIGATED

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### 6.1 SMITHFIELD DAM

#### 6.1.1 Deviation of the R617

Three alternative route options were investigated to deviate road R617 around or over the expected full supply level (FSL) water line of the Smithfield Dam, to ensure continuity of the road (refer to **Figure A0** in **Appendix A**).

Options 1 and 2 are the deviation of road R617 to ensure continuity of the surfaced route on the northern side of the dam, from a position at a village west of the dam wall to where it joins the surfaced section of this road on the northern side of the dam. Option 3 deviates the road on the western side of the dam, and will be south of the dam for the majority of the deviation, and end up on the north-eastern side of the dam.

As Option 2 and 3 will require long bridges over sections of the dam, these options were not further considered due to the high expense involved with bridges. Option 1 is considered the most appropriate solution for the R617 deviation.

#### *a) Length and cross section*

The deviation of road R617 will match the existing road which is a **7 m** wide surfaced road with a **3.5 m** lane in each direction and a **1 m** shoulder on each side. The length of the deviation is **12.06 km** and has a maximum slope of **13.9%**.

#### *b) Scope of construction work*

The approximate earthworks volumes for this road are indicated in **Table 6.1**.

**Table 6.1: Estimated earthworks volumes - deviation of the R617**

Description	Volume / Area
Wearing course and base course	16 280 m <sup>3</sup>
Gravel sub-base	16 931 m <sup>3</sup>
Selected layer	34 730 m <sup>3</sup>
Cut to fill	250 000 m <sup>3</sup>
Cut to spoil	60 000 m <sup>3</sup>
Import required	-
Asphalt / Double seal	84 413 m <sup>2</sup>

These quantities were used to estimate the cost of the proposed alternative.

**c) Cost estimate**

The cost of the detailed design and construction of the access road is estimated in **Table 6.2** below. It is assumed that sufficient amounts of material for layerworks will be obtainable by the roadworks contractor from nearby borrow pits.

**Table 6.2: Cost estimate – Deviation of the R617 (excl VAT, 2014 Rand)**

Item	Description	Amount (R)
1	Preliminary and General	15 067 074
2	Accommodation of traffic	482 360
3	Clearing and grubbing	1 205 900
4	Cut to fill	20 000 000
5	Cut to spoil	4 500 000
6	Import	-
7	Extra over for excavation in hard material	17 500 000
8	Formation preparation	602 950
9	Selected layer	6 251 386
10	Sub-base	3 724 784
11	Wearing course/base course	4 558 302
12	Surfacing	16 882 600
13	Stormwater drainage	2 411 800

Item	Description	Amount (R)
14	Bridges over uMkhomazi River (1:5 yr flood)	20 880 000
15	Erosion protection, landscaping & finishing	602 950
16	Erosion protection to high fill slopes	602 950
17	Road markings and road furniture	241 180
18	Contingencies	11 551 424
<b>19</b>	<b>Total for road- and bridgeworks</b>	<b>127 065 659</b>
20	Total cost per km	10 536 998*
21	Professional fees and disbursements (Including for gravel road upgrade)	16 518 536
<b>22</b>	<b>Total for professional fees</b>	<b>16 518 536</b>
<b>TOTAL</b>		<b>143 584 195</b>

\* This amount not included in total

### 6.1.2 Access road to Nonguqa

Three route options were considered to ensure access to Nonguqa, a village on the southern side of the dam, which is currently served by an unsurfaced road. Two of these options joined road R617 west of the dam. The third option considered is south of the dam.

Option 1 was found to be the most suitable option, primarily due to the acceptable slopes of this road. This option runs along the southern end of the dam, first in an easterly direction when it leaves the R617, turning south after a distance of 2 km, and then east again until it reaches Nonguqa, which is situated in close proximity of the proposed dam wall.

#### a) Length and cross section

The length of the deviation is **8.13 km** and it has a maximum slope of **12.8%**. The new route will have a gravel surface and a width of **8 m**, with a **2%** camber from the centre line.

#### a) Scope of construction work

The approximate earthworks volumes for this road are indicated in **Table 6.3**.

**Table 6.3: Estimated earthworks volumes – Access road to Nonguqa**

Description	Volume (m <sup>3</sup> )
Wearing course and base course	9 760
Gravel sub-base	10 126
Cut to fill	28 812
Cut to spoil	43 827
Import required	-

These quantities were used to estimate the cost of the proposed road.

**b) Cost estimate**

The cost of the detailed design and construction of the access road is estimated in **Table 6.4** below. It is assumed that sufficient amounts of material for layerworks will be obtainable by the roadworks contractor from nearby borrow pits.

**Table 6.4: Cost estimate – Access road to Nonguqa (excl VAT, 2014 Rand)**

Item	Description	Amount (R)
1	Preliminary and General	2 445 389
2	Accommodation of traffic	162 660
3	Clearing and grubbing	1 219 950
4	Cut to fill	2 593 051
5	Cut to spoil	3 944 470
6	Import	-
7	Extra over for excavation in hard material	1 750 000
8	Formation preparation	406 650
9	Selected layer	1 518 838
10	Sub-base	1 518 838
11	Wearing course/base course	975 960
12	Surfacing	-
13	Stormwater drainage	1 626 600
14	Bridges (1:5 yr flood)	-

Item	Description	Amount (R)
15	Erosion protection, landscaping & finishing	406 650
16	Erosion protection to high fill slopes	162 660
17	Road markings and road furniture	16 266
18	Contingencies	1 874 798
<b>19</b>	<b>Total for roadworks</b>	<b>20 622 779</b>
20	Total cost per km	2 535 692*
21	Professional fees and disbursements	2 680 961
<b>22</b>	<b>Total for professional fees</b>	<b>2 680 961</b>
<b>TOTAL</b>		<b>23 303 741</b>

\* This amount not included in total

### 6.1.3 Access road to tunnel inlet portal

As with the access road to the intake tower, the same route applies to the tunnel inlet portal.

#### a) Length and cross section

This road has a length of **0.23 km**, and turns off the main access road, **5.21 km** from the R617. The maximum slope on this proposed alignment is **13.9%**.

#### a) Scope of construction work

The approximate earthworks volumes for this road are indicated in **Table 6.5**.

**Table 6.5: Estimated earthworks volumes – Access road to tunnel inlet portal**

Description	Volume (m <sup>3</sup> )
Wearing course and base course	271
Gravel sub-base	281
Cut to fill	1 565
Cut to spoil	-
Import required	439

These quantities were used to estimate the cost of the various alternatives for this road.

**b) Cost estimate**

The cost of the detailed design and construction of the access road is estimated in **Table 6.6** below. It is assumed that sufficient amounts of material for layerworks will be obtainable by the roadworks contractor from nearby borrow pits.

**Table 6.6: Cost estimate – Access road to tunnel inlet portal (excl VAT, 2014 Rand)**

Item	Description	Amount (R)
1	Preliminary and General	70 156
2	Accommodation of traffic	9 040
3	Clearing and grubbing	6 780
4	Cut to fill	125 229
5	Cut to spoil	-
6	Import	35 129
7	Extra over for excavation in hard material	14 000
8	Formation preparation	11 300
9	Selected layer	50 647
10	Sub-base	61 901
11	Wearing course/base course	81 360
12	Surfacing	-
13	Stormwater drainage	45 200
14	Bridges (1:5 yr flood)	-
15	Erosion protection, landscaping & finishing	11 300

Item	Description	Amount (R)
16	Erosion protection to high fill slopes	11 300
17	Road markings and road furniture	4 520
18	Contingencies	53 786
<b>19</b>	<b>Total for roadworks</b>	<b>591 648</b>
20	Total cost per km	2 617 910*
21	Professional fees and disbursements	76 914
<b>22</b>	<b>Total for professional fees</b>	<b>76 914</b>
<b>TOTAL</b>		<b>668 562</b>

\* This amount not included in total

#### 6.1.4 Access road to dam wall

Access to the dam wall, can be taken off the route of the main access road, at a position 6.68 km from road R617.

##### a) Length and cross section

This road has a length of **1.56 km**, and the maximum slope on this proposed alignment is **13.8%**.

##### a) Scope of construction work

The approximate earthworks volumes for this road are indicated in **Table 6.7**.

**Table 6.7: Estimated earthworks volumes – Access road to dam wall**

Description	Volume (m <sup>3</sup> )
Wearing course and base course	1 874
Gravel sub-base	1 945
Cut to fill	6 866
Cut to spoil	-
Import required	4 321

These quantities were used to estimate the cost of the various alternatives for this road.

**b) Cost estimate**

The cost of the detailed design and construction of the access road is estimated in **Table 6.8** below. It is assumed that sufficient amounts of material for layerworks will be obtainable by the roadworks contractor from nearby borrow pits.

**Table 6.8: Cost estimate – Access road to dam wall (excl VAT, 2014 Rand)**

Item	Description	Amount (R)
1	Preliminary and General	517 114
2	Accommodation of traffic	62 480
3	Clearing and grubbing	46 860
4	Cut to fill	549 270
5	Cut to spoil	-
6	Import	345 682
7	Extra over for excavation in hard material	525 000
8	Formation preparation	78 100
9	Selected layer	350 044
10	Sub-base	427 832
11	Wearing course/base course	562 320
12	Surfacing	-
13	Stormwater drainage	312 400
14	Bridges (1:5 yr flood)	-
15	Erosion protection, landscaping & finishing	78 100
16	Erosion protection to high fill slopes	78 100
17	Road markings and road furniture	31 240
18	Contingencies	396 454
<b>19</b>	<b>Total for roadworks</b>	<b>4 360 995</b>



Item	Description	Amount (R)
20	Total cost per km	2 791 930*
21	Professional fees and disbursements	566 929
<b>22</b>	<b>Total for professional fees</b>	<b>566 929</b>
<b>TOTAL</b>		<b>4 927 925</b>

\* This amount not included in total

### 6.1.5 Construction road

The main access road and the construction road are located on the eastern side of the dam basin, and are mostly on the alignment of an existing route, except for a section (main access road), which will be above the FSL of the dam. The construction road, which is the existing alignment of the road, is an alternative that can be used as an access road during the construction of the dam.

The two routes investigated share a common alignment for the first 7.0 km; after which Route 1 continues in a southerly direction to link up with Road D874 while Route 2 turns eastward to link up with Road D874 (refer to **Figure A0** in **Appendix A**).

#### a) Length and cross section

This road has a length of **3.39 km**. The maximum slope on this proposed alignment is **10.6%**.

#### a) Scope of construction work

The approximate earthworks volumes for this road are indicated in **Table 6.9**.

**Table 6.9: Estimated earthworks volumes – Construction road**

Description	Volume (m <sup>3</sup> )
Wearing course and base course	4 073
Gravel sub-base	4 226
Cut to fill	34 198
Cut to spoil	-
Import required	10 764

These quantities were used to estimate the cost of the various alternatives for this road.

**b) Cost estimate**

The cost of the detailed design and construction of the access road is estimated in **Table 6.10**. It is assumed that sufficient amounts of material for layerworks will be obtainable by the roadworks contractor from nearby borrow pits.

**Table 6.10: Cost estimate – Construction road (excl VAT, 2014 Rand)**

Item	Description	Amount (R)
1	Preliminary and General	1 279 107
2	Accommodation of traffic	135 760
3	Clearing and grubbing	101 820
4	Cut to fill	2 735 840
5	Cut to spoil	-
6	Import	861 130
7	Extra over for excavation in hard material	525 000
8	Formation preparation	169 700
9	Selected layer	760 595
10	Sub-base	929 617
11	Wearing course/base course	1 221 840
12	Surfacing	4 887 360
13	Stormwater drainage	678 800
14	Bridges (1:5 yr flood)	-

Item	Description	Amount (R)
15	Erosion protection, landscaping & finishing	169 700
16	Erosion protection to high fill slopes	169 700
17	Road markings and road furniture	67 800
18	Contingencies	1 542 695
<b>19</b>	<b>Total for roadworks</b>	<b>16 969 649</b>
20	Total cost per km	4 999 897*
21	Professional fees and disbursements	2 206 054
<b>22</b>	<b>Total for professional fees</b>	<b>2 206 054</b>
<b>TOTAL</b>		<b>19 175 704</b>

\* This amount not included in total

### 6.1.6 Main access road

The main access road is on the eastern side of the dam basin, mostly on the alignment of an existing route, except for a section almost parallel to the construction road, which will be above the FSL of the dam. The access road will give permanent access to the dam wall, intake tower and tunnel inlet portal.

The main access road will be paved for use during construction, and also be re-sealed at the end of the construction period to serve as a permanent access road.

#### a) Length and cross section

This road has a length of **7.50 km**. The maximum slope on this proposed alignment is **11.16%**.

#### a) Scope of construction work

The approximate earthworks volumes for this road are indicated in **Table 6.11**.

**Table 6.11: Estimated earthworks volumes – Main access road**

Description	Volume/Area
Wearing course and base course	8 995 m <sup>3</sup>
Gravel sub-base	9 332 m <sup>3</sup>
Cut to fill	25 402 m <sup>3</sup>
Cut to spoil	48 251 m <sup>3</sup>
Import required	-
Asphalt/double deal	90 000 m <sup>2</sup>

These quantities were used to estimate the cost of the various alternatives for this road.

**b) Cost estimate**

The cost of the detailed design and construction of the access road is estimated in **Table 6.12**. It is assumed that sufficient amounts of material for layerworks will be obtainable by the roadworks contractor from nearby borrow pits.

**Table 6.12: Cost estimate – Main access road (excl VAT, 2014 Rand)**

Item	Description	Amount (R)
1	Preliminary and General	5 625 874
2	Accommodation of traffic	299 840
3	Clearing and grubbing	224 880
4	Cut to fill	2 032 178
5	Cut to spoil	3 618 839
6	Import	-
7	Extra over for excavation in hard material	525 000
8	Formation preparation	374 800
9	Selected layer	1 679 854
10	Sub-base	2 053 154
11	Wearing course/base course	2 698 560
12	Surfacing	21 600 000
13	Stormwater drainage	1 499 200

Item	Description	Amount (R)
14	Bridges (1:5 yr flood)	-
15	Erosion protection, landscaping & finishing	374 800
16	Erosion protection to high fill slopes	374 800
17	Road markings and road furniture	149 920
18	Contingencies	4 313 170
<b>19</b>	<b>Total for roadworks</b>	<b>47 444 867</b>
20	Total cost per km	6 329 358*
21	Professional fees and disbursements	6 167 833
<b>22</b>	<b>Total for professional fees</b>	<b>6 167 833</b>
<b>26</b>	<b>TOTAL</b>	<b>53 612 700</b>

\* This amount not included in total

## 6.2 TUNNEL

### 6.2.1 Access road to Ventilation/air shaft 1

#### a) Length and cross section

This road has a length of **70 m**. The maximum slope on this proposed alignment is **6.79%**.

#### a) Scope of construction work

The approximate earthworks volumes for this road are indicated in **Table 6.13**.

**Table 6.13: Estimated earthworks volumes – Access road to ventilation/air shaft 1**

Description	Volume (m <sup>3</sup> )
Wearing course and base course	2 522
Gravel sub-base	2617
Cut to fill	70
Cut to spoil	0
Import required	194

These quantities were used to estimate the cost of the various alternatives for this road.

**b) Cost estimate**

The cost of the detailed design and construction of the access road is estimated in **Table 6.14**. It is assumed that sufficient amounts of material for layerworks will be obtainable by the roadworks contractor from nearby borrow pits.

**Table 6.14: Cost estimate – Access road to ventilation/air shaft 1 (excl VAT, 2014 Rand)**

Item	Description	Amount (R)
1	Preliminary and General	491 169
2	Accommodation of traffic	84 080
3	Clearing and grubbing	63 060
4	Cut to fill	5 558
5	Cut to spoil	-
6	Import	15 503
7	Extra over for excavation in hard material	525 000
8	Formation preparation	105 100
9	Selected layer	471 058
10	Sub-base	575 738
11	Wearing course/base course	756 720
12	Surfacing	-

Item	Description	Amount (R)
13	Stormwater drainage	420 400
14	Bridges (1:5 yr flood)	-
15	Erosion protection, landscaping & finishing	105 100
16	Erosion protection to high fill slopes	105 100
17	Road markings and road furniture	42 040
18	Contingencies	376 563
<b>19</b>	<b>Total for roadworks</b>	<b>4 142 189</b>
20	Total cost per km	1 970 594*
21	Professional fees and disbursements	538 485
<b>22</b>	<b>Total for professional fees</b>	<b>538 485</b>
<b>TOTAL</b>		<b>4 680 673</b>

\* This amount not included in total

### 6.2.2 Access road to Ventilation/air shaft 3

#### a) Length and cross section

This road has a length of **68 m**. The maximum slope on this proposed alignment is **13.64%**.

#### a) Scope of construction work

The approximate earthworks volumes for this road are indicated in **Table 6.15**.

**Table 6.15: Estimated earthworks volumes – Access road to Ventilation/air shaft 3**

Description	Volume (m <sup>3</sup> )
Wearing course and base course	82
Gravel sub-base	85
Cut to fill	184
Cut to spoil	-
Import required	46

These quantities were used to estimate the cost of the various alternatives for this road.

**b) Cost estimate**

The cost of the detailed design and construction of the access road is estimated in **Table 6.16**. It is assumed that sufficient amounts of material for layerworks will be obtainable by the roadworks contractor from nearby borrow pits.

**Table 6.16: Cost estimate – Access road to Ventilation/air shaft 3 (excl VAT, 2014 Rand)**

Item	Description	Amount (R)
1	Preliminary and General	21 249
2	Accommodation of traffic	2 720
3	Clearing and grubbing	2 040
4	Cut to fill	14 708
5	Cut to spoil	-
6	Import	3 686
7	Extra over for excavation in hard material	35 000
8	Formation preparation	3 400
9	Selected layer	15 239
10	Sub-base	18 625
11	Wearing course/base course	24 480
12	Surfacing	-
13	Stormwater drainage	13 600
14	Bridges (1:5 yr flood)	-
15	Erosion protection, landscaping & finishing	3 400
16	Erosion protection to high fill slopes	3 400
17	Road markings and road furniture	1 360
18	Contingencies	16 291
<b>19</b>	<b>Total for roadworks</b>	<b>179 198</b>



Item	Description	Amount (R)
20	Total cost per km	2 635 263*
21	Professional fees and disbursements	23 296
<b>22</b>	<b>Total for professional fees</b>	<b>23 296</b>
<b>TOTAL</b>		<b>202 494</b>

\* This amount not included in total

### 6.2.3 Access road to centre adit entry

#### a) Length and cross section

This road has a length of **2.10 km**. The maximum slope on this proposed alignment is **13.88%**.

#### a) Scope of construction work

The approximate earthworks volumes for this road are indicated in **Table 6.17**.

**Table 6.17: Estimated earthworks volumes – Access road to centre adit entry**

Description	Volume (m <sup>3</sup> )
Wearing course and base course	2 522
Gravel sub-base	2 617
Cut to fill	37 249
Cut to spoil	13 708
Import required	-

These quantities were used to estimate the cost of the various alternatives for this road.

#### b) Cost estimate

The cost of the detailed design and construction of the access road is estimated in **Table 6.18**. It is assumed that sufficient amounts of material for

layerworks will be obtainable by the roadworks contractor from nearby borrow pits.

**Table 6.18: Cost estimate – Access road to centre adit entry (excl VAT, 2014 Rand)**

Item	Description	Amount (R)
1	Preliminary and General	1 272 967
2	Accommodation of traffic	84 080
3	Clearing and grubbing	63 060
4	Cut to fill	2 979 955
5	Cut to spoil	1 028 096
6	Import	-
7	Extra over for excavation in hard material	1 750 000
8	Formation preparation	105 100
9	Selected layer	471 058
10	Sub-base	575 738
11	Wearing course/base course	756 720
12	Surfacing	-
13	Stormwater drainage	420 400
14	Bridges (1:5 yr flood)	-
15	Erosion protection, landscaping & finishing	105 100
16	Erosion protection to high fill slopes	105 100
17	Road markings and road furniture	42 040
18	Contingencies	975 941
<b>19</b>	<b>Total for roadworks</b>	<b>10 735 355</b>
20	Total cost per km	5 107 210*
21	Professional fees and disbursements	1 395 596
<b>22</b>	<b>Total for professional fees</b>	<b>1 395 596</b>
<b>TOTAL</b>		<b>12 130 951</b>

\* This amount not included in total

## 6.3 LANGA DAM

### 6.3.1 Access road to tunnel outlet portal and Langa Dam (Option 1)

Two options were investigated for this road. Option 1 is shown in purple in **Appendix B**, whereas Option 2 is shown in green. The latter section of these roads follows the same alignment for the last 2.3 km.

From the earthworks volumes and the cost estimates, it is clear that Option 2 is the preferred option between these two routes. Option 2 is discussed in more detail in **Section 8.3.2**.

#### a) Length and cross section

This road has a length of **4.68 km**. The maximum slope on this proposed alignment is **13.9%**.

#### a) Scope of construction work

The approximate earthworks volumes for this road are indicated in **Table 6.19**.

**Table 6.19: Estimated earthworks volumes – Access road to tunnel outlet portal and Langa Dam (Option 1)**

Description	Volume (m <sup>3</sup> )
Wearing course and base course	5 614
Gravel sub-base	5 824
Cut to fill	64 314
Cut to spoil	-
Import required	11 799

These quantities were used to estimate the cost of the various alternatives for this road.

**b) Cost estimate**

The cost of the detailed design and construction of the access road is estimate in **Table 6.20**. It is assumed that sufficient amounts of material for layerworks will be obtainable by the roadworks contractor from nearby borrow pits.

**Table 6.20: Cost estimate – Access road to tunnel outlet portal and Langa Dam (Option 1) (excl VAT, 2014 Rand)**

Item	Description	Amount (R)
1	Preliminary and General	4 260 627
2	Accommodation of traffic	187 120
3	Clearing and grubbing	140 340
4	Cut to fill	5 145 135
5	Cut to spoil	-
6	Import	943 920
7	Extra over for excavation in hard material	525 000
8	Formation preparation	233 900
9	Selected layer	1 048 340
10	Sub-base	1 281 304
11	Wearing course/base course	1 684 080
12	Surfacing	15 718 080
13	Stormwater drainage	935 600
14	Bridges (1:5 yr flood)	-
15	Erosion protection, landscaping & finishing	233 900
16	Erosion protection to high fill slopes	233 900
17	Road markings and road furniture	93 560
18	Contingencies	3 266 481
<b>19</b>	<b>Total for roadworks</b>	<b>35 931 287</b>
20	Total cost per km	7 680 908*
21	Professional fees and disbursements	4 671 067
<b>22</b>	<b>Total for professional fees</b>	<b>4 671 067</b>
<b>TOTAL</b>		<b>40 602 354</b>

\* This amount not included in total

### 6.3.2 Access road to tunnel outlet portal and Langa Dam (Option 2)

As mentioned previously, Option 2 is the preferable option based on costs and earthworks volumes.

#### a) Length and cross section

This road has a length of **4.69 km**. The maximum slope on this proposed alignment is **8.79%**. Given the maximum slope, earthworks volumes and cost difference, this option is the preferred one.

#### a) Scope of construction work

The approximate earthworks volumes for this road are indicated in **Table 6.21**.

**Table 6.21: Estimated earthworks volumes – Access road to tunnel outlet portal and Langa Dam (Option 2)**

Description	Volume (m <sup>3</sup> )
Wearing course and base course	5 628
Gravel sub-base	5 839
Cut to fill	21 943
Cut to spoil	5 847
Import required	-

These quantities were used to estimate the cost of the various alternatives for this road.

#### b) Cost estimate

The cost of the detailed design and construction of the access road is estimated in **Table 6.22**. It is assumed that sufficient amounts of material for layerworks will be obtainable by the roadworks contractor from nearby borrow pits.

**Table 6.22: Cost estimate – Access road to tunnel outlet portal and Langa Dam (Option 2) (excl VAT, 2014 Rand)**

<b>Item</b>	<b>Description</b>	<b>Amount (R)</b>
1	Preliminary and General	4 332 419
2	Accommodation of traffic	93 800
3	Clearing and grubbing	703 500
4	Cut to fill	1 974 870
5	Cut to spoil	526 230
6	Import	-
7	Extra over for excavation in hard material	45 000
8	Formation preparation	7 035 000
9	Selected layer	875 858
10	Sub-base	875 858
11	Wearing course/base course	562 800
12	Surfacing	15 758 400
13	Stormwater drainage	93 800
14	Bridges (1:5 yr flood)	-
15	Erosion protection, landscaping & finishing	234 500
16	Erosion protection to high fill slopes	93 800
17	Road markings and road furniture	9 380
18	Contingencies	3 321 521
<b>19</b>	<b>Total for roadworks</b>	<b>36 536 736</b>
20	Total cost per km	7 790 349*
21	Professional fees and disbursements	4 749 776
<b>22</b>	<b>Total for professional fees</b>	<b>4 749 776</b>
<b>TOTAL</b>		<b>41 286 511</b>

\* This amount not included in total

## 6.4 GAUGING WEIRS

### 6.4.1 Access roads to gauging weir upstream of Smithfield Dam

#### a) Length and cross section

This road has a length of **0.170 km**. The maximum slope on this proposed alignment is **14%**.

#### a) Scope of construction work

The approximate earthworks volumes for this road are indicated in **Table 6.23**.

**Table 6.23: Estimated earthworks volumes – Gauging weir upstream of Smithfield Dam**

Description	Volume (m <sup>3</sup> )
Wearing course and base course	204
Gravel sub-base	211
Cut to fill	307
Cut to spoil	-
Import required	97

These quantities were used to estimate the cost of the various alternatives for this road.

#### b) Cost estimate

The cost of the detailed design and construction of the access road is estimated in **Table 6.24**. It is assumed that sufficient amounts of material for layerworks will be obtainable by the roadworks contractor from nearby borrow pits.

**Table 6.24: Cost estimate – Access road to gauging weir upstream of Smithfield Dam (excl VAT, 2014 Rand)**

Item	Description	Amount (R)
1	Preliminary and General	38 095
2	Accommodation of traffic	3 400
3	Clearing and grubbing	25 500
4	Cut to fill	27 630
5	Cut to spoil	-
6	Import	19 400
7	Extra over for excavation in hard material	70 000
8	Formation preparation	8 500
9	Selected layer	31 748
10	Sub-base	31 748
11	Wearing course/base course	20 400
12	Surfacing	-
13	Stormwater drainage	3 400
14	Bridges (1:5 yr flood)	-
15	Erosion protection, landscaping & finishing	8 500
16	Erosion protection to high fill slopes	3 400
17	Road markings and road furniture	340
18	Contingencies	29 206
<b>19</b>	<b>Total for roadworks</b>	<b>321 266</b>
20	Total cost per km	1 889 798*
21	Professional fees and disbursements	41 765
<b>22</b>	<b>Total for professional fees</b>	<b>41 765</b>
<b>TOTAL</b>		<b>363 030</b>

\* This amount not included in total

#### 6.4.2 Access roads to gauging weir downstream of Smithfield Dam

##### a) a) Length and cross section

This road has a length of **2.165 km**. The maximum slope on this proposed alignment is **8.3%**.



**b) Scope of construction work**

The approximate earthworks volumes for this road are indicated in **Table 6.25**.

**Table 6.25: Estimated earthworks volumes – Gauging weir downstream of Smithfield Dam**

Description	Volume (m <sup>3</sup> )
Wearing course and base course	2 598
Gravel sub-base	2 695
Cut to fill	8 513
Cut to spoil	-
Import required	247

These quantities were used to estimate the cost of the various alternatives for this road.

**b) Cost estimate**

The cost of the detailed design and construction of the access road is estimated in **Table 6.26**. It is assumed that sufficient amounts of material for layerworks will be obtainable by the roadworks contractor from nearby borrow pits.

**Table 6.26: Cost estimate – Access road to gauging weir downstream of Smithfield Dam (excl VAT, 2014 Rand)**

Item	Description	Amount (R)
1	Preliminary and General	436 422
2	Accommodation of traffic	43 300
3	Clearing and grubbing	324 750
4	Cut to fill	766 170
5	Cut to spoil	-
6	Import	49 400
7	Extra over for excavation in hard material	350 000

Item	Description	Amount (R)
8	Formation preparation	108 250
9	Selected layer	404 314
10	Sub-base	404 314
11	Wearing course/base course	259 800
12	Surfacing	-
13	Stormwater drainage	43 300
14	Bridges (1:5 yr flood)	-
15	Erosion protection, landscaping & finishing	108 250
16	Erosion protection to high fill slopes	43 300
17	Road markings and road furniture	4 330
18	Contingencies	334 590
<b>19</b>	<b>Total for roadworks</b>	<b>3 680 489</b>
20	Total cost per km	1 699 995*
21	Professional fees and disbursements	478 464
<b>22</b>	<b>Total for professional fees</b>	<b>478 464</b>
<b>TOTAL</b>		<b>4 158 953</b>

\* This amount not included in total

### 6.4.3 Access roads to gauging weir near IFR site

#### a) Length and cross section

This road has a length of **2.516 km**. The maximum slope on this proposed alignment is **8.8%**.

#### a) Scope of construction work

The approximate earthworks volumes for this road are indicated in **Table 6.27**.

**Table 6.27: Estimated earthworks volumes – Gauging weir near IFR site**

Description	Volume (m <sup>3</sup> )
Wearing course and base course	3 019
Gravel sub-base	3 132
Cut to fill	26 656
Cut to spoil	1 184
Import required	-

These quantities were used to estimate the cost of the various alternatives for this road.

**b) Cost estimate**

The cost of the detailed design and construction of the access road is estimated in **Table 6.28**. It is assumed that sufficient amounts of material for layerworks will be obtainable by the roadworks contractor from nearby borrow pits.

**Table 6.28: Cost estimate – Access road to gauging weir near IFR site (excl VAT, 2014 Rand)**

Item	Description	Amount (R)
1	Preliminary and General	758 586
2	Accommodation of traffic	50 320
3	Clearing and grubbing	377 400
4	Cut to fill	2 399 040
5	Cut to spoil	106 560
6	Import	-
7	Extra over for excavation in hard material	525 000
8	Formation preparation	125 800
9	Selected layer	469 863
10	Sub-base	469 863
11	Wearing course/base course	301 920
12	Surfacing	-

Item	Description	Amount (R)
13	Stormwater drainage	50 320
14	Bridges (1:5 yr flood)	-
15	Erosion protection, landscaping & finishing	125 800
16	Erosion protection to high fill slopes	50 320
17	Road markings and road furniture	5 032
18	Contingencies	581 582
<b>19</b>	<b>Total for roadworks</b>	<b>6 397 406</b>
20	Total cost per km	2 542 689*
21	Professional fees and disbursements	831 663
<b>22</b>	<b>Total for professional fees</b>	<b>831 663</b>
<b>TOTAL</b>		<b>7 229 069</b>

\* This amount not included in total

## 7 ACCESS ROADS COST ESTIMATE SUMMARY

The table below displays the cost summary of the access roads needed for the development. These costs are in 2014 Rands, and include preliminary, general and contingency costs, professional fees and disbursements, excluding VAT.

**Table 7.1: Cost estimate summary – Access roads (excl VAT, 2014 Rands)**

Item	Description	Amount (R) <sup>#</sup>
<b>1</b>	<b>Smithfield Dam</b>	
1.1	Deviation of the R617	143 584 195
1.2	Access road to Nonguqa	23 303 741
1.4	Access road to tunnel inlet portal	668 562
1.5	Access road to dam wall	4 927 925
1.6	Construction road	19 175 704
1.7	Main access road	53 612 700
<b>2</b>	<b>Tunnel</b>	
2.1	Access road to Ventilation/air shaft 1	4 680 673
2.2	Access road to Ventilation/air shaft 3	202 494
2.3	Access road to centre adit entry	12 130 951
<b>3</b>	<b>Langa Balancing Dam</b>	
3.1	Access road to tunnel outlet and Langa Dam (Option 2)	41 286 511
<b>4</b>	<b>Gauging Weirs</b>	
4.1	Access road to gauging weir upstream of Smithfield Dam	363 030
4.2	Access road to gauging weir downstream of Smithfield Dam	4 158 953
4.3	Access road to gauging weir at IFR site	7 229 069
	<b>TOTAL</b>	<b>315 324 507<sup>#</sup></b>

\* Access road to tunnel outlet portal and Langa Dam (Option 1) was not included in the total

# Include preliminary, general and contingency costs, professional fees and disbursements.

## 8 FINDINGS AND RECOMMENDATIONS

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- ◆ New access and construction roads as well as deviation of existing roads for the Smithfield Dam, tunnel, Langa Dam and the proposed gauging weirs were investigated for best alignment and allowable vertical slopes. Only the finally selected roads are discussed and a cost estimate carried out in this report, except for the access road to the tunnel outlet portal and the Langa Dam, where two alternatives (Options 1 & 2) were proposed. Although these two routes are very similar in length, it was found that Option 2 will be the preferred option from a geometric and cost point of view.
- ◆ The cost of the access road to the water treatment works was not included in the total cost of the raw water system, due to the fact that this road forms part of the potable water system. The cost will therefore be included in the total cost of the potable water system.
- ◆ No retaining structures are required on any of the routes, and an attempt was made to keep the fills to a minimum, also bearing in mind that at some sections, there will be huge volumes of spoil material which will be spoiled at the closest fill position and not at a spoiling site.
- ◆ It was assumed that road building material will be readily available and therefore do not need to be imported from distant quarries or other commercial sources.
- ◆ The cost estimates for the roads include a 15% premium on actual construction cost for contractor's preliminary and general, as well as a 10% contingency allowance.
- ◆ The total estimated cost per km for gravel roads ranges between **R 2.54 million** to **R 5.11 million**, depending on the amount of earthworks required.
- ◆ The estimated cost per km for the surfaced R617 deviation is **R 10.5 million**, which includes 2 bridges and a **30 mm** asphalt wearing course.

# Appendix A

## Smithfield Dam road layout plans

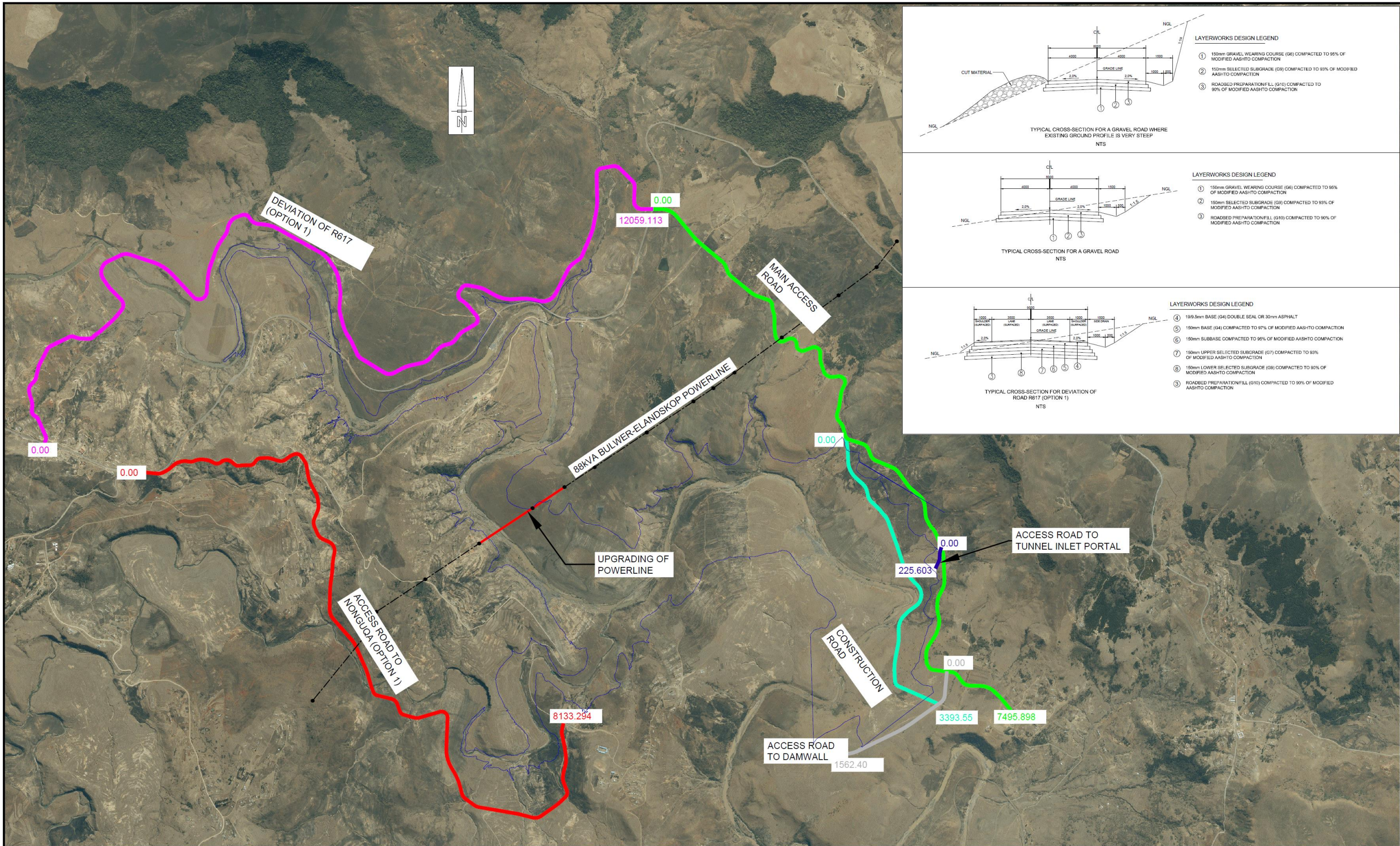


Figure A0: Smithfield Dam – Key plan of road deviation and upgrading of powerline



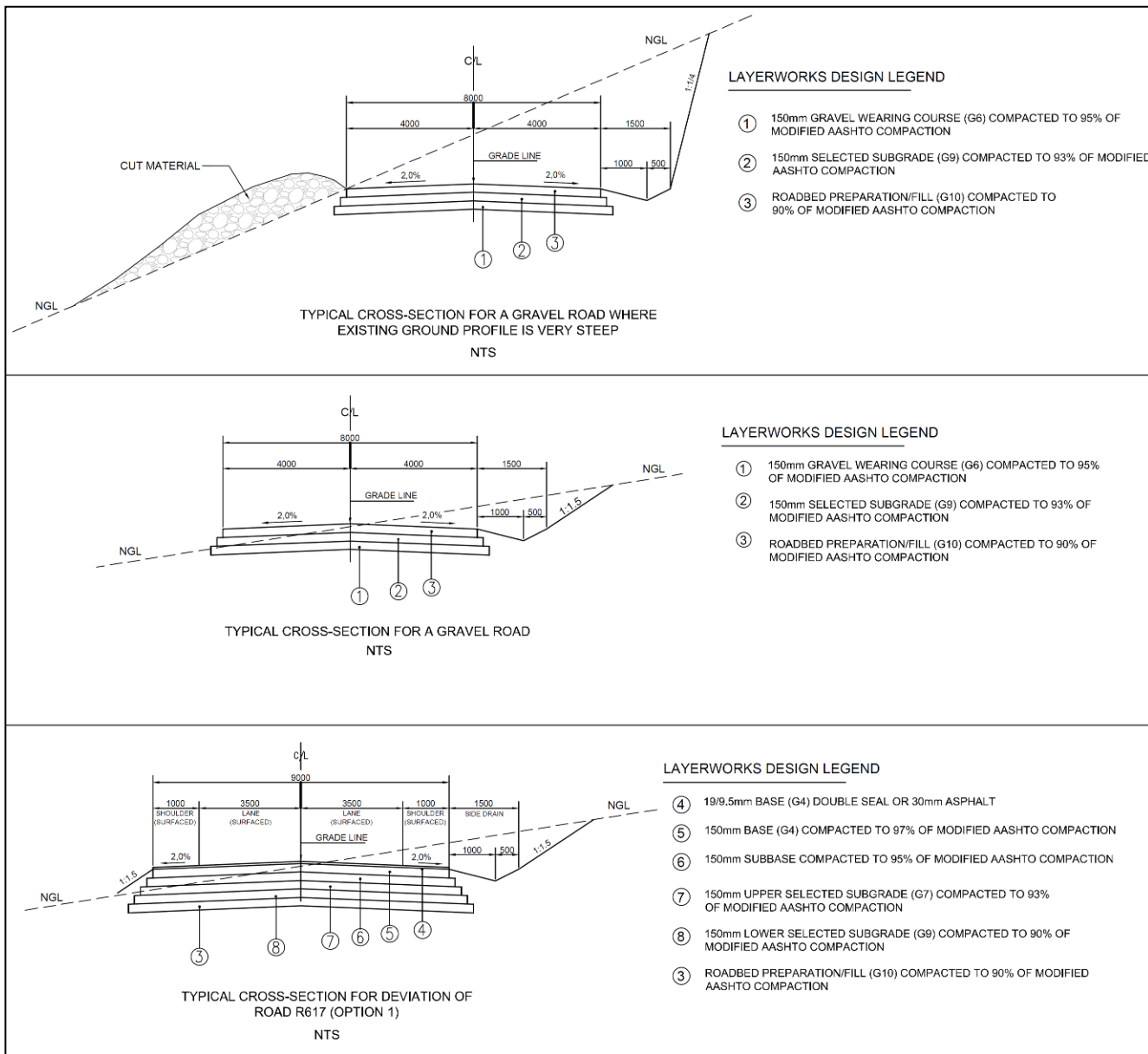


Figure A1.0: Smithfield Dam - Typical cross sections for road categories

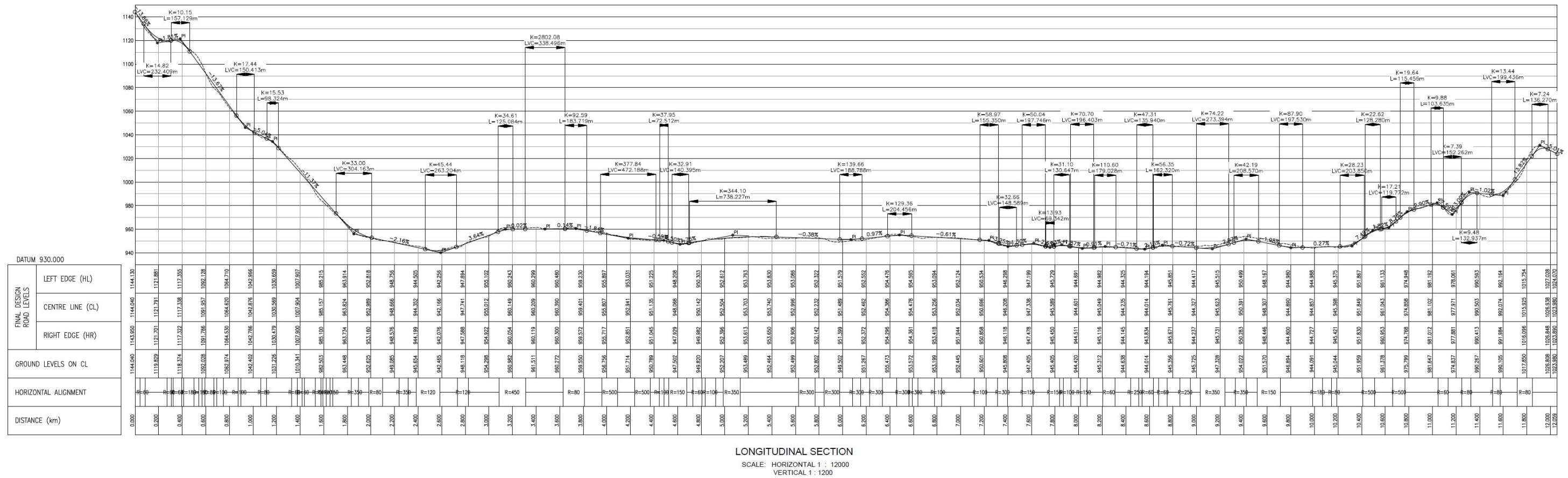
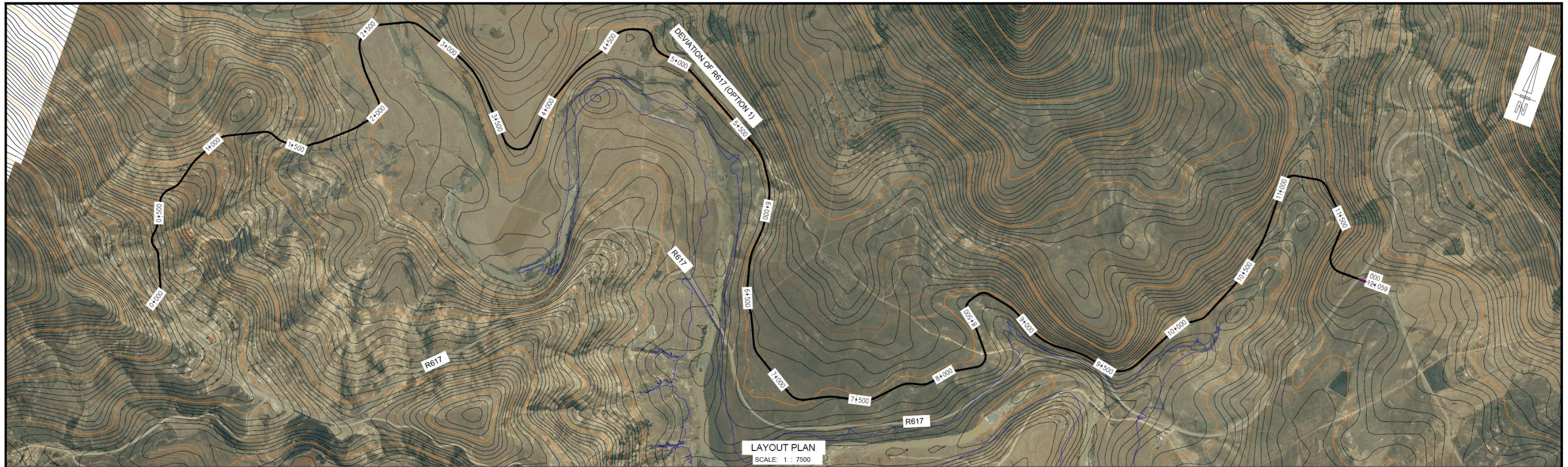


Figure A1.1: Smithfield Dam – Layout plan and longitudinal section of the deviation of road R617

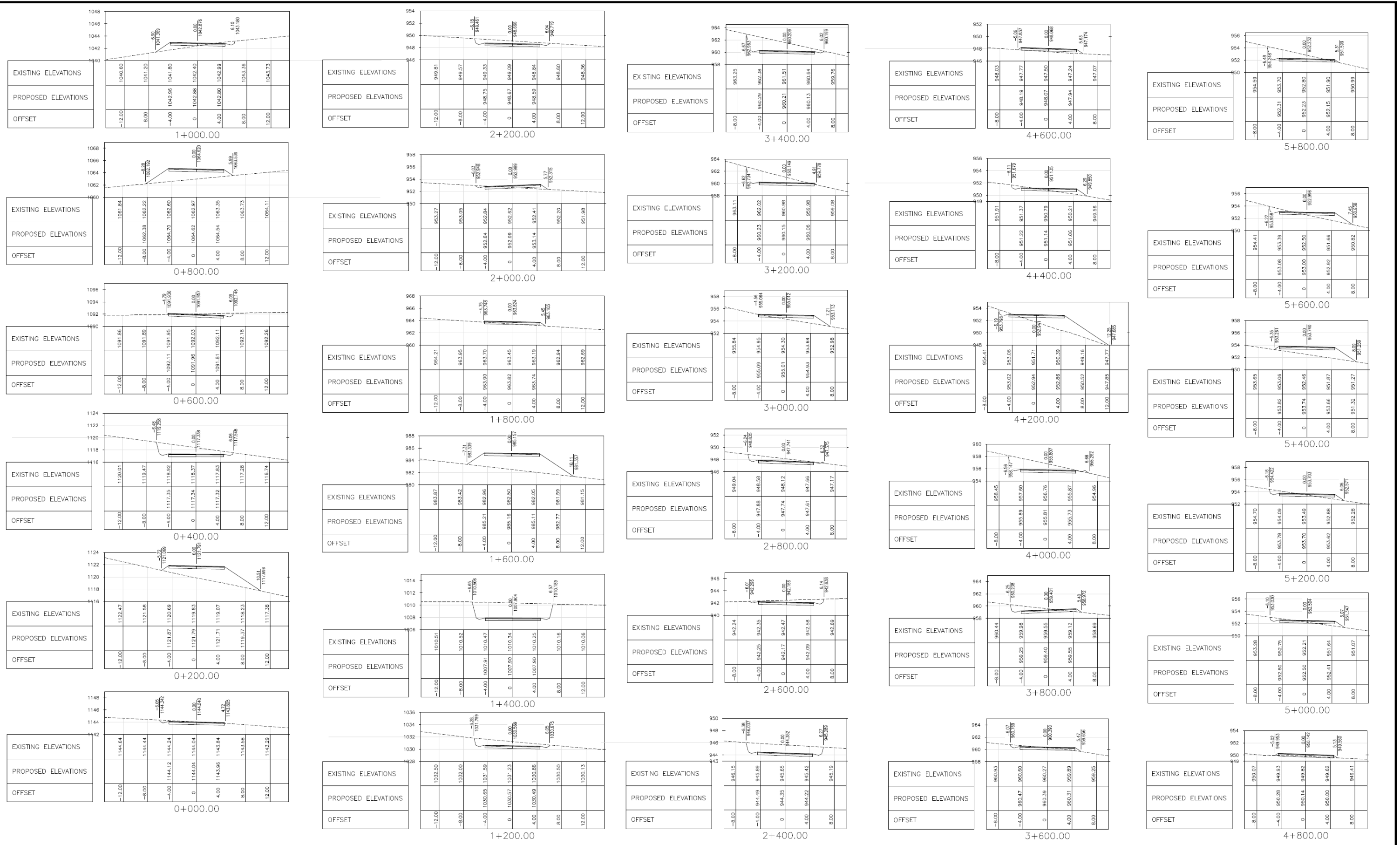


Figure A1.2: Smithfield Dam - Deviation of road R617 with cross sections

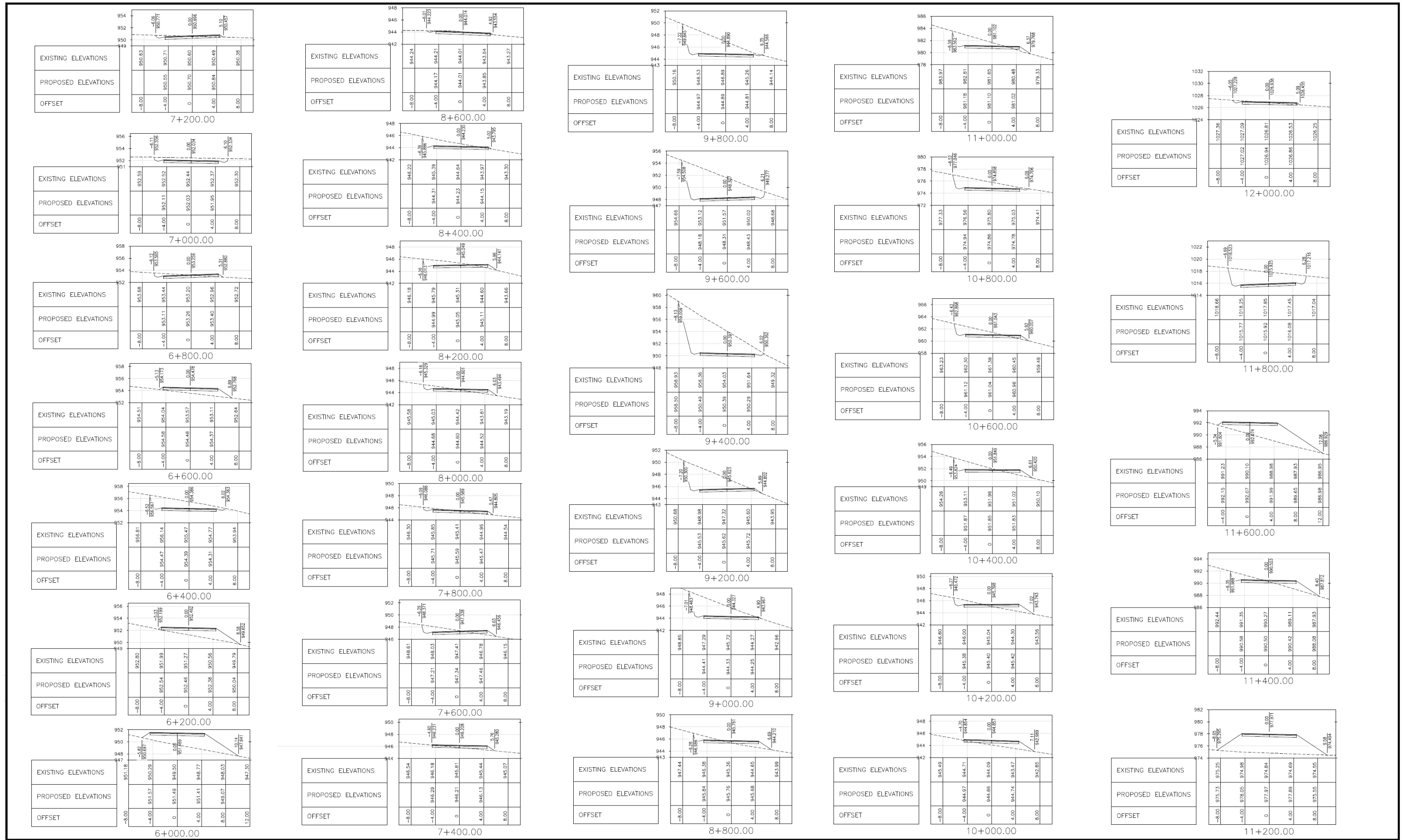


Figure A1.3: Smithfield Dam - Deviation of road R617 with cross sections

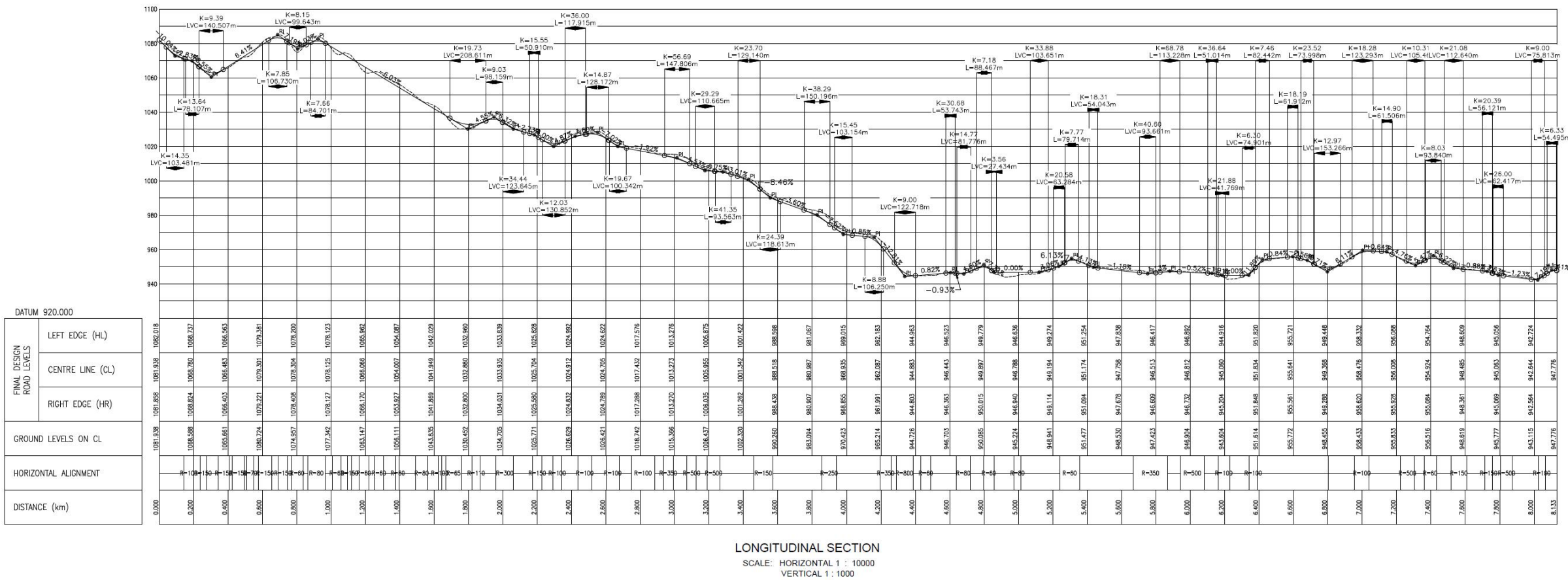
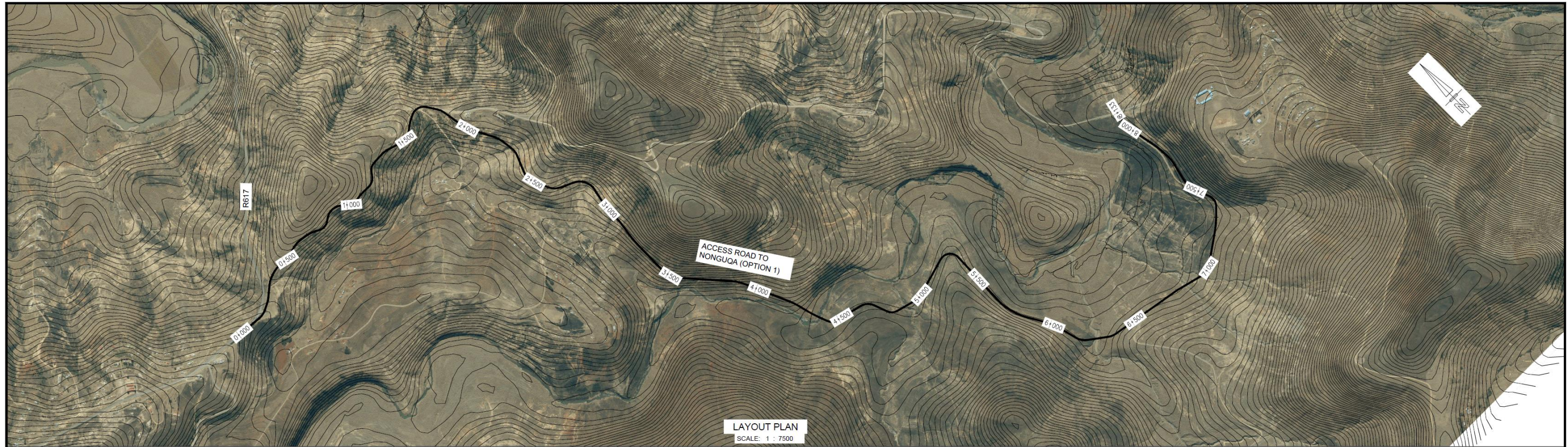


Figure A2.1: Smithfield Dam – Layout plan and longitudinal section of access road to Nonguqa

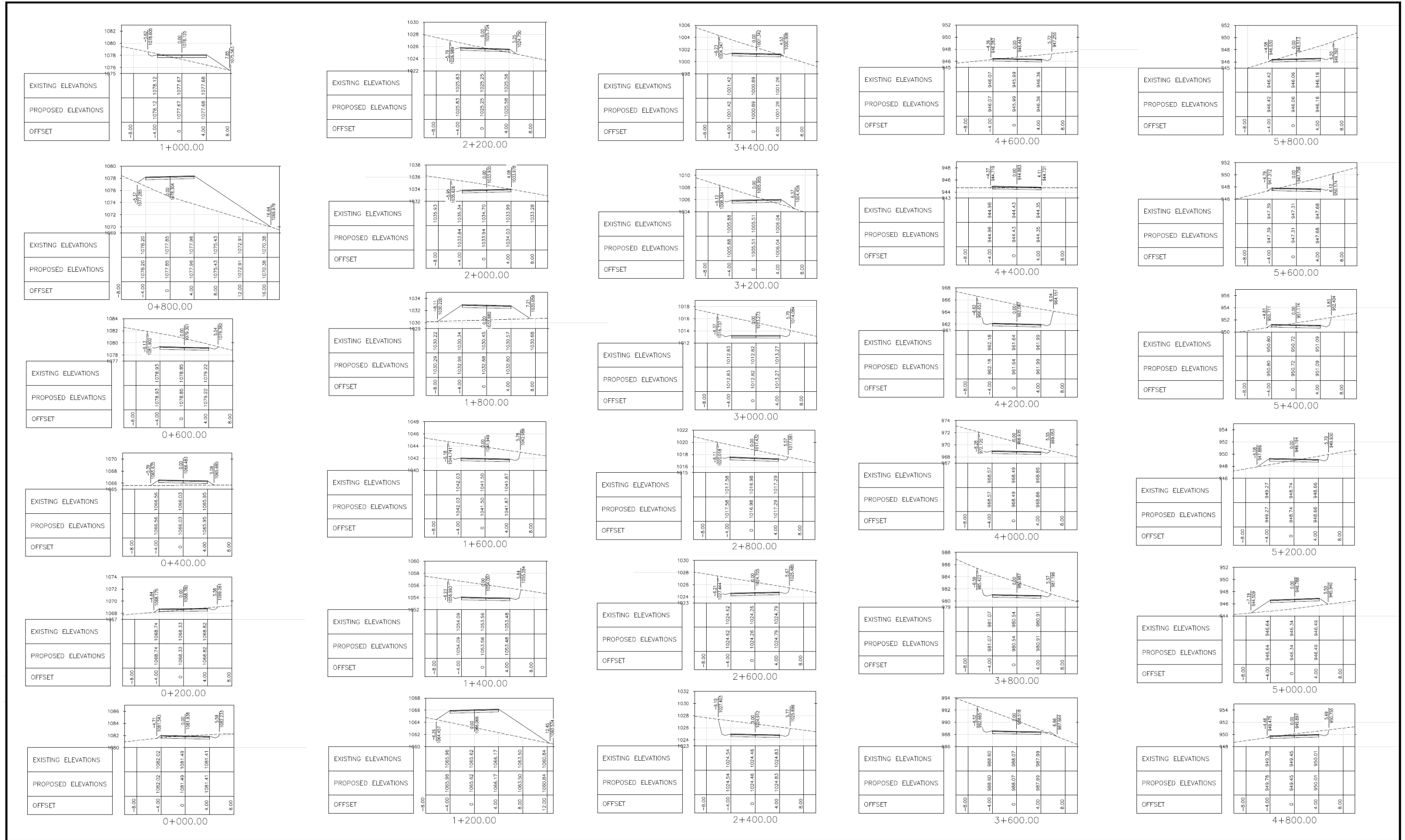


Figure A2.2: Smithfield Dam – Cross sections of access road to Nonguqa

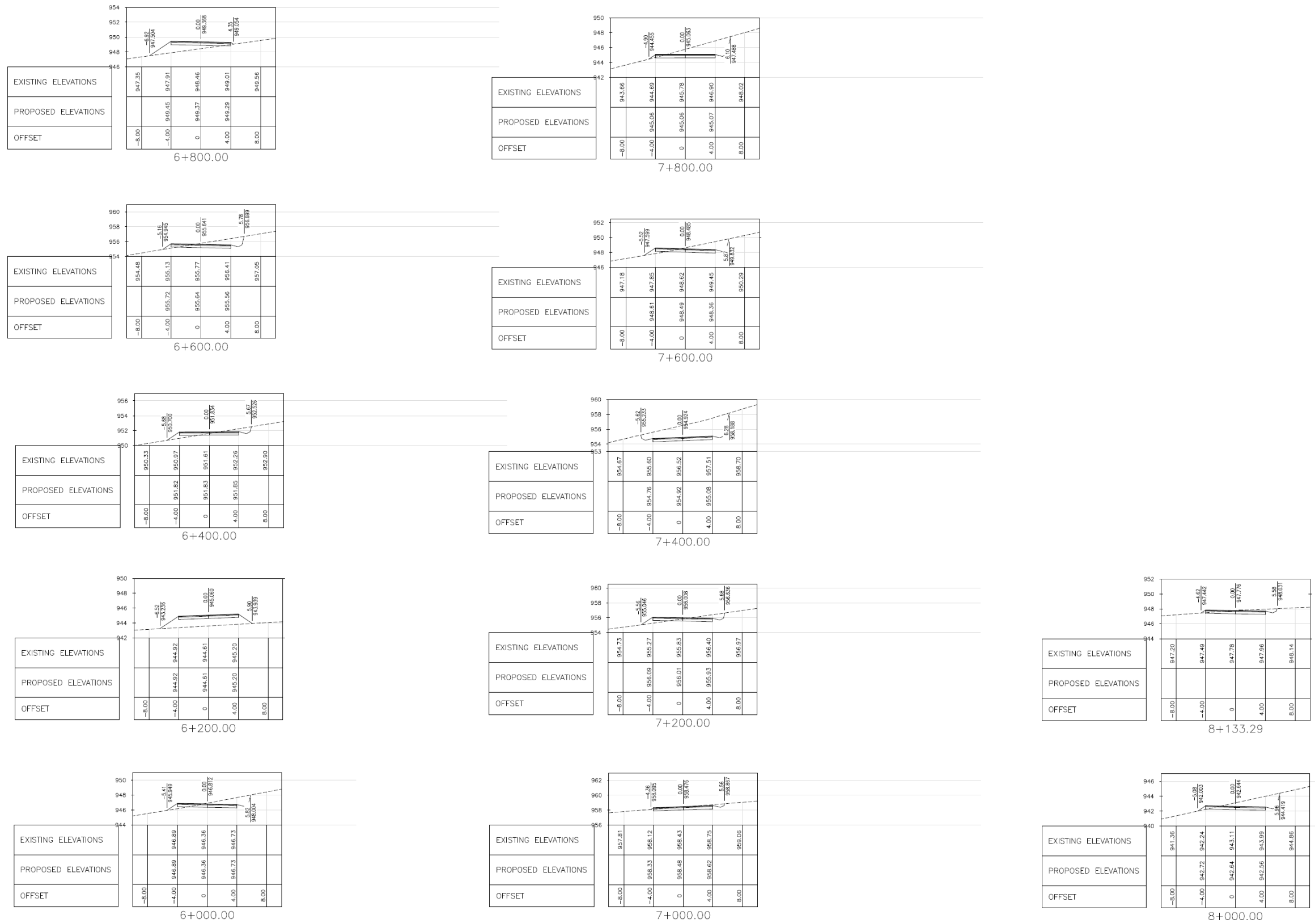


Figure A2.3: Smithfield Dam – Cross sections of access road to Nonguqa

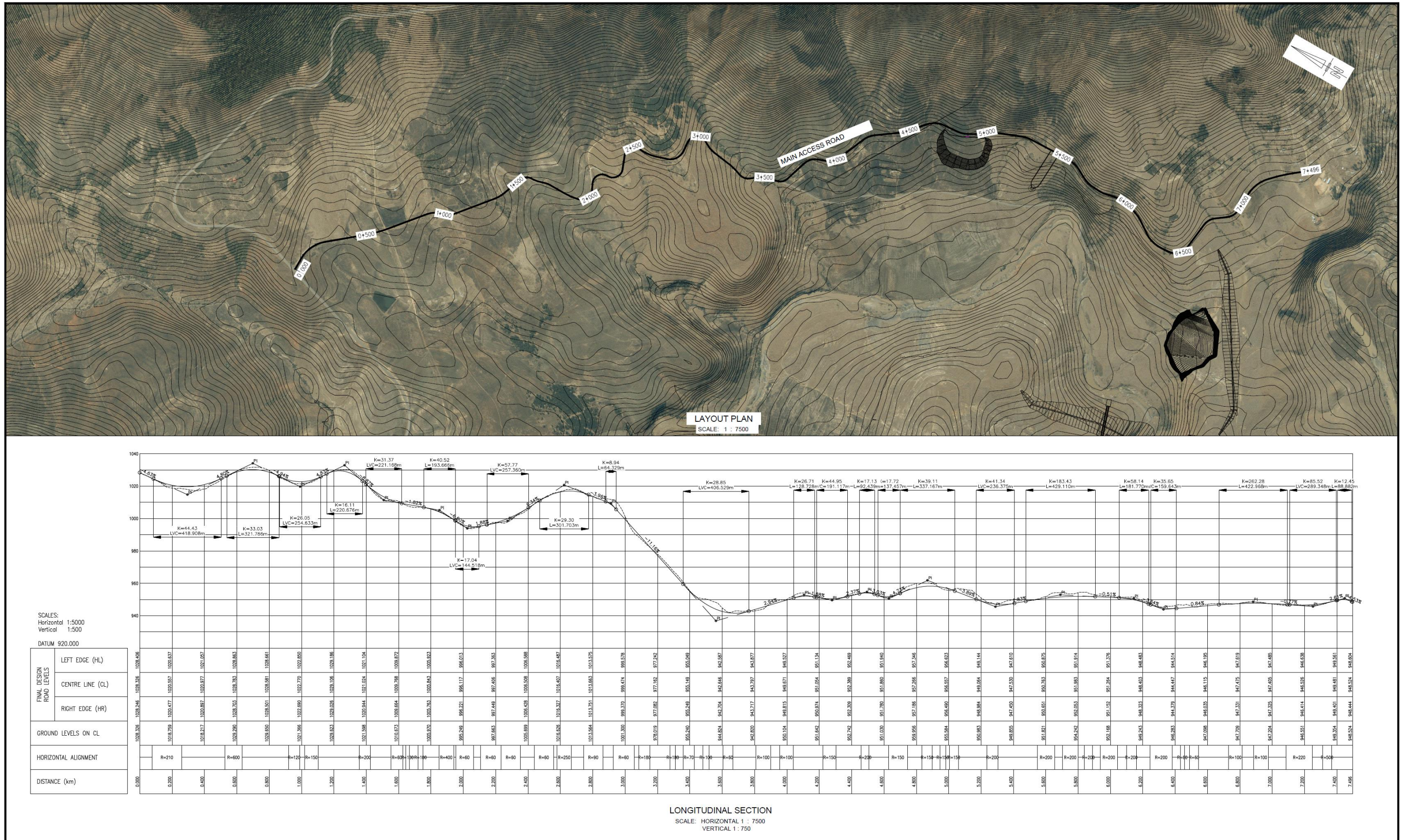


Figure A3.1: Smithfield Dam – Layout plan and longitudinal section of main access road



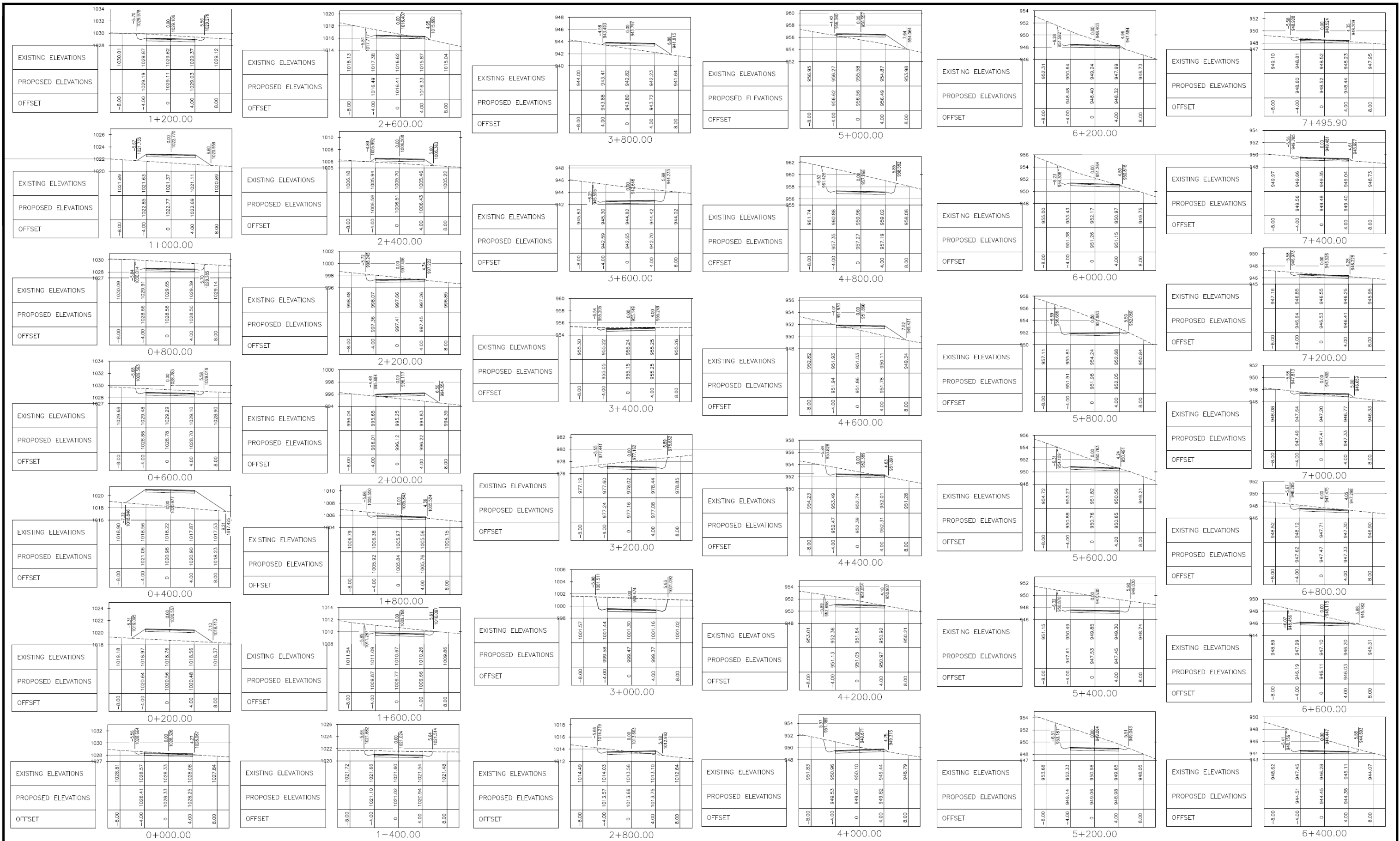


Figure A3.2: Smithfield Dam – Cross sections of main access road

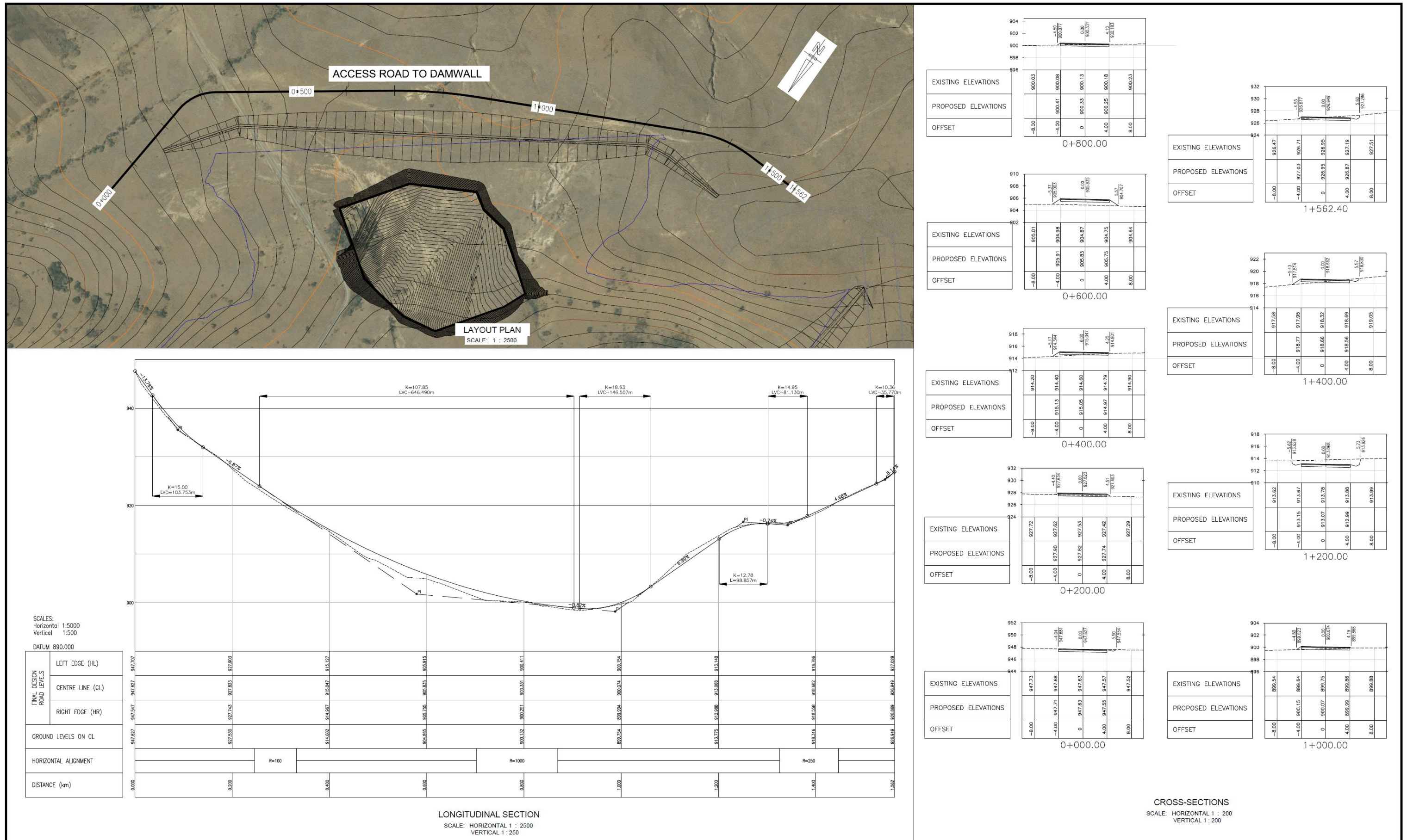


Figure A4.1: Smithfield Dam – Layout plan, longitudinal section and cross sections of access road to damwall

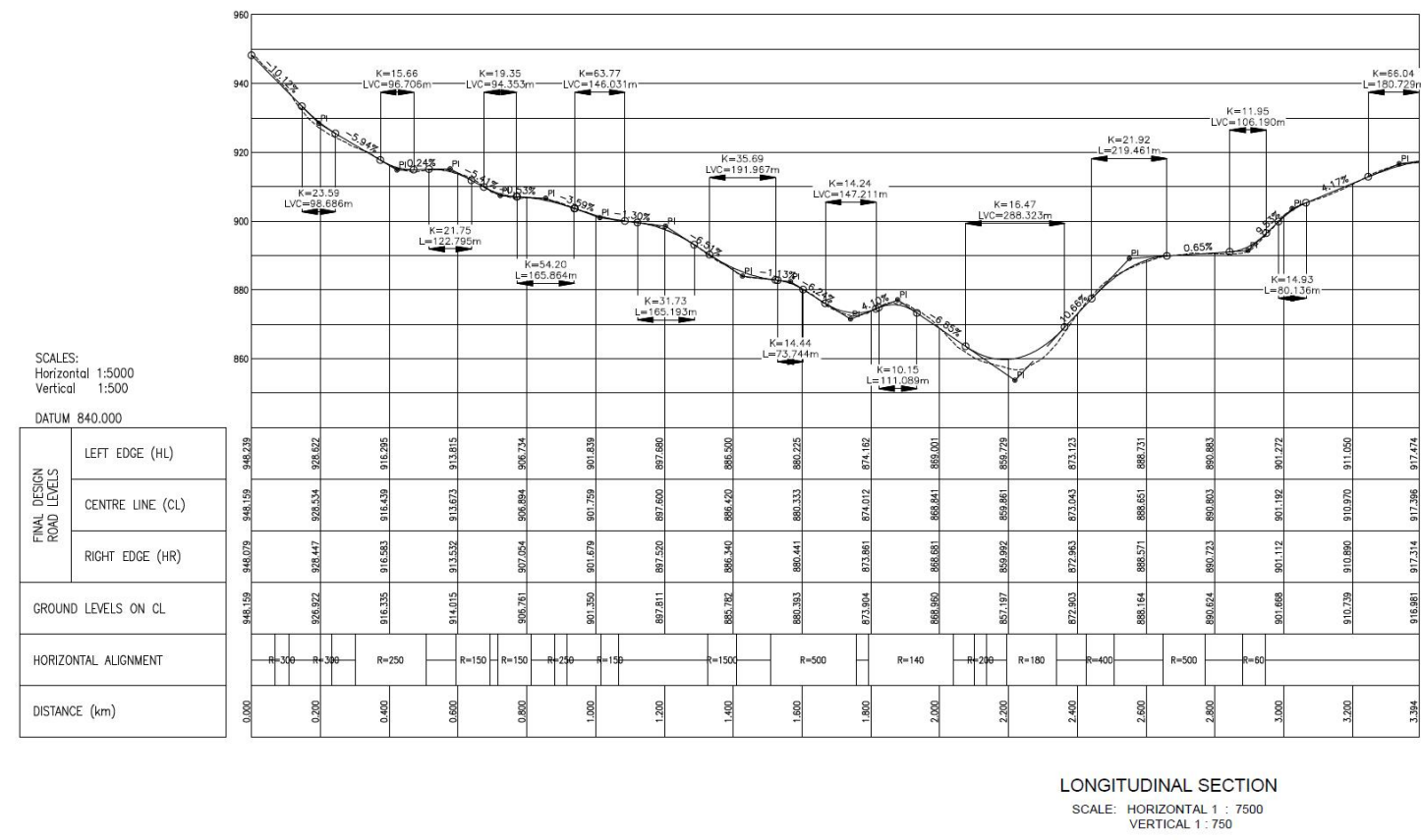
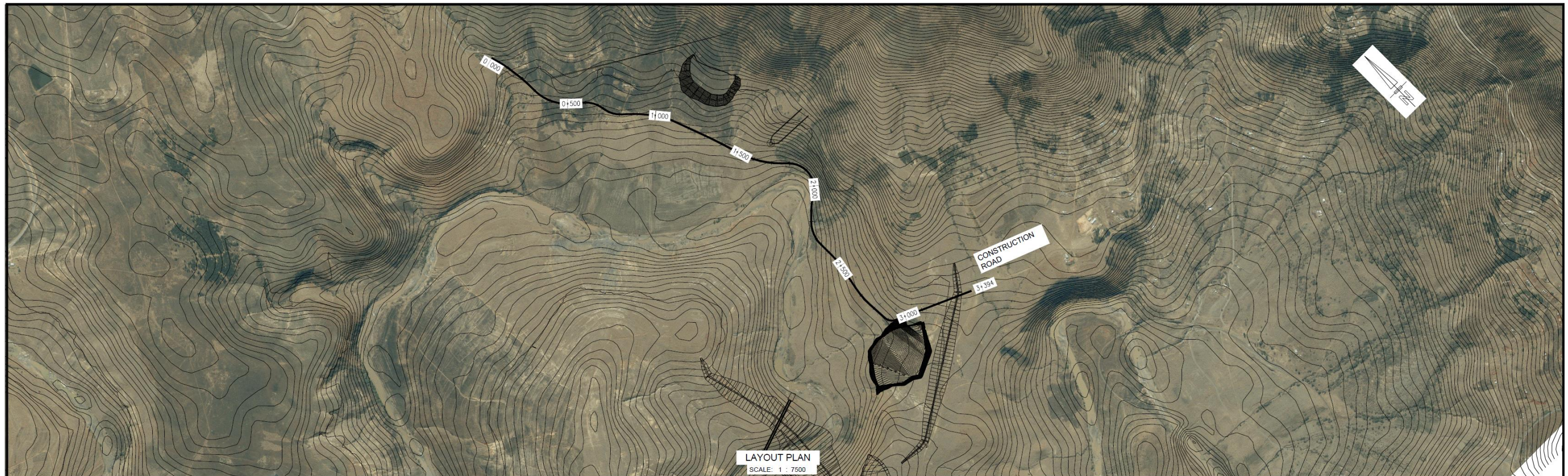


Figure A5.1: Smithfield Dam – Layout plan and longitudinal section of construction road

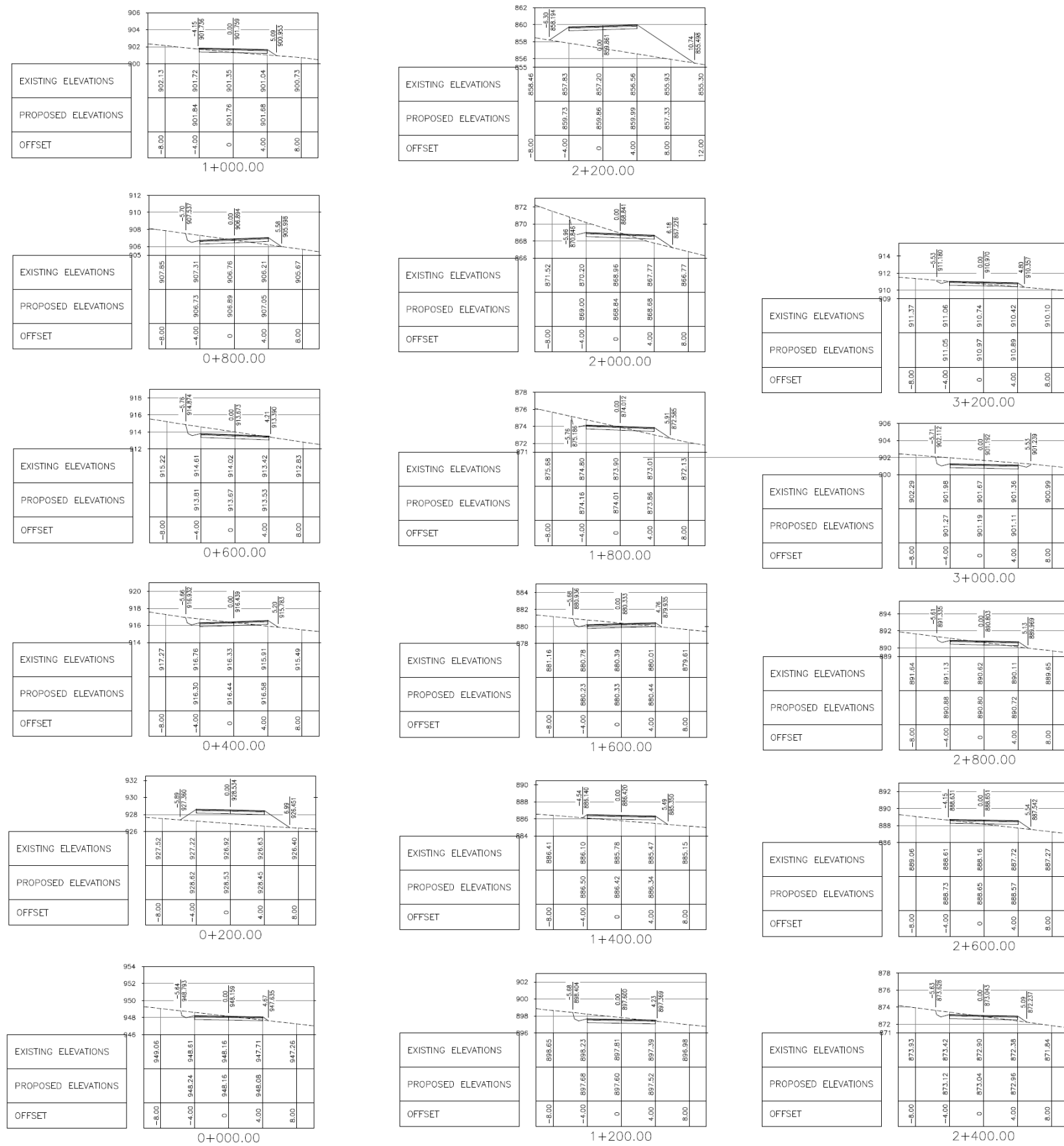


Figure A5.2: Smithfield Dam – Cross sections of construction road

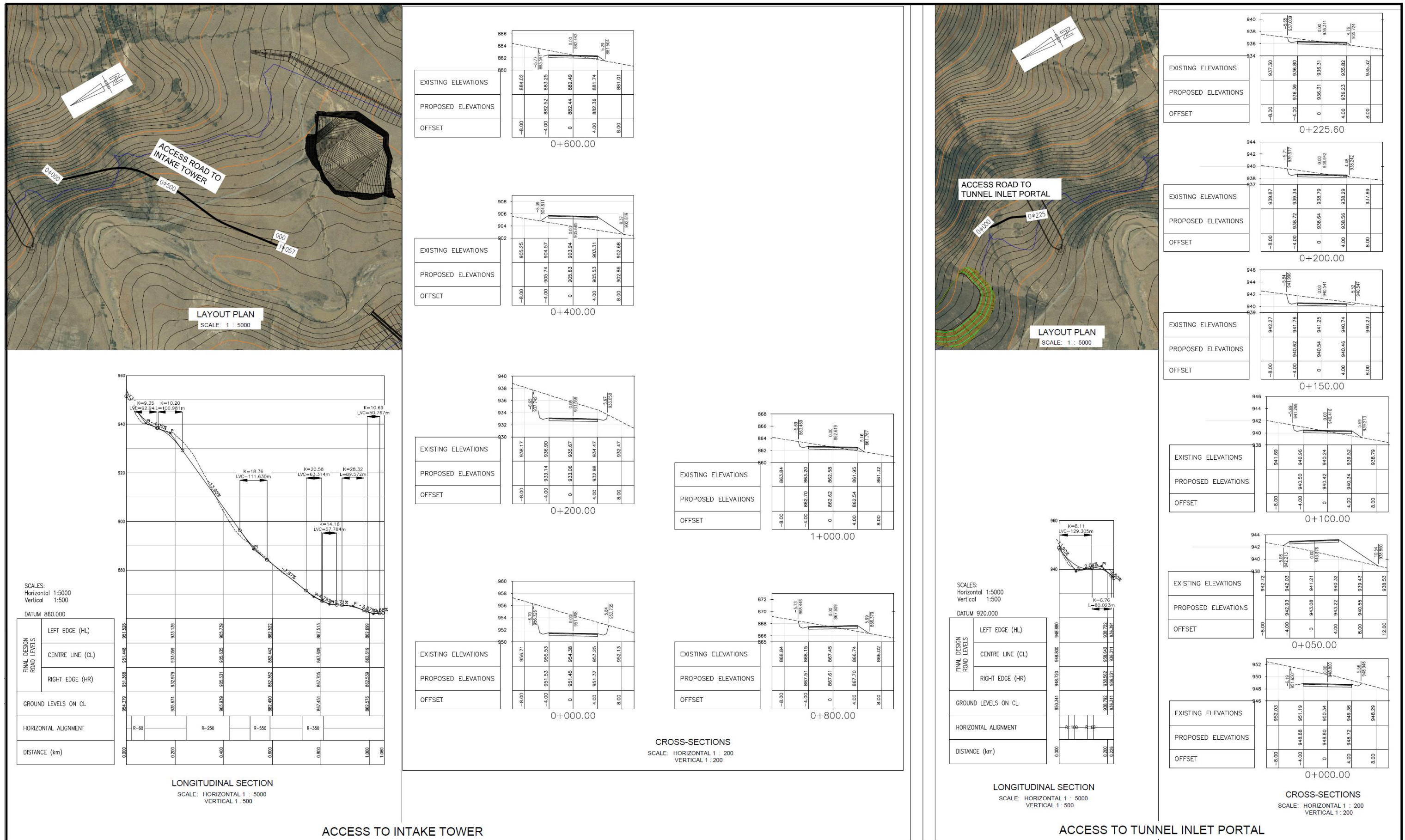


Figure A6.1: Smithfield Dam – Layout plan, longitudinal sections and cross sections of access road to intake tower and tunnel inlet portal

# **Appendix B**

## **Langa Balancing Dam road layout plans**

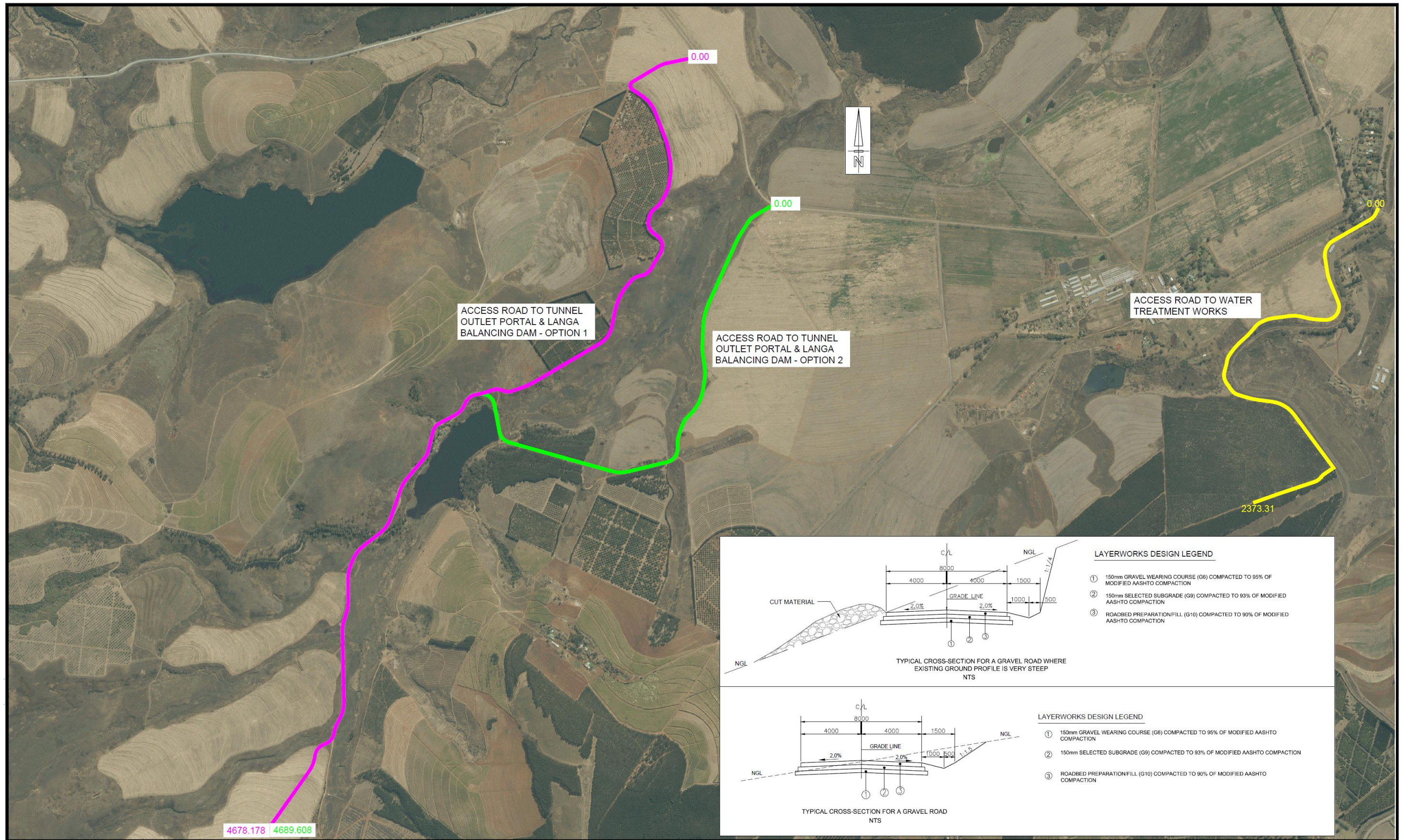


Figure B0: Langa Dam – Key plan of access roads

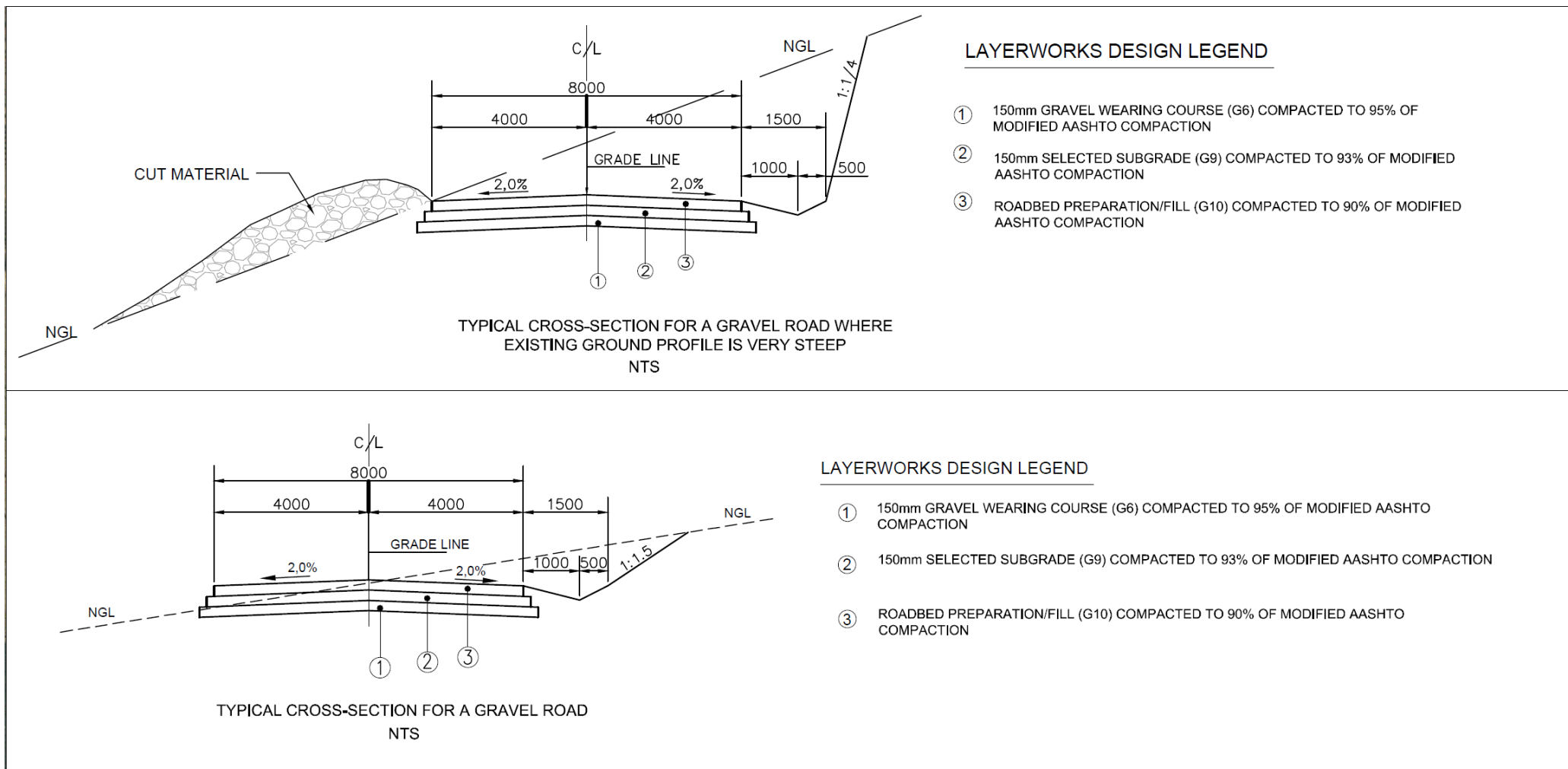


Figure B1.0: Langa Dam - Typical cross sections for road categories



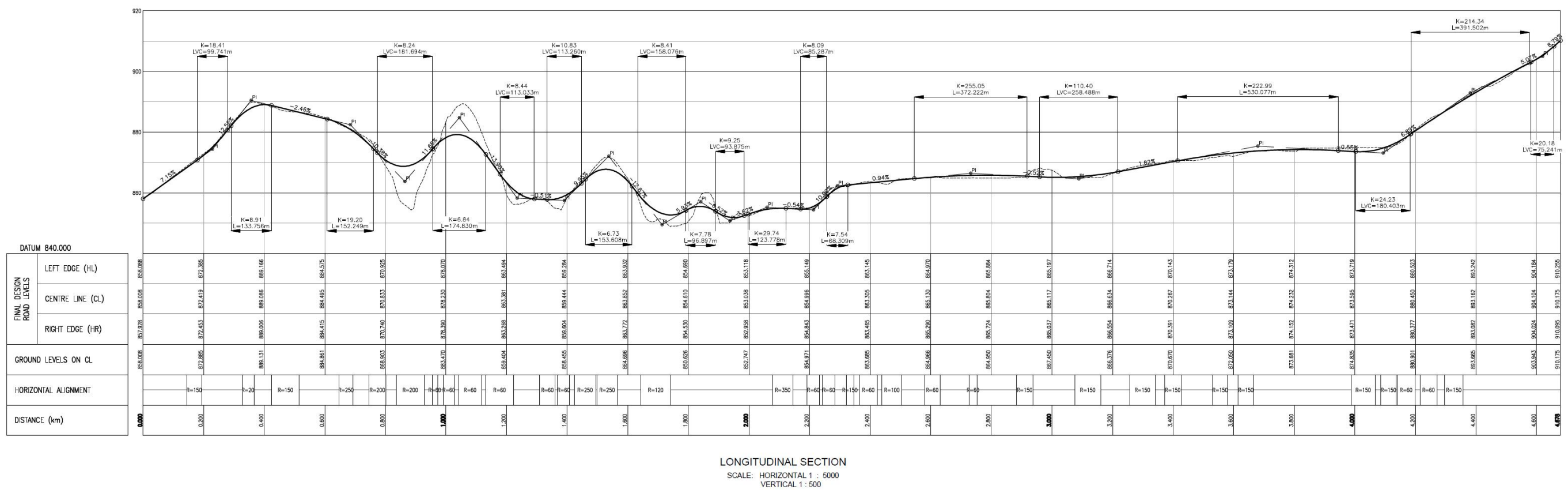
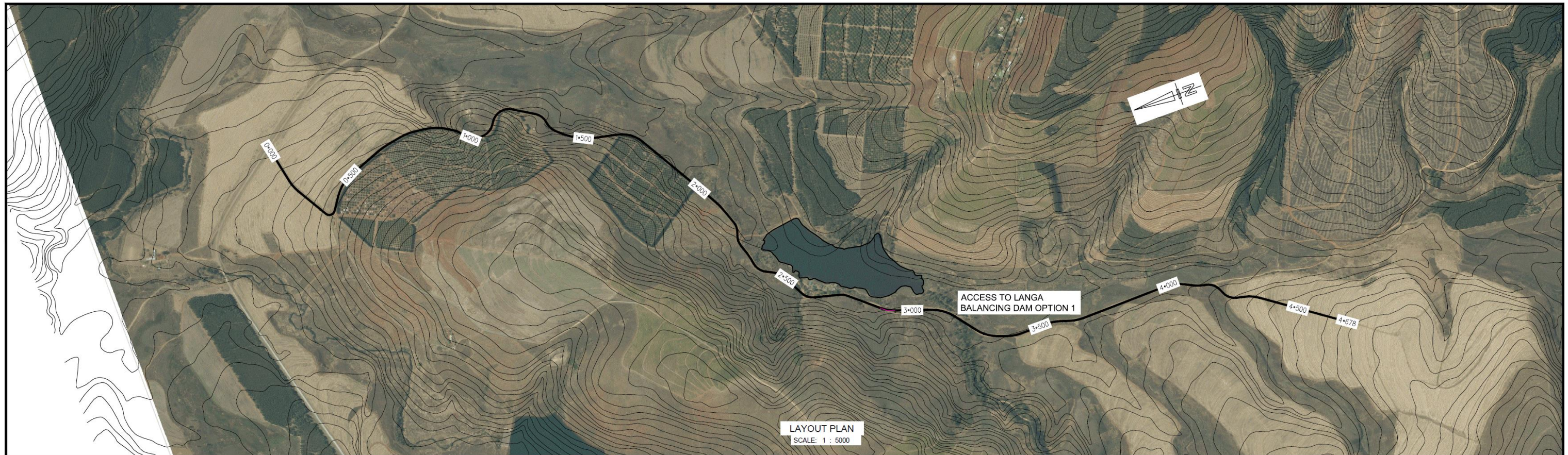


Figure B1.1: Langa Dam – Layout plan and longitudinal section of access road to tunnel outlet portal and Langa Dam Option 1

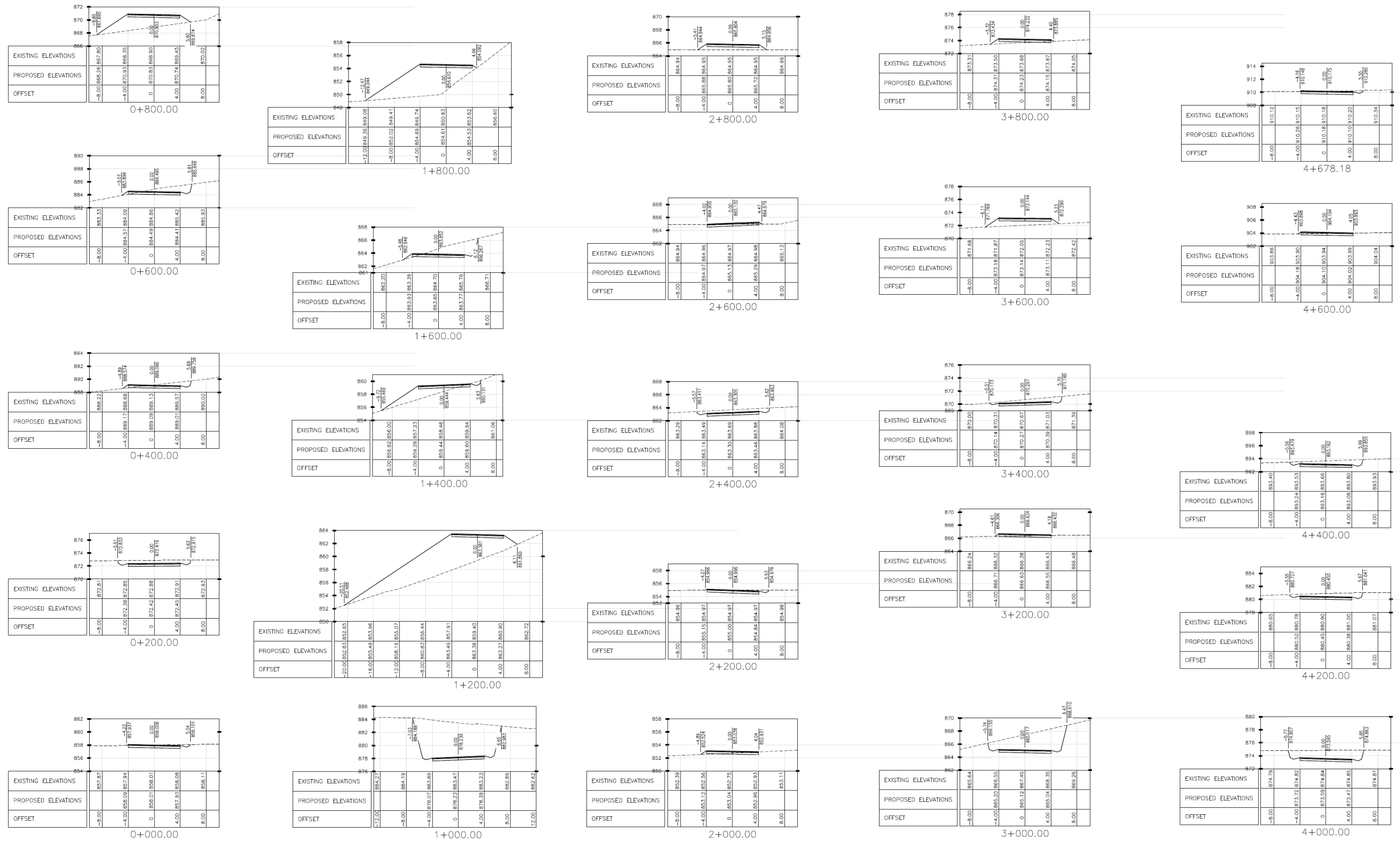


Figure B1.2: Langa Dam – Cross sections of access road to tunnel outlet portal and Langa Dam Option 1

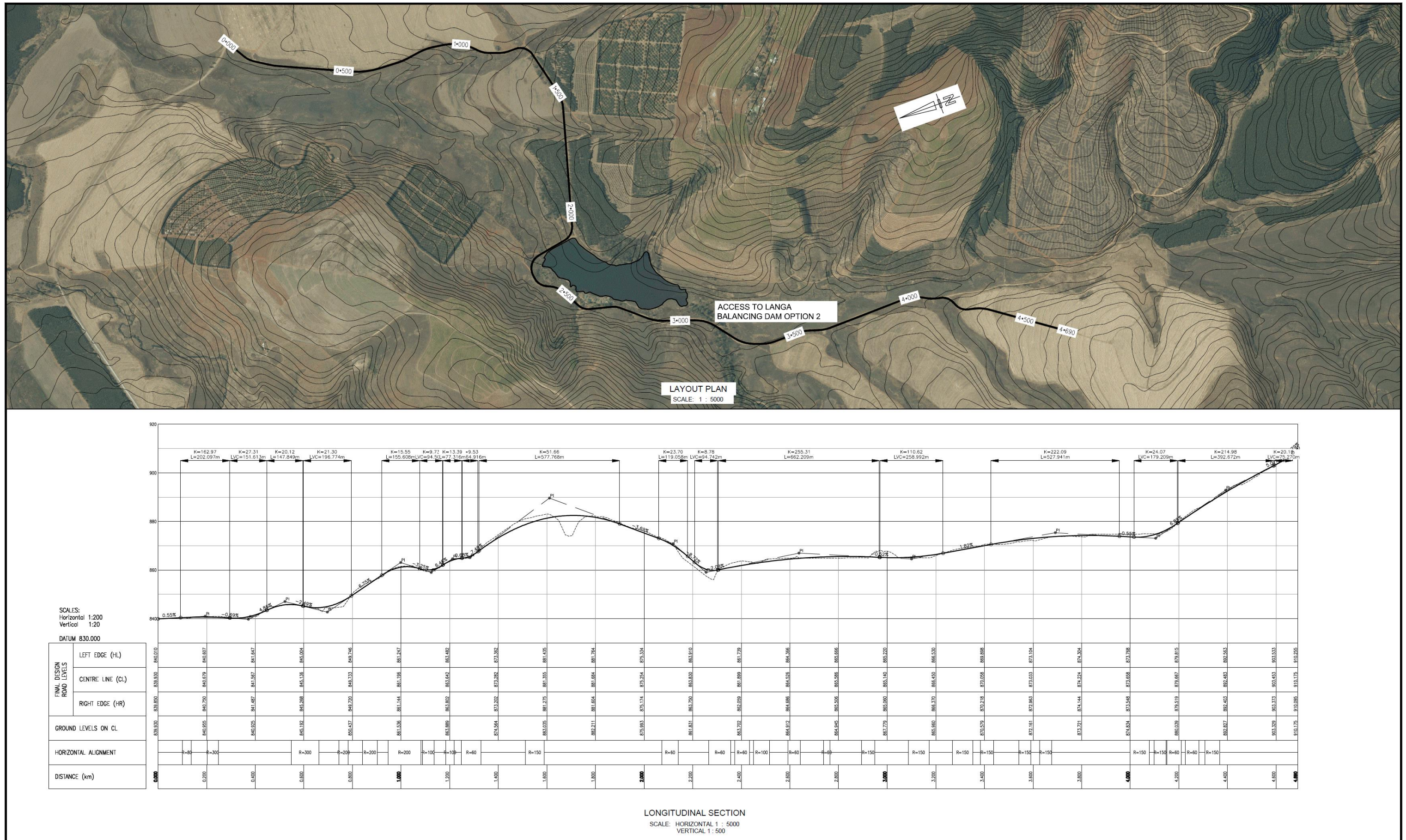


Figure B2.1: Langa Dam – Layout plan and longitudinal section of access road to tunnel outlet portal and Langa Dam Option 2

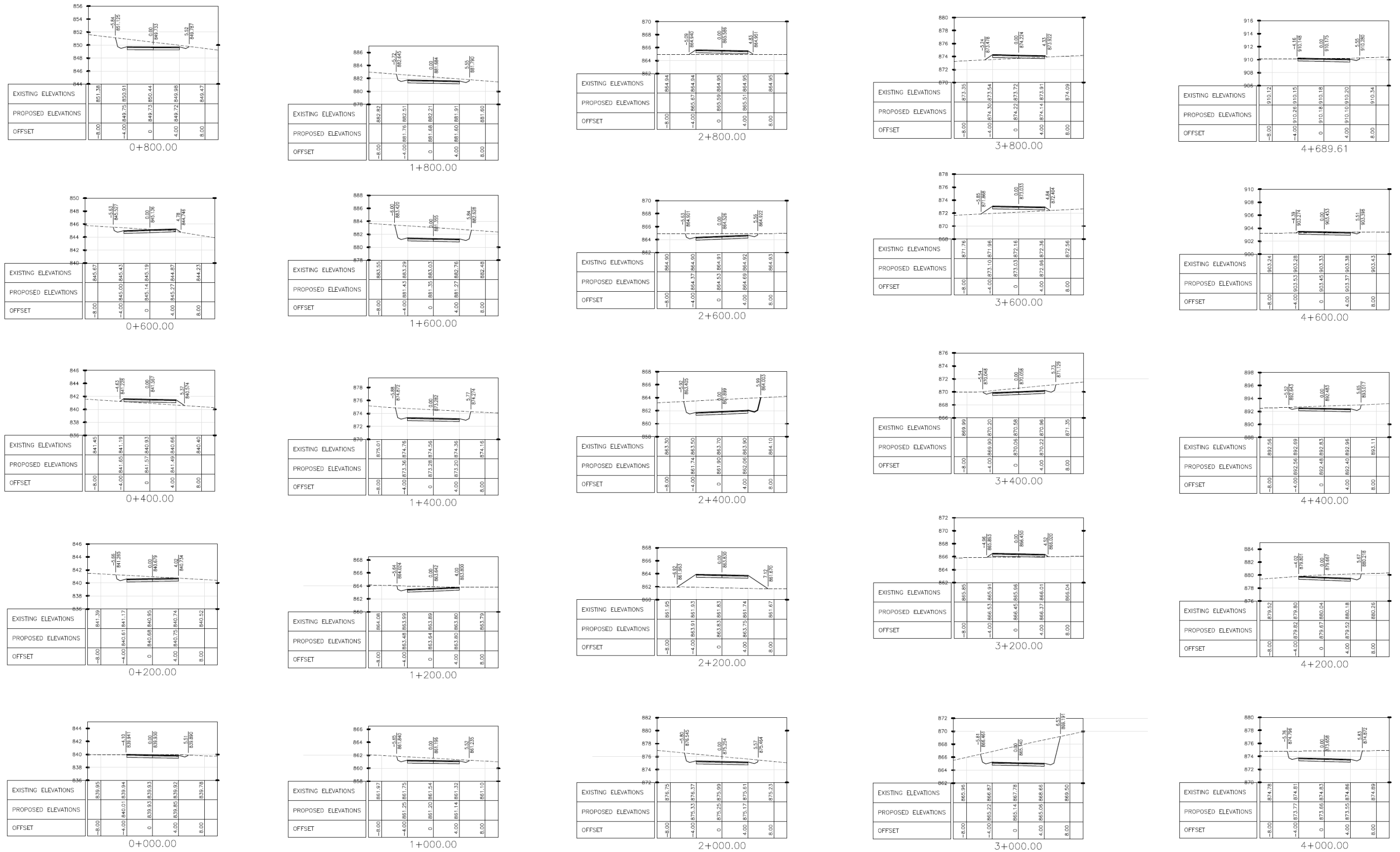


Figure B2.2: Langa Dam – Cross sections of access road to tunnel outlet portal and Langa Dam Option 2

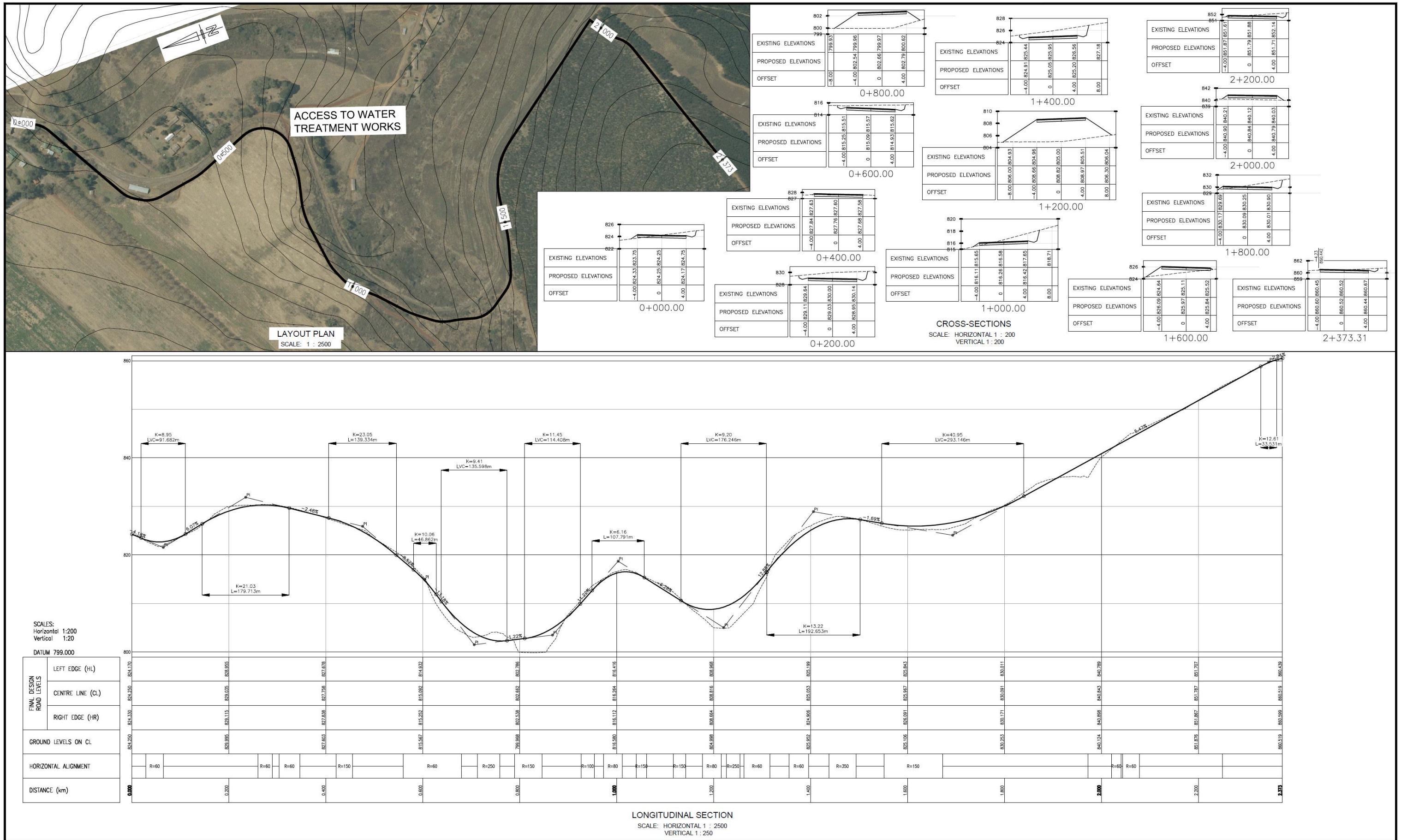


Figure B3.1: Langa Dam – Layout plan, longitudinal section and cross sections of access road to water treatment works

# Appendix C

## Transfer tunnel road layout plans

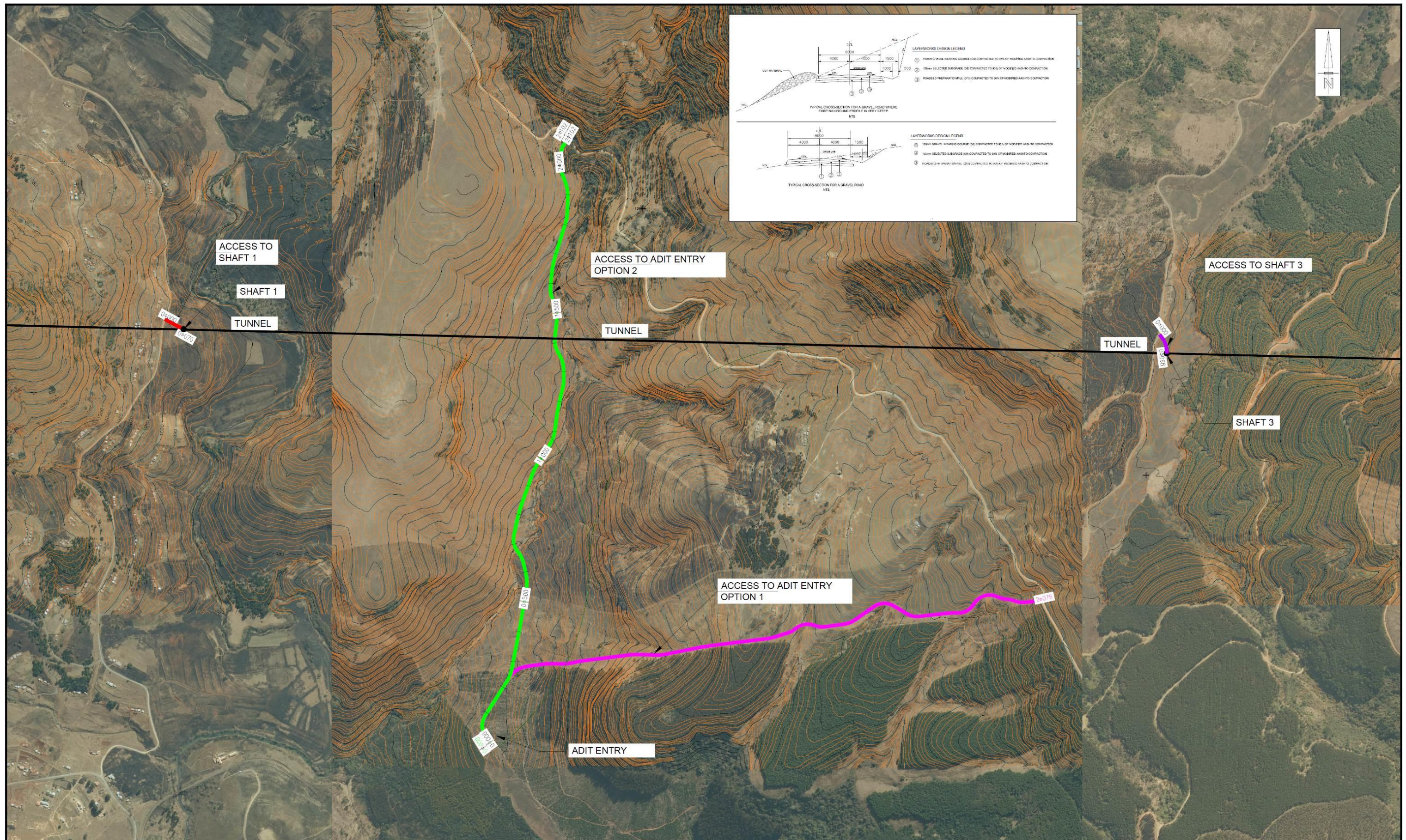


Figure C0: Transfer tunnel – Layout of access roads to shaft 1, adit entry and shaft 3

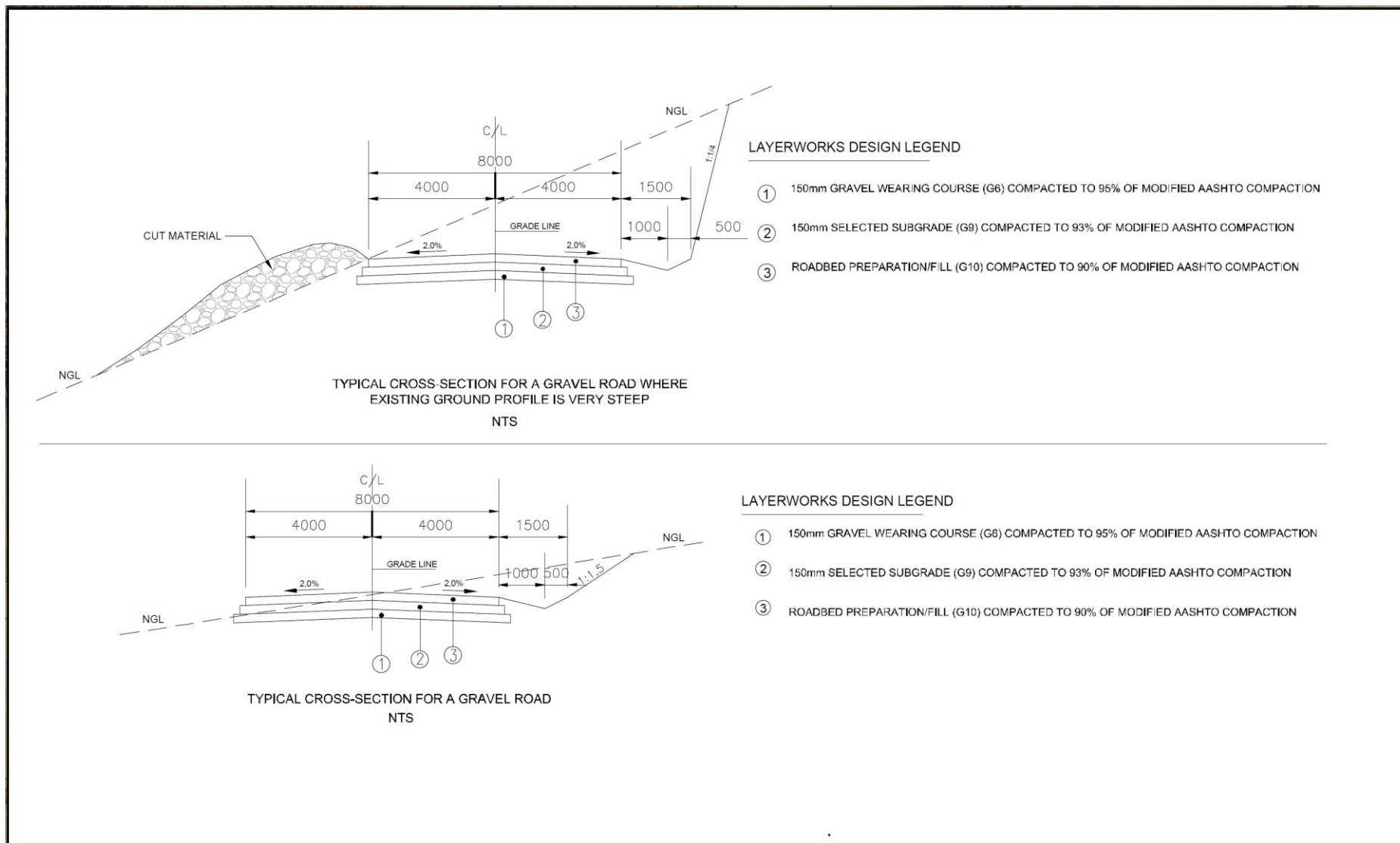


Figure C1.0: Transfer tunnel - - Typical cross sections for road categories



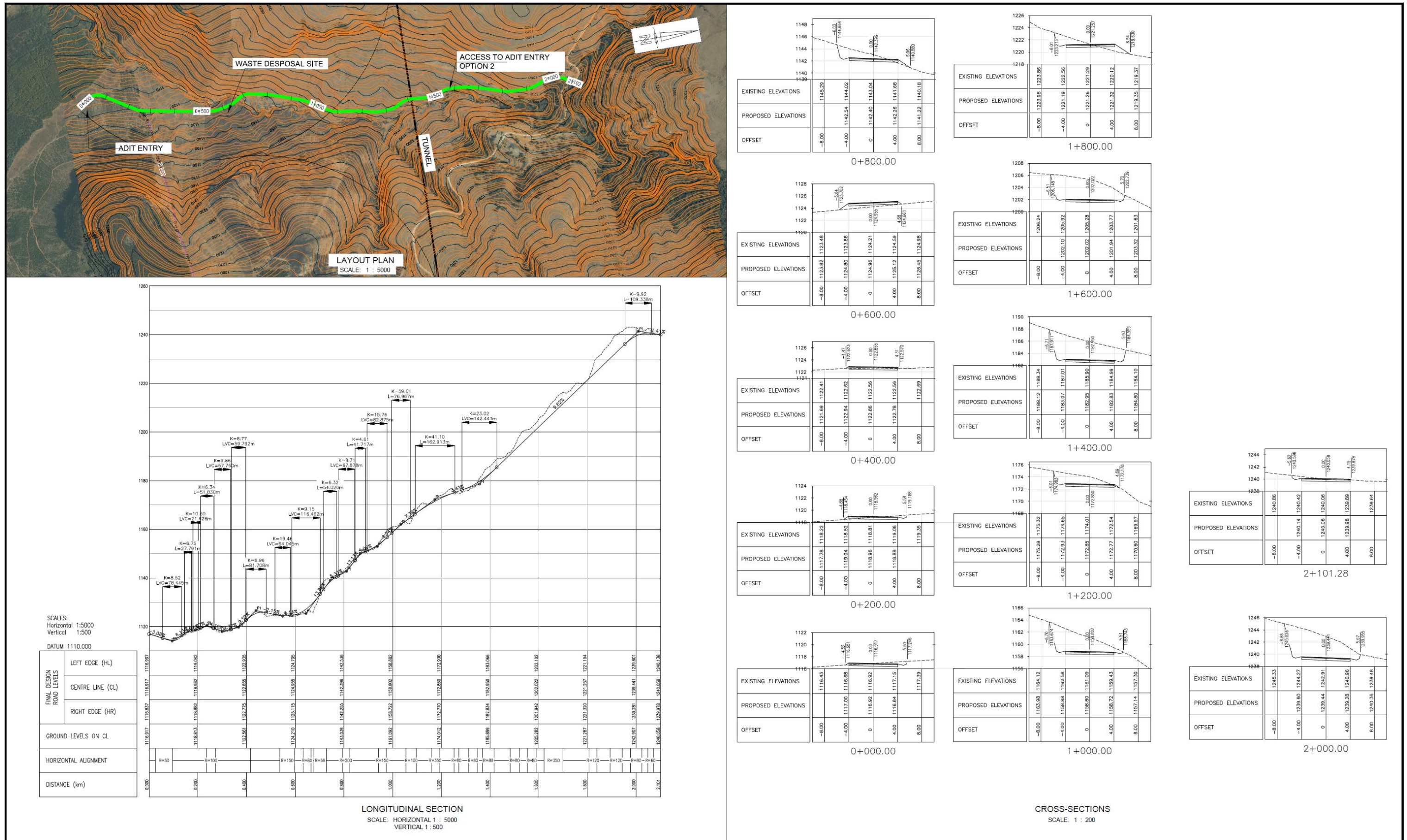


Figure C1.1: Transfer Tunnel – Layout plan, longitudinal section and cross sections of access road to adit entry

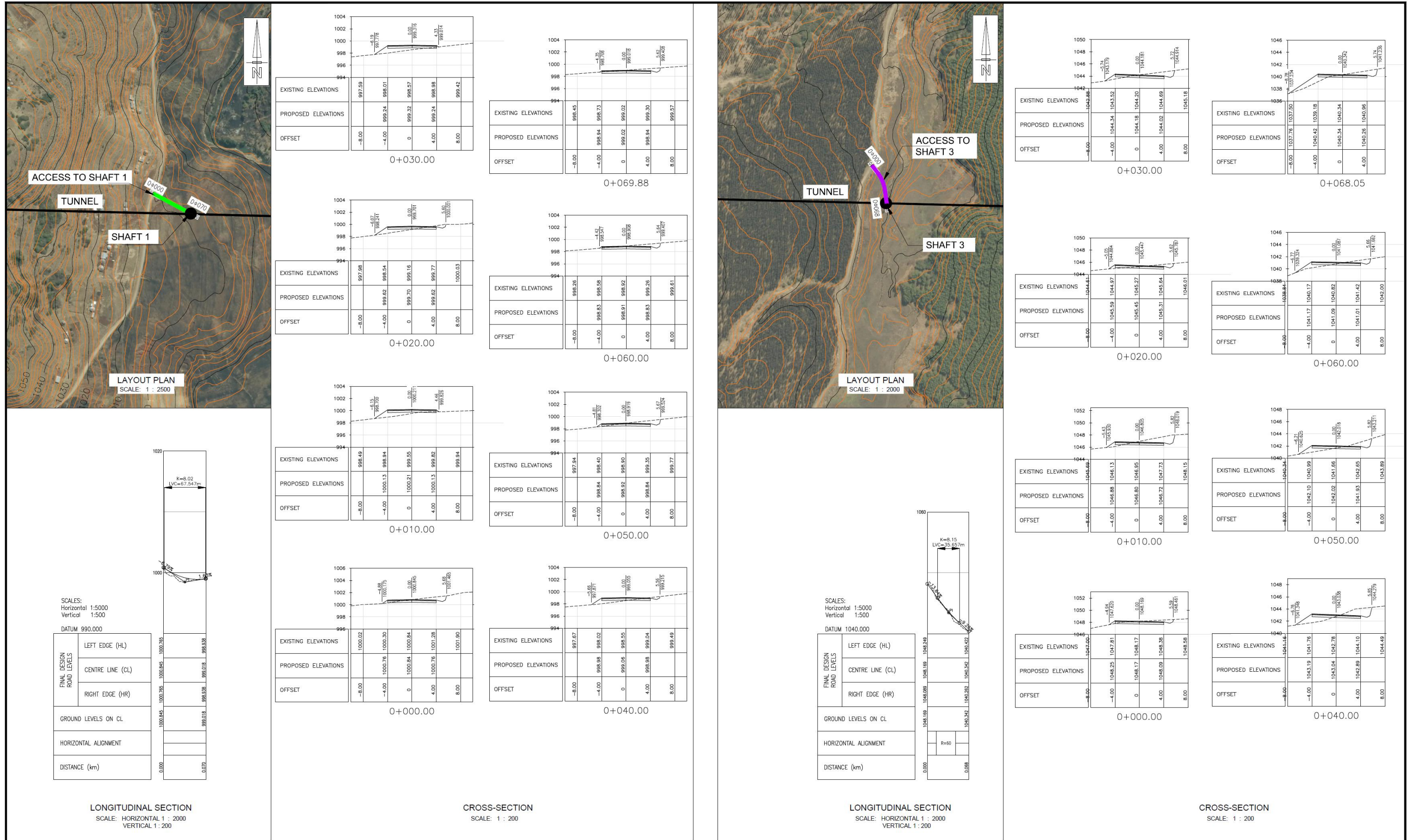


Figure C1.2: Transfer Tunnel – Layout plan, longitudinal section and cross sections of access road to shaft 1 and shaft 2

# Appendix D

## Gauging weirs road layout plans



Figure D1: Smithfield Dam – Contour plan of the gauging weir at the IFR site



Figure D2: Smithfield Dam – Contour plan of the gauging weir downstream of Smithfield Dam



Figure D3: Smithfield Dam – Contour plan of gauging weir upstream of Smithfield Dam